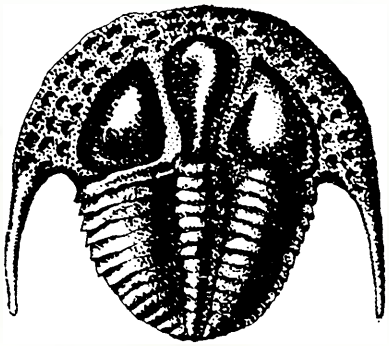
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Editor

F.J. Cockersole, Esq., F.R.C.O.G.,

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EXPLOSION BRECCIAS IN THE BORROWDALE VOLCANICS OF HIGH RIGG, NEAR KESWICK, CUMBRIA.

F. Moseley

ABSTRACT

The lower andesite lavas of High Rigg are intruded by several masses of breccia. This rock is made up of angular fragments of andesite, mostly between 5 and 10 cm. in diameter, but with occasional larger blocks, and some interstitial areas of smaller fragments, although there is no really fine grained matrix. In places the fragments have a 'jigsaw' fit, and appear to have been disrupted in situ, and they are also of similar composition to the andesite lavas which they intrude. There are both dykes and pipe-like forms, and they are interpreted as explosion breccias which formed at shallow depths, pene-contemporaneously with the andesite country rocks.

Structures of this kind are unusual in the Borrowdale Volcanics.

1. INTRODUCTION

The volcanic rocks of High Rigg, near Keswick in Cumbria, previously described in outline by Hadfield and Whiteside (1936) and mapped by Moseley (1972, fig.4), occupy the lower part of the Borrowdale Volcanic succession, and consist predominantly of andesite flows averaging about 20m. in thickness, with some thinner bands of bedded tuff and coarse tuff. The distribution of the various outcrops is shown in figure 1. It will be noticed that the succession, where the breccia is found, is bounded by faults to the north, east and south, and there is a broad area of alluvium and glacial deposits to the west. Since it is impossible to match the succession of this fault block with any of those across the faults, it remains an isolated one, and the displacements of the faults cannot be accurately estimated. Exposure is excellent in the series of crags which rise 150m. above the adjacent drift filled valley, and the mapping of the volcanic units presents no serious problem.

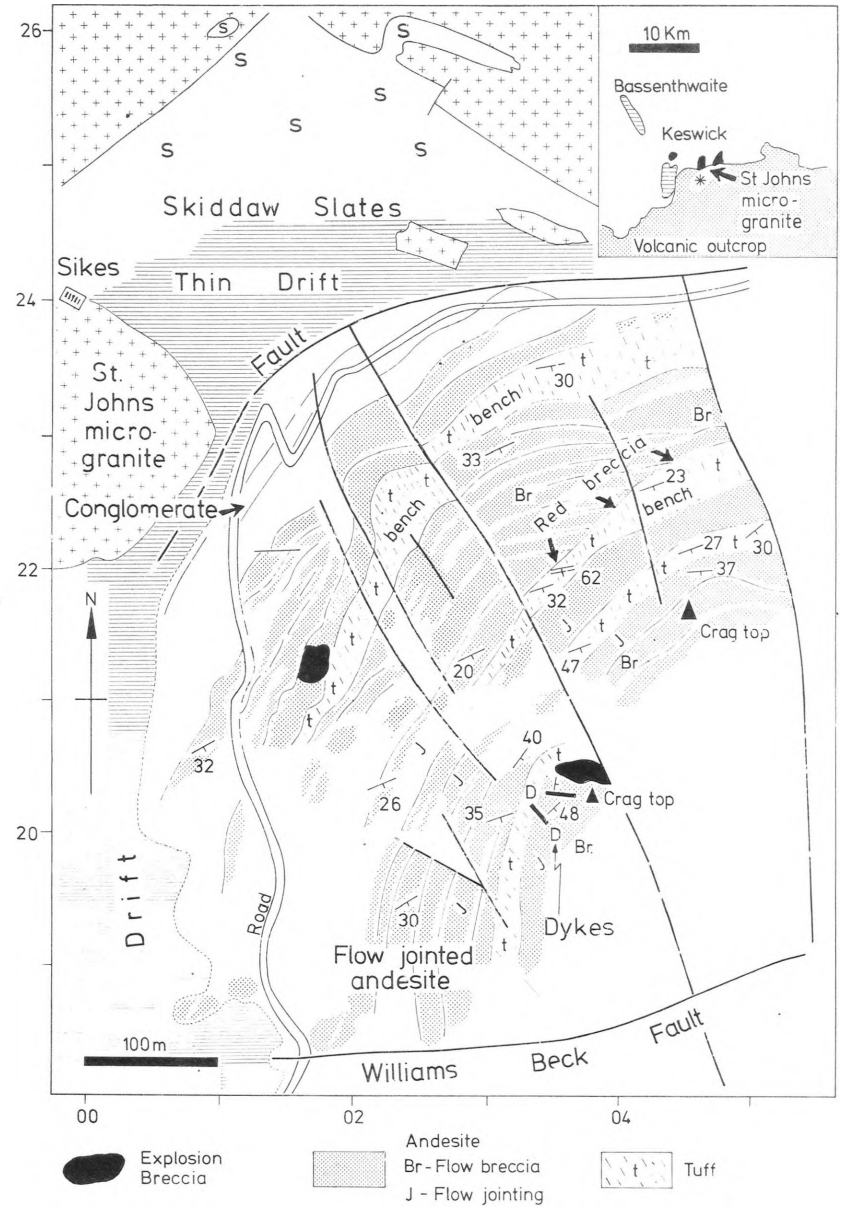


Figure 1. Geological map of the N.W. part of High Rigg, Cumbria.
Legend additional to volcanic rocks:

Crosses — St. John's Microgranite
S — Skiddaw Slates

Horizontal lines — drift (boulder clay & alluvium)
Blank — largely unexposed.

2. THE VOLCANIC SUCCESSION OF NORTHERN HIGH RIGG (Fig.1)

Flows of andesite lava predominate and can be readily mapped over the whole area of High Rigg. The flows are of variable character, but nearly all are flow brecciated to some extent. Generally, individual flows are massive or strongly flow jointed in the lower and central parts and flow brecciated towards the top, but there are some which are flow brecciated throughout. One sequence of the latter, in particular, gives trouble in interpretation since the rocks are not easily distinguished from coarse tuff, and in fact there is apparent gradation into tuff at the top of one of the mapping units. These rocks have been labelled 'red breccia' on figure 1 (037.222) because of their distinctive reddish-brown weathering.

The fault block which includes the intrusive breccias is principally made up of strongly flow jointed and partly flow banded medium grey andesites, the highest of which is a little thicker than the average for this area (about 30m.). This particular flow, illustrated by figures 2 and 3, is the one intruded by the most interesting of the breccias. It is an extremely fine grained, partly devitrified rock, composed mostly of feldspar with a little interstitial quartz, and occasional phenocrysts (up to 1 mm.) of chlorite, probably derived from pyroxene. The rock is permeated by patches of secondary calcite and there is a scatter of opaque ore. The other flows within this fault block are petrographically similar.

The andesite lavas shown on figure 1 are generally separated from each other by thin andesite tuff bands which are less resistant to erosion than the lavas, and form benches to give a characteristic 'trap' topography. These rocks include medium to fine bedded tuffs, coarse tuffs and lapilli tuffs, which grade into each other, the maximum thickness of individual bands being rather less than 10 m.

Near the base of the volcanic succession there is an interesting development of volcanic conglomerate, probably at more than one horizon (Fig.1). These beds consist mainly of water worn volcanic pebbles and some Skiddaw 'Mudstone' pebbles (uncleaved), which have previously been cited as evidence that the Skiddaw Slates were uncleaved at the beginning of vulcanicity (see discussion to Wadge, 1972).

3. THE BRECCIAS

Four breccia bodies have been located within the area of figure 1, all with definite intrusive relationships to andesite flows. The two occurrences illustrated by figures 2 and 3 and plate 1 are strongly transgressive to the flow banding and flow

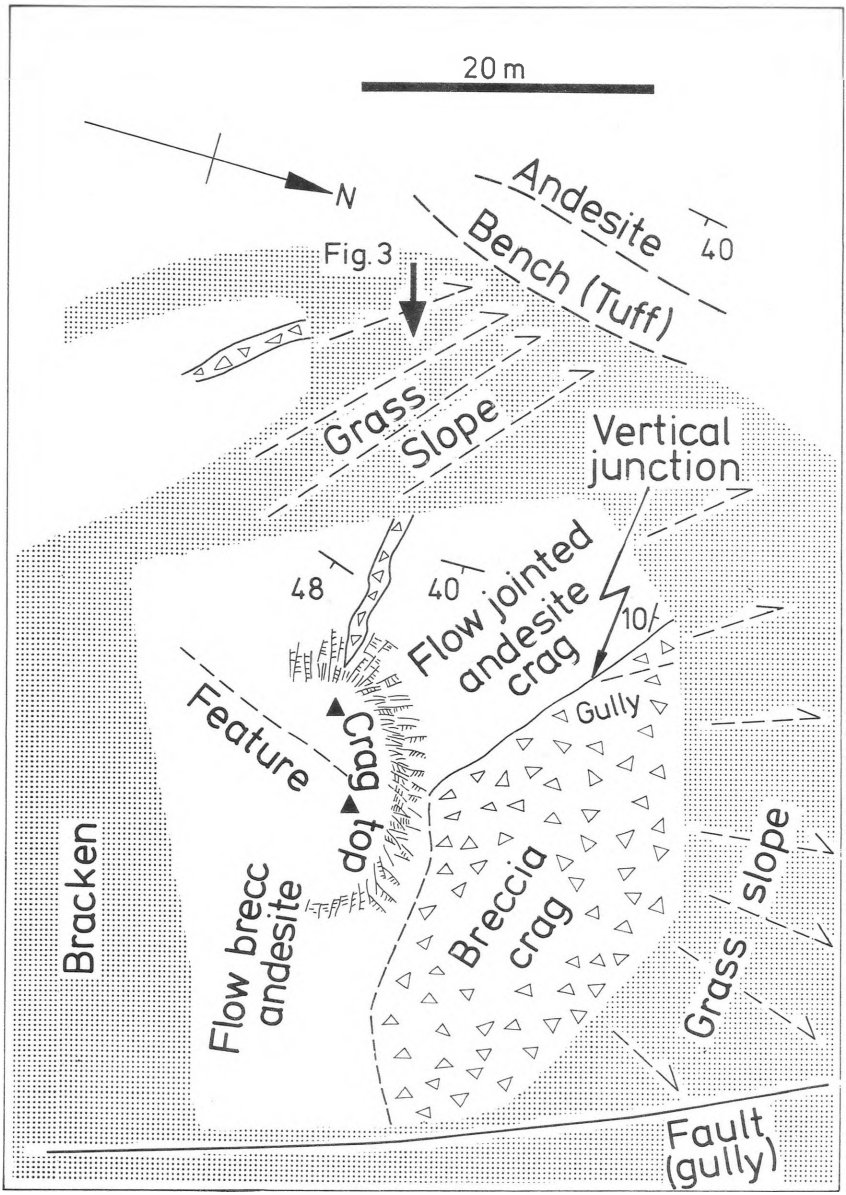


Figure 2. Map of the explosion breccias at 037.203.
Triangle ornament — Breccia
Blank areas — Andesite
Stipple ornament — unexposed (mostly grass, bracken and scree).

jointing of a well defined andesite flow, which now dips about 40 degrees to the south-east.

Mapping suggests that the larger breccia body has a pipe-like form and is intruded into the lower part of the flow only. It is composed of sharp angular blocks of andesite which fit closely together, so that in some cases the jigsaw-fit of smaller fragments into an original larger block can be seen. The fragments mostly range from 5 to 10 cm. in diameter, although there are larger pieces and patches where the material is more finely comminuted, but there is no really fine grained matrix (plate 1). Petrologically the fragments are very similar to the andesite lava previously described, being composed of fine grained andesite with small chlorite phenocrysts (? after pyroxene) and a good deal of secondary calcite. Structurally the intrusion is strongly discordant, and has a sharp, near vertical contact on its north-western side, which abruptly truncates the flow banding and flow jointing of the andesite lava. The south-eastern junction is more difficult to place, however, since the rock there is lichen covered, and the breccia comes into contact with the upper flow brecciated part of the lava (Fig.2).

The smaller breccia dyke immediately to the S.W. of the breccia just described (shown on figures 2 and 3 and plate 1) has an almost identical lithology to the larger one, with angular blocks of andesite fitting closely together. It approximates to one metre in width and has sharp vertical contacts which abruptly truncate the andesite flow jointing. The dyke can be followed upwards almost to the top of the crag, but then terminates.

Thirty metres to the S.W. of this breccia dyke, crossing the next outcrop of the same andesite flow, there is another breccia dyke of similar composition and width, but with one puzzling difference. Instead of truncating the flow jointing of the lavas, like other intrusions, a fact which is easy to understand and explain, the flow jointing passes uninterruptedly across the dyke.

There is one other breccia mass within the same fault block which penetrates a lava lower in the succession. It resembles those just described although it does contain some larger blocks several metres in diameter.

4. CONCLUSIONS

It is well known that explosion breccias are associated with vulcanicity, and that their origins may be shallow or deep seated (Wright and Bowes, 1968, Hardie, 1973). It is believed that underground explosions are generated by the release of gas, perhaps when gas charged magmas invade pervious rock beneath an impervious cover. Such explosions often fail to reach the surface and the rock is shattered in situ. Should the cover be breached the gas and its contained rock fragments will stream upwards and become

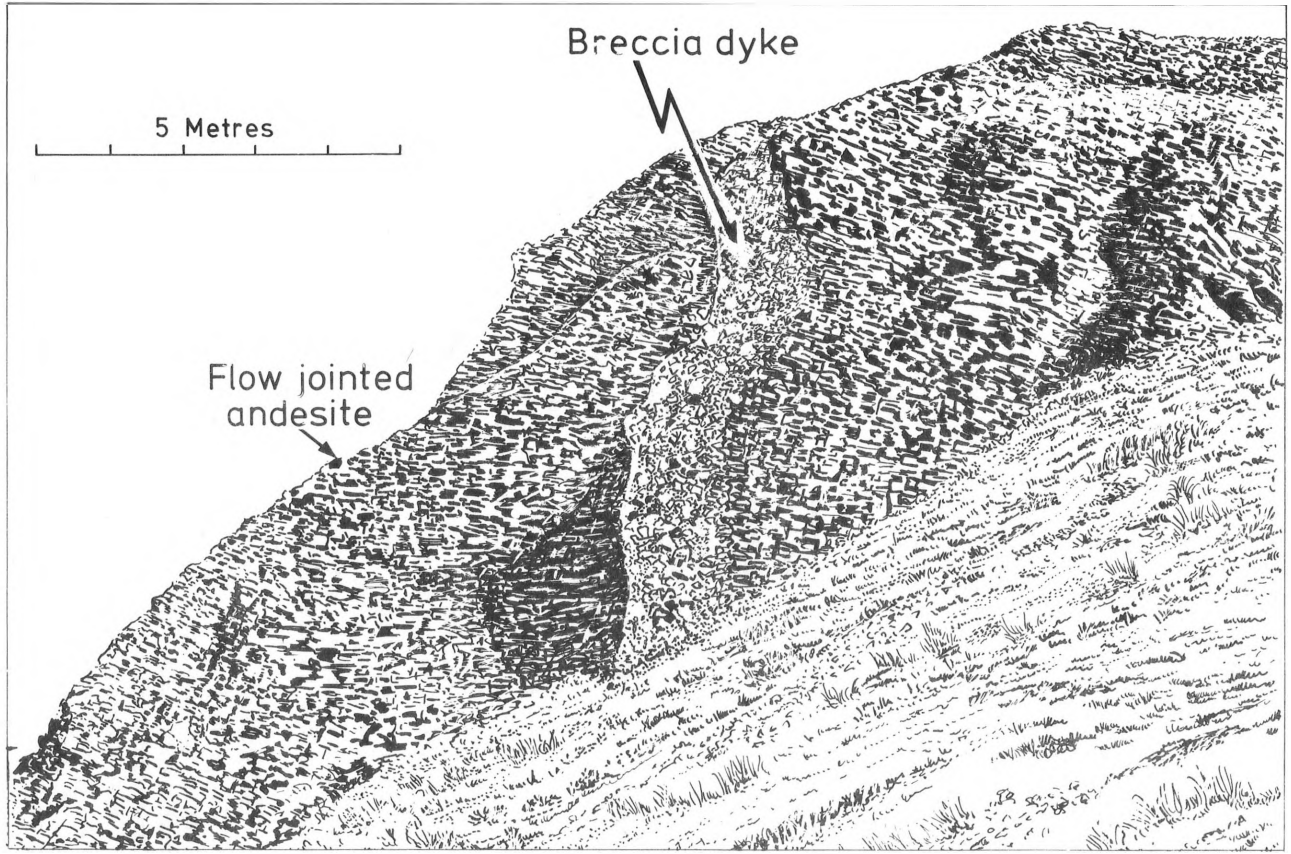


Figure 3. Sketch to show the field relations of the more northerly breccia dyke (035.203). Drawn from stereo-photographs and a field sketch. The view is at 070 T°(see figure 2).

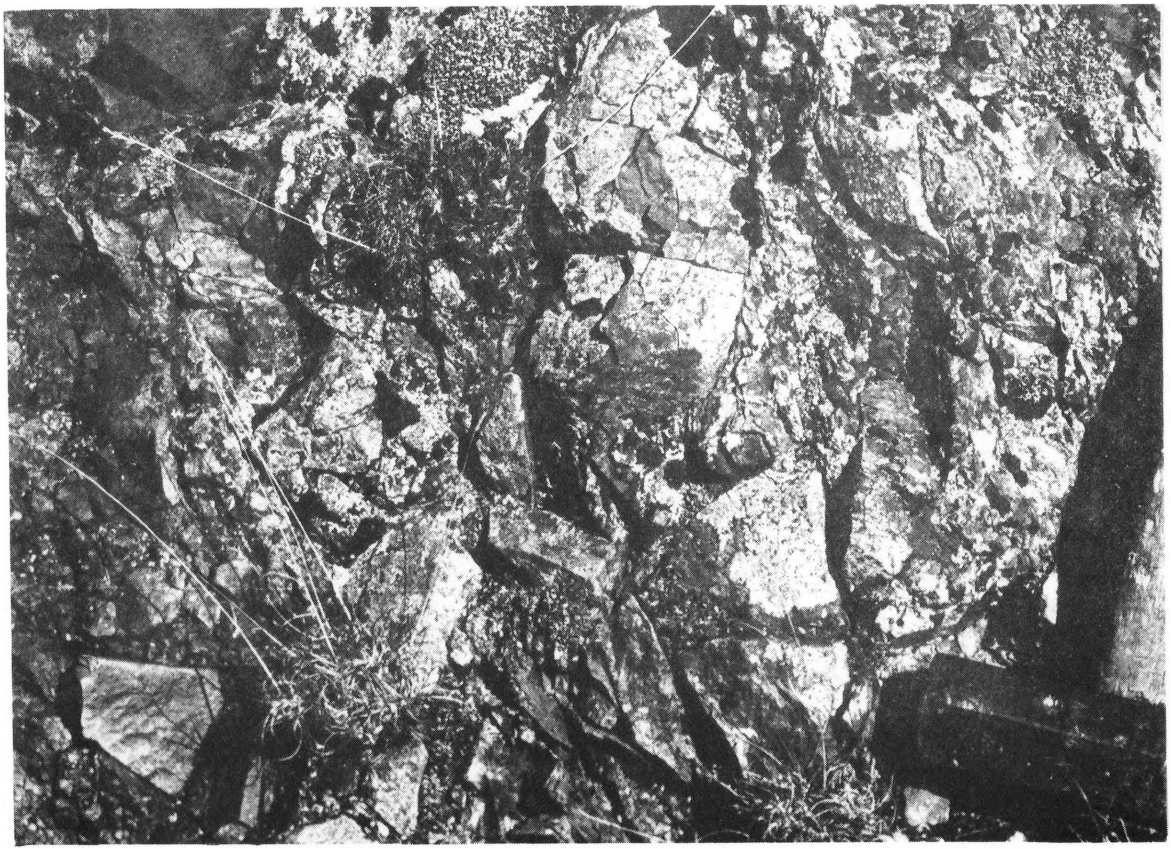


Plate 1. A detail of part of the breccia dyke illustrated by figure 3. The fragments are angular and tend to have a jigsaw fit.

intrusion breccia, but it will be understood that there can be a fine dividing line here, and it may be difficult to differentiate between explosion and intrusion breccia. When the breccias have a shallow origin as in the cases described here it is reasonable to suspect that groundwater may have had an important part to play and that the origins may have been at least partly phreatic.

The breccia bodies at High Rigg are obviously discordant, making perpendicular contacts with the lavas and the fragments are highly angular and fit together in such a way as to suggest that many of them have been very little removed from their original position. The monogenetic composition, identical to that of the andesite country rock, and the lack of much really fine matrix supports the conclusion that the breccias represent already solid andesite lava fragmented in situ by underground explosion in a manner similar to that indicated by Wright and Bowes and by Hardie (op. cit.). The dyke-like form shown in figure 3, which terminates near the top of the crag also suggests a fissure breccia resulting from underground explosion and it seems certain that when all these observations are taken together there can be only the single conclusion of an explosion breccia origin. There are some complications of detail, however, and the most important of these refers to the breccia dyke which is actually crossed by flow jointing continuous with that in the adjacent lava. The only reasonable explanation in this case seems to be that the flow jointing represents a post-consolidation phase of the lava, but was formed when the rock was still hot, and subject to contraction on cooling. The flow jointing can therefore be related to the cooling phase of the lava, rather than to the process of flow and flow banding. The brecciation of this dyke, it is suggested, immediately preceded the jointing phase, with the implication that it originated pene-contemporaneously with the lava flow, and at a shallow depth. It is likely that the other breccia bodies formed at substantially similar times in relation to the lavas which they penetrate, and that all had shallow origins, a conclusion similar to those expressed by others who have examined breccias from comparable environments (Durell, 1944; Wright and Bowes, 1968; Hardie, 1973), although one must remember that there are also deep seated explosion breccias forming in other different environments (Wright and Bowes op. cit.).

This discussion now leads to the suggestion that the High Rigg breccias were formed within andesite lavas during the later stages of solidification, but when the surfaces of the flows were already solid and impermeable flow breccia (Fig. 2). It is possible that local concentrations of groundwater escaping into the hot lower regions of the lavas resulted in phreatic explosions and the formation of breccia pipes and dykes. It is also worth noting that the volcanic successions of the High Rigg region follow an expected pattern of periodic eruption followed by

quiescence and erosion. For example, figure 1 shows a succession of 'red breccias' unconformably overlain by tuff (037.222). Each of these breccia bands becomes less red when traced along the strike away from the unconformity, all of which suggests that several flows of sub-aerial flow breccia were eroded and oxidised before deposition of the tuff. This further supports the contention that the explosion breccias were generated by volatile activity within single flows which had only recently been erupted, and that they were in fact confined to these flows, since the underlying rock would have been cold and hard by that time.

Finally for those unfamiliar with the many varieties of volcanic breccia within the Borrowdale volcanic succession it may be of value to mention some differences between rocks which at first sight resemble each other. It is for example decidedly easy to confuse explosion breccias (and intrusion breccias) with flow breccia and pyroclastic breccia. Flow breccia, associated particularly with the upper and frontal parts of lava flows, is composed of irregular, angular lava fragments which were engulfed by the still flowing lava from the interior of the flow. The lava fragments are generally softer than the lava matrix, and consequently become recessed on weathering (plate 2). Pyroclastic breccias differ in that the larger fragments are generally harder than the finer grained matrix and therefore stand out as lumps on the weathered surface (plate 3).

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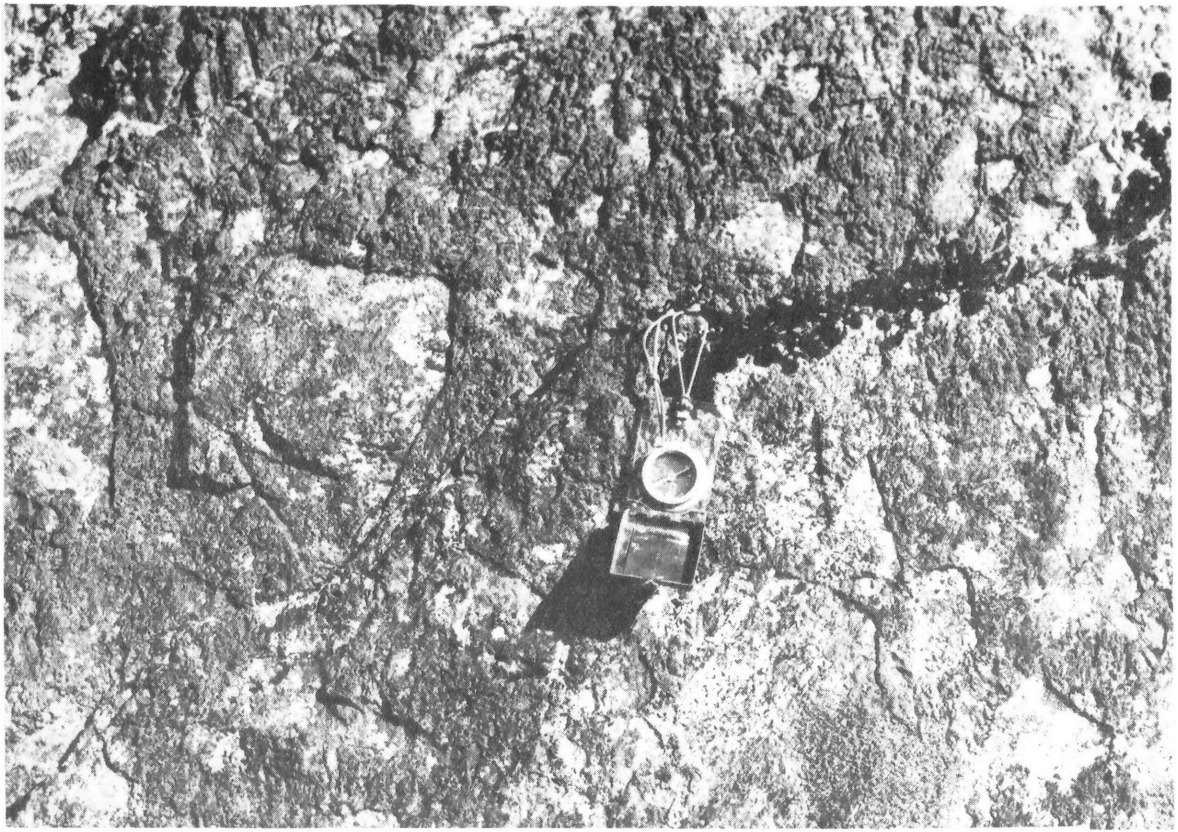


Plate 2. Andesitic flow breccia, Norman Crag, Gowbarrow (400.222). Notice the fragments are recessed by weathering and are softer than the matrix.



Plate 3. Pyroclastic breccia (coarse tuff), Threshwaite Mouth, High Street (435. 102). The fragments are harder than the matrix and stand out on weathering.

SOME ASPECTS OF CORRIE INITIATION AND EVOLUTION IN THE ENGLISH LAKE DISTRICT

R. McKenzie Clough

SUMMARY

The geomorphological characteristics of nearly 200 corries in the Lake District are analysed, using a variety of techniques and statistical methods, to study the factors in their initiation and subsequent evolution. Most Lake District corries appear to have been initiated in the upper parts of structurally controlled pre-glacial valleys, but the small late-glacial corrie glaciers appear to have been more sensitively controlled by the climatic factor, thus tending to produce asymmetry both in corrie morphology and in distribution of terrain types. The study of the distribution and nature of the terrain types within the corrie basins leads to the inference of at least two phases of glaciation.

1. INTRODUCTION

Nearly 200 corries have been identified in the Lake District, excluding those of the outlying Black Combe Fells of the extreme south-west (Fig.1).* They vary considerably in their morphometry and in the distribution and nature of their contained terrain types. The aim of this paper is to show how these properties, when interpreted in the light of corrie distribution, aspects and structural attributes, may contribute to the understanding of how the corries were initiated and subsequently evolved.

Relatively little morphometric work on the Lake District corries has been published. Excepting the few small-scale profiles constructed by Ward (1875) and Marr (1916), the first

* N.B. For the purposes of this paper corries are regarded as more or less semicircular recesses marking locations of concentrated ice formation (following Peterson, 1968). The additional criterion that a threshold should be present has been adopted to facilitate morphometric work, even though some workers would reject this as an essential diagnostic feature (see the discussion in Evans and Cox, 1974). Thus it is the true corries or 'Fjeldboten' type of Helland (1877) which are to be discussed.

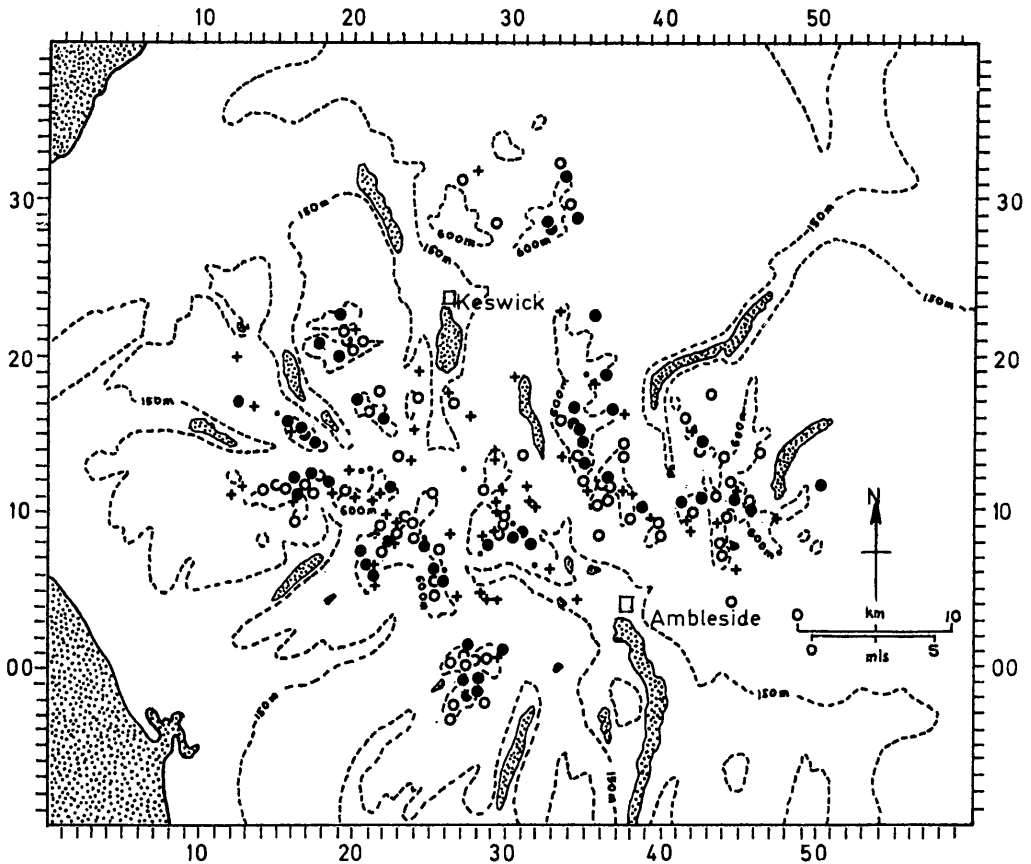


Fig. 1. — Distribution map of the Lake District corries. Black circles: Class (i) corries, open circles: Class (ii) corries, crosses: Class (iii) corries, dots: Class (iv) corries.

significant advance was made by Lewis (1960), who used the Brathay Exploration Group's survey of Blea Water corrie to illustrate his ideas on rotational slip. The earliest comprehensive regional treatment was by Manley (1959), who summarised the morphological properties and contributed a notable reconstruction of the local late-glacial conditions. Apart from the Brathay Exploration Group's continued and valuable tarn sounding activities (De Boer, 1964), most subsequent work has been directed towards studies of corrie distribution, location and aspect, e.g. Spencer (1959), Temple (1965), Sale (1970) and Whitaker (1973). Numerous comments on corrie terrains are also to be found in the literature, e.g. in the writings of Marr (1895 etc.), Hay (1934) and others, but the topic has never received the systematic treatment it deserves. In response to this the present author has recently suggested some methods of recording typical corrie terrains (Clough, 1974).

II. MORPHOMETRY

(a) Identification and classification. Cartographic analysis, chiefly of 1:25000 O.S. maps, and field observations have suggested 198 features to be possible corries in the Lake District. Since some of these are of doubtful origin and because of the large number of occurrences, it has been found convenient to classify them by using the relative state of development of the main corrie elements, headwall, basin floor and threshold, as the criterion.

Four classes of corrie are distinguished in this way:

Class (i) Very distinct (54 corries): all the corrie elements clearly represented, e.g. Nethermost Cove, Bowscale Tarn corrie etc.

Class (ii) Distinct (72 corries): distinctive on the 1:25000 map, but with one or more of the corrie elements rather poorly developed, e.g. Bannerdale (poorly developed threshold), Comb Head (restricted basin floor) etc.

Class (iii) Indistinct (60 corries): not clearly defined on the 1:25000 map but believed on locational or other grounds to have been sites of ice concentration, e.g. Langdale Comb, Stone Cove, etc.

Class (iv) Dubious (12 corries): possible corries, but either so small or so indefinite as to be of doubtful origin, e.g. Earing Crag, Bull Crag etc.

Continuation of terrain mapping should eventually enable this classification to be discarded, but for the present it is useful, since selected groups of corries can be investigated with minimum uncertainty about their status as glacial or glacially modified features.

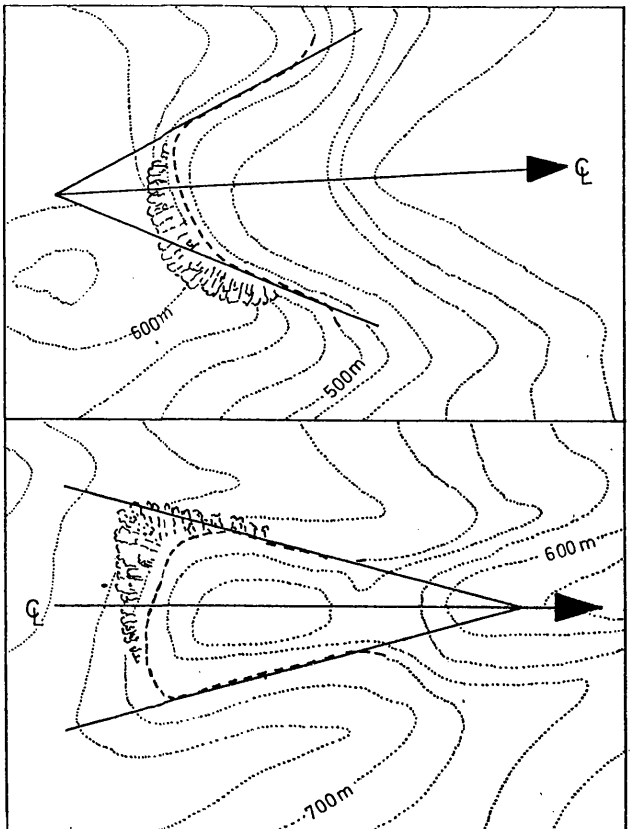
(b) Corrie centreline profiles. Inspection of centreline profiles is one of the simplest methods of distinguishing morphometric variations from corrie to corrie. A centreline is the bisector of the angle turned through by the longest continuous contour in a given corrie (Evans, 1968). Being derived from such a contour, the centreline orientation relates to the form of the basin as a whole (Fig. 2). While it can be used to measure basin aspect, however, it does not necessarily indicate the aspect of the dominant headwall in the corrie, e.g. at Gillercomb the measured aspect of the basin is 040°, but the dominant headwall faces 120°. Similarly, a centreline profile need not show the maximum relief in the corrie. Despite these shortcomings, which result from asymmetry, centreline profiles reveal major contrasts of size and form in a longitudinal direction.

These differences are reflected in variations of co-ordinates of important points on the profiles (Fig. 3). However, since the junctions between the various corrie elements are sometimes difficult to locate accurately on the profiles, particularly in the case of the more ill-defined corries, only the amplitude (H) and the length (L) are considered here. These two parameters alone suffice to demonstrate the considerable range of corrie size (Table 1). Both show an essentially unimodal distribution with a slight positive skew (Figs.4 & 5). As might be anticipated the 'very distinct' and 'distinct' corries tend to be larger than the 'indistinct' and 'dubious' ones, since the various corrie elements are more clearly differentiated both on the map and in the field, e.g. large headwalls are less likely to have been rendered unrecognisable by non-glacial processes than small ones.

Table 1. Interquartile ranges of values for amplitude (H) and length (L) in metres.

Class	(i)	(ii)	(iii)	(iv)	All classes
H	180-280	140-240	110-190	120-240	120-240
L	440-840	300-780	260-780	160-880	300-840

Since there is no more than an overall tendency for amplitude to increase proportionally with length (Fig. 6), it follows that the gradient of the straight line trace from the threshold to the profile summit is also variable, e.g. in Class (i) and Class (ii) corries the interquartile range is 16° to 26°. The median value of 20° is rather lower than expected, but is attributable partly to the effects of asymmetry, e.g. where the centreline misses the



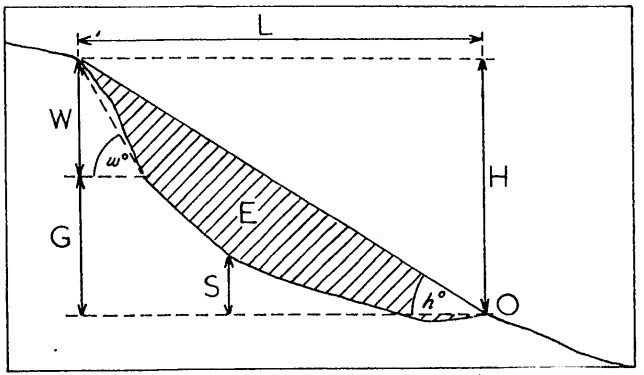


Fig. 3. — Key to measurements used in cartographic analysis of corrie centreline profiles:
O Origin, taken at intersection of centreline and threshold crest,
H Amplitude (height of headwall crest above threshold),
W Height of headwall (W = H-G),
G Height of headwall base above O,
S Height of footslope base above O,
L Horizontol length,
E Excavation, of a line joining headwall crest to the threshold.

Fig. 2. — Diagram to explain the construction of corrie centrelines. The centreline bisects the angle formed by lines drawn tangential to the longest continuous contour (dashes). **Top**: open plan type. **Bottom**: Closed plan type. Arrow indicates aspect direction.

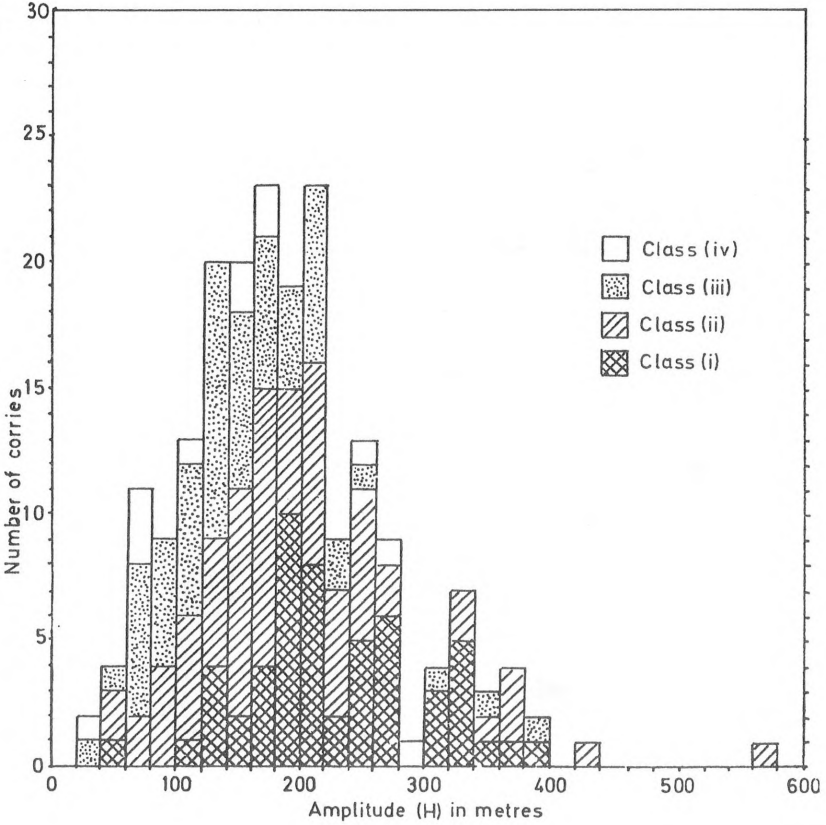


Fig. 4. — Histogram showing absolute frequencies of values for amplitude (H) along the centrelines.

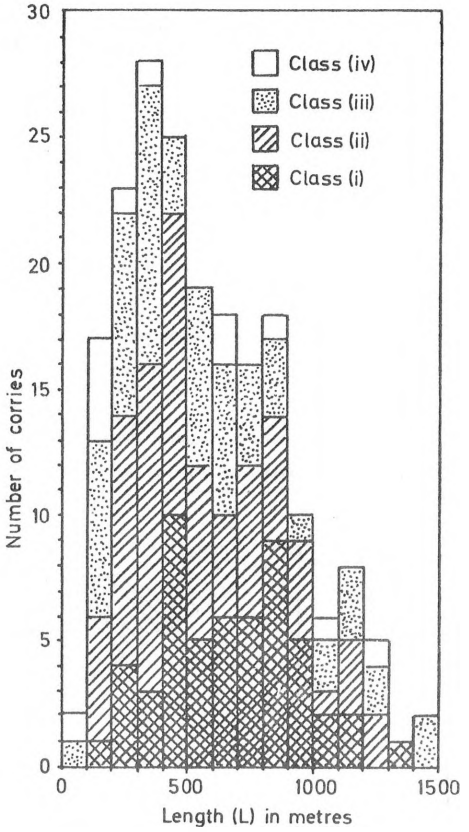


Fig. 5. — Histogram showing absolute frequencies of values for length (L) along the centrelines.

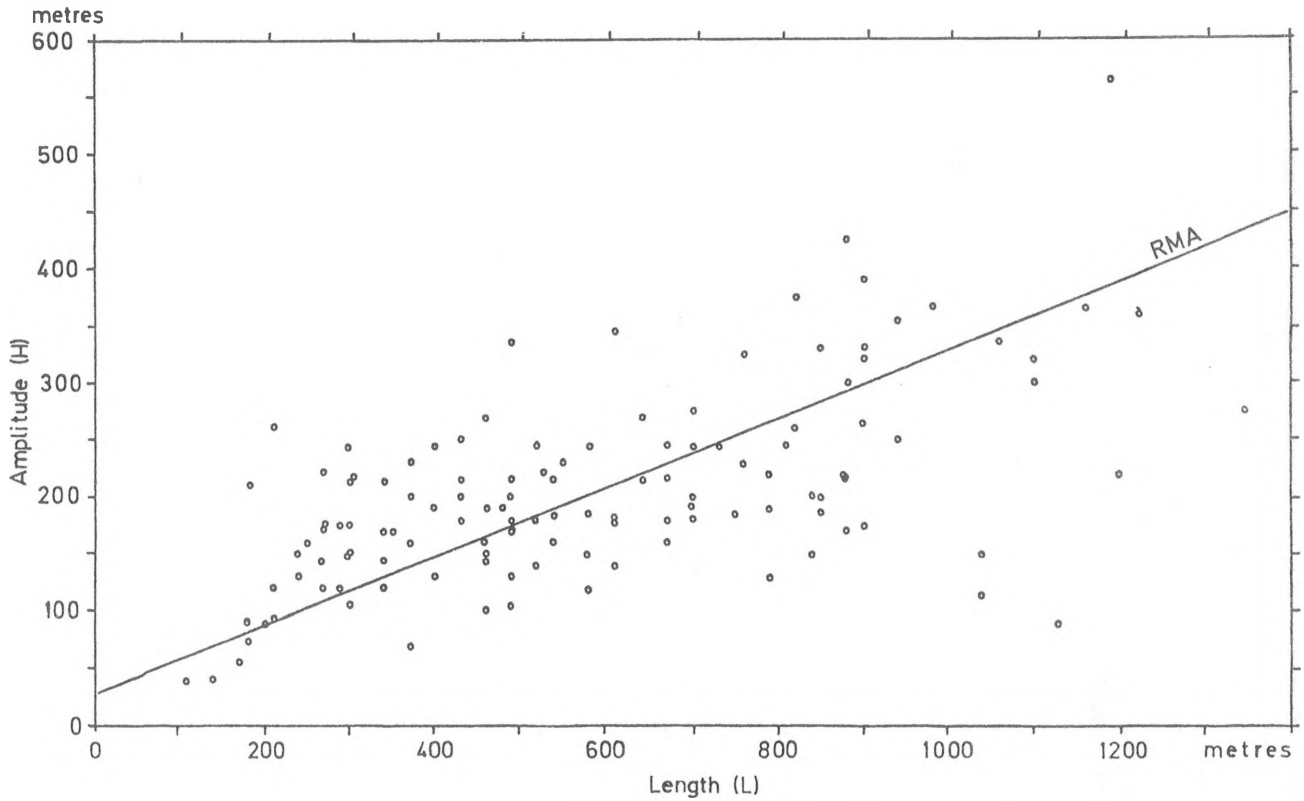


Fig. 6. — Amplitude (H) and length (L) plotted for corries of Classes (i) & (ii). RMA: reduced major axis, — the line of best fit, used when dependency cannot be assigned to either variable.

dominant headwall, and, in several instances to coincidence of the centreline with a col in the headwall slopes, as at Keppel Cove, Brown Cove and Greenburn Bottom corrie.

A similar method has been used to examine form, but all the co-ordinates were first divided by the value for amplitude for each corrie to facilitate comparison of this property. Inspection of the centreline profiles shows that more corries are of the shallow than the overdeepened type, a characteristic also identified in the Scottish corries by Haynes (1968), who, however, used a different method for locating the profiles. Of the 126 corries in Classes (i) and (ii) 17 show overdeepening below the threshold on the centreline profiles. To these may be added a further 9 corries with tarns either just missed by the centrelines or of uncertain depth but believed to lie in substantial rock basins, while 37 corries in the group possess relatively extensive tracts of marshy ground, which may or may not conceal rock basins. It seems, therefore, that at the most 63 corries could be over-deepened. The correct figure probably lies between 26 and 63, i.e. 20% to 50% of the Class (i) and (ii) corries. There seems little hope of settling this problem other than by an ambitious programme involving borings.

(c) The corries in plan. Traces of corrie outlines in plan reveal considerable differences in shape and area even among those of the very distinct category, which tends to include the more 'perfect' forms, i.e. those approaching a semi-circular shape. Using plan closure as a descriptor, a pilot investigation of the Class (i) corries has yielded comparable results to those obtained by Evans (1974) for the corries in the fells round Hawes Water (Table 2). The frequency distribution is similarly positively skewed with 22.2% of the corries having angles of closure (change in azimuth of the longest continuous contour in the corrie) less than 90°, 57.4% between 90° and 180° and 20.4% more than 180°.

Table 2. Area and plan closure of the Class (i) corries. Plan closure of corries round Hawes Water (Evans, 1974)

	Area Class (i) corries	Plan closure Class (ii) corries	Plan closure corries around Hawes Water (Evans, 1974)
Range	0.01 - 1.68 Km^2	50° - 253°	60° - 210°
Median	0.39 Km^2	128°	118°
S.D.	0.32 Km^2	34.59°	-
Number	54	54	14

Since no viable correlation has been detected between area and angle of closure nor between size and centreline profile form, interpretations based purely on theoretical glacier dynamics are unlikely to be successful. To explain the morphological differences each corrie should be analysed not only in the light of the structure of the rocks into which it has been incised, but also from the standpoint of the different geomorphological processes which have affected it at various times since its inception.

III. DISTRIBUTION AND ASPECT

(a) Altitudinal distribution. All corries of Classes (i) and (ii) and most of those of Classes (iii) and (iv) lie above 150m O.D. The better formed corries of Classes (i) and (ii) show a relatively low standard deviation for threshold altitudes (S.D. = 116.9m compared to Unwin's (1973) calculation of 152.2m for Snowdonia). Since two-dimensional representations of height data which have areal distribution provide only a partial picture, trend surface analysis might be considered as a potentially useful method of investigating the distribution. Construction of trend surfaces constitutes a technique for spatially generalising the altitudes and produces an improved estimate of the gradient and trend of the broad regional surface which dominates the local factors in the distribution. However, an analysis by Sale (1970) did not produce very positive results for the Lake District. In another attempt to apply the method trend surfaces for the 126 Class (i) and (ii) corries and for all the corries have been generated using the computor program by O'Leary et al. (1966). The results, unfortunately, only appear to confirm Sale's comment that ".. on the whole, trend surface analysis would appear not to be so suitable for studies of variations in cirque basin altitudes of small areas" (Sale, 1970, p.45). It is suspected that these difficulties may have arisen because of the possibility that the samples include several generations of corries initiated at various times during the Pleistocene.

(b) Distribution in plan. Locational relationships of the corries with their parent mountain masses in the west-central Lake District have been discussed by Temple (1965). However, in considering the Lake District as a whole (Fig.1), some complications have emerged. Firstly, self contained mountain masses are not always easy to define. Secondly, the correct location of a centre from which to measure corrie position becomes very problematical if the mountain mass is irregularly shaped. Thirdly, the significance of the distribution is less for a range than for a more or less circular mountain group, a point illustrated by Sale's remark, "The more north-south trend in the mountains of the Lake District and Scotland's Southern Uplands produced a maximum of basins with an easterly orientation." (Sale, 1970, p.93). For example, the presence of the excellently demarcated corrie at Wolf Crags at the northern end

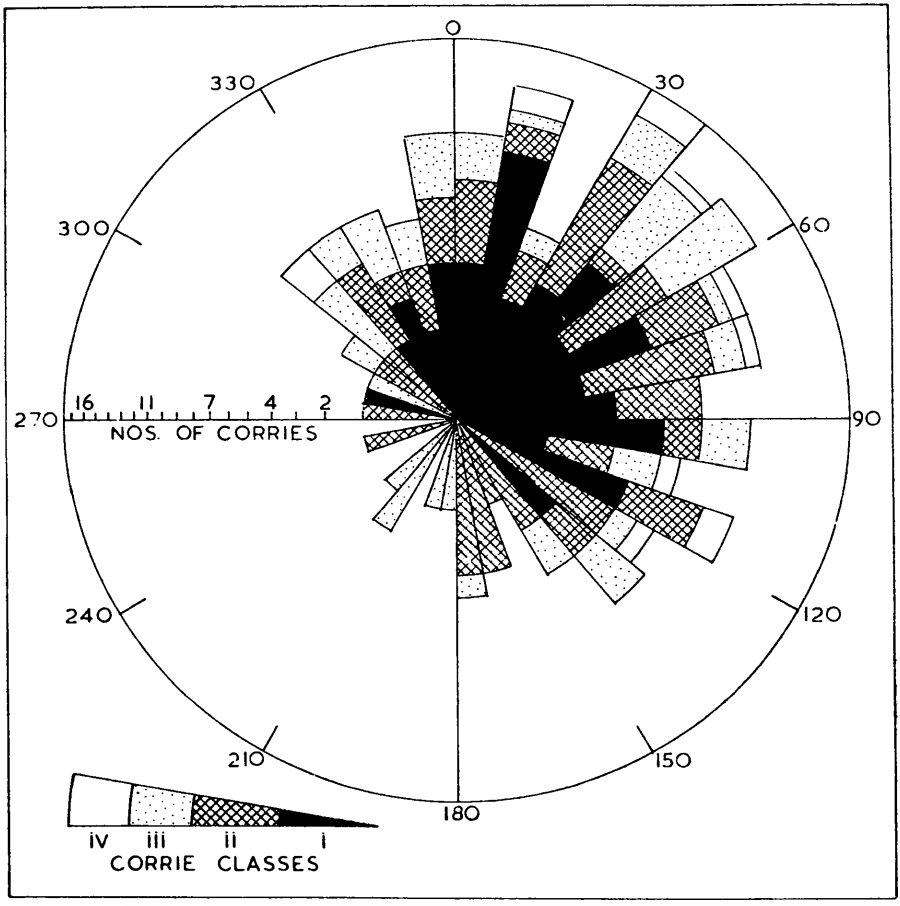


Fig. 7. — Rose-diagram of corrie aspects for corries of Classes (i), (ii), (iii) and (iv).

of the north-south aligned Helvellyn range suggests that more corries would have developed on its northern slopes had they extended along a broader front. The distribution of ranges such as those of Helvellyn and High Street merely shows that the eastern rather than the western flanks have been preferred for corrie formation. Fourthly, a mountain mass may contain within it a diversity of slopes of different aspect, many of which may offer potential corrie sites. For instance, in the Skiddaw-Blencathra group, which could be regarded as a virtually isolated mountain mass most of the corries lie towards or on its eastern margins, i.e. Swineside Comb, Bowscale Tarn corrie, Bannerdale and South Bannderdale combs, Foule Crag and Scales Tarn corries. However, Swineside Comb and Bowscale Tarn corrie lie on north facing slopes, while a corrie in the south-central part of the area is found on the north-eastern slopes of Lonscale Fell. Two more corries, Dead Crags and the rather degenerate feature of Little Calva Comb, are situated on north-facing slopes in the western part of the mass. Such a distribution is probably more realistically interpreted in terms of the aspects of the slopes into which the corries have been cut, although, as Manley (1959) has shown, the location of related drifted snow source areas is another important factor to consider.

(d) Corrie aspect and corrie associations. Measurements of aspect indicate that rather more than half the corries face the north-east quadrant and that these include well over half the corries of Classes (i) and (ii) (Fig. 7). The distribution is similar to that given by Temple (1965) for the west-central Lake District, except for a relative gain (+6.5%) in the south-east quadrant at the expense of the north-west (-4.0%) and south-west (-2.5%) quadrants (Table 3). These differences again probably result chiefly from the effects of the marked north-south grain of the mountains in the eastern part of the area.

Table 3. Percentages and numbers (in brackets) of corries facing each quadrant. *Data for the west-central area from Temple (1965).

Quadrant/ aspect	*West central Lake District	Corrie classes				All Classes
		(i)	(ii)	(iii)	(iv)	
N.E.	52.0 (38)	63.0 (34)	50.0 (36)	41.7 (25)	66.6 (8)	52.0 (103)
S.E.	19.2 (14)	22.2 (12)	31.9 (23)	23.3 (14)	16.7 (2)	25.7 (51)
N.W.	23.3 (17)	14.8 (8)	16.7 (12)	26.7 (16)	16.7 (2)	19.3 (38)
S.W.	5.5 (4)	0.0 (0)	1.4 (1)	8.3 (5)	0.0 (0)	3.0 (6)
Total No.	73	54	72	60	12	198

At this point it is desirable to consider the corries in terms of their mutual locational associations rather than simply as more or less clearly defined features.

Four types of corrie association have been noted in the Lake District:-

1. Discrete where the form is completely isolated from other corries, e.g. High Hole.

2 Composite where one or more secondary corries have modified the headwall slopes of a larger (primary) corrie, e.g. Bleaberry Tarn corrie (primary) with High Stile Comb, Chapel Crags Cove and White Pike Comb (secondaries).

3 Merged where adjacent corries have coalesced to form a lateral sequence of embayments, e.g. the corrie complex below the Crinkle Crags ridge that includes Green Hole, Buscoe Sike and Great Cove.

4 Nested where adjacent corries are set in a rising or step-like sequence. This type is both rarer and harder to define that the others, but the most convincing is the combination of Boulder Valley (lower) and Low Water (upper) corries on Coniston Old Man. (Marr (1915) described a sequence of four cliffs and flats here, but the writer can distinguish only two in true down-valley sequence.)

Comparison of resultant vectors for the mean quadrant/aspects of each of these groups, and their subsidiary features, raises two interesting points (Table 4). Firstly, the resultant vectors in the composite group show a 31° swing from 056° in the primary corries northwards to 025° in the secondary corries. Secondly, the merged corries, which contained relatively large glaciers at some period of their development, have a stronger easterly component in their resultant vectors than the discrete group, which contains many of the smaller corries. The differences are consistent with the concept of at least two phases of glaciation, one more intense than the other. The former tended to have been associated with larger basins and more easterly aspects, the latter with smaller basins, e.g. the secondary corries, and more northerly aspects. Work on corrie terrains currently in progress may shed more light on the validity of this hypothesis by enabling comparisons to be made between the aspects of the main corries and those of contained subsidiary basins occupied by underfit glaciers.

Table 4. Lakeland corrie aspects expressed as vectors

	Resultant vector	Vector strength	No. of corries	Landform type
Sale (1970) *	061°	28.0%	104	corries
Spencer (1959) *	051°	49.0%	67	corries
Temple (1965)**	040°	46.8%	73	corries
Whitaker (1973) *	049°	50.0%	102	corrie moraines
Clough (1974)	049°	52.7%	129	discrete corries
	056°	56.5%	17	main (primary) } composite corries
	025°	75.5%	23	secondary } composite corries
	076°	95.0%	18	embayments } merged corries
	080°	92.9%	7	mean of complex } merged corries
	076°	90.0%	5	upper } nested corries +
	070°	86.0%	5	lower } nested corries +
	047°	71.3%	54	Class (i) corries
	064°	51.1%	72	Class (ii) corries
	043°	43.8%	60	Class (iii) corries
	040°	68.4%	12	Class (iv) corries
	051°	54.67%	198	All corries

* As calculated by Evans and Cox (1974)
** As calculated by Evans (1969)
\+ One corrie excluded owing to uncertain classification

IV. TERRAIN TYPES

Embleton and King (1968) suggested that intensive study of corries now vacated by ice may contribute to the understanding of corrie origins. Appreciation of the nature and distribution of corrie terrain types offers a useful approach not only to this particular problem but also to the reconstruction of subsequent corrie evolution. A suggested classification of terrain types is presented in Table 5, and the terrain distribution is commonly as shown in Fig. 8.

Table 5. Classification of terrains typically found in the Lake District corries.

Corrie zones	Sub-zones	Terrain types	Typical subsidiary landforms
HEADWALL ZONE	HEADWALL SLOPES	Continuous crag Discontinuous crag Broken crag	crag elements, e.g. walls, arêtes etc.
		Talus slopes	scree, clitter, channels
		Vegetated slopes	dry and wet channels, earth scars, solifluction features, vegetated talus
	FOOT SLOPES	Fallen block zones	concentrated and dispersed boulders
		Talus slopes	scree, clitter, channels
		Vegetated slopes	dry and wet channels, earth scars, solifluction features, vegetated talus, ice-marginal features
BASIN ZONE	AREAS OF IMPEDED DRAINAGE	Tarns	water surfaces, deltas, beaches, mudflats
		Marshy tracts	water surfaces, vegetated surfaces, peat haggs, wet channels
	FREELY DRAINED AREAS	Firm vegetated tracts	dry and wet channels, mounds, ridges, hollows, rock blocks, peat haggs
		Rocky tracts	dry and wet channels, roches moutonnées, erratics
		Loose debris tracts	boulder accumulations
THRESHOLD ZONE	INNER (REVERSED) SLOPES	Rocky tracts	talus, discontinuous crags, erratics, channels
		Vegetated slopes	dry and wet channels, earth scars, terracettes
	CRESTS	Rocky tracts	rocky bosses, cols, rock debris
		Vegetated tracts	mounds, ridges, hollows, wet and dry channels
	OUTER SLOPES	Rocky tracts	talus, discontinuous crags, rock debris, channels
		Vegetated tracts	channels, earth scars, terracettes, talus

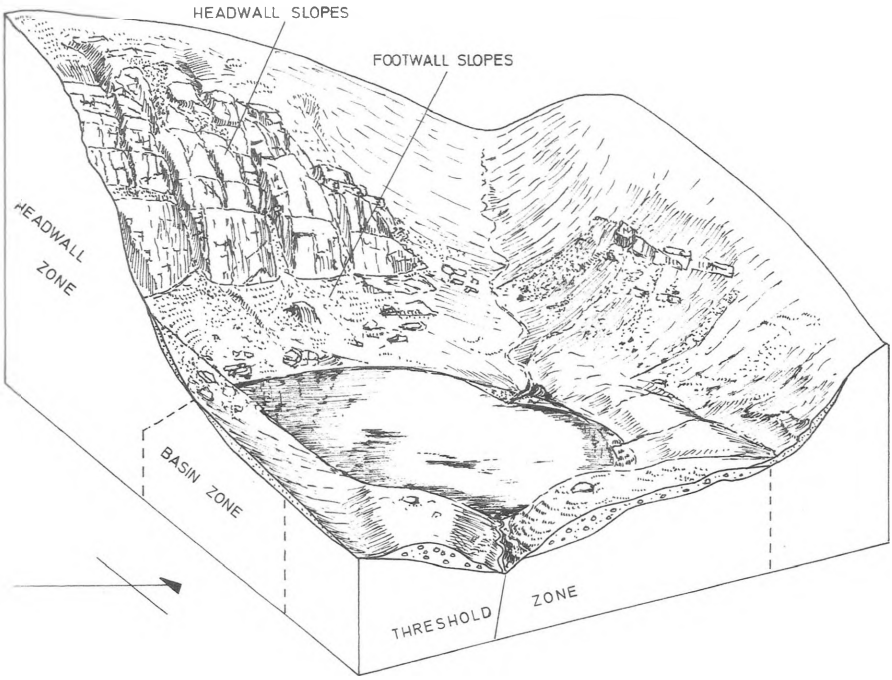


Fig. 8. — Block-diagram to show a typical distribution of terrain types in a Lake District corrie.

The most significant points about the distribution appear to be that,

(1) Headwall crags tend to occupy only part of the headwall slopes,

(2) The main headwall crags tend to be located one side or the other of the basin centreline,

(3) The headwall slopes often show a marked nick or col,

(4) The exit stream is not infrequently aligned with such a weakness in the headwall slopes,

(5) Slopes away from the main headwall crag zone often feature degenerate crags with much scree and other debris, which, although more or less vegetated, is present in quantities often apparently greater than below the main headwall crags themselves.

It is difficult to explain this type of terrain distribution without (a) considering the rôle of structure in corrie initiation and (b) examining subsequent morphological development both in terms of possible polyglacialism and also giving regard to the rôle of contemporaneous non-glacial processes.

V. CORRIE INITIATION AND EVOLUTION

Many corries in the west-central Lake District are known to be situated on lines and zones of structural weakness (Temple, 1965). If faulting is acceptable as an indicator of 'structural weakness', then this seems to be true of a high proportion of corries elsewhere in the area (Clough, 1974). In a preliminary investigation of 44 corries, despite considerable variations in the angles of divergence between known faults and centreline trends, it seems that longitudinal faults (angle of divergence less than $22\frac{1}{2}^{o}$), e.g. Blea Cove, Small Water and Scales Tarn corries, and transverse faults (angle of divergence between $67\frac{1}{2}^{o}$ and 90^{o}), e.g. at Easdale Tarn, Blindtarn Moss and Bowscale Tarn corries, are the most common (Fig. 9). In addition to such cases there are numerous examples where the presence of faults may be suspected from topographical indications. For instance, alignment of slacks and headwall cols with tolerably straight stream courses may be tentatively attributed to structural factors, provided there is accordance with a known local pattern of structural trends, e.g. in the Helvellyn area (Fig. 10). This suggestion, however, cannot be vindicated until more detailed information on the structures is available.

Accepting that many of the corries are associated with geologically favoured zones, it has been further suggested that since the major corries enclose significant minor streams, the streams, or at least their ancestors, were there before the corries

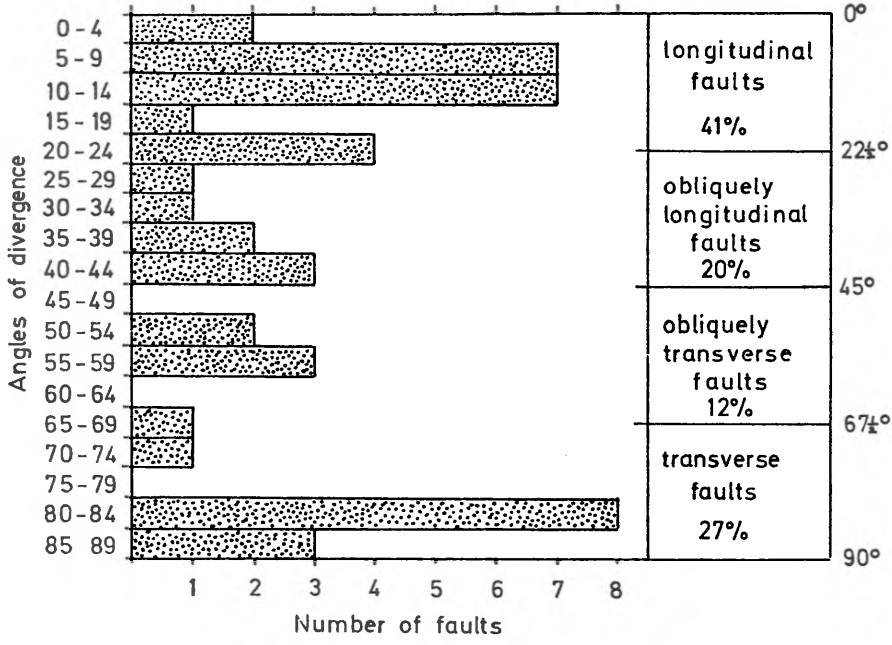


Fig. 9. — Numbers of faults compared to angles of divergence between fault and centreline trends, based on 44 corries, two of which contain two faults.

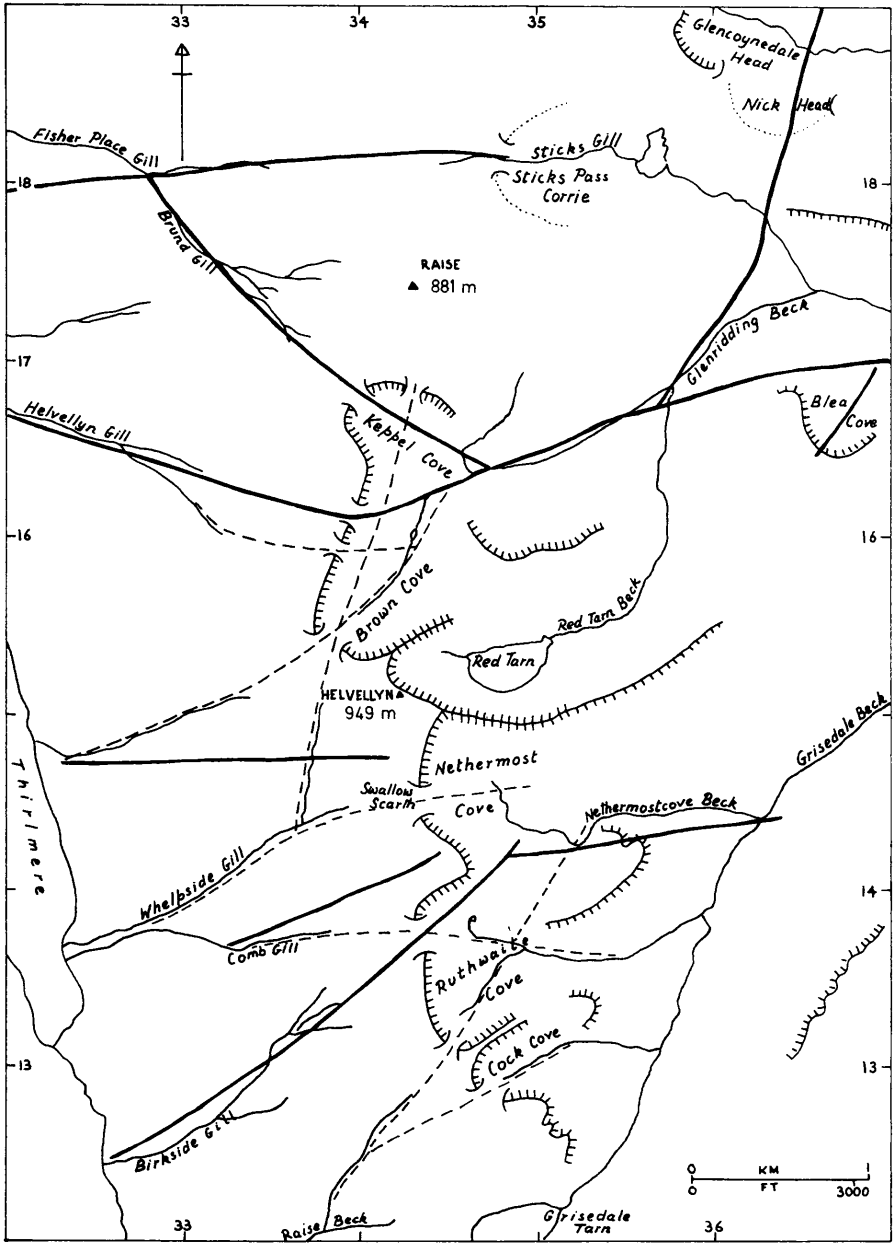


Fig. 10. — Established faults (full lines), after Hartley (1941), and suggested faults (dashed lines), based on topographical inference.

(Garwood, 1910, Temple, 1965). Indeed it is tempting to interpret headwall cols as relics of preglacial water courses, later to be abandoned following corrie encroachment. This would have caused lowering of the water table and a reduction in the areas of upland surfaces contributing run-off. Whether the headwall cols are inherited features or not, there is little doubt that far more Lake District valleys are accordant with structure than was once supposed, e.g. every valley mapped by Moseley (1960) south-east of Ullswater is closely related to a fault-line.

If the corries were mostly initiated in the upper parts of such structurally controlled river valleys, they probably developed where confluent tributaries had created suitable snow accumulation sites. On the other hand, Linton (1963, p.17) claimed that "By no means all corries arise from the enlargement of pre-existing valley heads", and (p.18), "Fully fashioned corries may develop on suitable hillslopes even though these are almost unindented by anything deserving the name valley." Corries of this type certainly occur in the Lake District and seem to be associated with structures conducive to localised glacial incision, e.g. High Hole and Blea Cove, where the cleavage dips steeply inwards. In other cases the length of lateral pre-glacial stream valleys could have been reduced by widening in their trunk valleys, e.g. the corries on the south-west side of the Buttermere-Crummock Water trough, to result in features apparently unrelated to "anything deserving the name valley". There appears, therefore, to be no need to abandon the hypothesis that, apart from a few exceptions, corrie location can usually be interpreted in terms of a pre-glacial drainage pattern, itself reflective of the structural framework.

The evidence of the centreline profiles, as previously summarised, indicates that the majority of the corries developed towards larger open forms, although a minority became overdeepened. Linton (1963) suggested that after initial deepening corries tend to enlarge laterally. However, as the size range of open types is substantial and since both small and large overdeepened corries occur, e.g. at Codale Tarn and Stickle Tarn respectively, it may be that early morphological tendencies were essentially maintained as the corries enlarged. As Haynes (1968) has demonstrated with reference to the Scottish corries, different types of form may be attributable to structural influences. However, confirmation of this principle in the Lake District is hampered by concealment of rock basins, sometimes by tarns and more generally by peat and other deposits, so that the structure has to be inferred from outcrops on the peripheral slopes. Despite this difficulty the indications are that structure has played an equally significant rôle in the area.

The relatively low incidence of overdeepening probably results from special structural circumstances. In the Bowfell-Langdale

fells area, overdeepened basins are found at Angle Tarn, Stickle Tarn, Easedale Tarn, Codale Tarn and Blindtarn Moss. An inwards or transverse dip can be deduced from inspection of the headwall crags in all these examples, except at Angle Tarn. Here high angle joints are exceptionally well developed with one set dipping inwards at about 70°. These combined with low angle joints dipping outwards at about 20° appear to have promoted excavation by joint block removal. This corrie well illustrates Linton's observation that "The Borrowdale Volcanics....furnish an obvious example of the quarrying of large blocks from a massive rock" (Linton, 1963, p.2). Further, several of the more deeply incised basins feature intersecting faults, e.g. at Scales Tarn, Stickle Tarn and Angle Tarn, or single faults transverse to the centreline, e.g. at Easedale Tarn and Blindtarn Moss. At Bowscales Tarn, in the Skiddaw-Blencathra group, a transverse fault exists, but the dominant structure is a plunging anticline (Eastwood et al.,1968), which may have facilitated overdeepening through erosion along its crest. Although the circumstantial evidence suggests a correlation between overdeepening and transverse faulting, the formation of the basin as a whole cannot be ascribed to the presence of a single linear structure. In all the examples cited the faults lie well away from the foot of the headwall, so that even if they did encourage a particular style of glacial erosion, their influence must have quickly diminished. Alternatively the view could be taken that as the majority of the transverse faults are strike faults, their presence is both to be expected and is completely irrelevant and that the most important factor is the dip of the bedding, jointing or cleavage.

The most satisfactory explanation seems to be that appropriate conditions for overdeepening are created by a combination of structural circumstances, as at Angle Tarn or at Scales Tarn. At the latter corrie the Skiddaw Slates are closely jointed, cleaved and affected by a series of faults which extend southwards from Sharp Edge well into the basin, in addition to a well marked fault which runs longitudinally through the corrie parallel to the centreline.

As corrie growth continued the various types of association evolved to give large merged features through coalescence following at least partial destruction of the inter-corrie arêtes, or substantial enough slopes for secondary corries to form, resulting in the composite types. Terrain distribution in the larger corries, including subsidiary hollows with their associated moraines, indicates that many of them were only partially occupied at a late stage. A good instance is seen in Bannerdale, where Eastwood et al.(1968,p.231) assign the "crescentic triple ridge of moraine" to the late glacial period.

That the terrain types tend not to be bisymmetrically distributed and that the secondary corrie centrelines are at variance with

their respective primary corrie centrelines suggest that when secondary corries were being formed climatic factors exerted a more subtle control over the location of ice masses. This accords with Ahlmann's (1948) axiom that the smaller glaciers become, the more they react to 'disadvantageous' climatic conditions. It may also explain the relatively strong northern component in the aspect vectors of the secondary corries. This interpretation is supported by the contiguity of relatively freshly glaciated zones with zones characterised by landforms associated with periglacial environments, e.g. extensive scree and clitter related to the breakdown of older headwall crags, as occurs on the south-east facing slopes of Small Water corrie, and soliflucted terrains, such as those so well developed on the north-west facing slopes of Black Brow corrie.

It is not proposed in this paper to discuss post-glacial modifications to the corries except to mention that the general configuration of the corries appears to have been little altered since the late-glacial phase. Moraines are still recognisable as such; the thresholds have rarely been deeply incised by exit streams; most erratics show but superficial signs of weathering and rock headwalls retain their steepness, particularly in the Borrowdale Series. Some exceptions are found, for instance at Little Calva Comb, where the slopes are thickly mantled with debris and only vestigial crags remain. As Eastwood et al. (1968) have remarked, it is difficult here to envisage occupancy by a late-glacial glacier. In other cases flat marshy tracts may indicate complete silting up of former tarns, e.g. at Blindtarn Moss and Blea Crag corries.

VI. CONCLUSION

Reconstruction of the initiation and evolution of the Lake District corries must accomodate the variations revealed by analysis of centreline profiles, plan shapes and aspect. When combined with studies of the geology and terrain types and by adopting a similar line of reasoning to that used by Sugden (1969) with reference to the Cairngorms, the following sequence of events seems reasonable:

1. Etching out of structural lines of weakness by pre-glacial streams to create potential corrie sites.
2. Occupation, through climatic selection, of actual corrie sites.
3. Enlargement of corries, leading ultimately to coalescence in some cases.
4. Formation of secondary and smaller discrete corries.
5. Late stage partial occupancy of higher large corries and more complete occupancy of climatically favoured higher

secondary and small discrete corries.

6. Post-glacial modification.

Appreciation of structural attributes therefore seems to be fundamental to the understanding of potential corrie location and of the development of less common forms, such as overdeepened corrie basins. The climatic factor appears to be of relatively greater significance to the actual location of corrie glaciers, variations in aspects between large and small corries and the asymmetrical distribution of terrain types within the corries.

Continuation of terrain mapping and detailed investigations of corrie fills, including the application of absolute dating methods, are probably the most hopeful methods of approach towards the deciphering of the details of corrie development. However, the solution to the problem of fitting the various stages of evolution into a Pleistocene chronology remains tantalisingly elusive.

VII. ACKNOWLEDGEMENTS

The author is extremely grateful to Mr.C.E.Everard and to Dr. Murray Gray for their supervision. He is also indebted to Dr.I.S. Evans both for encouraging the production of this paper and for helpful criticism in the process.

VIII. MAP REFERENCES OF PLACES MENTIONED IN THE TEXT

Angle Tarn	NY 246077	Gillercomb	NY 224117
Bannerdale	NY 340295	Great Cove	NY 252047
Black Brow	NY 386104	Greenburn Bottom	NY 315106
Black Combe	SD 135855	Green Hole	NY 258055
Bleaberry Tarn	NY 167155	Helvellyn	NY 342152
Blea Cove	NY 367167	High Hole	NY 200171
Blea Crag	NY 301081	High Stile Comb	NY 168150
Blea Water	NY 448108	High Street	NY 441112
Blencathra	NY 324277	Keppel Cove	NY 342167
Blindtarn Moss	NY 316079	Langdale Comb	NY 262085
Boulder Valley	SD 280985	Little Calva Comb	NY 278323
Bowscale Tarn	NY 357314	Lonscale Fell	NY 285272
Brown Cove	NY 342157	Low Water	SD 275984
Bull Crag	NY 270130	Nethermost Cove	NY 348145
Buscoe Sike	NY 253061	Scales Tarn	NY 329281
Chapel Crags Cove	NY 166150	Sharp Edge	NY 327283
Codale Tarn	NY 296087	Skiddaw	NY 261291
Comb Head	NY 251114	Small Water	NY 456100
Coniston Old Man	SD 273978	S.Bannerdale Comb	NY 342289
Crinkle Crags	NY 250051	Stickle Tarn	NY 288077
Dead Crags	NY 269312	Stone Cove	NY 212107
Earing Crag	NY 258064	Swineside Comb	NY 333322
Easedale Tarn	NY 308087	White Pike Comb	NY 163152
Foule Crag	NY 325284	Wolf Crags	NY 356225

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STRATIFIED SCREES IN THE NORTHERN LAKE DISTRICT.

J. Boardman

(Short Communication)

Stratified screes or grèze litées are formed by the transport and deposition of rockfall by running water. Their characteristics are governed by the amount of material available and the effectiveness of the channel or sheet flow. Typically these deposits are composed of angular, usually pebble-size rock chips and interstitial finer material (Washburn, 1973), and in some areas they are rythmically bedded with alternating fine and coarse beds (Dylik, 1960). Stratified scree deposits have been described in many parts of the world, especially Poland and France, and have also been recorded in Central Wales (Watson, 1965).

During the construction of the Keswick Northern Bypass across the southern face of Latrigg (Fig.1) deposits of stratified scree were exposed, and recorded in borehole logs. This paper gives a brief record of these deposits, and discusses their significance in terms of the origin and age of the scree deposits which characterize the slopes of much of the English Lake District.

Latrigg is a glaciated hill composed of indurated and cleaved mudstones of the Skiddaw Group (Ordovician) buried on the lower slopes by till drumlins. Exposures and boreholes show that the scree deposits comprise an upper and a lower bed made up largely of mudstone clasts. The upper bed is generally less than 1m. in thickness and the total depth of the screes in places exceeds 12m. Particle size analysis (Table 1) shows that the upper bed contains a high proportion of fine interstitial material, and the lower bed is mainly gravel-size mudstone clasts.

Table 1. Particle size analysis of samples from the stratified screes of Latrigg.

	Sediment analysis			
	Sample weight (Kg.)	% gravel	% sand	% silt & clay
Upper bed	4.2	52.5	42.8	4.7
Lower bed	3.6	86.8	10.8	2.4

Table 2. Particle shape analysis. Latrigg samples compared with stratified scree in Central Wales (Central Welsh data from Potts, 1972).

	Measurement of shape		
	Latrigg Lower bed	Latrigg Upper bed	Central Wales Stratified scree
No. of specimens	100	100	80
Ratio of thickness to major axis	0.259	0.221	0.144
Ratio of thickness to minor axis	0.441	0.352	0.231

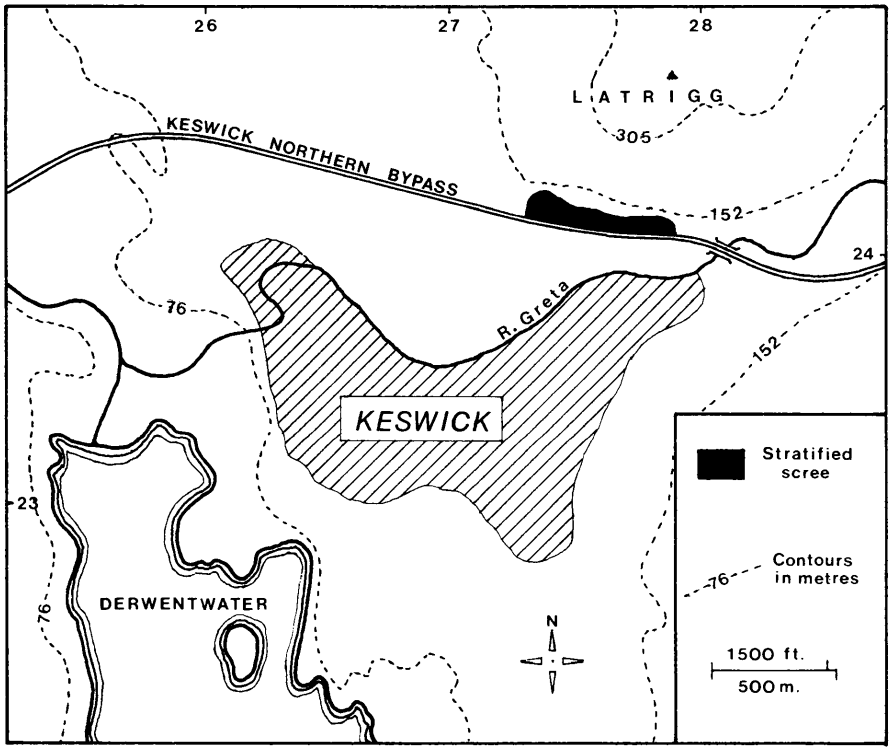


Figure 1. The Keswick area: to show the location of the stratified screes.

Analysis of particle shape (clasts greater than 1 cm. in length), indicates little difference between the upper and lower beds but the Latrigg samples differ considerably from the lithologically similar samples from the stratified screes of Central Wales (Potts, 1972). (See Table 2).

Tentatively it may be suggested that the intensity of frost action, which it is assumed produced the original rockfall deposit, was greater in Central Wales than in the Northern Lake District. The fabric of the lower bed shows that the majority of the particles had a pronounced up-slope dip with respect to the plane of deposition. This imbricate structure is typical of deposition by flowing water.

The full areal extent of the stratified screes of Latrigg is not known. The borehole data shows that they are absent south of the by-pass, i.e. below 117m.O.D. (Fig.1). Up slope a coarse talus deposit is present at the surface. This may represent the relatively unweathered rockfall from which the stratified scree material was partially derived. Fig. 2 illustrates the possible relationship of the slope deposits on Latrigg.

The processes envisaged in the formation of the stratified scree involve climatic control. Seasonal melting of snow in a periglacial environment will provide a source of water which is able to flow over normally porous scree slopes. Howarth and Bones (1972) report that in a High Arctic environment during the short summer period, meltwater is a particularly effective agent where the permafrost table is at or near the surface of the talus slopes. From the evidence available it seems probable that the stratified screes of Latrigg were formed in a period of periglacial climate with considerable amounts of water available from snow-melt. The distance of transport is not great, being in the order of hundreds of metres.

The stratified scree rests on till. In the northern Lake District this extensive till forms drumlins and is thought to be Late Devensian in age: 17,000 years B.P. $\pm$ 3,000 (Evans and Arthurton, 1973). Since the stratified screes overlie the drumlinoid till they must therefore post-date the Late Devensian glacial period.

After the glacial maximum and the retreat of the glaciers from most of the British Isles, the climate deteriorated to a period of severity known as the Younger Dryas or the Late Devensian stadial which lasted from 11,000 to 10,000 years B.P. Cooper et al. (1971) have suggested that the temperature in this period fell to just below 10°C July mean in lowland England. In the Lake District a well-documented readvance of corrie glaciers took place (Manley, 1959), and involutions in head deposits were formed (Johnson,1975). In other parts of the British Isles at the same time periglacial activity resulted in extensive changes in the landscape, e.g.

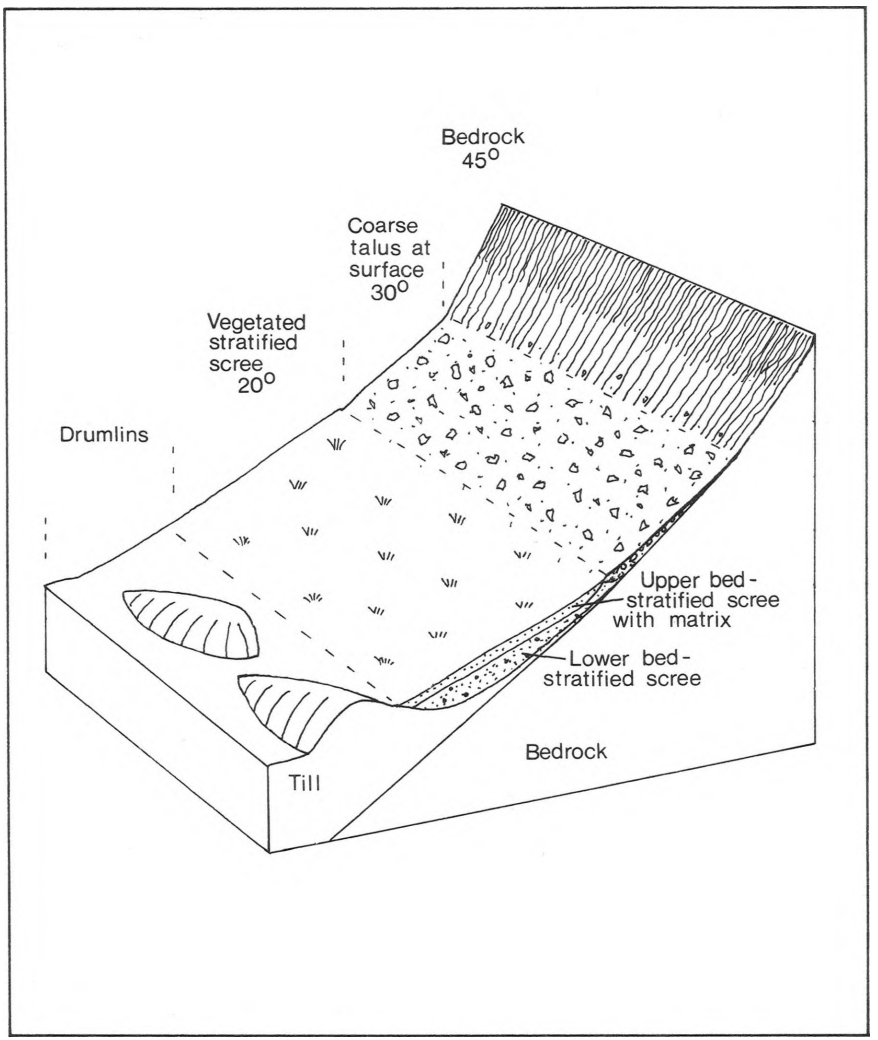


Figure 2. Diagrammatic relationship between slope deposits and till at the foot of Latrigg. Characteristic slope angles are given.

Rowlands and Shotton (1971); Kerney et al. (1964). In each case great amounts of frost-weathered material were moved by high snow-melt discharges. There is no reason why the Lake District should have deviated from this widespread pattern and the stratified screes of Latrigg are considered to be the result of these same intense periglacial processes operating in a lithologically ideal environment of thinly-cleaved mudstones, over the short period of time between 11,000 and 10,000 years B.P.

It is suggested therefore that the stratified scree development combined with the deposition of cross valley and corrie moraines to make Younger Dryas time a period of considerable landscape change. It is probable that many of the Lake District's non-stratified screes were also formed at this time, especially those whose vegetated character bears witness to their non-active state under present day climatic conditions.

The author wishes to acknowledge the many helpful suggestions made by Mr. J. Rose during the preparation of this article.

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THE ROSTHWAITE MORAINES

P. Wilson

1. INTRODUCTION

The well-preserved terminal moraines at Rosthwaite in Borrowdale have been described by both Raistrick (1925) and Hay (1944). In more recent years Millward and Robinson (1972, 1974) have contributed to the literature. However, general agreement concerning both the number and position of the moraines is lacking. This lack of consensus, along with a suggested age for the moraines by Johnson (1971) and Johnson et al. (1972) prompted the author into this re-examination of the features described. Although their age is not questioned the position regarding moraine morphology needs clarifying.

Raistrick states that the Rosthwaite moraines "form a group of three concentric moraines encircling the mouth of the Stonethwaite valley". He terms them "the outermost or western, the middle, and the inner or eastern moraine", and produces a section across the valley showing their relation to one another (Fig. 1). He also shows them diagramatically on a small scale map as being concave towards the Stonethwaite valley.

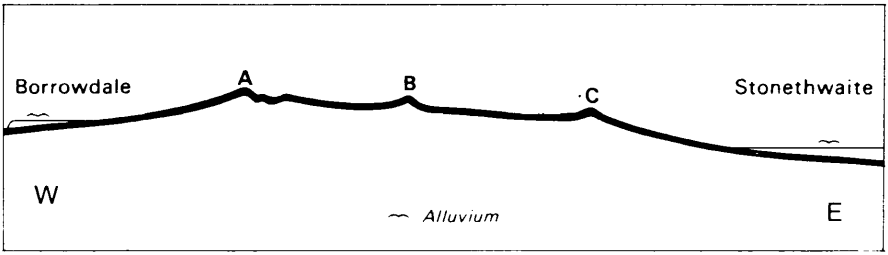


Figure 1. Section across the Rosthwaite moraines (after Raistrick, 1925).

On the other hand Hay refers to "two nearly complete terminal moraines" at Rosthwaite. He goes on to state that "they mark the ends of the Seathwaite and Stonethwaite glaciers". His diagram clearly shows that one moraine is concave towards the Seathwaite valley while the other is concave towards the Stonethwaite valley (Fig. 2).

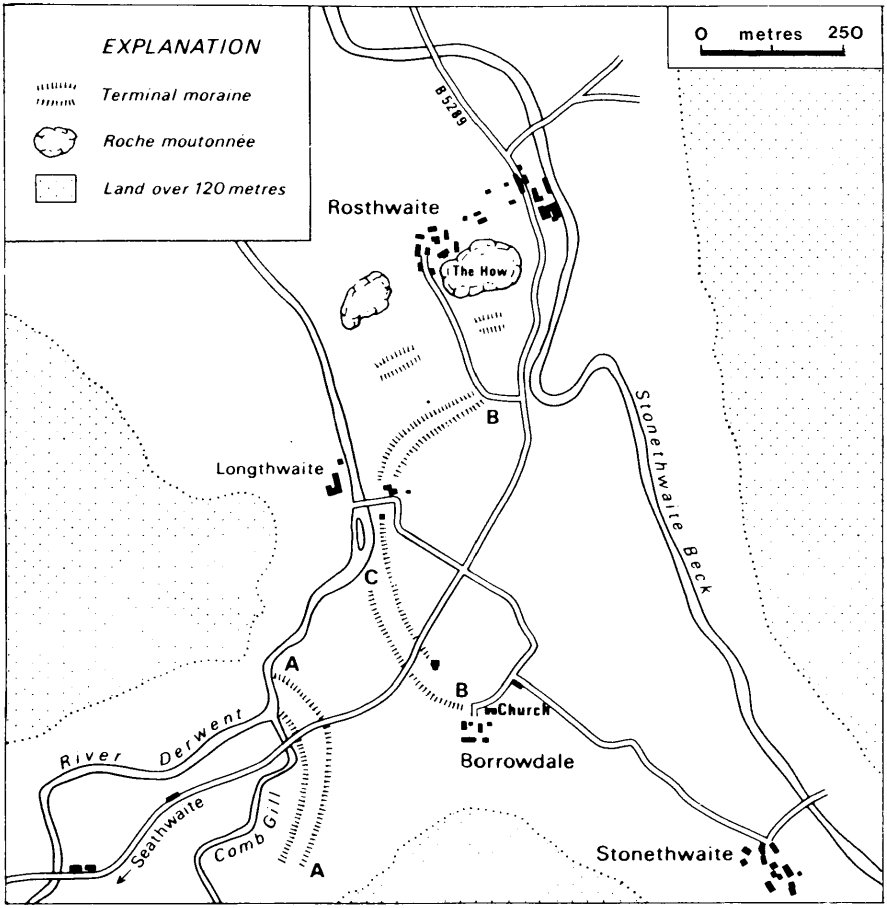


Figure 2. The Rosthwaite moraines (after Hay, 1944).

Millward and Robinson appear to favour the picture portrayed by Hay of terminal moraines for both valleys. These features are described as "a series of recessional moraines.....south of Rosthwaite village". A further description makes no mention of the source valley(s) although it implies that these moraines mark the limit of the Stonethwaite glacier. A view that is somewhat inconsistent with the diagram (Fig. 3).

During the summer of 1976 the present author visited the locality and the results of his field observations on the disposition of the moraines is shown in Fig. 4.

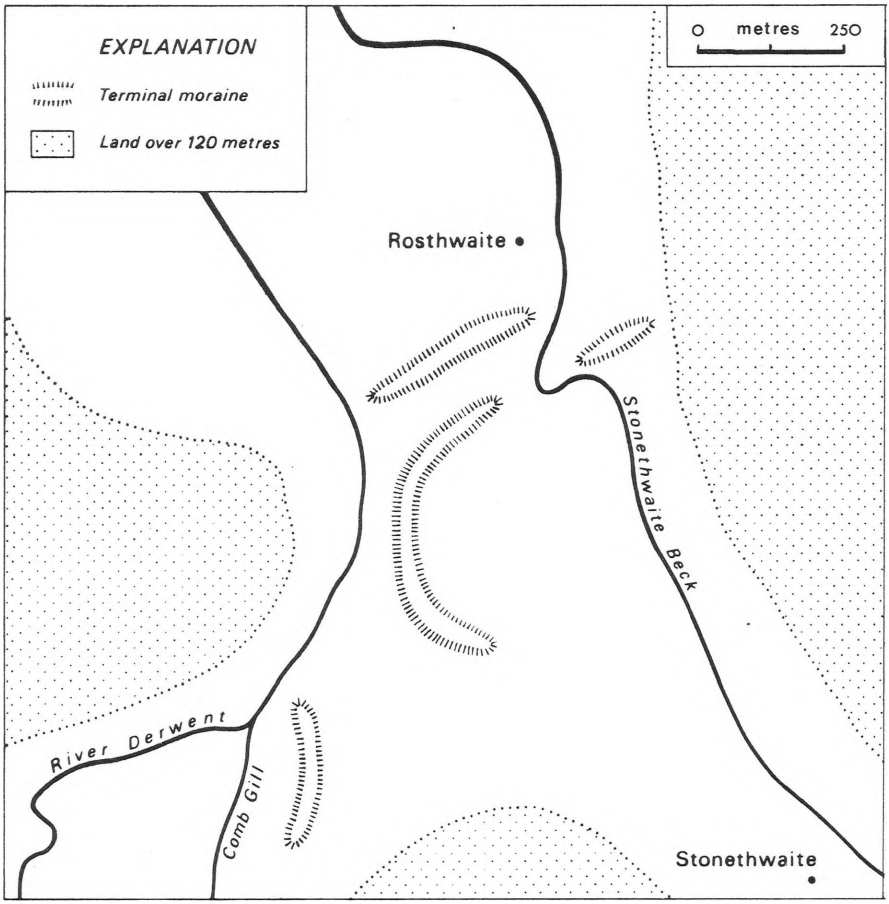


Figure 3. The Rosthwaite moraines (after Millward & Robinson, 1972)

2. FIELD OBSERVATIONS

The Rosthwaite moraines (Fig. 4) do in fact form a group of three concentric moraines concave towards the Stonethwaite valley and not as shown by Hay and by Millward and Robinson. In view of this the terminology used by Raistrick to identify the moraines is retained in the following description.

(a) The Outermost or Western moraine

It is this moraine that has been the chief source of confusion in the literature. Raistrick claims that it is convex towards the

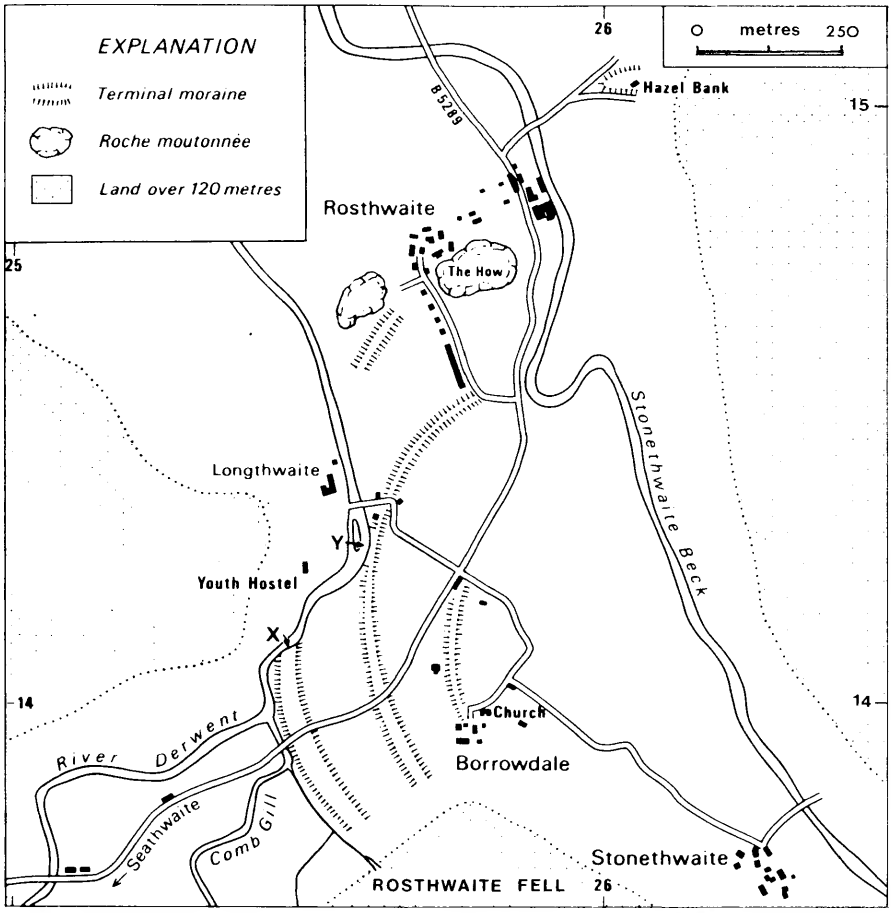


Figure 4. The Rosthwaite moraines

Seathwaite valley whereas Hay clearly shows it to be concave to that valley and terms it the Seathwaite moraine (AA Fig.2). Millward and Robinson appear to share the same view as Hay (Fig.3). The author's field observations support the findings of Raistrick.

The moraine itself starts as a prominent ridge at the north-west corner of Rosthwaite Fell (Fig.4 Grid Ref. NY 2558.1379) and runs north-north-west to north across the valley. It is partially covered by a small larch plantation as far as the main road cutting beyond which a fine exposure is revealed on the east bank of the River Derwent. As far as this latter point the moraine is described by Raistrick as being a wide hummocky ridge, while Hay

claims that the moraine is a double belt. Both authors agree, however, that there is some ground within this moraine that was formerly occupied by a swamp or pool. The claim by Raistrick that this moraine is convex towards the Seathwaite valley is substantiated by viewing from the slopes of Rosthwaite Fell and also by a study of air photographs (Lewis and Walton, 1970). Stereo pairs indicate that the moraine is convex to the south-west. Further evidence is provided by the small stream descending the hillside to join Comb Gill at Burthwaite Bridge. Its course has been determined by the moraine itself for it runs at the foot of its Seathwaite face. This small stream is convex towards the Seathwaite valley.

The exposure on the east bank of the River Derwent (Grid Ref. NY 2545.1407, Plate 1, and locality X in Fig. 4), was described by Raistrick as two boulder clays separated by current bedded sands. No mention has been made by either Hay or Millward and Robinson of this exposure.

The section must have changed somewhat since examined by Raistrick but much of what he said is still applicable and can be seen if visited. It extends for a distance of 50 metres and has a maximum height of 5 metres. A number of small landslips have reduced the height of the section and the base of the exposed material is now approximately 1 metre above water level. At the northern end of the exposure a great deal of the basal material has been obscured by slumping but the bedded sands are visible varying from 5 cms. to 50 cms. in thickness. Above these sands $2\frac{1}{2}$ metres of till can be seen. The central part of the exposure is that showing the maximum thickness of material. The sands can be traced into this area and are seen to overlie thin pebble beds. At the southern end of the exposure the bedded sands are found in an excellent state of preservation and reach 20 cms. in thickness. Thin pebble beds are seen both above and below the sands (Plate 2).

Evidence supporting the interpretation given to this section by Raistrick has been found by the present author. The distinctive intrusive rocks of Langstrath, comprising a coarse pink granophyre and a dark green quartz diabase of the Blea Crag complex, are found in abundance in the upper till but are lacking in the till beneath the bedded sands. Similar findings led Raistrick to conclude that the lower till was englacial and sub-glacial material deposited by Seathwaite ice, the sands representing outwash deposits during a retreat of the glacier, the upper till being deposited by ice from Stonethwaite during a readvance.

Raistrick also describes another exposure in this moraine on the opposite bank of the River Derwent approximately 100 metres downstream. The lower till is said to be covered by talus and beach material and the sands are reported to be thicker while the upper till is of the same thickness. The erratic content is stated

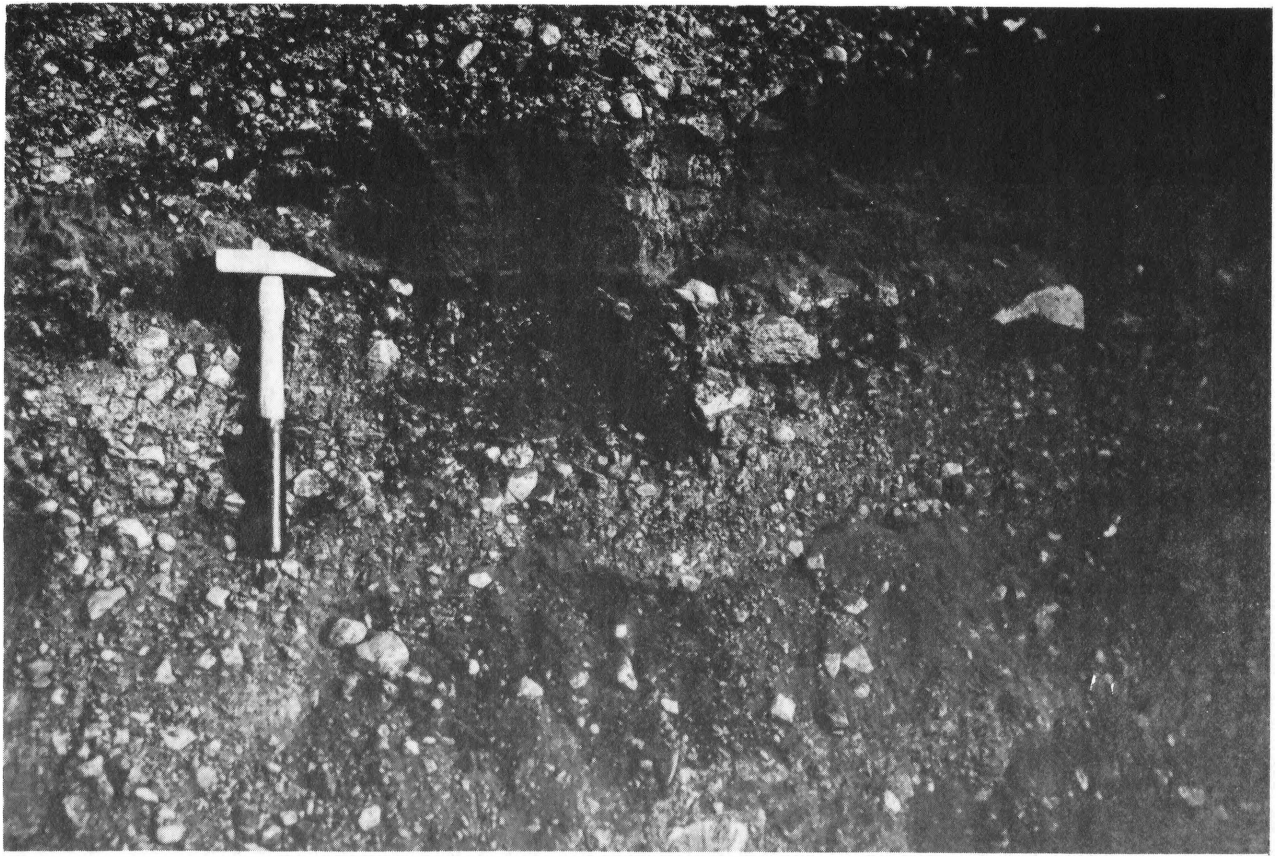


Plate 1. Exposure in the outermost or western moraine. Locality X in Fig. 4. (Grid ref: NY 2545 1407). Height of section approximately 5 metres.



Plate 2. The bedded sands in the outermost or western moraine. Locality X in Fig. 4. Scale 30 cms.

as being the same and apart from the thickness of the sands this section is like the first. This exposure is no longer visible, the construction of Longthwaite Youth Hostel in 1938 and the strengthening of the river bank with war-time concrete road blocks have removed all traces of this section.

The moraine reappears to the north of Longthwaite Farm on the east bank of the river where it runs in a north-easterly direction towards The How. This appears to correspond to the small parallel moraine-roll of Hay. This author shows two such moraine-rolls (Fig. 2), the smaller of which, immediately south of The How, can no longer be traced.

Two further exposures of till probably associated with the moraine occur where the main road squeezes between The How and Stonethwaite Beck. According to Raistrick the moraine is plastered against the south side of The How, thus the two exposures may be part of this moraine. In the main road cutting approximately 2 metres of till overlies the tuff forming The How (Grid Ref. NY 2587.1472). The second exposure is below road level on the west bank of Stonethwaite Beck; here approximately 1 metre of till is exposed (Grid Ref. NY 2592.1470).

To the east of Stonethwaite Beck the moraine is thought to occur in the grounds of Hazel Bank. The hotel is certainly built on a morainic mound but whether this belongs to the moraine under discussion is not clear. Raistrick found a similar assemblage of erratics at this site but exposures do not exist at present. In fact, the position regarding the moraines east of Stonethwaite Beck and north of the meander loop is rather confusing. Little mention of this area is made in the literature although moraines are figured here by Millward and Robinson who show a different arrangement on each of three diagrams. Raistrick mentions only the Hazel Bank moraine, while Hay does not describe any moraine in this territory. It appears to the author that apart from the Hazel Bank moraine the area in question is probably composed of morainic material cut by the stream to form a high terrace. Well-defined ridges that characterise the moraines to the west of Stonethwaite Beck are not in evidence here and it is therefore impossible to distinguish the exact position of any moraine by visual means.

(b) The Middle moraine

According to Raistrick this moraine is the most complete of the series and runs almost perfectly concentrically inside the outermost at a distance of 120 metres. This would appear to be the Stonethwaite moraine of Hay (BB Fig. 2) and is said to be similar to the Seathwaite moraine. Millward and Robinson agree with Hay regarding the position and form of this moraine (Fig. 3). Raistrick states that there are no visible exposures in this moraine whereas Hay indicates the presence of a partial breach at locality C (Fig. 2).

The moraine extends as a distinct ridge from the northern end of Rosthwaite Fell (Fig. 4 Grid Ref. NY 2567.1390). Beyond the main road cutting it assumes a more well-defined form and along the narrow crest runs the public footpath to Longthwaite. The north-western side of the ridge presents a steep drop of some 12 metres to river level whereas the drop on the south-eastern side to field level is only 4 metres. The partial breach mentioned by Hay is seen in this section as a dip of some 4 metres in the moraine crest bringing it down to field level for a short distance.

A fine exposure, (Grid Ref. NY 2562.1439), occurs just to the south of Longthwaite Bridge on the east bank of the River Derwent almost directly beneath the school-house. It is probable that this exposure post-dates the work of Raistrick and Hay thus accounting for the lack of its mention in their articles. Millward and Robinson do refer to the exposure briefly. The exposure (Plate 3, and locality Y, Fig. 4) extends for a distance of 35 metres with a maximum height above water level of 6 metres. This section is regarded by the author as one of the finest exposures of till in Central Lakeland. However, rapid erosion by the Derwent is continually taking place and undercutting has resulted in the basal notch visible in Plate 3.

Beyond the school-house the moraine swings away to the north-east and assumes a more subdued, although still well-defined, form to the stone built houses behind The How. The public footpath from Longthwaite to Rosthwaite skirts the moraine at this point.

(c) The Inner or Eastern moraine

The group of moraines is completed by the inner or eastern moraine which runs concentrically inside the middle moraine at a distance of 110 metres from it. While neither Hay nor Millward and Robinson have recorded its presence, Raistrick does describe it adequately.

Beginning at the northern end of Rosthwaite Fell (Fig. 4 Grid Ref. NY 2574.1396) the moraine assumes the form of a low bank as it runs through the camp site and vicarage garden in Borrowdale village to the Stonethwaite road junction. Here it forms a very marked feature rising above the valley floor. No exposures are visible in this moraine.

3. AGE CONSIDERATIONS

The precise age of the moraines is unknown. It has been suggested (Johnson, 1971, Johnson et al., 1972), that they could date from the time of the Perth Readvance 13,000 - 12,500 years B.P. This reasoning is based on the radio carbon date obtained from an organic layer at Blelham Bog near Ambleside, where ice-free conditions are known to have prevailed from circa 14,300 years B.P. (Pennington, 1969). The moraines mapped by Gresswell (1962) at



Plate 3. Exposure in the middle moraine. Locality Y in Fig 4. (Grid ref: NY 2562 1439). Height of section approximately 6 metres.

Nibthwaite, Haverthwaite, Church Town and Newby Bridge in the valleys of Southern Lakeland are thought to pre-date the Blelham Bog organic layer as they occupy positions to the south of this site. Ice in Borrowdale at this time would have extended much further down valley than Rosthwaite and it is unlikely that such well-preserved moraines could have survived being overrun by ice and therefore an earlier age for these features is doubted. The succeeding climatic deterioration that manifested itself in the Perth Readvance would thus seem to be a highly likely time for the formation of the Rosthwaite moraines.

4. CONCLUSIONS

Field evidence along with air photograph analysis indicates that Raistrick's interpretation of the Rosthwaite moraines is correct. He concludes that they form a group of three concentric moraines encircling the mouth of the Stonethwaite valley and that they were deposited during the retreat of the Stonethwaite glacier. The views of other authors that at Rosthwaite there are terminal moraines of both the Seathwaite and the Stonethwaite glaciers have been found to be untenable.

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AUTHORS OF MAIN ARTICLES IN THIS ISSUE

John Boardman, B.A., B.Sc.,
[redacted]

R.McKenzie Clough, B.Sc., M.Phil.,
[redacted]

F.Moseley, D.Sc., Ph.D.,
[redacted]

P.Wilson, B.Sc.,
[redacted]

EXCURSION NOTES

THE LOWER CARBONIFEROUS STRATIGRAPHICAL PALAEONTOLOGY OF FURNESS AND GRANGE*

Leader: Mr. Murray Mitchell, M.A.,F.G.S.

A weekend excursion. 27th - 29th June, 1975.

On Friday evening, 27th June, 1975, a small group of members and friends collected at the Sun Hotel, Ulverston, where Mr. Mitchell, a Principal Scientific Officer at the Leeds Office of the Institute of Geological Sciences, gave a brief outline of the weekend's programme.

On the following morning in bright sunshine an augmented group consisting of some 30 members and their friends congregated on the summit of Birkrigg Common (283.742) and feasted their eyes on the beautiful panoramic view of the Lake District mountains, stretching from the Skiddaw Slate inlier of Black Combe in the west, passing through the Borrowdale Volcanics of Coniston Old Man, Helvellyn and High Street and then further afield to the limestone country of Ingleton and Settle in the east. In contrast to the rugged peaks of the volcanic area, the rounded hills of the Carboniferous and Silurian rocks formed the features in the near and middle distance.

With some effort the members dragged their eyes away from this captivating scenery and settled down to concentrate on the structure of this part of the Furness Peninsula, which spread before them down in the valley. Mr. Mitchell explained that the Lower Carboniferous strata dipped in a south-easterly direction with a syncline running through the Gleaston-Urswick area, so that the Urswick Limestone cropped out on either side and the Gleaston Formation occupied the trough. The whole area is complicated by a series of northwest-southeast trending faults which are displaced at some points by east-west faulting.

Having familiarised themselves with the general structure of the area, the party visited a small quarry on the south side of Birkrigg Common (284.740) where an irregular bedding plane marks the junction between the S_2 Park Limestone and the pseudo-brecciated D_1 Urswick Limestone. Discussion followed on the genesis of the pseudo-brecciation, one current explanation being that its formation was due to the action of burrowing worms.

The procession of cars then wound its way through the country lanes to Stainton Quarries (249.727), where the pseudo-brecciation can be clearly seen about 2 metres above the quarry floor. The well-known horizon of the Woodbine Shale was also examined. Specimens of

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* A report of a lecture given to the Society by Mr. Mitchell on this subject will be found on page 178 of the previous issue of the Proceedings. (Vol.3., Part 3).

Davidsonina septosa and other fossils were eagerly collected in Devonshire quarry.

After parking the cars in front of the ruins of Gleaston Castle (261.714), the old Norman manor house of the de Fleming family, a small nearby quarry in the D_2 Gleaston Formation was visited; this horizon is considered to be the next main limestone above the one exposed at Humphrey Head (393.740). The very dark well-bedded limestones yielded excellent examples of Lonsdaleia which is one of the main D_2 fossil horizons in the N.W.Province; whilst in the shale partings samples of the brachiopods Rhipidomella, Spirifer bisulcatus and the coral Aulophyllum were obtained.

Following a restful lunch on the foreshore at Bardsea the party visited Plumpton Quarries (312.787) and near the railway line at Plumpton Junction stood on Silurian rocks and discussed the nature of the junction with the Carboniferous Limestone, which outcrops some 60 metres away. Mr. Mitchell explained that two boreholes in Plumpton quarries had reached Silurian strata at 54 metres and 83 metres respectively, and in his opinion the junction is an unconformity.

Having examined the upper beds of the Furness Lower Carboniferous during the morning, the rest of the afternoon was occupied by examining the top beds of the Red Hill Oolite and the bottom of the Dalton Beds in the first of the Plumpton Quarries (309.787). Here specimens of Delepinea (chonetes) carinata, Athyris, and Caninia cylindrica were collected. The second of the Plumpton Quarries (311.786) in higher Dalton Beds was entered by following the Plumpton haematite vein, the mining of which dates back to approximately 1220. Unfortunately this quarry is now used by Ulverston as a tip and it was not possible to pause and search for more fossils. The third of the Plumpton Quarries (314.784) is in the upper Dalton beds (the Gastropod beds of Garwood) and 5 metres from the top can be seen the junction of the overlying Park Limestone.

The first day was concluded with a walk along the foreshore of Plumpton Bight, where samples of Lithostrotion minus and the fasciculate Lithostrotion martini were collected from the Park Limestone.

Sunday, 29th June, 1975, proved to be another hot sunny day with the rendezvous at the car park at the north end of Old Park Wood, Holker, at 10.00 a.m. From here the party proceeded to High Frith Farm (337.806) where the cars were parked before the short walk to Skelwith Hill (332.808).

At this point the junction between the Martin Limestone and the Red Hill Oolite was examined. This is marked by a fine example of limestone breccia at the top of the Martin Limestone, indicating a regression of the sea before the return to clear water bioclastic limestone. At this point there was some discussion on the mechanics of dolomitisation and Mr. Mitchell expounded a theory suggested by Dr. W.H.C.Ramsbottom, whereby in the case of primary dolomitisation, a relatively open sea providing bioclastic limestones becomes restricted to form a lagoon. Under the hot climatic conditions evaporation takes place and the salts become concentrated, so that the substitution of calcium by magnesium can occur. The amount of dolomitisation indicated

GENERALISED SECTION FOR LOWER CARBONIFEROUS ROCKS OF FURNESS AND GRANGE

Lithological unit		Faunal bands &c.	Fauna	Cycles (Zones)	Stages
GLEASTON FORMATION 200m		Orionastraea Lonsdaleia floriformis Girvanella Nodular Bed	Dibunophyllum bipartitum Dibunophyllum lateseptatum Lonsdaleia spp. Palaeosmilia regia	⑥ (=D_2)	BRIGANTIAN
URSWICK LIMESTONE 120m (160 max.)		Davidsonia septosa Woodbine shale	Carcinophyllum vaughani Palaeosmilia murchisoni Dibunophyllum bourtonense	⑤ (=D_1)	ASBIAN
PARK LIMESTONE 120m			Linoprotonia corrugato-hemispherica Lithostrotion minus	④ (=S_2)	HOLKERIAN
DALTON BEDS 120m		Clisiophyllum multiseptatum Delepinea carinata	Palaeosmilia murchisoni Michelinia megastoma Caninia cylindrica grp. Caninia subibicina	③ (=C_2S_1 pars.)	ARUNDIAN
RED HILL OOLITE 60m		Michelinia megastoma	Palaeosmilia murchisoni Koninckophyllum praecursor & Koninckophyllum ingletonense		
MARTIN LIMESTONE 50m		Algal Band Thysanophyllum pseudovermiculare Algal layer	Carcinophyllum simplex Carruthersella sp. Composita spp.	② (=C_2S_1 pars.& C_1 pars.)	CHADIAN
BASEMENT BED 0 - 100m (240 max.)				① (Tournaisian)	COURCEYAN

Excursion stops

(1) BIRKRIGG QUARRY
(2) STAINTON QUARRY
(3) GLEASTON Q.
(4) PLUMPTON QUARRY
(5) SKELWITH HILL
(6) BARKER SCAR
(7) HUMPHREY HEAD
(8) MEATHOP QUARRY

at this locality is more than that experienced in Furness and therefore could indicate a phasing out of the lagoonal conditions. Good examples of Michelinia megastoma and Palaeosmilia could be seen in the overlying Red Hill Oolite.

Retracing our steps to High Frith Farm, a small quarry in the bottom section of the Dalton Beds was visited, where good examples of Delepinea carinata were seen.

After examining the outcrops of the Dalton Beds at Low Frith (339.797), the party returned to the car park and proceeded to Barker Scar (332.784), where the first outcrop contains a band of the coral Clisiophyllum multiseptatum which marks the top of the beds. The base of the massive Gastropod Beds of Garwood forms the cliff face a few metres further on. The exposure continues along the shoreline and each of the top beds of the Dalton Limestone can be seen to be identified by a permanent marker in the form of a letter of the alphabet. This locality is important, being chosen by the Geological Society of London's Dinantian Working Party to define the junction between the proposed Arundian (C_2S_1) and the Holkerian (S_2) stages; the actual junction chosen being some 20 metres further along and marked J - K.

Following lunch the convoy of cars wound its way to Flookburgh, where a welcome ice-cream van supplied the weary travellers with some cool refreshment before their onward journey to Humphrey Head (392.740). Approaching the foreshore by a narrow lane, the topmost beds of the Urswick Limestone could be seen outcropping on the left of the causeway, while to the right the bottom beds of the Gleaston Formation were well represented. Following the shoreline northwards, an excellent specimen of the compound coral Palaeosmilia regia was examined in the Gleaston Formation and in the beds above this horizon the Girvanella Nodular Bed provided some fine specimens for the keen collectors. About 0.5 metres above the Girvanella band the coral Lithostrotion pauciradiale was collected, whilst some 2.5 metres above this the primitive foraminifera Saccamminopsis was abundant. Samples of Diphyphyllum lateseptatum were also quite readily to be found.

The party then made its way to Meathop Quarry (432.793) near Grange-over-Sands. Here the thin-bedded limestones with shale partings are excellently presented and of particular interest was the pale algal band, with an over-lying shale containing desiccation polygons, possibly indicating the limit of a lagoon during one of the minor cycles. Following the path up the face of the quarry silicified fossils could be seen in the rock and the brown beds of dolomitised limestone contained plenty of fragments of corals and brachiopods indicating they were probably washed into place. About 3 metres from the top is a brecciated limestone, probably equating with the breccia seen at Skelwith Hill and this is the Spirifer furcatus Band of Garwood which marks the base of the Red Hill Oolite.

The excursion being completed, the members expressed their thanks to Mr. Mitchell for providing them with a very enjoyable and informative weekend.

Derek Leviston.

EXCURSION TO THE SKIDDAW GRANITE IN SINEN GILL

Leader: Mr.T.Shipp, B.Sc.,F.G.S.

7th September, 1975.

The final geological excursion of the 1975 summer season was led by the Society's Secretary Mr. Tom Shipp and consisted of a visit to the most southerly outcrop of the Skiddaw Granite in Sinen Gill.

The granite is exposed in three localities; in Mosedale, where Grainsgill beck joins the River Caldew (327.326); in the vicinity of Wiley Gill (304.305), and in Sinen Gill (299.282). It is confidently supposed that the outcrops are connected underground at no great depth since the surrounding Skiddaw Slate country rock has undergone thermal metamorphism over an area of about 70 km^2 to the north and east of Skiddaw mountain. Recent work by the Institute of Geological Sciences suggests that the granite intrusion is of stock-like form, flat-topped and steep-sided. This view is supported by Bott whose work on gravity anomolies envisages a major batholith underlying the whole of the northern Lake District and extending eastwards under the northern Pennines. Radiometric age determinations give a mean age of 399 million years for the granite indicating late Silurian - early Devonian emplacement.

The granite is composed of orthoclase feldspar, plagioclase feldspar (oligoclase), biotite mica and free quartz. The northern outcrop in Mosedale has been extensively greisenised with progressive replacement of the feldspars by muscovite mica. That this process is due to metasomatism is shown by the development of minerals containing additional fluorine, water and silica not seen in the 'normal' granite, and by the passage of mineral veins from the greisen into the surrounding rocks. The Sinen Gill outcrop contains a rather higher ratio of plagioclase/orthoclase than the 'normal' granite of the central outcrop, so that it could be termed a biotite granodiorite.

The Skiddaw Slates into which the granite is intruded form a succession of mudstones and sandstones which had previously undergone mild regional metamorphism. This converted the mudstones to 'greenschist' grade leaving the sandstones scarcely affected. The thickness of the metamorphic aureole is some 800 metres and it shows characteristic zoning.

The group started out from the old Sanatorium above Threlkeld (303.256) and first surveyed the broad sweep of Lakeland scenery to the south. The leader interpreted the features in terms of the underlying geology. The unaltered Skiddaw Slates were examined and then, moving up the Glenderaterra valley, the party crossed the metamorphic aureole and noted the successive changes in the rock. First, small aggregations of carbon in the 'slate' produced a spotted texture and then, nearer in towards the granite, the distinctive development of white chiastolite crystals was seen. On reaching Roughten Gill (297.274) the 'slate' had become much hardened and shot through with dark crystals of cordierite. This locality had been the source of the 'musical

stones' so popular in the area during the last century.

Entering Sinen Gill a bank of decomposed granite was investigated. This had resulted from the action of acid peaty surface water decomposing the feldspars to produce kaolinite. A little further upstream the unaltered granite was seen exposed at a waterfall. A little further on still the contact between the granite and the hornfels forming the roof of the intrusion was seen exposed in the stream bank.

The party climbed out onto the open moorland bordering the gill and lunch was taken at some outcrops of Skiddaw Slate close to the source of the beck. The weathered surfaces revealed complex folding patterns. It was evident that the rock had first been folded into broad open folds and superimposed on this pattern were smaller tight, frilly folds with axes parallel to the cleavage. This evidence of two-phase folding, showing an earlier and a later stage of deformation, has been the subject of much discussion of late, throwing some light on the earlier history of the Skiddaw Slates prior to the first major upheaval of the area during the Caledonian orogeny.

In the afternoon the party descended to the bottom of the Glenderaterra valley to investigate the mineralised quartz veins and evidence of old mine workings. The copper minerals chalcopyrite, malachite, azurite and chrysocolla were found. Galena was in great abundance, together with cerussite and pyromorphite, whilst good specimens of vein quartz, barytes and dolomite were picked up.

On returning to the starting point the Vice-President of the Society, Mr. Mervyn Dodd, thanked the leader for what had been an interesting and informative tour.

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EXCURSION TO THE LOW CLOSE OPENCAST COAL SITE

Leaders: Mr.E.Lawrence, B.Sc.,F.G.S.
and Mr.G.Jackson, B.Sc.,F.G.S.

6th March, 1976.

The President and 25 members visited the Low Close Opencast Coal Site near Broughton Moor on Saturday morning, 6th March.

Permission for the visit had been given by the National Coal Board Opencast Executive and the party were conducted round the site by Area Opencast Geologist Eric Lawrence and Geologist Graeme Jackson.

At the commencement of the visit the geology of the site was explained in the site office with the aid of geological plans and sections. Coal mining has been a major industry in the Broughton Moor area for a considerable length of time, dating back to at least the Eighteenth Century. In recent years the winning of coal by underground methods has been replaced by surface opencast mining and this site is the latest to commence operations at Broughton Moor.

The site is worked under contract to the Opencast Executive by Messrs.Shepard Hill. The site covers a working area of approximately 110 acres, and it is planned that initially 900 000 tons of good quality coal will be won from 13 seams varying in average thickness from 0.17m to 2.14m.

The party had picked a fine dry day for the visit and, suitably equipped with hard hats, proceeded to walk the site and examine the exposed strata.

The geological succession proved on the site comprises part of the Middle and Lower Coal Measures of the Carboniferous system; the strata apart from the coal seams consisting mainly of shales, mudstones and siltstones, with subordinate sandstones grading into shaly sandstones.

The method of working allowed the examination of most of the coal seams and intervening strata. The party commenced at an excavation to the lowest exposed strata, the Six Quarter seam, and by walking to successive 'cuts' were able to examine the Lickband, Eighteen Inch, Little Main, Two Foot, Yard and Main seams. In general the dip of the strata was to the south-west but this was observed to vary with localised folding and faulting. Faults were particularly well displayed with throws ranging from as small as one metre to more than twenty metres. Well developed fossil beds were demonstrated and specimens of lamellibranchs such as Carbonicola and Naiadites, (the latter with Spirobis worm casts displayed on the shells), and the brachiopod Lingula, marking the Solway Marine Band which separates the Lower and Middle Coal Measures, were collected.

Another interesting feature is the well exposed old workings in the Main Band, viewed in the high wall of the site. Although extensively worked it was demonstrated that sufficient remained in the pillars between the galleries to make exploitation worthwhile.

During the tour of the site the method of working by dragline and face shovel was explained, much of the overburden being transported by massive 70 ton Dump Trucks to spoil heaps. Clean coal is dug by smaller machines and transported to the Executive's Disposal Point at Maryport, where it is screened and distributed by road and rail. A large proportion of the coal is send to C.E.G.B. power stations at Barrow and Carlisle, local industries accounting for a smaller tonnage, and shipments are also made from Whitehaven to Northern Ireland. Certain seams comprise good quality coking coal and this is conveyed to the North East for use by the Steel Industry - a true case of 'coals to Newcastle'.

An important part of the working of the site is the restoration. It was explained how top soil and sub-soils are separated and replaced in the correct order, and how the management and drainage of the land is supervised by the Ministry of Agriculture, so that what formerly may have been poorly drained, low quality land is returned to agricultural use much improved. Also associated with this site is the restoration of derelict land areas including the old tip heaps of Alice Colliery. An improved road scheme planned in conjunction with the County Council will allow access to coal under a former road on the western part of the site.

EXCURSION TO THE SKIDDAW SLATES OF THE BUTTERMERE AREA

Leader: Dr.B.Webb

3rd April, 1976.

Despite the threatening look of the weather some twenty members met under the leadership of Dr. Webb at Buttermere to examine structures in the Skiddaw Slates.

Dr. Webb was to demonstrate sedimentary structures and features in the Skiddaw Slates indicative of the considerable deformation they have undergone.

The first locality examined was the small quarry just outside Buttermere village (173.173) and the fellside immediately above. Here the leader pointed out:

1 'Way-up' criteria,

2 Fold form,

3 The relationship between first and second folds and the main cleavage,

4 Third folds and their related cleavage.

In deteriorating weather conditions there was some discussion as to whether all the folding was the result of polyphase deformation or whether some of the features viewed were the result of 'slumping' in unconsolidated sediments.

After a further examination of similar features in the rock pavements above the village, the whole party made its way to Goat Crag (189.164). Here Dr. Webb explained that detailed examination of sedimentary structures in the Skiddaw Slates could be used to show that in the Goat Crag area there is an inverted succession of psammitic strata. However, heavier rain and sleet, punctuated by blustery hail showers, made the viewing of these detailed structures increasingly unpleasant.

In view of the deteriorating weather conditions the rest of the excursion was curtailed and the party retired to the Bridge Hotel where soup and other liquid refreshment revived flagging spirits and the discussion of structures in the Skiddaw Slates.

Dr. Webb was thanked for his detailed exposition in adverse conditions with the hope expressed that at some later date he would lead a further excursion - hopefully on a warm sunny summer's day.

GLACIAL MELT-WATER CHANNEL SYSTEMS

SOUTH OF ENNERDALE.

Director: Mr.T.Shipp, B.Sc., F.G.S.

9th May, 1976.

About a dozen members met at the Stone Circle, Blakeley Moss, 2 km. S.S.W. of Ennerdale Bridge on the Cold Fell road (NY 062.142). The group first walked to the vicinity of Cockhow (056.143) to obtain a view of Meadley Reservoir and lower Ennerdale. It is now considered unlikely that Ennerdale ever contained a vast ice-dammed lake, but the excursion director, Mr.T.Shipp, pointed out a spread of sand and gravel at Meadley suggesting a small marginal glacier lake site. The flat-topped deposits at Cockhow were suggested by Huddart to have been laid down in a sub-glacial tunnel. The party then walked along the fine melt-water channel of Nannycatch Gorge to its confluence (055.129) with another melt-water channel draining the area between Dent and Flat Fell, and from there made their way downstream to the disused Uldale Farm (046.123). During the walk the director commented upon the misfit drainage, the obviously riverine valley profiles, and the large area of silty-peaty deposition around Uldale Farm.

After a picnic lunch, the group walked across the fields to the Winder Channel (038.116) which cuts across the spur immediately north of the hamlet of Wilton. This channel has a humped profile and was cut sub-glacially. The view westward showed how the open end of the valley had been choked, at Moss Dalts, by moraine. This had caused the Kirk Beck to turn abruptly S.E. into the Stockbridge-Haile Gorge instead of proceeding westwards to join the Ehen at Egremont. In order to view the Stockbridge end of the gorge, the party walked down the road to Stockbridge Farm (036.106), and from there turned back uphill along an ill-defined field path to High House and Dike Nook (042.111). The farm track at this point runs through a splendid rock-floored melt-water channel cut along the hillside.

The final part of the excursion led back along the road to Cold Fell Gate, with a detour to the left along a rough lane leading to Mousegill Quarry (047.106). The lane follows the line of a fault; a line of weakness excavated by yet another melt-water channel. The quarry is of interest, being situated in a down-faulted outlier of Carboniferous Limestone. The effect of glacial melt-water dissolving out the limestone along the joints was demonstrated, and the director showed where a small stream disappeared into a sink hole leading to a miniature cave system known locally as Goosey Tyson's cave.

The excursion was voted an enjoyable and worth-while look at a little-known corner of Cumbria.

WEEKEND EXCURSION TO THE CORNEY AND BOOTLE AREAS OF SOUTH WEST CUMBRIA.

19th June, 1976.

THE GLACIAL LANDFORMS AND DEPOSITS OF THE CORNEY AND BOOTLE AREAS.

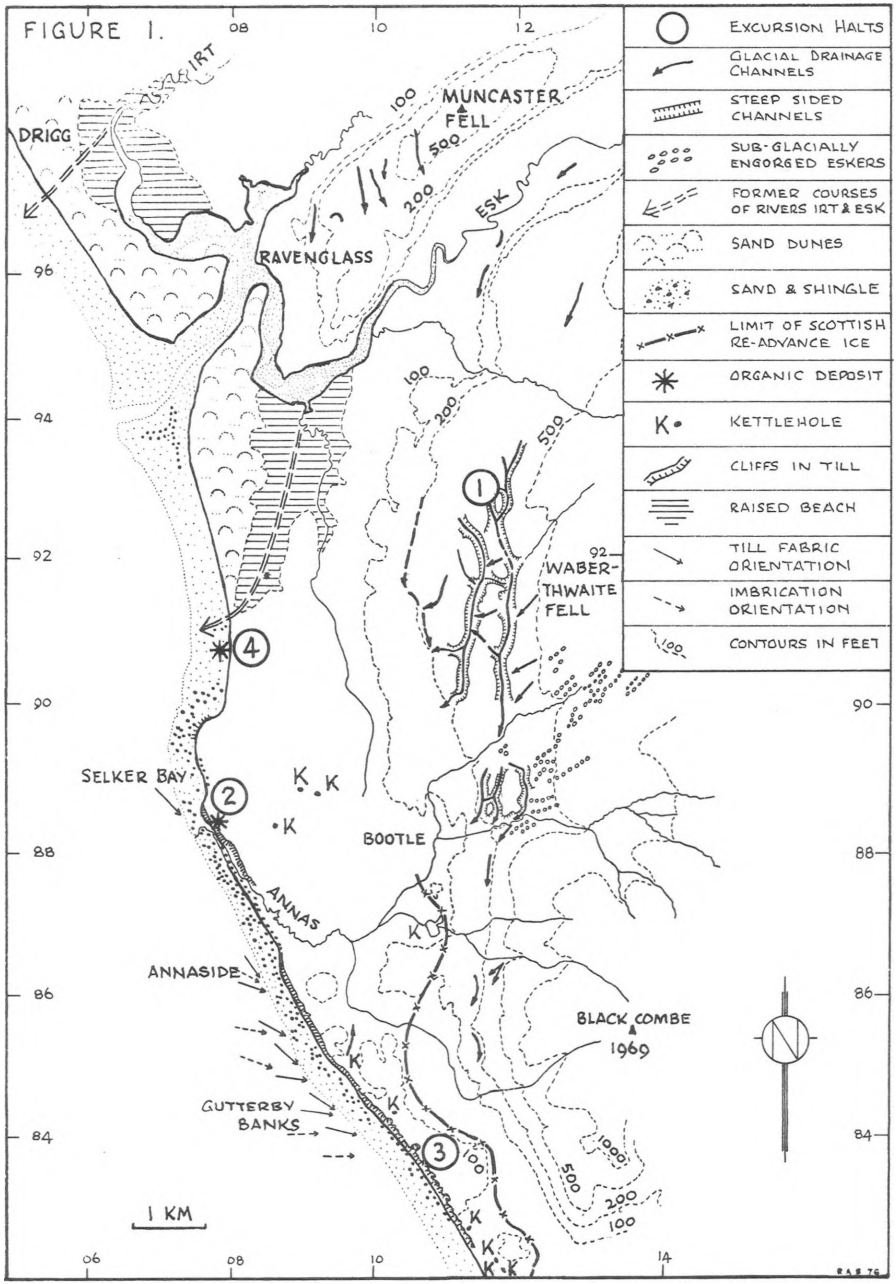
Leader: Dr.R.A.Smith, M.A.,

This expedition constituted the first day of a weekend excursion to that part of S.W. Cumbria which lies to the south of the Ravenglass estuary. The party assembled in the car park at Ravenglass where the leader explained that four localities would be visited which would provide evidence of the glacial history of the area. By way of introduction he pointed out that south of the River Esk the coastal lowland of Cumbria forms quite a narrow band of territory 2 - 3 km. wide around Eskmeals and Bootle but tapering southwards to little more than 1 km. at Silecroft (130.820). The Waberthwaite Fells (Eskdale Granite), and the bulky mass of Black Combe (Skiddaw Slate), overshadow the coastal belt on the east. The lowland lies mostly below the 30 m. contour but it has an intricate relief pattern reflecting its complex geomorphological history. A thick blanket of Quaternary tills and superficial deposits of peat, marine warp, alluvium, blown sand and beach shingle overlie the Triassic sandstones which are rarely exposed.

The height of the fells to the west is no more than 600 m. but it is evident that this was sufficient to form an effective barrier, so that the final advances and retreats of the Pleistocene ice were acted out on the lower fellsides and on the coastal strip in comparative isolation from events over the watershed. Within this narrow coastal zone the party would examine some of the evidence which makes it possible to attempt a reconstruction of the events of the final decay of the Devensian ice-sheet, the last readvance of the Scottish ice onto the coastal lowland, and the subsequent changes brought about by oscillating sea levels in the Flandrian.

Dr. Smith mentioned that he had described deglaciation features in a paper in the Proceedings of the Society (Smith, 1967) and in a subsequent Excursion Note (Smith, 1968). More recently a considerable amount of research on this and other areas of the Cumbrian Lowland had been done and the details collected together in a volume edited by D. Huddart and M. J. Tooley for the Quaternary Research Association. (Huddart & Tooley, 1972). The map reproduced as Fig. 1 was part of some excellent hand-out material provided for the members of the party and is an attempt at a synthesis of current interpretations of landforms in the area.

The party then proceeded to the first locality which was the system of melt-water channels in the Corney and Bootle areas shown on the map. The particular section visited was in the grid square 1192 and the leader explained that the channels were considered to have been cut sub-


FIGURE 1.
08
10
12
IRT
ASKAM
DRIGG
MUNCASTER FELL
100
500
200
ESK
RAVENGLASS
96
94
92
90
88
86
84
100
200
500
1
92
WABER-THWAITE FELL
4
SELKER BAY
2
K
BOOTLE
ANNAS
ANNASIDE
BLACK COMBE
1969
GUTTERBY BANKS
3
1000
500
200
100
1 KM
06
08
10
14
EXCURSION HALTS
GLACIAL DRAINAGE CHANNELS
STEEP SIDED CHANNELS
SUB-GLACIALLY ENGORGED ESKERS
FORMER COURSES OF RIVERS IRT & ESK
SAND DUNES
SAND & SHINGLE
LIMIT OF SCOTTISH RE-ADVANCE ICE
ORGANIC DEPOSIT
KETTLEHOLE
CLIFFS IN TILL
RAISED BEACH
TILL FABRIC ORIENTATION
IMBRICATION ORIENTATION
CONTOURS IN FEET
100
N

glacially. The humped profile of some of them indicates that they were cut under hydrostatic pressure in ice tunnels. A useful description is to be found in the article and excursion note in Volume 2 of the Proceedings which have already been mentioned.

The party then drove via Bootle Station to Broadwater (081.891). A short walk brought them to Selker Point and the mouth of the River Annas near the Coastguard Station (076.884) where 2 m. of dark reddish-brown, sandy, pebbly till are exposed. Dr. Smith explained that these tills are considered to date from the final stage of the Main Glaciation when the fells were emerging from their ice cover and the melt-water was moving generally southward in channel systems such as those already examined. The distinctive features of these tills are the high pebble content and a high sand/silt ratio of the matrix of about 0.55.* This is much higher than the values obtained for till units higher in the stratigraphical sequence. Till fabric orientations show an average value of 316° and it is suggested by Huddart (in Huddart & Tooley, 1972) that the unit at Selker can be correlated with the Lowca till at St.Bees.

The next locality to be visited was at Gutterby Banks (096.845). The cars were taken to a point beyond Gutterby (104.844). In this locality there are some magnificent exposures of sands, gravels and tills which are assigned to the Scottish Readvance phase, the existence of which was first postulated by the Officers of the Geological Survey in the 1920's. This is envisaged as a separate re-advance of ice from southern Scotland onto the Cumbrian lowland after the Main Glaciation. The limits, and even the existence, of such a re-advance have been contested ever since. Dr. Smith said that there was good evidence for suggesting that the ice did re-advance in this area up to the line indicated on fig. 1, leaving behind a complex series of sands, gravels and tills forming a distinct belt of irregular topography along the coastal fringe from Annaside to Gutterby and Silecroft. The deposits are particularly well exposed in long cliff sections along the coast from Annaside Banks to Gutterby Banks and Gutterby Spa. These sections show a succession of deposits which denote continuous fluvial deposition. In general, fine sands grade upward through coarser sands to gravels. The sequence, though locally showing rapid facies changes, is relatively constant in height and thickness throughout the coastal sections and is consistent with 'sandur' conditions. A sandur (plural sandar) is an Icelandic term meaning a sand and gravel plain. Dr. Smith painted a picture of this environment of deposition with pro-glacial braided river systems emerging from the ice and producing fluviatile deposits with compositions varying rapidly both laterally and vertically. Lying above these sand and gravel deposits in the cliff sections it is possible to distinguish a complex succession of tills, sandy clays, sands and gravels. The type section is seen at Gutterby Spa (101.842). The sequence is considered to have formed from the slow melt out of debris from basal debris-rich ice. The Irish Sea ice is believed to have advanced over the pro-glacial fluvial sediment with little disturbance to the underlying material.

The ice advance failed to reach as far as the foothills of Black

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* For explanation of sand/silt matrix ratios see Huddart, D., 1971.

Combe but the narrow belt of country over which it did extend has a highly irregular and very distinctive morphology. The ice probably decayed in situ, isolated blocks of dead ice in the sediment gradually producing the kettle holes which still mark the surface.

At the fourth stop of the day at Tarn Bay, Eskmeals (080.906) Dr. Smith pointed out the site of Williamson's Moss. This marshy area between the shingle spit of the coastline and rising slopes of till to the east is interpreted as a former course of the River Esk. Cores examined by Mrs. Tutin, (for details see Huddart & Tooley, 1972, pp. 53-4), have demonstrated that the blue-grey clay underlying the moss is estuarine in origin, containing an assemblage of brackish water diatoms. The party went down onto the beach at Tarn Bay close to the south end of the M.O.D. Firing Range (079.909) and investigated the top part of the metre or so of peaty deposits found under a thin layer of beach sand. Dr. Smith here suggested a tentative framework of Flandrian sea-level oscillations in Cumbria. The available evidence suggests three possible transgressions; Cumbria I, 7100 years B.P., is well established in the Solway and is also supported by evidence from this site at Tarn Bay. Cumbria II, 6800 - 6050 years B.P., is again reconstructed from evidence from the Solway coast but Cumbria III, 5600 - 5000 years B.P., is substantiated at a number of sites in the county including Williamson's Moss. The pattern has close similarity with the scheme of transgressions established by Tooley (1974) in south west Lancashire and identified as Lytham I - IX. Suggested correlations are shown in Table I.

Table I Suggested Stratigraphy and Sequence of Events.

Date (Years B.P.)	S.W.Cumbria	Elsewhere in Cumbria	Stages
300	Deflection of Rivers Irt & Esk by shingle		
5000		Cumbria III Cumbria II	FLANDRIAN
7100		Cumbria I	
10000	Gutterby Spa Complex Annaside Sands & Gravels	St.Bees Till St.Bees Sands & Gravel. St.Bees Silts & Clays.	SCOTTISH RE-ADVANCE
20000 ?	Selker Till Cutting of Corney & Bootle Channels	Lowca Till	DEVENSIAN MAIN GLACIATION

Finally, Dr. Smith pointed out that very recent coastal changes in south west Cumbria have been associated with the movement of beach material and the building up of sand dunes. The southward drift of beach material is suggested in the section of coast between St. Bees and Ravenglass. The River Ehen has been diverted southwards for nearly 3 km. by the growth of a narrow shingle spit. Similarly, southerly drift at Drigg seems to have blocked the former course of the River Irt and forced it to a joint outlet with the Mite. The apparent northern deflection of the River Esk, however, and the similar confinement of the mouth of the River Annas to a northerly route by a shingle ridge is apparently contradictory. Steers (1964), however, has argued on cartographical evidence that these deflections have taken place in the last 300 years.

Late in the afternoon the party dispersed after a warm vote of thanks had been paid to Dr. Smith for an unusual, interesting and well organised excursion.

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20th June, 1976

THE JUNCTION BETWEEN THE SKIDDAW SLATES AND THE BORROWDALE VOLCANICS IN CROOKLEY BECK.

Following the full day excursion led by Dr. Smith the previous day a small group of about twelve members met on the Sunday morning in Bootle village to investigate the Skiddaw Slate - Borrowdale Volcanic junction in Crookley Beck (116.883). Descriptions of this junction and its significance in the general controversy about the nature of the Borrowdale Volcanic rocks are to be found in papers by Helm (1970) and Soper (1970).

The members spent the morning examining the exposures in the light of the expert evidence relating to the conformable or unconformable

nature of the junction. After lunch the group extended its examination of the B.V.S. to a nearby quarry section where there were fine exposures of a volcanic sequence which included andesites, tuffs, ignimbrites and bedded tuffs. No definite conclusions were reached but the excursion was at least of value in demonstrating how difficult the Skiddaw Slate - B.V.S. junction problem can be.

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SHORT EVENING EXCURSIONS

During the summer of 1976 the excursion programme was expanded by a series of short Wednesday evening visits to localities of geological interest within easy reach of Whitehaven. These proved very popular and may well become a regular feature of the Society's activities.

A list of the visits made is as follows:-

12th May, 1976 Cliff sections in the Carboniferous between Parton and Redness Point.

19th May, 1976 The Coal Measures on the shoreline between Parton and Harrington.

9th June, 1976 The junction of the Skiddaw Slates with the Ennerdale Granophyre at Bowness Knott, Ennerdale.

30th June, 1976 The St.Bees Sandstone at Fleswick Bay.

7th July, 1976 The Permian Brockram at Millyeat, Frizington.

LECTURE REPORTS

HISTORICAL AND SOCIAL ASPECTS OF COAL MINING IN WEST CUMBERLAND

Mr.F.J.Carruthers

The first lecture meeting of the 1975 winter session was held on 8th October at Richmond School, Whitehaven, by kind permission of the Head Master, Mr. E. E. Medland. The speaker, Mr. F. J. Carruthers, dealt with some of the historical and social aspects of the mining of coal in West Cumberland down the centuries.

Whilst it has been proved archaeologically that coal was used in the Roman town of Alauna (present-day Maryport), there is no documentary evidence of the mining of coal until the 13th century, when it was probably used for heating the pans in the process of making salt from seawater. For several hundred years coal was mined in small workings at outcrop by groups of men who often combined farming with mining as a traditional way of making a living. Many of these shallow workings have been laid bare by recent opencast operations, whilst at least one mine, unworked since the early 17th century, was re-opened by chance during the General Strike of 1926. The pattern of coal mining prior to the Industrial Revolution was one of a very large number of small mines worked intermittently, thus causing no great social upheaval. It was only when mining became 'big business' during the Industrial Revolution that the social problems of miners became acute. For example, the importation of Irish workmen into the area by the Curwen family provoked civil unrest. The relatively high wages (five shillings per day in the early 1800s) attracted agricultural labourers into the towns which became crowded with slum dwellings. The population of the pit villages also increased. The mine owners built many things such as houses, village store and even the church, but the fact that the miners had to buy their own equipment and live in the tied houses and shop at the Company store, whilst they were paid by piecework only for the coal they produced, led to a great deal of misery.

Mr. Carruthers went on to talk about the hazards of mining, commenting that whilst gas explosions were soon recognised and guarded against, the much more violent explosions caused by coal dust were not fully understood for a long time. Even then the remedy of spreading large quantities of silica dust in the mines led to a high incidence of the lung disease, silicosis. The introduction of safety lamps giving out a very feeble light led to many miners developing a characteristic eye disease called miners' nystagmus, the cause of which was only recognised following a lengthy Royal Commission.

Finally the lecturer commented on the present state of the Industry. There were 14 active collieries in West Cumberland in 1944. Nationalisation soon brought this down to 6, whilst a continued policy of closure of uneconomic mines and absorption of redundant miners into neighbouring pits has further reduced the number to one, the Haig Pit. The future of coal mining, even allowing for the contribution made by opencasting, is very bleak in West Cumbria.

FRAGIPAN IN CUMBRIAN SOILS - ITS ORIGIN AND SIGNIFICANCE

Dr. Barry Mathews, M.A.

The second meeting of the 1975 winter session was held at the Ullswater Centre, Penrith on 12th November. Some 25 members and friends gathered to hear a talk given by Dr. Barry Mathews of the Soil Survey of England and Wales and himself a member of the Society.

The speaker began by giving a brief outline of the work of the Soil Survey. This is a semi-independent organisation financed by the Ministry of Agriculture and Fisheries and engaged on the mapping of soil types over the country. Descriptive material in Memoir form is also produced. Dr. Mathews described his work in making soil maps of Cumbria and explained how this is important for agriculture, forestry, civil engineering and land evaluation. The accompanying book or memoir will contain additional information on vegetation, climate, agriculture, geology, and on the potentiality and use of the land. The book should be of interest to students and teachers of botany, geology, geography, climatology, pedology and agriculture. Dr. Mathews described the techniques used in soil survey work from the simple hand auger up to the interpretation of aerial photographs. As an introduction to the main subject of his talk he also defined the main soil types and the various horizons developed in mature soils.

Turning to his main topic the speaker defined 'fragipan' as a reddish coloured, indurated soil material sometimes encountered beneath sandy or loamy soils derived from glacial drift. The name fragipan indicates the qualities of brittle hardness of the material forming this horizon which is widespread throughout the glaciated tracts of the Northern Hemisphere. It is also known by a variety of other local names such as roach, sammel and pinnel. Roach is supposed to be derived from the French 'roche' or rock, while sammel and pinnel are Old English words. Sammel was imperfectly burnt brick and pinnel was a type of cement or concrete. All these terms testify to the hard and brittle nature of the material. The speaker had prepared thin sections of Cumbrian fragipan which had revealed a platy particle structure with pin-head sized pores and cavities. There were coatings of clay material on the sand grains.

It is only in recent years that much attention has been paid to the extent and significance of fragipan which is often deeply buried by post-glacial accumulations and by soil creep. It occurs at depths which may vary from 5 to 200 feet and when more is known of its occurence it may be found to be quite widespread under the glacial drift. Its significance for agriculture is that it restricts drainage and tends to lead to the development of a wet 'gley' soil with consequent reduction of crop yields.

The speaker has been interested in mapping the occurrence of fragipan in the Penrith area. The work is difficult because of the sporadic occurrence of the layer at varying depths. It has been found

in excavations, in river bank exposures, in pits left by up-rooted trees and in boreholes.

The origin of fragipan is still the subject of much theorising. It seems that it must be related to glacial and peri-glacial conditions. An important clue is that in the Penrith district it seems to be related to areas where a reticulated crop-pattern is seen in aerial photographs. This in turn is thought to be evidence of the existence at one time of ice-wedge polygons. These are a feature of soils affected by permafrost; contraction cracks develop in the ground in a polygonal pattern and become permanently ice-filled until the onset of milder climatic conditions. When thawing occurs the cracks become filled with fine soil particles and this permits greater root penetration and more vigorous plant growth which in turn shows up in favourable conditions on aerial photographs.

If the development of fragipan is related to permafrost conditions the induration may be due to subsequent cementation and compaction. Precise mechanisms are not yet understood but the lecturer's own research in present day permafrost regions in Northern Canada indicates a polygenetic origin and possibly the process of cementation by clay particles may have taken place in milder periods in later Pleistocene times.

Soils can be regarded as a palimpsest preserving and recording a series of environmental conditions if only the changes can be interpreted.

A most interesting and unusual talk was rounded off by questions and discussion and a warm vote of thanks was accorded to Dr. Mathews.

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PERMIAN DESERTS OF BRITAIN

Dr. Brian Waugh, F.G.S.

A meeting of the Society was held at the Derwent Centre, Cockermouth on 20th December, 1975. Dr. Brian Waugh, Lecturer in geology at the University of Hull and a native of Maryport, spoke about Permian Deserts of Britain.

The speaker began by showing a series of slides, taken in the deserts of New Mexico and Arabia, which he used to illustrate the mode of formation of various desert rock types and sediments. Rock waste derived from weathering and erosion in mountainous regions is transported by occasional 'flash floods' down steep sided valleys, - 'canyons' in Mexico, 'wadis' in Arabia. These flood waters deposit the boulder and gravel fractions as huge alluvial fans adjacent to the mountains, while shallow, muddy and salty lakes, - 'playas' or 'sabkhas' - are formed in the inter-montane basins. Evaporites are deposited in a hot climatic environment giving rise to layered anhydrite, gypsum and rock salt.

Sandy desert material is transported by wind and moulded into dunes of two main types, 'barchan' or crescentic dunes and 'seif' or longitudinal dunes. Today the major deserts of the world lie between latitudes 30°N and 30°S. In these latitudes constant winds blow from the north-east in the northern hemisphere and the south-east in the southern hemisphere; the Trade Winds of the mariner.

The speaker then turned to the rocks of Lower Permian age in Britain. At the end of the Upper Carboniferous the Hercynian orogeny gave rise to mountainous tracts, perhaps 6,000 to 9,000 feet high, in the regions we now know as Cornwall, Wales, the Pennines and the Lake District. As in present day Mexico and Arabia there formed, between these mountainous tracts, spreads of deposits of varying texture. Bouldery and gravelly material gave rise to the Brockram encountered in many boreholes in West Cumbria, whilst elsewhere wind-blown sands are preserved, for example, in the 'fossil' dunes of the Penrith sandstone.

The very fine-grained materials, originally deposited in the playa lakes of Permian times, are to be found in the rocks underlying the North Sea and the Irish Sea basins as deposits of mudstones with rock salt and anhydrite layers. Whilst these minerals have great economic importance in the chemical industries of Britain, it is in the fossil sand dune deposits, fringing these ancient playa lake sites, that there is special interest at the moment. These porous sandstones have become reservoir rocks for natural gas and the successful exploration of the southern North Sea is now being followed by drilling off the Lancashire coast with some promising indications.

In his talk Dr. Waugh demonstrated how the study of erosion and sedimentation patterns in modern desert areas led to an understanding of the Permian desert rocks outcropping in this country. At that time N.W. Europe lay just north of the equator with, presumably, prevailing winds from the north-east. Palaeo-wind directions, deduced from the study of fossil dune orientations in the Permian sandstones, are consistent with this concept.

It was James Hutton, the 'father of modern geology', who, nearly 200 years ago, put forward the principle that 'the present is the key to the past', a principle that the speaker had clearly used. Predictions about the arrangements of various grades of sedimentary rocks in these ancient deserts have led to the discovery of important sources of fuel and chemicals. The making of such informed predictions is one of the most important tasks of the geologist today.

A vote of thanks to Dr. Waugh was proposed by Mr. Ken Bond of Keswick.

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THE OCCURENCE AND MINING OF EVAPORITES

Dr. T. Elliott, F.G.S.

At a meeting of the Society held on 14th January, 1976, at the Workington Branch of the West Cumberland College of Science and Technology, Dr. Elliott, manager of the Marchon anhydrite mine, gave a talk on the Occurrence and Mining of Evaporites.

Dr. Elliott explained that evaporite deposits consist of the various salts normally present in sea water which have been laid down by precipitation from saturated solutions under certain special circumstances. The salts in sea water amount to about $3\frac{1}{2}$ per cent by weight, and of this amount 77 per cent is sodium chloride. In arid climates evaporation occurs and as the sea water becomes more and more concentrated the least soluble salts are precipitated first. In experimental evaporation of sea water calcium sulphate, as anhydrite or gypsum, is precipitated first when the initial volume has been reduced by about four fifths. When one tenth of the original volume is left the sodium chloride comes out, and when only one fiftieth is left the potassium and magnesium salts precipitate. The precise mechanisms in nature, however, are not as simple as this, because the proportions of different evaporites found are not the same as in sea water and it is difficult to explain great thicknesses, such as 300 ft. of anhydrite, which would require the evaporation of 80 miles depth of sea water! One theory is that evaporation occurs in partially land-locked basins where there is a limited exchange with the open sea, so that replenishment can take place with very little out-flow. There seems to be no place in the world at the present time where this process can be demonstrated, although relatively recent evaporite deposits under the Mediterranean may have been formed in this way. In the Caspian Sea and in the Persian Gulf contemporary evaporites are forming but here the mechanism seems to be different. It appears that anhydrite particularly, can build up in supra-tidal salt flats where ground water circulation and diagenetic processes are also involved. Characteristic crystal habits and textures found in these present day environments have been demonstrated also in some ancient evaporite deposits.

Whatever the mechanisms involved, most evaporite deposits are Permo-Triassic in age, although Silurian salt deposits are known. In this country anhydrite, or anhydrous calcium sulphate, occurs as thick beds or in nodular form and has been mined in the North at Bellingham, in the Eden valley and at Whitehaven, and is used for the commercial production of sulphuric acid for the chemical industry and for fertiliser. Mines now closed, like that at Whitehaven, could be re-opened if new uses for the material were found.

Gypsum, or hydrated calcium sulphate, is mined by British Gypsum Limited in ten mines and several quarries in various parts of the country. Four million tons a year are used for building plasters.

Halite, or Rock Salt, sodium chloride, is mined in Cheshire and its greatest use is for de-icing roads.

Potash, mostly potassium chloride, is mined on the North Yorkshire coast and used mainly for fertilisers.

Turning to the techniques used for mining evaporites, the speaker explained that thick seams were mostly mined on the 'bord and pillar' system since the strength of the material was usually enough to support the workings. In some instances rock-salt can be recovered by 'brining', - the controlled solution of the deposit by water -, although this method could lead to subsidence problems as in Cheshire. In North Yorkshire the potash is mined at depths of up to 4,000 ft. and freezing techniques have been used to drill shafts down through water-logged sandstone strata to reach the mineral. Another hazard was encountered in Germany where potash deposits were dissected by basaltic dykes producing CO_2 inclusions which exploded violently. This section of the talk was illustrated by excellent slides showing scenes underground and the various techniques and plant involved.

Dr. Elliott was accorded a warm vote of thanks for a most interesting and informative lecture.

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SOME PROBLEMS CONNECTED WITH THE ORIGINS OF THE METALLIFEROUS ORES OF THE LAKELAND AND NORTH PENNINE OREFIELDS.

Dr. A.J.McMahon Moore

On 22nd September, 1976, at the Derwent Centre, Cockermouth, the Society met to hear a lecture given by Dr.A.J.McMahon Moore, of the Royal School of Mines, on 'Some Problems connected with the Origins of the Metalliferous Ores of the Lakeland and North Pennine Orefields'.

The lecturer opened by stating that progress in research into the processes of mineral genesis and emplacement necessitated the formulation of 'rules' for finding orebodies that could be exploited economically. He stated that he would confine his arguments to mineral deposits of the Mississippi Valley type. These were defined as lead and zinc minerals, with associated fluorine and barium, occurring in limestones and characteristically found in continental areas that had been tectonically stable for considerable lengths of time.

Minerals of this type are to be found in the Carboniferous Limestones of Northern England, but not in the Culm Measures of the South nor in the Midland Valley of Scotland.

Dr. Moore continued by describing the types of emplacement found in these deposits in veins and flats and the association of these with the successions of limestones, shale and gritstone. In general there seemed to have been three modes of movement of the ore-bearing fluids, namely, downward movement, upward movement along the vein, and inward movement from the country rock (lateral secretion). The popular view

in the past has been that hot, mineral bearing fluids emanated from deeply buried bodies of magma (usually granitic), during their later stages of cooling. This was tested by Professor Dunham during his work on the experimental borehole into the Weardale Granite, the supposed source of the mineralisation in this part of the North Pennines.

However, the fact that the Weardale Granite, of Caledonian age, had been emplaced and later unroofed during the 100 or so million years before the Carboniferous was laid down unconformably over it, coupled with the further knowledge that the North Pennine mineralisation is undoubtedly of Permian age, made the apparently simple hypothesis of the granitic source untenable.

The lecturer then switched his attention to mineralisation of similar age and type found in Derbyshire. He mentioned the existence of volcanic activity there during Carboniferous times and pointed out that the mineralisation was found in veins that terminated upwards against impervious Edale Shale or Millstone Grit. These formations had clearly acted as barriers to upward-migrating fluids. He then showed slides of the structures and of some localities of the Derbyshire ore-bodies. One in particular at Windy Knoll, showed a bitumen deposit full of tiny crystals of sphalerite and galena beneath a cover of Edale Shale. This and similar observations had led Dr. Moore to consider the hypothesis that lead and zinc deposits had a mode of origin similar to that of oil-fields. Oil is thought to accumulate as finely disseminated organic detritus which migrates along and upwards through porous rocks until it either meets a 'trap', such as a dome formation with an impervious cap-rock, or escapes to the surface. There is some evidence to support this hypothesis, namely the uneven growth of crystals pointing to fluids flowing upwards through fractures, crystallizing as they went, thus enlarging the fractures and forming veins. 'Damming up' of these solutions could give rise to the replacement ore-bodies and the ore-flats.

Mineralogists were at present showing particular interest in the 'oil-trap' structures in carbonate rocks, as these could be considered likely sources of metalliferous ores for the future. Many such highly eroded structures still contained workable ore. The lecturer cited the Lake District Dome as a case in point, - he considered that in Permian times, when the Lower Palaeozoic core would have been still largely covered by Carboniferous sediments, there was probably a large ore-field above Skiddaw and Scafell!

The origin of these minerals was then discussed, the lecturer stating that aragonitic shelly material in the early limestone almost certainly would have contained a few parts per million of isomorphous carbonates of cobalt, cadmium, lead and zinc (but not iron or copper carbonates as these are not isomorphous with aragonite). During lithification, the change from aragonite to calcite would cause the expulsion of these trace metals which would then migrate and collect in 'oil-trap' structures. It is perhaps significant that there is little copper associated with the lead and zinc of the Pennines, and that in the Lake District the copper veins and lead veins have different trends.

Dr. Moore's explanation of the obvious association of ore-bodies with underlying granitic masses was that the granite continues to

emanate vast quantities of heat long after emplacement, and thus act as a heat engine to maintain the convective movements in mineral-bearing fluids.

The lecturer concluded by explaining how buried ore-bodies were now being sought by gravity and magnetic surveys, by the measurement of heat-flow variations, and by analysis of pictures from satellite probes. The vast amount of data being produced at present gave rise to problems of analysis and assessment, but he was hopeful that discoveries would keep pace with increasing demand for many years to come.

There followed a lively question and comment session, during which the President strongly associated himself with theories of ascending mineralisation.

At the end of the meeting Dr. Moore showed some recent photographs of the wolfram-scheelite vein and the mine workings at Carrock, where he had been carrying out some investigations.

A vote of thanks to Dr. Moore was proposed by Mr.S.H.Gate.

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THIS DYNAMIC EARTH

Mr.T.Shipp, B.Sc.,F.G.S.

At a meeting of the Society held on 8th December, 1976, at the West Cumbria College of Science and Technology, Whitehaven, the Society's Secretary, Mr. Tom Shipp, stepped in at short notice to deputise for the advertised lecturer, who had been called away to South Arabia on an urgent programme of geological field work.

Mr. Shipp chose as his topic 'This Dynamic Earth' and outlined how the 'jig-saw' pattern of the continents, noted by early explorers and geographers, has been explained with the aid of modern developments in geophysical measurement. Seismology, vulcanology, geomagnetism, gravity anomalies and heat-flow studies had all been involved. In developing his theme, Mr.Shipp explained that ideas of continents 'floating around' over the surface of the earth, as proposed by Wegener at the turn of the century and laughed to scorn by the conventional scientists of the day, had now been fully vindicated. Continents are moving relative to each other but at very slow rates of a few centimetres a year.

Earth science - geology - has been revolutionised by the application on an international basis of the latest techniques of measurement. The crust of the Earth can be likened to a fragile skin, proportional in thickness to a layer of paper stuck onto a football, so it is perhaps not surprising that it is cracked into a series of slabs or 'plates'. This unifying concept of modern geology is known as

'Plate Tectonics', and the lecturer showed how the theory could be used to explain the formation of rift valleys, mountain chains, volcanoes and earthquakes. The earth can be considered as a heat engine, the heat generated by radioactive minerals at depth causing huge convection currents which slowly mobilise the plates of crustal rock. Even more surprising is the magnetic record of movement 'frozen' into the igneous rocks underlying the deep oceans, which can be said to resemble the magnetic patterns on cassette tape. 'Truth is stranger than fiction', and this has certainly been the case when the dynamics of the Earth have been investigated.

Mr. Shipp's talk was well illustrated with slides prepared at short notice and in being thanked for his talk the speaker was complimented on the way he had 'stepped into the breach' with such an interesting lecture.

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FIELDWORK IN IRAN

Mr.R.S.Arthurton, B.Sc., F.G.S.

On 12th January, 1977 at a meeting of the Society held at the Workington Branch of the West Cumbria College of Science and Technology, members were addressed by Mr.R.S.Arthurton from the Leeds Office of the Institute of Geological Sciences.

The speaker took as his subject 'Fieldwork in Iran' and explained that he had been involved in basic geological mapping in the region of the Elburz Mountains to the north and west of Teheran. Such mapping by I.G.S. teams in the period 1968 - 1975 had helped to establish the history of the structural, sedimentary and volcanic events that had taken place in the area since pre-Cambrian times.

Modern techniques of geological mapping had been employed based on aerial photo-interpretation controlled by a large number of ground traverses. The territory is rugged, varied and largely inaccessible. The elevation varies from - 27 m. on the Caspian shore to more than 5000 m. on the summits of the Elburz range. On the northern Caspian slopes there is a high rainfall and lush forest vegetation with rice paddies in the coastal strip. By contrast, arid desert conditions prevail to the south of the range. On the peaks of the Elburz there is permanent snow and some small glaciers. The control traverses were up to 100 km. in length and involved a rough outdoor life for one or two weeks at a time. Mule transport was used, often over primitive animal tracks. In between these 'safaris' there were periods of laboratory work in the capital with palaeontological studies and thin-section work.

Mr. Arthurton explained that it has emerged from the work that from

late pre-Cambrian times up to the late Triassic the region must have received spasmodic platform type sedimentation. There were major non-sequences and the Silurian period for example is completely unrepresented. From the late Triassic onwards there have been a number of pulses of tectonic and/or volcanic activity which have resulted in the creation of a system of east-west troughs. These were variously filled with sediments or volcanic deposits. Clastic, carbonate and evaporite types of sedimentation all occurred. From time to time there were major movements on high angle faults with an east-west trend and these were accompanied by folding. Volcanic activity was maximal in the Palaeogene (= Eocene + Oligocene) though movement on the faults has continued till the present.

The first major pulse of tectonic activity in the late Triassic, which interrupted the long history of platform sedimentation, may represent a collision between the Iranian and Eurasian continental plates. Another possibility is that a further collision took place between the Iranian plate and the Arabian plate to the south.

The speaker drew attention to the very sharp topographical boundary between the Elburz mountains and the flat territory of the Caspian to the north. Very little is known, however, about the geology of this area which is, of course, in the U.S.S.R.

Mr. Arthurton illustrated his talk with a series of splendid colour slides which not only portrayed the topography and the geology but also showed something of the difficulties of the survey work and also glimpses of the archaeology of the area, the flora and fauna and the lives of the local people.

The talk stimulated a number of questions and the meeting ended with a vote of thanks to the speaker.

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A NOTE ON THE BANDED RYOLITE FROM CLEWS GILL.

Many members will be acquainted with the occurrence of the remarkable and intriguing 'banded' rhyolite in Clews Gill, Ennerdale. Mr.P.Cox, of Whitehaven, submitted a specimen to the Petrographical Department of the Institute of Geological Sciences in London, and we are indebted to him for a copy of the report which states:

> 'The rock specimen is a banded 'felsite' or rhyolite. The colour banding is caused by variations in grain-size, iron-staining and the development of finely divided sericite. These variations indicate an original inhomogeneity of the magma and the disposition of the bands was probably brought about by eddies in the molten magma'.

A HUNDRED-YEAR-OLD GEOLOGICAL MAP OF THE BRITISH ISLES.

The following note has been contributed by the Secretary, Mr. Tom Shipp.

An old rolled up geological map discovered last year at the back of a cupboard at the Haig Colliery, Whitehaven, has been given to the Society by the National Coal Board through the good offices of the Colliery Manager. The map, compiled in 1870 by J.A.Knipe and revised in 1871, is hand coloured and on a scale of 12 miles to the inch. It covers the British Isles, including Ireland and part of Northern France.

The dedication on the map reads as follows:-

'Geological Map of the British Isles and part of France showing also the inland navigation by means of rivers and canals. The railways and principal roads and sites of minerals. Under the patronage of H.R.H. the late Prince Consort. To whom this map was by express permission Humbly Dedicated. J.A.Knipe, London, second Edition, 1870'.

On writing round for information concerning this map I was informed by Mrs. Judith Diment of the Palaeontological Library of the British Museum that the series was first published before 1850, being based on information from the Greenhough map (1819) and the Smith map (1815). The Map Librarian of the Institute of Geological Sciences, Mr.D.S.Paterson, comments that J.A.Knipe was one of many commercial geological map makers and sellers who thrived in the early days of nineteenth century geology. He seems to have been more persistent than most and kept in touch with the work of eminent geologists of the day through the meetings of the British Association. No personal details of his life seem to be forthcoming, except that Sedgwick referred to him as 'that parasitic geologist Knipe', although he did actually work as a mineral surveyor mainly in connection with coal. In the I.G.S. Map Library Index 1972/5/30(27) Mr.Paterson gives details of five series of Knipe maps dating from 1835 to 1859, based on information from articles by North (1928) and Bassett (1967), and from individual copies held by the British Museum (Natural History) and by the I.G.S.

The Society's copy of the map has now been lodged in the Cumbria County Archives where it is at present being cleaned and re-mounted. When this work is completed the map will be available for inspection by arrangement with the County Archivist, Mr. Bruce Jones, at Carlisle Castle.

I wish to record the thanks of the Society to the National Coal Board for donating the map, and to Mrs. Diment, Mr. Paterson and Mr. Jones for their help in identifying and preserving the map.

OBITUARIES

DR. G. H. MITCHELL, C.B.E., F.R.S., F.R.S.E.

Many of the older members of the Society who knew Dr.G.H.Mitchell, were saddened to learn of his death on 11th March, 1976, at the age of 73.

He was born in Liverpool where he received his early education.

He graduated at the University in the early 1920's gaining a first class honours B.Sc. in Geology. Dr. Mitchell carried out post-graduate research on the Coniston Limestones for which he was awarded an M.Sc. in 1925. Between 1926 and 1929 he worked at Imperial College and at this time turned his attention to the Borrowdale Volcanic Series which was to be a major interest for the rest of his life. This research gained him a Ph.D. also from Liverpool University.

In 1929 he joined the Geological Survey of Great Britain. He worked initially on the concealed coalfield of Yorkshire and later on the coalfields of Leicestershire, Staffordshire and South Derbyshire, becoming an authority on the geology of these areas. In 1941 his own University conferred on him its Doctorate of Science.

In 1954 he was transferred to Edinburgh to take charge of the South Lowlands Unit and five years later he was promoted to be Assistant Director in charge of the Geological Survey Office in Scotland. During his career he was responsible for the production of many official maps, memoirs, reports and papers and he also published many articles arising from his private geological interests.

Dr. Mitchell was closely associated with the Yorkshire Geological Society for many years and was its President from 1954 to 1956. He was awarded its Sorby Medal in 1965. He was President of the Geology Section of the British Association in 1957 and he was elected a Fellow of the Royal Society of London and the Royal Society of Edinburgh. He received many other honours from various scientific institutions, and he was made a C.B.E. on his retirement in 1967.

He was a good friend to our own Society ever since its inception. His name appears amongst the first list of members published in 1962 and in 1964 Dr. Mitchell and Mrs. Mitchell were the Guests of Honour at the Annual Dinner. One of the more recent occasions when he participated in the Society's activities was in 1971 when he led an excursion to the Seathwaite Tarn area in the Duddon Valley. The writer recalls the way Dr. Mitchell built up a picture of the volcanic episodes that must have given rise to the B.V.S. and of its subsequent history. Especially noteworthy was his authoritative interpretation of the field evidence and his mastery of the detailed petrology of the tuffs and lavas examined. Refreshing his memory from his minutely detailed and beautifully written field slips, he set a cracking pace over the ground. Appeals from the rear to slow down were of no avail but for the

enthusiasts who could keep up it was a rare day indeed.

Dr. Mitchell will be remembered with affection in our Society. His career is an example of application and service which should inspire all of us. He was a man of unassuming confidence yet with a kindly and helpful nature. Characteristically, right up to a few months before his death he was helping the Officers of this Society by correspondence from his home in Edinburgh. When we needed a wise head and authoritative and experienced professional judgements we turned to him.

Geoffrey Gowing, another long-standing member and close friend of Dr. Mitchell's, represented the Society at a Memorial Meeting held in the rooms of the Royal Society of Edinburgh. Many tributes were paid to him by colleagues from the old Geological Survey and from its successor, the Institute of Geological Sciences. Eminent geologists from the academic world and from amateur and professional Societies also spoke.

The Society is especially glad to know that its links with Dr. Mitchell's family will be maintained. Mrs. Mitchell has recently joined the Society to our great delight and their son Murray Mitchell, himself a geologist with the I.G.S. is already well known to us as a member, lecturer and excursion leader.

F.J.C.

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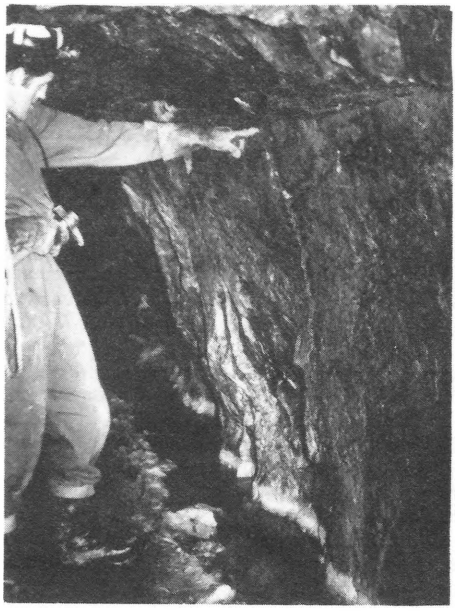
JOHN MOON, F.G.S.

On the 19th November, 1975, John Moon died in hospital after a tragic accident at work. He was 42.

By coincidence his name appears immediately after that of Dr. Mitchell in the first list of Members of the Society and he had been associated with its fore-runner, the West Cumberland Geology Group, for ten years before that.

He was a quiet unassuming man who asked little from life in the way of material things. As long as he had a job which provided him with enough for his pint and to get himself out into the country he seemed happy.

While at Cockermouth Grammar School in the early '50's his deep and lifelong interest in geology was implanted and fostered by Mr.Don Rigby, whose pupils as a group have contributed widely and successfully to the academic, professional and amateur geological world. John later developed his interest through evening classes and came under the influence of our President Mr.E.H.Shackleton. At this stage he was working underground at Lowca Pit and later he was promoted to be a mine surveyor with the N.C.B. His geological interest centred on mines and mining and he worked with another of our members Mr.J.D.J.Wildridge on the exploration and recording of old mine workings in Cumbria. His professional skill and inbuilt caution underground in old workings was



John Moon in Goldscope Mine pointing to the pick marks of the German miners c. 1566.

a valuable asset in tempering the enthusiasm of underground novices. He also did much solitary work in the Newlands area which was carefully recorded and he made discoveries, particularly in the Barrow Mine area of Newlands, which have greatly contributed to the assessment of the working of the mine.

John Moon became a Junior Member of the Geological Society of London in the mid-1950's and later received the honour of being elected a Fellow. He was closely associated with the Workington Rambling Association and it is typical of his outlook and reserved manner that he was happy to plod along with the 'B' party, perhaps because its leisurely approach enabled him to scan the country round for future study.

The Proceedings of the Society testify to his interest and looking through back numbers one sees his name repeatedly as an excursion leader and contributor of articles. His considerable geological library, together with papers and some unfinished work have been very generously given to the Society by his mother so that the results of his endeavours will be available to members in future years.

The accident in which he was involved has taken from us one of nature's gentlemen - a modest and very genuine character who contributed much and will be greatly missed.

ANNUAL DINNERS

1976

The 1976 Annual Dinner of the Society was held at the Red House Hotel, Keswick, on Friday 26th March. The Guests of Honour were Sir Kingsley Dunham, F.R.S., and Lady Dunham. In addressing a gathering of over 50 members and their guests, Sir Kingsley spoke of his geological links with Cumbria, beginning as a University Student and continuing through to his Directorship of the Institute of Geological Sciences from which he had recently retired. Sir Kingsley, whose main geological interest lies in the field of mineralogy, spoke of his early painstaking work on the North Pennine Orefield which resulted in an encyclodaedic research paper covering the zoning of the copper, lead, zinc, fluorine and barium minerals of the Alston Block and adjoining areas. From there he moved to the Furness area where he worked on the occurrence and nature of the sops and flats of haematite ore found there. During the war he was actively concerned with the location and assessment of mineral resources in Britain. After the war years he moved back to the problems of the North Pennine Orefield, suggesting that the useful minerals had possibly emanated from a large concealed mass of granite, similar to the mineralisation in Cornwall. Funds were made available for a drilling programme, and a borehole was sunk at Rookhope in Weardale, locating the granite beneath Carboniferous rocks. Investigation of this showed that the granite was in fact older that the overlying Carboniferous rocks containing the mineral deposits, and therefore may not have been the direct source of those minerals. After a very busy and interesting period as Director of the Institute of Geological Sciences, Sir Kingsley commented that he had now retired to his home in the north east of England, and would be able to take up again some geological studies that he had started to carry out, but had been unable to complete due to the pressures of a very busy career.

During the evening the President, Mr. Edgar Shackleton, made a presentation of the Charles Edmonds Prize to Dr. Dennis E. Jackson of the Open University. The Prize is awarded in memory of the late Alderman Charles Edmonds, the first President of the Society, to persons who have made a significant contribution to the understanding of the geology of Cumbria and its neighbouring counties. Dr. Jackson, who spent his boyhood in the Cockermouth area, did a great deal of detailed work on the graptolite fauna of the Skiddaw Slates. Following this piece of research Dr. Jackson moved to North America as an oil geologist and was able to pursue his researches into the graptolites found in the more ancient rocks of that continent. He has become a world authority on these obscure organisms which have great value as a means of correlating strata which cannot be traced directly from one area to another. Returning to this country Dr. Jackson took up a post in the Department of Earth Sciences at the Open University.

A very successful evening was brought to a close by Mr.Mervyn Dodd who proposed a vote of thanks to the Guests. The Society was particularly pleased to welcome representatives from two of the old mining families of the Alston area, and colleagues from the Institute of Geological Sciences and from the Open University. Mr. Ken Bond and his staff of the Red House Hotel had gone out of their way to ensure a pleasant evening for everyone.

1977

The 1977 Annual Dinner of the Society was held on Friday 25th March at the Red House Hotel, Keswick. About fifty members and their guests were welcomed by the Society's President, Mr. E.H.Shackleton, who introduced the guests of honour, Mr. and Mrs. Colin Rose.

Addressing the gathering after dinner, Mr. Rose spoke of his early links with Cumbria as a field worker with the Geological Survey in the 1930's and also of his more recent work and continuing interest in the area. More latterly he has been one of the United Kingdom representatives at the International Conference on the Law of the Sea. Mr. Rose commented that representatives of 156 nations (more than in the United Nations), meet to debate and plan the future use by mankind of the vast, scarcely-explored regions of the ocean bed. He stated wryly that as well as the great maritime nations land-locked countries such as Chad, Switzerland, Austria, Afghanistan and even the Holy See were represented.

Geologists from many of the official delegations had formed an unofficial dining club called the Seabed Drill and Dredge Club. One meeting of this group, at the Hilton Hotel in a South American capital city, found itself listed as 'The Seabottom Grill and Bridge Club'! At present the two main interests of these deep sea geologists, said Mr. Rose, lay in the possibility of petroleum accumulations in the thick wedges (up to 3 miles thick) of sedimentary rocks at the base of many continental slopes, and also in the curious nodules dredged up from the deep ocean plains from depths as great as 20,000 feet. These nodules had first been discovered by the famous Challenger Expedition in the 1870's and had been found to consist mainly of hydrated oxides of manganese, nickel, copper and cobalt. They are very widespread, and litter the ocean floor to the extent of several per square yard. The technicalities of dredging them, raising them to the surface and processing them, to recover their valuable metallic contents, have been largely solved by the major international companies. Mr. Rose passed one such nodule round for inspection. An object about the size of a walnut, having the appearance and texture of a piece of dense coke. Yet such a material could provide for certain of the non-ferrous metallic needs of mankind for many decades to come. The main problem now is - who owns them?

A formula has been proposed that national jurisdiction should extend outwards from the base of the Continental Slope as far as the

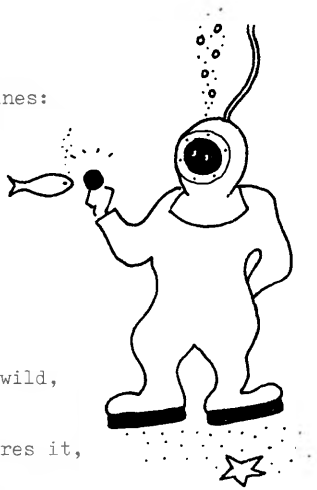
thickness of the sedimentary (i.e. potentially oil-bearing) rocks exceed one hundredth of the horizontal distance. Thus a country could claim the ocean bed as its own beyond, say, a distance of 200 miles from its shore provided the thickness of sediments there exceeded two miles. This formula still leaves huge tracts of ocean bed for international jurisdiction and management.

Mr. Rose's talk provoked a good deal of comment and questions. Sir Kingsley Dunham, lately Director of the Institute of Geological Sciences, commented that there were large detached blocks of essentially continental rocks to the west and north-west of the British Isles, the only part of which appeared above the waves as the tiny islet of Rockall.

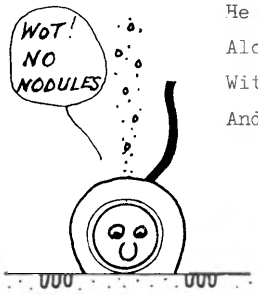
In proposing a vote of thanks to the Guests, Dr. F. J. Cockersole, the Society's Editor, commented on the rapport that had always existed in the world of geology between the professionals, as exemplified by the Officers of the Institute of Geological Sciences, and the interested amateurs. Such a relationship which works very pleasantly for geologists did not seem to exist in many other scientific disciplines, apart from astronomy, and it was quite firmly discouraged in his own profession (gynaecology!). Dr. Cockersole also thanked Mr.G.C.Winn for auditing the Society's accounts during the past years, Messrs. Bob and Jim Bennett for providing floral decorations, and Mr. and Mrs. Ken Bond for their pleasant hospitality at the Red House Hotel.

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A member present contributed the following lines:



Behold the wonders of the deep,
The latest science scene,
A geologist with water wings -
He's very seldom seen.



He hunts the nickel nodule wild,
Along the ocean floor.
With cunning skill he captures it,
And brings it to the shore.

Its capture being noised abroad,
Our geologist is sad,
He thought it had belonged to him,
But finds it claimed by Chad!

15th ANNUAL GENERAL MEETING

The fifteenth Annual General Meeting of the Society was held at the West Cumbria College of Science and Technology, Workington, on 11th February, 1976, with the President, Mr.E.H.Shackleton, in the Chair.

GENERAL SECRETARY'S REPORT

Membership. A survey of the Membership list showed that by the end of December, 1975, the Society had 198 paid-up Members. There were 149 Ordinary, 14 Associate and 11 Institutional Members. There were also 12 instances of Husband and Wife Joint Membership after the first full year of operation of this new category. Approximately 30 members covenanted their subscriptions during 1975 (a number that has since risen to about 50), allowing the Society to recover Income Tax already paid.

It is with sadness that I record the deaths of three Members during the last twelve months; Frank Monkhouse, Alfred Holden and John Moon.

The Council felt obliged to expel one Member during the course of the year.

Contact with Members. Two circulars were sent out during the year. Each Member received a copy of the Membership List, and the Proceedings, Vol.3, Part 3, was sent out in June. The virtual doubling of postal charges has hit the Society hard, but this has been off-set to some extent by the delivery of communications to local Members by hand. My thanks to those who have kindly acted as postmen.

Meetings. There have been six indoor meetings during the course of the year:-

1. The 14th Annual General Meeting was held on 12th February, 1975, at the West Cumbria College, Workington. Members arranged displays of minerals and rocks, and a film, 'Volcanicity in France', was shown. 16 Members and one guest attended.

2. A lecture on 'The Lower Carboniferous Stratigraphical Palaeontology of the Furness and Grange Area' by Mr. Murray Mitchell, at the West Cumbria College, Whitehaven, on 12th March. 24 Members and 1 guest attended.

3. A lecture on 'Aspects of the History of Coal Mining in West Cumbria' by Mr. Frank Carruthers at Richmond School, Whitehaven on 8th October. 20 Members and 10 guests attended.

4. A lecture entitled 'Fragipan in Cumbrian Soils, its origin and significance' by Dr. Barry Mathews. Held at the Ullswater Centre, Penrith on 12th November. 17 Members and 4 guests attended.

5. A lecture on 'Permian Deserts of Britain' by Dr. Brian Waugh, at the Derwent Centre, Cockermouth on 10th December. 28 Members and 17 guests attended.

6. A lecture on 'The Occurrence and Mining of Evaporites' by Dr. Tom Elliott at the West Cumbria College, Workington, on 14th January, 1976. 35 Members and 7 guests attended.

The Annual Dinner was held at the Red House Hotel, Keswick, on 14th March, 1975. Some 40 Members and their guests attended. The Guests of Honour were Dr. and Mrs. Pat Brenchley of the Liverpool Geological Society.

The Council has met on 8 occasions, and the Society is indebted to Miss Slater and to Messrs. Dodd, Cockersole and Shipp for hospitality for the meetings.

Publicity for Society functions has been kindly accorded by Radio Carlisle, CN Print, Cumbria Education Authority, Cumbria Library Services and Cumbria Magazine. The Society reciprocates publicity and attendance at meetings (by arrangement with the appropriate Secretaries) with the Geological Society, the Geologists' Association, the Yorkshire Geological Society, the Liverpool Geological Society and the Westmorland Geological Society.

Correspondence. Apart from routine correspondence with Members, Lecturers and other Societies, there has been the usual crop of requests from outsiders for information. Sadly, as ever, the valuable time spent in looking up references to provide information, or answering lengthy (and often seemingly pointless) questionnaires, is seldom followed by thanks, or even acknowledgement. It seems a pity that so many students engaged in research or project work seem to consider themselves beyond the code of common courtesy.

Conclusions. For your Officers another busy year. It is my hope and belief that we are providing an interesting and acceptable programme for Members. Certainly attendances at lectures are encouraging, and Membership numbers have not declined significantly during the year, despite the rise in subscriptions at the beginning of 1975.

To my fellow Officers and Council Members, and to the many Members to whom I have chatted or written, my thanks for your enthusiasm and support.

T. SHIPP

HONORARY TREASURER'S REPORT

Our financial situation may be described as reasonably satisfactory. We began the year with a total of £288.99 to our credit in bank accounts and cash in hand. During the year we had two large items of expenditure. We repaid to the Liverpool Geological Society the £200 they very generously lent us to help to finance the printing of the revised edition of the Bibliography. The cost of printing 750 copies of the 'Proceedings' Volume III, part 3, was also exactly £200. This issue was produced by a somewhat more economical process than the previous issue which cost £273 for 1000 copies.

In spite of these two large expenses, we finished the year with £283.45 in cash and bank balances, a decline over the year of only some £5. Subscription income at just over £200 has kept up well, and, of

course, reflects the increase in subscription effective from 1st January, 1975. This covers what may be termed the 'running expenses' of the Society. Sales of publications at over £250 show an increase of almost 30% on the previous year, which itself was double the year before. It was mainly the result of a steady demand for the new edition of the Bibliography from colleges all over the country, and this cannot be expected to continue at the same rate in future. Two useful items of income are derived from advertisements in the 'Proceedings' (£16), and from the refund of £21 from the Inland Revenue in respect of deeds of covenant executed in our favour by some 30 members.

On the expenditure side it is not surprising to find that cost of postage ranks as one of the largest items, in spite of the rigid economy exercised in the issue of circulars. One or two items such as 'Expenses of lecturers and leaders' and 'Subscriptions to other Societies' are certain to increase in the current year.

The receipt of some £7 from 'Donations' is chiefly due to the generous gift made every year by the Marchon Division of Messrs. Albright and Wilson, and begun several years ago by Lord Schon of Whitehaven. Several Members also make a practice of paying more than their annual subscription and their generosity is much appreciated. About 50 Members now pay their subscriptions by Banker's Order, which is a great convenience to themselves and the treasurer.

The trustees of the Charles Edmonds Memorial Fund have not made an award in 1975, and the balance stands at £21.

In conclusion I must express by sincere thanks to our Honorary Auditor, Mr. Gerald Winn, for his help in analysing our accounts and for the patience and care with which he verified their correctness.

H. A. WHITE

The following Officers and Members of the Council were elected to serve for the year 1976:

President	E.H.Shackleton, F.G.S.
Vice-President	M.B.Dodd, M.A.
General Secretary	T.Shipp, B.Sc.,F.G.S.
Treasurer	H.A.White, B.A.
Excursions Secretary	Miss D.Slater
Publications Secretary	S.H.Gate, M.Sc.,A.R.I.C.
Editor	F.J.Cockersole, F.R.C.O.G.
Librarian	M.F.Burton
Members of the Council	E.L.Day, A.R.S.M.,C.Eng.,F.I.M.M.
	G.S.Gowing, M.A.,F.G.S.
	J.D.Hinde
	E.Lawrence, B.Sc.,F.G.S.
Honorary Auditor	G.C.Winn, B.Sc.

CUMBERLAND GEOLOGICAL SOCIETY

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR 1975 ENDING 1 JANUARY 1976

EXPENDITURE

(1974) £		£
(32)	Stationery, materials, membership cards &c.	41.61
(6)	Telephone (Secretary)	2.96
(66)	Postages	56.61
(3)	Subscriptions to other Societies	-
(724)	Printing: Proceedings 1973/4 (750 copies)	200.00
	Xerox off-prints of out-of-print publications	16.52
(5)	Expenses of lecturers and leaders	-
(-)	Hire of room for lectures &c.	3.90
(4)	Hire of film	14.95
(-)	Repayment of loan from Liverpool Geological Society to help with printing of Bibliography	200.00
(-)	Refund of overpaid subscription	1.25
(10)	Cash in hand 1.1.76	2.19
(-)	Cheques in hand 1.1.76	16.65
(278)	Balance in Bank 1.1.76 Current account	95.76
	Deposit a/c including interest £12.32)	168.85
(-)	Bank Commission	1.66
		822.91

INCOME

(1974) £		£	£
(599)	Balance at Bank on 1.1.75		
	Current account		43.97
	Deposit account		234.68
	Cash in hand 1.1.75		10.34
(172)	Subscriptions:		
	Arrears: 1 Member @ 75p	0.75	
	2 Members @ 50p	1.00	
	1975: 111 Members @ £1.25	138.75	
	10 Joint Members (Husb'd. & Wife) @ £2.00	20.00	
	14 Associates @ 75p	10.50	
	1 Member @ 75p	0.75	
	11 Institutions @ £1.50	16.50	
	1976 & 1977 in advance: 14 Members @ £1.25	17.50	
	1 Joint Membership @ £2	2.00	207.75
(-)	Overpaid subscription (Bank's error)		1.25
(201)	Sales of publications		259.06
(-)	Advertisements in 'Proceedings'		16.00
(-)	Surplus from Annual Dinner		8.31
(191)	Donations		7.67
(-)	Refund from Inland Revenue of tax on covenanted subscriptions		21.56
(13)	Bank Interest		12.32
			822.91

STATEMENT OF ASSETS AND LIABILITIES AT 1 JANUARY 1976

LIABILITIES	£	ASSETS	£
Subscriptions paid in advance	19.50	Cash & cheques in hand and balance at bank on 1.1.76	283.45
		Duplicator (cost price £50, less depreciation)	10.00
		Typewriter (cost price £15, less depreciation)	5.00
Balance, being excess of assets over liabilities	1288.95	Estimated value of stock of publications, at 50% of nominal selling price	1010.00
	£ 1308.45		£ 1308.45

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CHARLES EDMONDS MEMORIAL FUND

Balance at Bank on 1.1.75	£ 15.01
Interest for one year on 3½% War Stock (nominal value on purchase £146.25)	5.10
Bank Interest on Deposit Account	1.20
Balance at Bank on 1.1.76	£ 21.31

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16th ANNUAL GENERAL MEETING

The sixteenth Annual General Meeting of the Society was held on 9th February, 1977, at the West Cumbria College of Science and Technology Whitehaven, under the chairmanship of the President, Mr.E.H.Shackleton.

GENERAL SECRETARY'S REPORT

Membership. At the end of December, 1976, the paid-up membership of the Society stood at 230, a net increase of 32 during the year. In fact 41 members were admitted during 1976, and there was a loss of only 7 members due to resignation or non-payment of subscription, a record which shows, I think, that the Society is providing its members with the geological interests and activities they seek.

I regretfully record the death of G.H. (Mick) Mitchell and of Geoffrey Kiernan during the year. Dr.G.H.Mitchell attended the Society's Annual Dinner in 1964 as Guest of Honour, and joined the Society in 1962. Over the years he gave his encouragement to a number of the Society's activities. He leaves with us the results of a distinguished career with the Geological Survey including a number of authoritative papers on aspects of Lakeland Geology, but his personal qualities of friendliness and unaffacted interest will be greatly missed. Geoff Kiernan joined in 1973 after attending a series of geology classes at the Derwent Centre. He came to several lectures and joined in a number of field excursions in 1974 before illness overtook him.

An interesting feature of the membership 'pattern' this year is the sudden influx of 'Husband and Wife' Members (7) and Associate Members (10). Totals in the various categories are 159 Ordinary Members, 21 Husband and Wife Joint Members, 17 Associates and 12 Institutional Members.

The response to the request for members to covenant their subscriptions has been most rewarding. The Society was able to recover nearly £50 from the Inland Revenue for a modest outlay in terms of extra postage and paperwork. I have endeavoured to send out the Inland Revenue form R 185 (AP) with the January Circular, and the inclusion of a ready stamped addressed envelope has resulted in members returning these very promptly.

Two circulars to members were issued during the year together with a list of recently joined members and changes of address. I believe it to be important to give members the chance to keep in touch in this way. Once again, postage has proved very expensive, and local mail has been delivered by hand as far as possible. My thanks to all members who helped with the deliveries.

Meetings. There have been seven indoor meetings during the year:-

1. The Annual General Meeting, held on February 11th, 1976, at the West Cumbria College, Whitehaven. A film 'The Hortus Cave'

was shown by countesy of the French Scientific Institute. 26 members attended.

2. Haroun Tazieff's film 'Volcano', a roaring technicolour spectacular, was shown at the West Cumbria College, Workington, on 10th March. 30 members and 26 guests attended.

3. A lecture entitled 'Problems connected with the Origins of the Metalliferous Ores of the Lakeland and North Pennine Orefields' was given by Mr.A.J.McMahon Moore on 22nd September at the Derwent Centre, Cockermouth. 27 members and 8 guests attended.

4. A members evening was held on 6th October at Distington Junior School by kind permission of the Headmaster, Mr.George Rudd. Some interesting displays of rocks, minerals and fossils were on show, as well as a mapping project on Blengdale, and a display of children's work. Disappointingly, perhaps, under 20 members attended.

5. A lecture entitled 'The Ironstone Story' was given by Professor J.E.Hemingway on 10th November at the Derwent Centre, Cockermouth. 28 members and 7 guests attended.

6. A lecture on 'The Evolution of the Geological Structure of the Lake District' was to have been given by Dr. Frank Moseley on the 8th December, but had to be cancelled at short notice as the lecturer had been called to Masirah Island, Southern Arabia. I stepped in to give a lecture entitled 'This Dynamic Earth'. I would like to record my thanks to Mrs. Phoebe Wallace who arranged to have 30 or so plates photographed and mounted as transparencies at 4 days' notice. The lecture was held at the West Cumbria College Whitehaven. 36 members and 10 guests attended.

7. A lecture on 'Geological Fieldwork in Iran' was given by Mr. R.S.Arthurton on 12th January, 1977, at the West Cumbria College, Workington. 26 members and 4 guests attended.

Average attendances at indoor meetings have risen from 26 in 1975 to 35 in 1976.

The Annual Dinner was held at the Red House Hotel, Keswick on 26th March, 1976. 53 members and guests were present. The Guests of Honour were Sir Kingsley and Lady Dunham. During the evening, the Charles Edmonds Prize was awarded to Dr. Dennis E. Jackson of the Open University in recongition of his work on the Skiddaw Series.

The Council has met on seven occasions (average attendance 9.5 out of 12 members), and there has been one meeting of an Editorial Sub-Committee. We are indebted to Messrs. Cockersole, Dodd and Shipp for hospitality for these meetings.

Publicity for Society functions has been accorded by Radio Carlisle, CN Print, Cumbria Magazine, The Lake District National Park, Copeland Diary, and the Journal of the Association of Teachers of Geology. The Society reciprocates publicity and attendance at meetings (by arrangement with the appropriate Secretaries) with the Geological Society, the Geologists' Association, the Yorkshire Geological Society, the Liverpool

Geological Society, the Westmorland Geological Society and the Eden Field Club.

Correspondence. Apart from circulars and other routine correspondence with members - some 600 or so items - I have written some 75 letters dealing with such matters as lecture arrangements, requests for information, and an investigation of the 'pedigree' of a hundred-year-old map showing the geology of the British Isles. This gift to the Society is at present undergoing restoration at the County Archives Department.

Conclusions. This has been a year of consolidation and further expansion in terms of both numbers and of activities. Whether we can maintain our activities at the present rate during a period of economical stringency and rising prices remains to be seen. It is my belief that the Society gives really excellent value for money to those members who take advantage of its activities.

May I conclude by thanking all officers and members who have assisted me in my task as secretary during the year.

T. SHIPP

HONORARY TREASURER'S REPORT

The end of the year 1976 finds the Society in a satisfactory condition financially, chiefly because this has been a year in which there was no issue of 'Proceedings'. Beginning the year with a total of £283.45 in bank balances and cash in hand, we finished it with a total of £697.85, an increase of more than £400. It must be borne in mind, however, that the printing of the next number of the 'Proceedings'. which is planned for 1977, will be a costly item, even with the economical method now adopted for its production, and there may be other expensive printing items before the end of the year.

On the income side, an increase in membership accounts for the rise in subscription income from £207 to £263, and sales of publications also show a pleasing growth from £259 to £339, though this is mainly the result of one large order for a reprint of the article by Frank Moseley in the last number of 'Proceedings'. The refund of £47 from the Inland Revenue reflects a gratifying increase in the number of members who have agreed to execute deeds of covenant on the payment of their subscriptions. The item 'Donations' includes the generous gift made annually by the Marchon Division of Messrs. Albright and Wilson, which was begun several years ago by Lord Schon of Whitehaven. It also includes gifts from a number of members and friends of the Society, among whom I might mention particularly Mr.James Edmonds, son of Alderman Edmonds who helped to found the Society.

On the expenditure side it is perhaps surprising that items such as stationery and postages are not much more than last year. This is explained by the fact that the number of circulars sent to members during the year has been kept to a minimum. The only large expenses for printing was for the special reprint of Frank Moseley's article mentioned

above. This was asked for by the Lake District Special Planning Board, and the payment for it is included in 'Sales of Publications'.

The Trustees of the Charles Edmonds Memorial Fund made an award during the year to Dr. Dennis Jackson, and the fund now stands at £12.43.

Once again I am greatly indebted to our Honorary Auditor, Mr. Gerald Winn, for his valuable help and advice, and for the care with which he has verified the correctness of our accounts.

H. A. WHITE

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The following Officers and Members of the Council were elected to serve for the year 1977:-

President	E.H.Shackleton, F.G.S.
Vice-President	M.B.Dodd, M.A.
General Secretary	T.Shipp, B.Sc.,F.G.S.
Treasurer	H.A.White, B.A.
Excursions Secretary	Miss D. Slater
Publications Secretary	S.H.Gate, M.Sc.,A.R.I.C.
Editor	F.J.Cockersole, F.R.C.O.G.
Librarian	M.F.Burton
Members of the Council	R.Bennett
	E.L.Day, A.R.S.M.,C.Eng.,F.I.M.M.
	J.D.Hinde
	E.Lawrence, B.Sc.,F.G.S.
Honorary Auditor	G.C.Winn, B.Sc.

CUMBERLAND GEOLOGICAL SOCIETY

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR 1976 ENDING 1 JANUARY 1977

EXPENDITURE

(1975) £		£
(42)	Stationery, materials, membership cards &c.	41.94
(3)	Telephone (Secretary)	4.80
(57)	Postages	64.37
(-)	Subscriptions to other Societies	2.00
(217)	Printing: Reprint of article by F. Moseley	104.50
	Xerox copies of out-of-print proceedings	7.22
(-)	Expenses of lecturers	16.00
(-)	Advertisement in 'Star'	4.92
(4)	Hire of rooms for lectures	5.20
(-)	Wreath (J.Moon)	1.25
(-)	Photographs	1.50
(1)	Refund of overpaid subscriptions	2.50
(-)	Member's cheque (unsigned) returned by Bank	1.25
(-)	Refund of overpayment by customer	1.06
(2)	Cash in hand 1.1.77	8.14
(2)	Bank Commission	1.58
(265)	Balance in Bank 1.1.77 Current account	100.63
	Deposit a/c including interest £6.29)	589.08
		976.42

INCOME

(1975) £			£
(289)	Balance at Bank on 1.1.76		
	Current account		95.76
	Deposit account		168.85
	Cash in hand 1.1.76		2.19
	Cheques in hand 1.1.76		16.65
(208)	Subscriptions:		
	Arrears: 3 Members @ 1.25	3.75	
	1 Member (1974) @ 75p	0.75	
	1 Joint Members @ £2	2.00	
	1 Member (1975) @ 50p	0.50	
	1976: 1 Member @ £1.11	1.11	
	144 Members @ £1.25	180.00	
	19 Joint Members @ £2	38.00	
	16 Associates @ 75p	12.00	
	10 Institutions @ £1.50	15.00	
	1977: 5 Members @ £1.25	6.25	
	1 Joint Members @ £2	2.00	
	1 Institution @ £1.50	1.50	
	1 Part payment @ 25p	.25	263.11
(8)	Surplus from Annual Dinner		10.00
(8)	Donations		24.25
(22)	Refund from Inland Revenue of tax on covenanted subscriptions		47.32
(-)	Overpaid subscriptions		2.50
(259)	Sales of Publications		339.50
(12)	Bank Interest		6.29
			976.42

STATEMENT OF ASSETS AND LIABILITIES AT 1 JANUARY 1977

LIABILITIES	£	ASSETS	£
Subscriptions paid in advance	10.00	Cash in hand and balances at the bank on 1.1.77	697.85
		Duplicator (cost price £50, less depreciation)	10.00
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