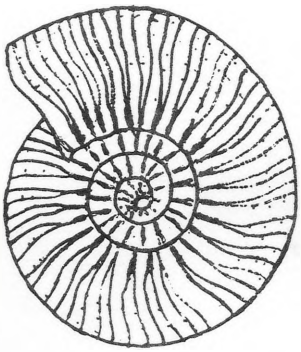
THE CUMBERLAND GEOLOGICAL SOCIETY



PROCEEDINGS

Volume 4 1979-81 Part 2

THE CUMBERLAND GEOLOGICAL SOCIETY

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1979-81

Volume 4 **Part 2**

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DRUMLINS AT WATENDLATH

P. Wilson

(Short Communication)

SUMMARY

This brief note describes three drumlins that lie due south of Watendlath Tarn, Cumbria. Morphometric parameters indicate that although these features are of small size by comparison with those elsewhere in Cumbria they do exhibit the characteristic drumlin morphology. It is considered that the drumlins date from the last major phase of glaciation c. 26,000 - 15,000 years B.P.

1. INTRODUCTION

Drumlins are one of the most distinctive of all glacial landforms and are commonly defined as elongated oval-shaped mounds or hillocks composed predominantly of glacial drift. Usually they possess a steep proximal slope (stoss) and a gentler distal slope (lee). Whilst all workers accept drumlins as characteristic glacial bedforms and valuable indicators of the direction of ice-flow there is still no single generally acceptable theory as to the mechanism of their deposition. Indeed it seems likely that drumlins may develop in response to a number of conditions prevailing in the subglacial environment and that these conditions are neither constant nor the same for all glaciated zones.

Drumlins generally occur in 'fields' numbering tens, hundreds or even thousands, but isolated features have also been noted. Drumlins are frequently regarded as occupying low-lying areas and located near to terminal or end-moraines. Hence a close relationship between drumlin fields and ice-limits is recognised in the literature. However, drumlins located in highland regions and far from inferred ice-limits are also known.

Clearly, although drumlins may be typical of glaciated lowlands and occur in vast swarms in such areas the conditions for their development may also exist within other glacial terrain environments. For a recent review on the formation and location of drumlins see Menzies (1979).

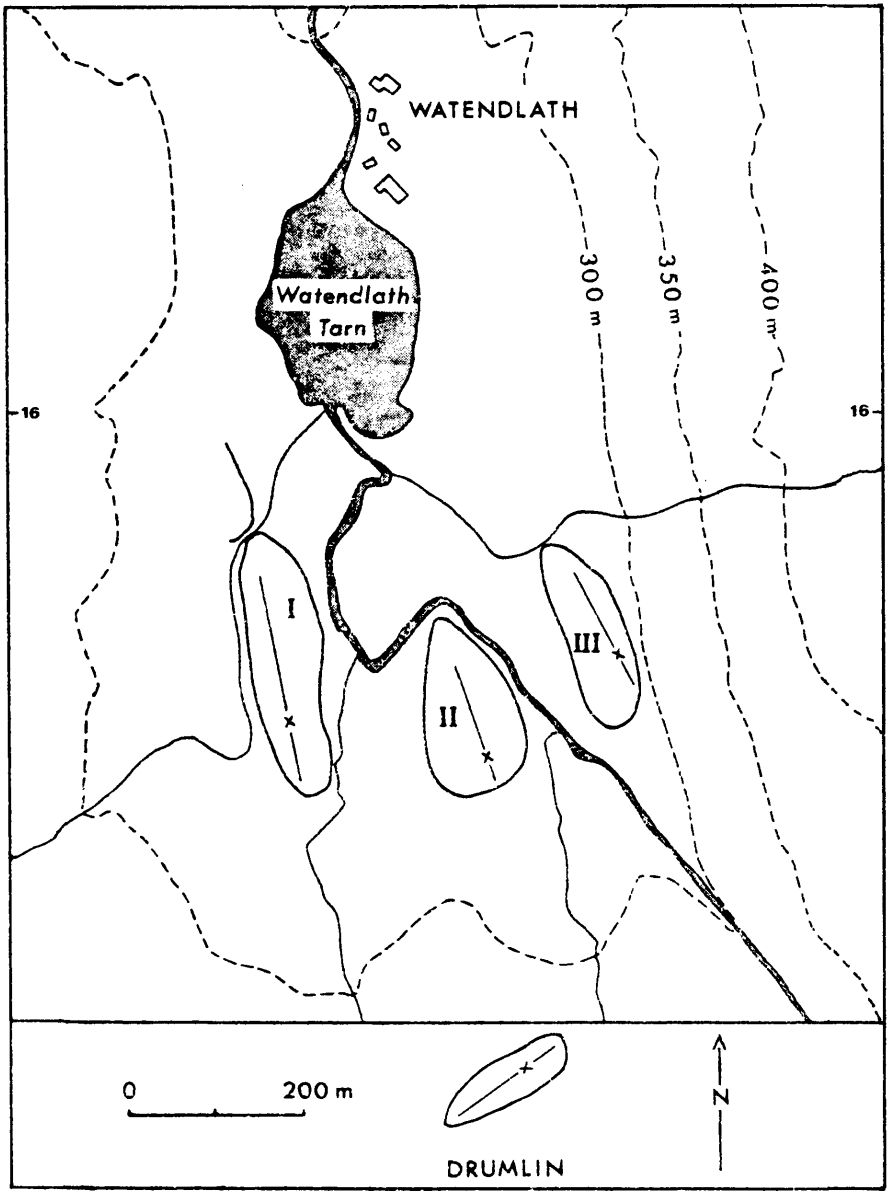


Fig. 1 POSITION OF DRUMLINS AT WATENDLATH

2. DRUMLINS IN CUMBRIA

Drumlins exist in several areas of Cumbria and generally conform to the typical pattern of occurring in 'fields' in low-lying and open areas. These drumlin fields are mentioned in several studies, for example: the Eden Valley (Hollingworth, 1931; Dóornkamp and King, 1971; Rose and Letzer, 1975, 1977), Threlkeld Common (Boardman, 1975) and Furness and south-east Cumbria (Greswell, 1952, 1962; Grieve and Hammersley, 1971; Johnson, 1975). These drumlins are believed to date from the Late Devensian glaciation c. 26,000 - 15,000 years B.P.

3. THE WATENDLATH DRUMLINS

The drumlins occur in the area south of Watendlath Tarn at elevations between 265 and 295 metres (Fig. 1) and may be referred to for convenience as I (Western), II (Central) and III (Eastern) (Plates 1 and 2). Ward (1876) considered this area to possess 'moraine-like matter upon rounded bosses of rock' and to the present author's knowledge this statement represents the only previous description of the deposits under consideration.

(a) Morphometry. Drumlin boundaries, crest-lines and highest points were determined by field mapping at a scale of 1 : 10,000 and by air-photo interpretation. Measurements of drumlin parameters and the calculation of other attributes were made from the field map information. These data are presented in Table 1.

Table 1. MEASURED AND CALCULATED PARAMETERS FOR THE WATENDLATH DRUMLINS

DRUMLIN	I	II	III
Crest-line orientation	348°	341°	333°
a Axis (km)	0.32	0.22	0.24
b Axis (km)	0.095	0.125	0.075
Area (km^2)	0.022	0.019	0.014
Tapering value (k)	3.36	2.00	3.23
Elongation Ratio (E)	3.37	1.76	3.20
Stoss-point Ratio (Sp/R)	0.328	0.204	0.375

(for explanation of parameters see Rose & Letzer, 1975)



Plate 1 DRUMLIN I - THE WESTERMOST AND LARGEST OF THE THREE. PLOUGH MARKS RUNNING ACROSS THE DRUMLIN ARE CLEARLY VISIBLE.

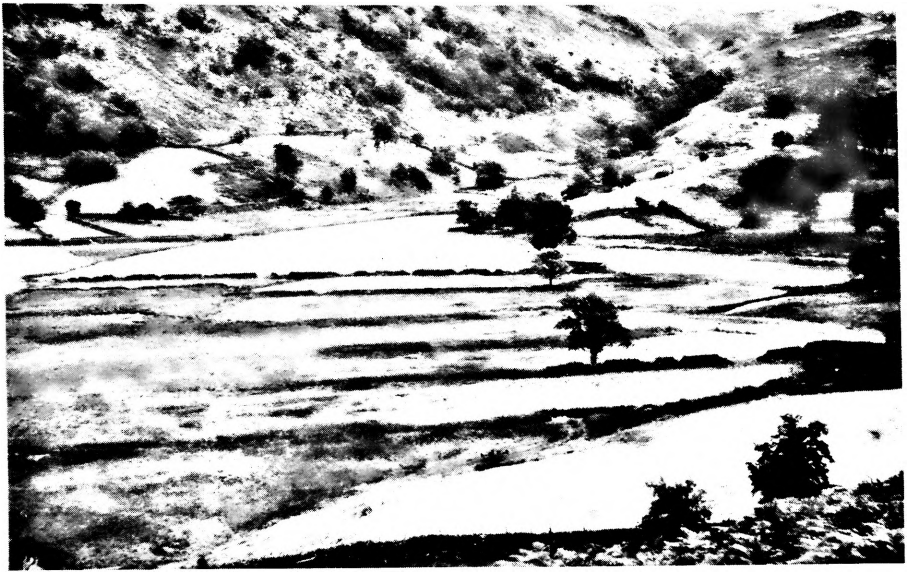


Plate 2 DRUMLINS II (RIGHT OF CENTRE) AND III (LEFT OF CENTRE)

Crest-line orientations reveal that the drumlins conform to the general trend of the Watendlath Valley (c. 340°). The drumlins vary slightly both in size and shape. Drumlin I is the largest and has the greatest k and E values. It is likely that this drumlin was formerly larger than is shown on Figure 1. At the northern end a small stream appears to have breached the distal slope for an ill-defined mound continues the general directional trend. Drumlin III, the smallest, is of similar shape to I, while II is the most circular or compact. The highest points are all on the stoss side of the drumlin mid-points and are located nearer to the mid-point for I and III than for II as the Sp/R values show (Table 1). The stoss slope is also the steeper slope for Drumlins I and III, whereas for II the stoss slope merges with the valley slope and does not extend for more than a few tens of metres. Drumlin III merges with the valley wall on its east side giving the effect of 'plastering on' to the slope (Plate 2). This drumlin has numerous large boulders scattered over its surface, presumably derived by frost shattering of the rock outcrops higher on the valley side. Surface boulder accumulations are absent from the other drumlins.

(b) Internal Composition. The absence of exposures in the drumlins prevented any assessment of their internal composition and sedimentary properties. Information from the landowner revealed that the drumlins were ploughed for crops during the Second World War and plough marks are still clearly visible on drumlin I (Plate 1). Consequently attempts to obtain sedimentological data from shallow surface pits were abandoned, although such pits did show unsorted material typical of till. In addition a small exposure in the stream bank immediately south of drumlin III showed 1.5 metres of till indicating that till is present locally.

(c) Age Considerations. In the absence of datable remains associated with the drumlins a consideration of age must be based on the currently accepted sequence of Quaternary events in Cumbria as a whole. This topic has recently been reviewed by Pennington (1978) and almost all the superficial Quaternary deposits are considered to be the product of the last major phase of glaciation (Late Devensian) dating from c. 26,000 - 15,000 years B.P. Following the decay of this ice-sheet a period of climatic amelioration occurred, now known as the Windermere Interstadial, only to be succeeded by another cold stage in which limited glaciation of the corries and some valleys took place. This final cold period (c. 11,000 - 10,000 years B.P.), termed the Loch Lomond Stadial, is well documented regarding the extent of the glaciers (Manley, 1959; Pennington, 1978; Sissons, 1980). There is no evidence for ice in the Watendlath valley at this time and the nearest glacier as determined by Sissons (1980) was some 3 km to the south in Greenup. It is most likely, therefore, that the drumlins relate to the last major phase of glaciation.

4. CONCLUSIONS

Morphometric parameters indicate that the drumlins conform in shape to their larger counterparts of the Cumbrian lowland and they probably developed between 26,000 and 15,000 years B.P., but it is difficult to explain why the drumlins developed at this particular location. Their orientation shows that at the time of formation the ice was moving in accord with the general valley trend. The tarn itself represents an area of localised glacial overdeepening in response to the presence of a prominent rock bar at the outflow, but whether the drumlins also formed in response to this event must remain a speculative hypothesis until, perhaps, such time as their internal composition is known.

5. REFERENCES

BOARDMAN, J., 1975. Morphometric Analysis of Drumlins. Classroom Geographer. May. 8 - 13.

DOORNKAMP, J.C. and KING, C.A.M., 1971. Numerical Analysis in Geomorphology. Edward Arnold.

GRIEVE, W. and HAMMERSLEY, A.D., 1971. A re-examination of the Quaternary Deposits of the Barrow Area. Proc. Barrow Naturalists Field Club. 10. 5 - 25.

GRESSWELL, R.K., 1952. The Glacial Geomorphology of the South-Eastern part of the Lake District. Liverpool and Manchester Geological Jour. 1. 57 - 70.

GRESSWELL, R.K., 1962. The Glaciology of the Coniston Basin. Liverpool and Manchester Geol. Jour. 3. 83 - 96.

HOLLINGWORTH, S.E., 1931. The Glaciation of Western Edenside and Adjoining Areas and the Drumlins of Edenside and the Solway Plain. Quat. Jour. Geol. Soc. Lond. 87. 281 - 359.

JOHNSON, R.H., 1975. Some Late-Pleistocene involutions at Dalton-in-Furness, Northern England. Geol. Jour. 10. 23 - 34

MANLEY, G., 1959. The Late-Glacial Climate of North-West England. Liverpool and Manchester Geol. Jour. 2. 188 - 215.

MENZIES, J., 1979. A Review of the literature on the Formation and Location of Drumlins. Earth Science Reviews. 14. 315 - 359.

PENNINGTON, W., 1978. Quaternary Geology. In Moseley, F.,(ed.) The Geology of the Lake District. Yorks. Geol. Soc. Occ. Pub. No. 3. 207 - 225.

ROSE, J. and LETZER, J.M., 1975. Drumlin measurements: a test of reliability of data derived from 1 : 25,000 scale topographic maps. Geol. Mag. 112. 361 - 480.

ROSE, J. and LETZER, J.M., 1977. Superimposed Drumlins. Jour. of Glaciology. 18. 471 - 480.

SISSONS, J.B., 1980. The Loch Lomond Advance in the Lake District, Northern England. Trans. Royal Soc. Edinburgh: Earth Sciences. 71. 13 - 27.

WARD, J.C., 1976. The Geology of the Northern Part of the Lake District. Mem. Geol. Survey. 12 plus 132 pp. Page 87.

FURTHER VERTEBRATE FOOTPRINTS FROM THE LOWER PERMIAN SANDSTONES OF CUMBRIA

W. A. S. Sarjeant

Vertebrate footprints were first reported from the English Permian almost one hundred years ago, by an amateur geologist, George Varty Smith. They were discovered in what was then called the Penrith Red Sandstone. The better impressions were found in a quarry 3½ miles east of Penrith, north of the Penrith - Alston road; these were cast by Smith and exhibited to the Geological Society of London when, on May 28th, 1884, he presented an account of his discovery to its members. A second discovery of footprints was also made by Smith on a hilltop at Whinfell Wood 3 miles south east of Penrith, but these were too poor for casting or description.

Oddly, Smith's published account of his discovery (1884) contained no illustration of his find. Fortunately, the casts were later made available for study to the stratigrapher George Hickling, who illustrated them in his account of 'British Permian Footprints' (1909), fortunately, because the casts have since disappeared. Hickling recognised prints of three principal types. Two were of large quadrupedal reptiles, then considered 'Chelichnoid' (i.e. produced by turtles), but now known to be the footprints of caseasaurs, a group of primitive, herbivorous mammal-like reptiles. The third type was much smaller and 'Lacertoid' (i.e. of lizard type): these prints would nowadays be regarded as the track of a cotylosaur, a member of the stem group of primitive reptiles.

In 1937, fossil footprints were discovered at a third locality, a small quarry operated by Messrs. William Graves, quarriers, of Carlisle, on the top of Lazonby Fell, near Penrith, Cumberland, (latitude approx. 54°41'N, longitude approx. 2°45'W; National Grid reference NY 5138). Three slabs were extracted. Two were presented to Carlisle Museum (specimen nos.6.1937.1 and 6.1937.2); the present whereabouts of the third is unknown. Not until thirty years later were the tracks on the two surviving slabs described by Justin B.Delair; one was illustrated but considered of uncertain type (Delair, 1967, p.3, fig.1), the other noted as consisting of 'Chelichnoid' prints of poor quality. The bed in

which they occurred is now styled the Lazonby Sandstone, which is wholly of dune origin, and is considered of younger Early Permian (Lower Zechstein) age, probably equivalent to the Rotliegendes Sandstein of Germany and the North Sea region.

Recently a further slab from the Lazonby Fell quarry, extracted by Mr.W.S.Graves in 1955, was acquired by the Carlisle Museum (specimen no. 23-1981). Through the courtesy of Mr. David Clarke four photographs of it, taken under different directions of illumination, were made available to me for study.

The tracks consist of incomplete impressions of a manus (forefoot) and pes (hindfoot) of a reptile of large size. In each print, two digits only are impressed, probably the second and third, together with a part of the palm and sole of the foot. Each is acute, the digits of the pes somewhat longer and slimmer than those of the manus. The overall length of the manus impression is 33.83 cm, the longer digit (?III) being 9.67 cm in length and the shorter digit (?II) 7.98 cm. The overall length of the pes impression is 33.83 cm, the longer digit (?III) being 12.51 cm in length and the shorter digit (?II) 11.60 cm.

These, then, are the partial imprints of the feet of a large quadrupedal reptile, only the central two of four functional digits being impressed. It appears probable that the animal was travelling at speed, but a complete trackway would be needed to confirm this, since other causes why only two digits were impressed may be imagined.

The prints are certainly those of a caseasaur and may be assigned to the ichnogenus Laoporus Lull, a type of caseasaur print encountered widely in the later Early Permian and Late Permian continental sediments of Europe and North America. Though their assignment to a particular ichnospecies is impossible without fuller information on foot morphology and track pattern, their similarity in form to the ichnospecies Laoporus (ex Herpetichnus) robustus (Delair, 1966) Haubold, 1971, may be noted. This is a form of footprint first described from the Permian of Corncockle Muir, Dumfries-shire, Scotland; the described footprints are considerably smaller than those from Lazonby Fell, but their second and third digits are of similar proportionate size.

Since the Lazonby Fell quarry is now in disuse and overgrown, it is unlikely to furnish further information on the reptile life of Permian Cumbria. However, new discoveries are to be expected in other localities and much might be learnt from them. Society members are urged to look for fossil tracks on road cuts, excavations for buildings, and other temporary exposures of the Permian and, if any finds are made, to communicate their observations to the Carlisle Museum and Art Gallery, so that any worthwhile specimens may be extracted in time and preserved for study.



Plate 1. INCOMPLETE REPTILIAN FOOTPRINTS (LAOPORUS SP.) FROM LAZONBY SANDSTONE, NR. PENRITH, CUMBRIA. Illumination is from the left. (Photo: Carlisle Museum & Art Gallery)

REFERENCES

DELAIR, J.B., 1966. Fossil Footprints from Dumfriesshire, with descriptions of new forms from Annandale. Trans. Dumfriesshire and Galloway Nat. Hist. Soc. Series 3. 43, 14 - 30.

DELAIR, J.B., 1967. Additional records of British Permian Footprints. Trans. Dumfriesshire and Galloway Nat. Hist. Soc. Series 3. 44, 1 - 5.

HAUBOLD, H., 1971. Ichnia Amphibiorum et Reptiliorum Fossilium. Handbuch der Palaoherpetologie. part 18. Gustav Fischer Verlag, Stuttgart, Germany. 124 pp.

HICKLING, G., 1909. British Permian Footprints. Mem. Proc. Manchester Lit. Phil. Soc. 1908-09, 1 - 30.

SARJEANT, W.A.S., 1974. A History and Bibliography of the study of Fossil Vertebrate Footprints in the British Isles. Palaeogeog. Palaeoclimatol. Palaeoecol., 16. I - II + 265 - 378.

SMITH, G. VARTY., 1884. On further discoveries of the Footprints of Vertebrate Animals in the Lower New Red Sandstone of Penrith. Quat. Jour. Geol. Soc. Lond., 40. 479 - 481.

GLACIAL GEOMORPHOLOGY OF THE KESWICK AREA, NORTHERN CUMBRIA.

J. Boardman

SUMMARY

Streamlined landforms, erratics and till macrofabrics show that ice from the Thirlmere basin flowed both to the northwest and to the northeast around the Skiddaw massif. Some variation in flow pattern occurred with time in parts of the Keswick area. During deglaciation ice stagnated in the valleys and kame and kettle topography characterise these areas. The Greta Gorge results from a change in the direction of meltwater flow after ice stagnation, allowing water to escape by the lowest available route. Catastrophic drainage of an ice-dammed lake may possibly have supplied much of the meltwater. All events appear to relate to the closing stages of the Late Devensian glaciation.

1. INTRODUCTION

This article considers the distribution and significance of glacial and glacifluvial sediments and landforms in the area around Keswick, northern Cumbria. The area is bounded on the west by the Derwentwater - Bassenthwaite glacial trough and to the north by the Skiddaw - Blencathra massif rising to 1000 metres. Blencathra is separated from Clough Head, the most northerly peak of the Helvellyn range, by the broad, glacially abraded Vale of Threlkeld (Fig.1).

The River Glenderamackin leaves the Vale of Threlkeld just west of Threlkeld village and, for 4 km, is confined within a steep-sided gorge. Before entering the gorge it is joined by St. John's Beck and becomes the River Greta. Two tributaries, Naddle Beck and Glenderaterra Beck, join the Greta during its gorge section. Between the Vale of St. John's and the Naddle valley is an interfluve rising to about 350 metres. An area of similar height separates the Keswick lowland from the Naddle valley.

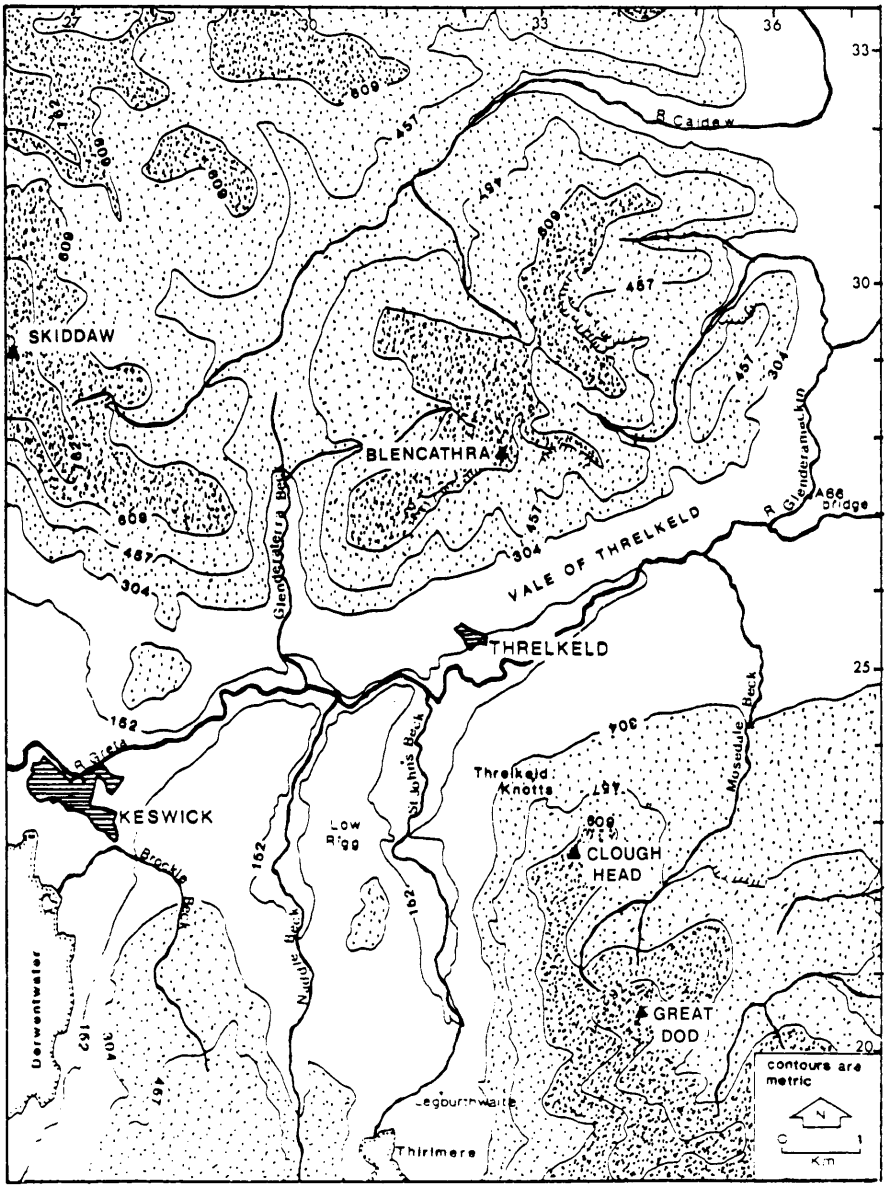


Fig.1 TOPOGRAPHY OF THE KESWICK AREA.

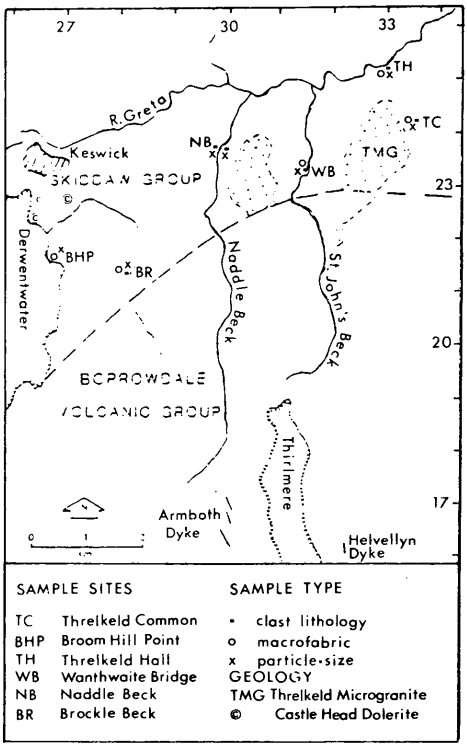


Fig.2 GEOLOGY AND SAMPLING SITES IN THE KESWICK AREA.

The major geological boundary between the Skiddaw Group (SG) and the Borrowdale Volcanic Group (BVG), both of Ordovician age, crosses the area (Fig.2). The former is represented by the Kirk Stile Slates which are thinly-cleaved mudstones (Jackson, 1978) and the latter by a variety of basaltic, andesitic and dacitic lavas and pyroclastic rocks especially ashfall tuffs (Millward et al., 1978). Threlkeld Microgranite (TMG) occurs in the form of a laccolithic intrusion on either side of the Vale of St. John's, and Armboth Quartz Porphyry outcrops as dykes near Thirlmere (Fig.2).

Previous work on the Keswick area is almost non-existent. Nicholson (1869) suggested that the Derwentwater basin is a result of glacial erosion aided by the presence of soft Skiddaw Slate. In the 1870's Ward, using striae and the distribution of erratic boulders, showed that ice originating in the central Lake District moved from south to north across the area. He recognised that at a late stage the ice was confined to the valleys and formed moraines (Ward, 1873,1876). Unpublished work by Smith (1959) comments on parts of the area and some aspects of the Quaternary geomorphology have recently been discussed in other contexts (Boardman, 1977,1978,1979,1980).

Field mapping was carried out at 1:10,000 scale and sediment samples were examined in terms of moist Standard Soil Colour, particle-size distribution, macrofabric and clast lithology.

2. THE THRELKELD AREA

The south-facing valley side of the Vale of Threlkeld is till covered below about 300 metres, scree and vegetated scree being dominant above this altitude. On the valley floor the

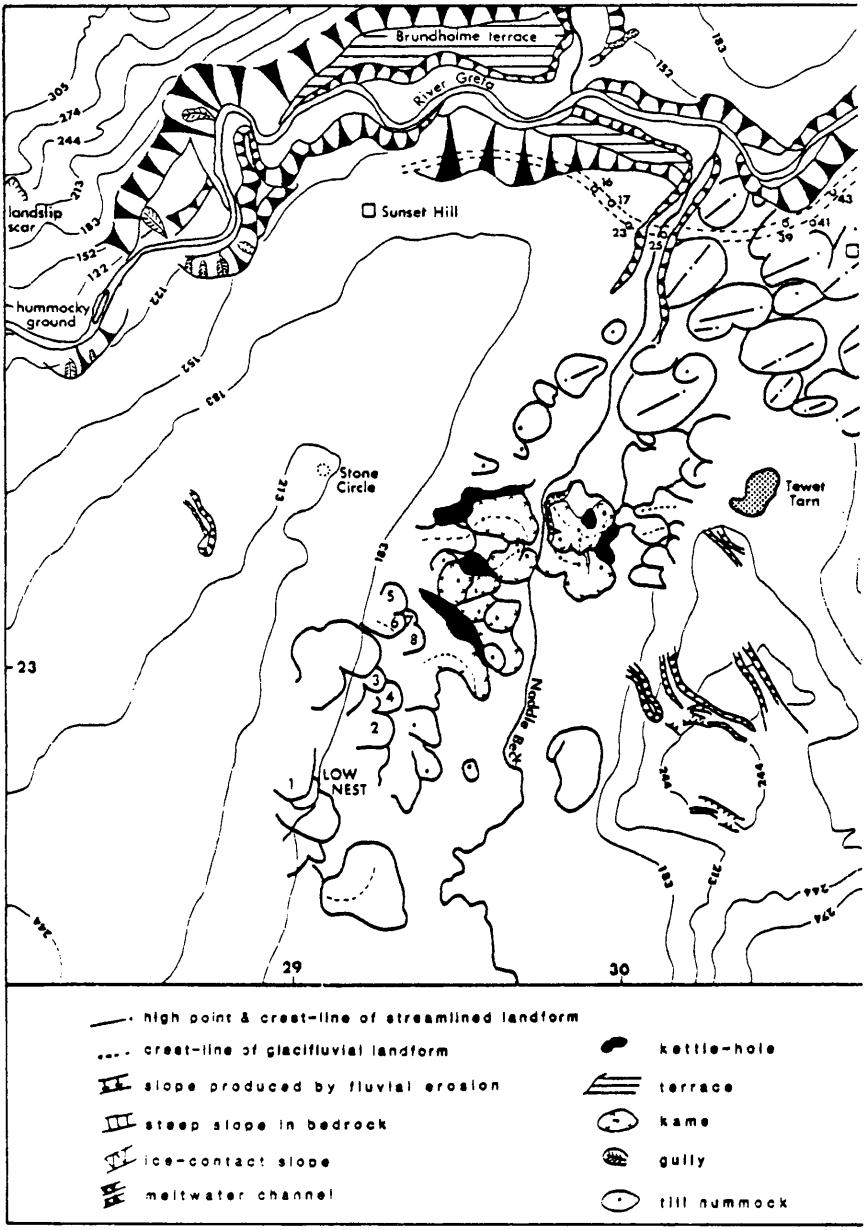
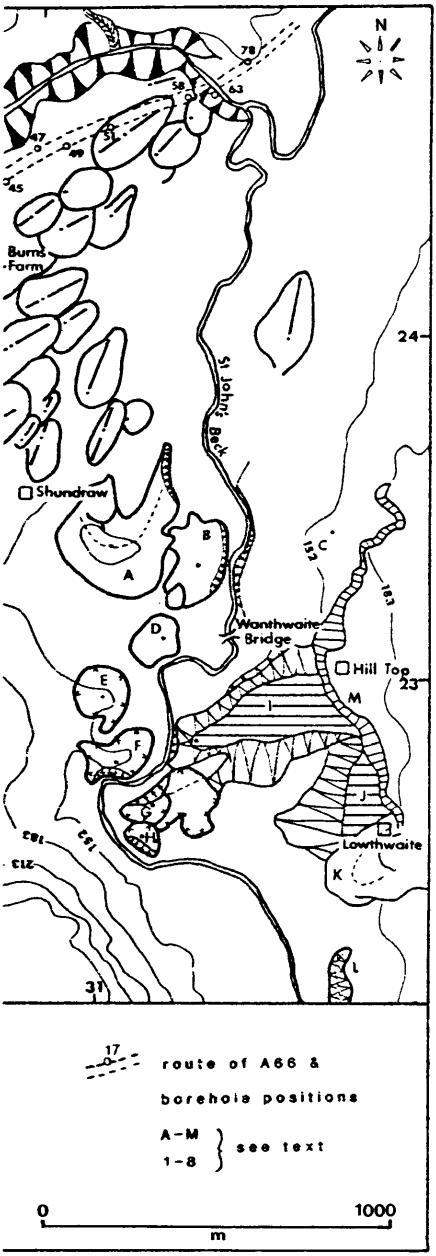


Fig.3 LANDFORMS OF THE VALE OF ST.JOHN'S AND NADDLE.



Glenderamackin meanders over a wide flood plain occasionally impinging on the valley-side till slopes, particularly those facing north, to form river cliffs.

The north-facing gentler slope is covered by a thick mantle of till which, below 300 metres, shows many signs of reworking by gelifluction and landslipping. The higher, steeper slopes on Threlkeld Knotts (Fig.1) are underlain by microgranite and frequently covered by angular boulders. Stone-banked lobes occur and frost shattering is seen to have been responsible for partially infilling small meltwater channels at NY 327.237, 328.235 and 328.233. Each of these is orientated directly down the maximum slope in a northerly direction and the highest begins at an altitude of 460 metres.

Till exposures in the area are generally small and poor, and most occur in river cliffs along the course of the Glenderamackin and St. John's Beck. The best exposed river-cliff section is near Threlkeld Hall (Fig.2). In the cliff (NY 328.250), 2.5 metres of dark olive grey (2.5GY 4/1)* till is overlain by 2 metres of brown till which becomes lighter towards the ground surface. The colour change is attributed to oxidation. Particle-size analysis of this till shows mean values of 36.7% gravel, 27.2% sand, 23.8% silt and 12.3% clay, which is relatively gravel-rich

* Munsell Soil Colour Number.

in comparison with till samples from other parts of the north-eastern Lake District (Fig.2 and Table 1). The Threlkeld Hall sample is dominated by resistant BVG clasts (TH1, Table 2), with a component of TMG from nearby outcrops (Fig.2). The macrofabric from the grey till shows a NW-SE trend conflicting with the land-form and lithological evidence which implies ice movement down the NW-facing slope. Evidence for similar activity is seen at a till exposure on Threlkeld Common (Fig.2). This evidence, and macro-fabric data from Laddray Wood (NY 347.268) 3 km to the east, together with the presence of gelifluction lobes on Threlkeld Common, indicates substantial post-depositional till movement.

Excavations for the foundations of the new A66 road bridge across the River Glenderamackin flood plain (NY 363.272) revealed laminated silts and clays. Boreholes show that this unit overlies till and is itself overlain by coarse, flood-plain gravels. It occurs across the full width of the valley and reaches a maximum thickness of 5 metres and a maximum elevation of 174 metres. The silts and clays are interpreted as having been deposited in a lake of considerable extent and depth with a surface elevation of at least 174 metres O.D. An ice dam in the western end of the Vale of Threlkeld is necessary in order to impound such a lake as the elevation of the drift surface is about 160 metres.

3. THE VALE OF ST. JOHN'S

At the northern end of the vale, on the higher ground around Burns Farm (NY 307.243) is a group of small, low drumlins and

Table 1. KESWICK AREA. PARTICLE-SIZE ANALYSIS.

Sample ref.no.	% of total sample					% particles <2mm			
	gravel	sand	silt	clay	50% value phi units	sand	silt	clay	50% value phi units
WB1	37.7	28.8	22.4	11.1	0.8	46.3	35.9	17.8	4.5
BR1	36.9	27.1	23.5	12.5	0.8	43.0	37.1	10.0	4.8
TH1	35.4	25.7	25.7	13.2	1.4	39.8	39.7	20.5	5.3
BH1	60.5	17.6	15.7	6.2	-2.5	44.5	39.7	15.8	4.9
NB1	47.6	37.4	14.1	0.9	-0.7	71.4	26.8	1.8	2.7
NB2	74.2	19.1	5.8	0.9	-2.3	73.9	22.5	3.6	0.5
TC1	50.2	33.6	11.3	4.9	-1.1	67.5	22.6	9.9	1.8

Table 2. KESWICK AREA. CLAST LITHOLOGY (4-8 mm size range)

Sample ref.no.	n	SG	BVG	TMG	Q	ARM	UNID
WB1	512	2.7	87.0	7.2	2.3		0.8
BR1	325	9.5	89.3		0.9	0.3	
TH1	691	22.0	61.1	13.3	3.3	0.3	
NB1	934	1.2	69.1	29.4	0.3		
NB2	911	0.4	91.7	7.5	0.2		
TC1	855	33.9	9.9	54.4	0.4		1.4

All figures are percentages except 'n' column.
Location of sample sites is shown on Fig.2.

n = number
SG = Skiddaw Group
BVG = Borrowdale Volcanic Group
TMG = Threlkeld Microgranite
Q = Quartz
ARM = Armboth & Helvellyn dyke rock (Quartz Porphyry)
UNID = Unidentified

associated non-streamlined, till hummocks (Fig.3). The mean length of the drumlins is 209 metres (n = 25), and they rise to less than 5 metres above the surrounding area. Crest-lines clearly trend 050/230° which, in combination with the clast lithology of the regional till indicates movement from the SW to the NE. Borehole evidence indicates that the drumlins are composed wholly of till (Fig.4). The drumlins represent small-scale, streamlined glacier bedforms developed in response to late-stage ice movement. They are concentrated on an interfluve and valley sides in the areas of thick till and are absent from the higher ground to the south where till cover is sparse.

On the higher ground of Low Rigg, south of Tewet Tarn (Fig.3), a series of small meltwater channels, cut in bedrock, is aligned SE-NW. Two of the channels are incised across the N-S watershed of the hill and have humped profiles. There is now general agreement that such channels are the result of sub-glacial meltwater (Sissons, 1958). The direction of the channels is to some extent governed by a major joint trend in the microgranite, but must principally reflect a regional direction of sub-glacial water movement.

On the floor of the vale is a series of hummocks (A-H, Fig3). An exposure where St. John's Beck undercuts those to the north of Wanthwaite Bridge indicates gravel-rich till with BVG clasts (WB1, Tables 1 and 2), and an anisotropic macrofabric reflecting slump processes (Rose, 1974). Hummocks E, F and G are kames composed of sand and gravel exposed near the base and top. Hummock H is till on bedrock and I and J are kame terraces with clearly defined ice-contact slopes. In the south is a small esker (L), with exposures of gravel in its eastern slope. K is a crescentic ridge of till, and sand and gravel. It is at a higher level than J and is not clearly related to any other landform so that its origin is obscure. All sand and gravel mounds and terraces reach an elevation of about 155 metres.

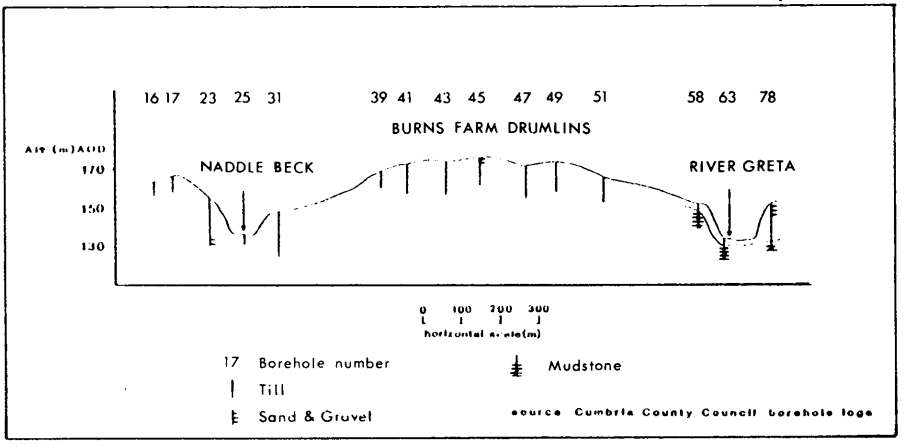


Fig.4 BOREHOLES AND TRIAL PITS BETWEEN NADDLE BECK AND THRELKELD

The till hummocks and kames appear to be part of a single assemblage and represent the effects of ice down-wasting in the vale. Sand and gravel washed from the ice surface and valley sides would accumulate in holes in the stagnant, disintegrating ice to form terraces whose altitude would be controlled by the water table in the ice mass, as indicated by the accordant altitude of the high points of the kames and the surfaces of the terraces. Holes in the disintegrating ice, away from the valley sides, were filled with sand and gravel to form kames. The existence of stagnant ice in the basin to the south of the kame terrace is confirmed by the survival of a small esker, formed subglacially by water flowing towards the north, as indicated by exposures of imbricate gravels.

The landform assemblage described is similar to that proposed by Flint (1929) for deglaciation with respect to stagnating valley glaciers. In addition, till hummocks occur which appear to be the result of till melting out, or flowing from, debris-rich bands in the stagnant ice. The close association of till and sand and gravel in G and H indicates that both sediments were being deposited contemporaneously. This is similar to the situation envisaged by Hartshorn (1958) for the formation of flow tills.

Ice stagnation in the Vale of St. John's would be caused by separation, during thinning, of ice in the Vale from its up-glacier continuation in the Thirlmere basin due to the emergence of high ground around Legburthwaite (NY 318.197) which would have obtruded, as a rock bar, into the long profile of the ice-sheet.

4. THE NADDLE VALLEY

Parts of the valley bottom and east-facing valley side are characterised by a randomly distributed collection of small sand and gravel kames separated by kettle holes (Fig.3). The Geological Survey noted the presence of many boulders on the surface of the mounds (Ward, 1878), but these have now been cleared. To the south on the valley side are less steep-sided till hummocks, a number of which have a lobate form, especially near Low Nest (Nos. 1-8, Fig.3) suggesting downslope post-depositional movement of material.

The kames on either side of the footbridge across the Naddle Beck at NY 298.234 are formed of sandy gravels (NB1 and NB2, Table 1) with a content of clay and silt which is much lower than the typical till in the area. The clast lithology shows NB1 to have a high proportion of TMG which implies transport from the east or southeast (Table 2).

The broad similarity of the land form assemblages in the Naddle valley with that in the Vale of St. John's suggests a comparable origin. Decaying ice occupied the valley, with sand and gravel being washed from it into holes, together with till flowing or slumping from the ice surface. Some of the till of the valley side may have been deposited prior to deglaciation as a lodgement till, but most of the hummocks seem to date from the wastage phase. Some were subsequently modified by solifluction.

The direction of the meltwater channels on Low Rigg and the high proportion of TMG in the sample from a kame, necessitates meltwater flow from the interfluve and valley side to the east onto and into the stagnant ice. This would commence as subglacial flow, but since the channels do not descend below 183 metres they seem not to have operated for long, and certainly not during the later stages of deglaciation and kame formation.

Meltwater from stagnant ice in the Naddle valley incised a

deep channel now occupied by the Naddle Beck which grades into the Greta in its gorge section. The Naddle channel is cut through till which forms the Burns Farm drumlins (Fig.4).

5. THE GRETA GORGE

Morphologically, the Greta Gorge is divisible into two sections, that above the confluence with Naddle Beck, and that below (Fig.3). Below the confluence the gorge contains a meandering river and remnants of a high-level terrace, and it is wider and deeper that the upper section. The northern valley side has frequent exposures of Skiddaw Group mudstones and constitutes the over-steepened lower slope of Latrigg, where a major landslip scar with hummocky ground below it occurs (NY 282.244). The southern valley side is cut in till, although bedrock outcrops along the river channel. Above the confluence with the Naddle Beck the gorge is narrow and relatively straight, with outcrops of mudstone on both valley sides, for example at Whitehead Coppice (NY 312.248) and at Low Cat Crag (NY 309.247). Borehole logs show solid rock at shallow depth below the southern wall of the gorge at its eastern intake (Fig.4). It appears possible that a wide drift-filled valley underlies the Burns Farm area and continues westwards towards Keswick.

The morphological contrast between the east and west sections of the gorge is probably simply a reflection of valley-side materials; mainly till to the west of the Naddle Beck confluence and, in part at least, bedrock to the east.

The gorge is incised into streamlined landforms and sediments which, in the vicinity of Burns Farm, indicate ice movement to the NE. The gorge is therefore not likely to have been initiated until the ice body in the Vale of Threlkeld stagnated and meltwater within and under it was able to escape by the lowest route. This is not to the north and east where altitudes of 230 metres at Mungrisdale and 275 metres at Troutbeck would have to be surmounted. In contrast, the maximum height of the break of slope at the top of the gorge is at about 160 metres. The meltwater from the Vale of Threlkeld would have escaped along the lowest point even though this involved the erosion of bedrock rather than the less resistant but higher areas of till (Fig.4). Initiation of the gorge by westward flowing water must have occurred while ice still covered the area and it would function for some time as a subglacial channel. Subsequent downcutting of the channel would control the water table in the melting ice in the Vale of Threlkeld and the Vale of St. John's. Ice in the Naddle valley also contributed meltwater to the gorge since the Naddle Beck channel, cut entirely in till, leads from a series of kames into the gorge below the level of the incision limit, adjusting to the level of the latter in the manner of roughly contemporaneous channels.

The major source of meltwater for the cutting of the Greta Gorge was probably an ice-dammed lake in the Vale of Threlkeld. The elevation of the lake and the lack of an alternative exit route for meltwater from the Vale means that it must have drained through the gorge. The depth of fine-grained sediment revealed in the A66 boreholes previously referred to, suggests that the ice dam persisted for some time, perhaps in the order of hundreds of years. There are many documented examples of contemporary (Paterson, 1981) and Pleistocene (Sissons, 1981) ice-dammed lakes draining catastrophically beneath an ice dam.

The south bank equivalent of the Brundholme Terrace (Fig.3) begins at the confluence of Naddle Beck and the gorge. A trial pit on the edge of the terrace (NY 301.246) showed 2 metres of sandy, coarse gravel underlying 0.5 metre of slope deposits. The terrace must represent deposition by meltwater (Smith, 1959), and it is probably no coincidence that it occurs at the widest part of the gorge where discharge increased due to inputs from the Naddle Beck channel and perhaps also from the Glenderaterra valley.

Smith (1959) suggests that all downcutting of the gorge subsequent to the formation of the terrace represents post-meltwater erosion. However, phases of deposition and erosion are characteristic of meltwater channels and the terrace is likely to be the product of renewed meltwater incision rather than fluvial events. Downcutting of this magnitude, amounting to about 30 metres, in post-meltwater time, would be very difficult to justify in relation to the size of the catchment area for the gorge. One would have expected erosion on this scale to have been associated with incision into, and degradation of, glacigenic landforms in the Naddle Valley and the Vale of St. John's, and this has not occurred. Indeed, if anything, aggradation seems to have been the norm in these areas.

Minor modification of the gorge may be ascribed to Post-Glacial time, such as the landslip already referred to.

6. THE KESWICK AREA

Around the town of Keswick and the shores of Derwentwater is a lowland area with abundant evidence of glacial and glacifluvial processes (Fig.5). To the south of the mapped area the sides of the glacial trough are steep and its floor is occupied by lake or alluvial flats.

The interfluve between the Naddle Valley and the Keswick lowland runs NE for 3 km from Rakefoot Farm (NY 283.221) passing through the site of Castlerigg Stone Circle (NY 292.236, Fig.3).

Along most of its length it is a featureless, till-covered area with occasional low hummocks. There are no exposures of solid rock. One small, dry channel, 400 metres to the SW of the

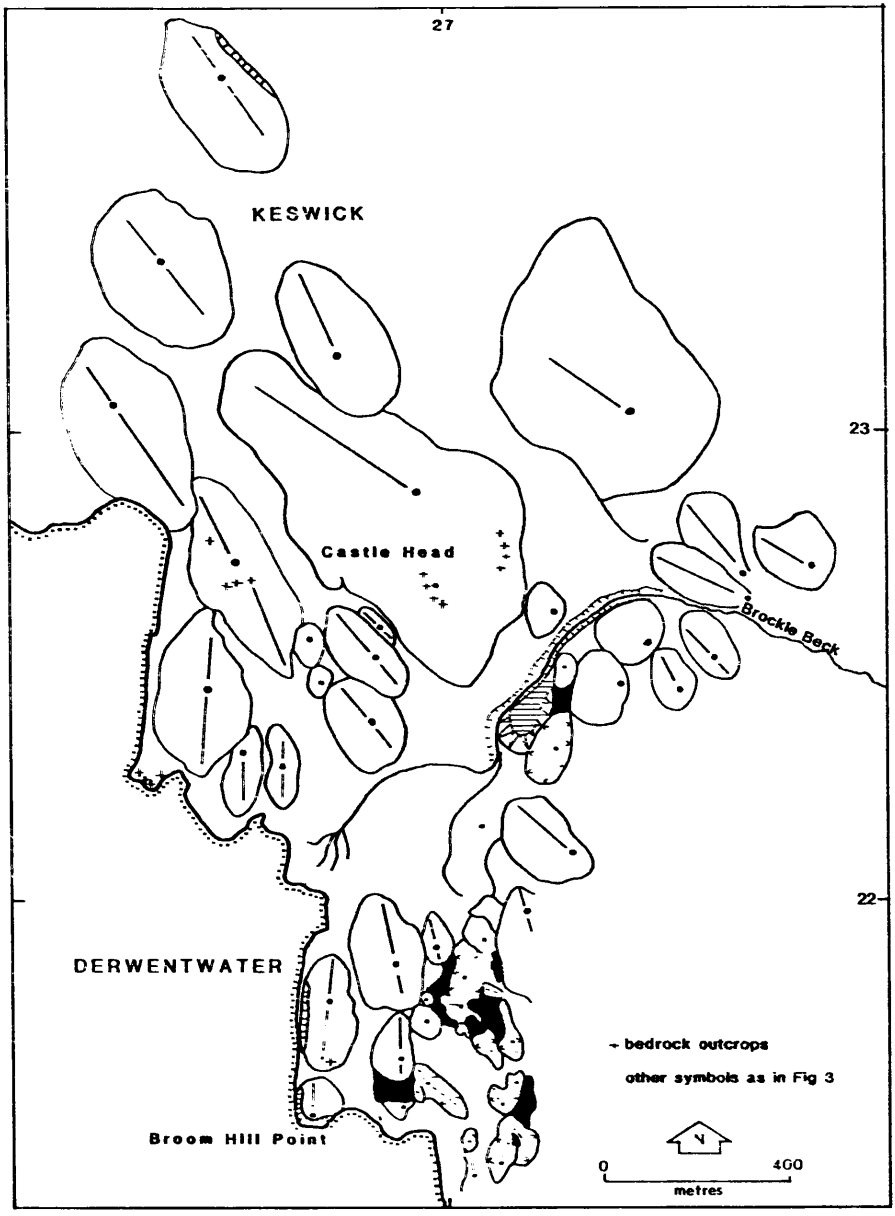


Fig.5 LANDFORMS OF THE KESWICK LOWLAND

Stone Circle, may be of glacifluvial origin. Below the 183 metre contour, on all sides of the interfluve, till hummocks are commonplace. Many are low, flat and lobate on the downslope side and appear to be soliflucted or slumped. Gullying is probably responsible for long, low ridges of till on the NW-facing slope around High Fellside (NY 286.237). At the northern end of the interfluve, till ridges lead directly into the Burns Farm drumlins.

The main feature of the Keswick lowland is a group of drumlins clearly developed to the south of the town and continuing through the urban area and onto the lowland between Derwentwater and Bassenthwaite Lake. Drumlins in the southern area are shown in Fig.5. Rock outcrops occur on three of the drumlins and in all cases this is the Castle Head Dolerite. Exposures, in what is probably the centre of a drumlin, at Broom Hill Point (NY 266.215) allow sampling of the till. This is an unusual deposit, being extremely gravelly (BH1, Table 1) and indurated, probably with manganese. The clasts have silt and clay coats and textural analysis is difficult because much clay adheres to the clasts even after attempts at dispersion. Silt and clay coats indicate illuviation of fines, and this may be a fragipan feature (Fitzpatrick, 1956), although Bolton and Dent (1974) point out that translocation of silt and clay to greater depths forming a dense, silty horizon, is also a result of immediately post-depositional processes.

Morphometric analysis of the Keswick drumlins shows that by comparison with other Cumbrian drumlins they are rather variable. The Standard deviation of the mean for both area and length is higher than that for drumlins around Motherby and Skelton (Boardman, 1981). The mean value for shape parameters, elongation ratio (E/R) and tapering value (k) (Embleton and King, 1975,p.404), are lower than at Motherby or Skelton, which indicates that the Keswick drumlins are less well streamlined. These values are also low compared with those for drumlins in eastern Cumbria and the Glasgow area (Rose and Letzer, 1975).

Lithological evidence at Broom Hill Point, although not quantified because of the high number of unidentified clasts, indicates a BVG-rich till, which must imply ice movement from the south and east. Crest-line orientations (Fig.5) therefore reflect ice movement from the Borrowdale valley lying to the south and, perhaps, from the interfluve between the Naddle valley and the Keswick lowland. Further to the NE, the ice flow is consistently towards the NW, down the Derwentwater-Bassenthwaite valley.

Macrofabric analysis carried out at three positions at Broom Hill Point indicates a S-N trend from below the crest-line of the drumlin (BHPa), and a NW-SE trend from the exposure 20 metres to the east (BHPc, Fig.6). Other studies of macrofabrics in drumlins have also shown flow patterns along the side of the drumlin oblique to the crest-line (Andrews and King, 1968).

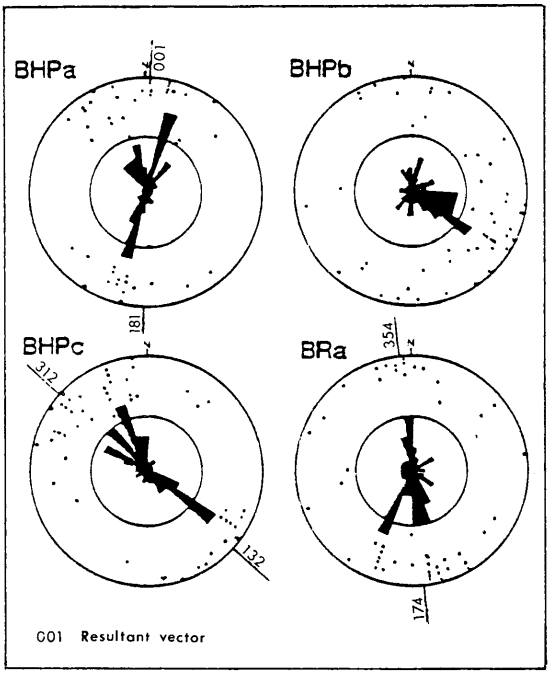


Fig.6 TILL MACROFABRICS FROM BROOM HILL POINT AND BROCKLE BECK SITES.

Orientation is plotted with respect to true north. Circular histograms show numbers of stones in each 10° class. BHPa is from below the crest-line of the drumlin; BHPb is from 20m to the west and BHPc is from 20m to the east.

This obliquity is especially noteworthy high on the drumlin near to its centre. Macrofabrics in drumlins must be expected to reflect local directions of ice movement related to the developing surface. However, such flow will be broadly related, especially in small drumlins, to the general regional pattern, recorded, for example, by crest-line orientations. At Broom Hill Point this is clearly the case.

As a check on the direction of regional ice movement, till macrofabric was analysed at a higher altitude site (310 metres) in the Brockle Beck valley (Fig.2). This exposure at the foot of a river-cliff on the west bank of the stream consists of 2 metres of bouldery till (BR1, Table 1) texturally similar to that at other sites in the area. Bedrock outcrops in the stream channel nearby and the exposure is overlain by 10 metres of very poorly exposed till. The results (BRa, Fig.6), show a clear S-N trend with a typical lodgement till pattern (Boulton, 1971). The high BVG content at this site, just north of the BVG/SG junction, shows conclusively that ice moved from south to north (Ward, 1876).

To the east and southeast of Stable Hills (NY 267.219) drumlins are intermixed with smaller glacifluvial landforms. Many poor exposures show sand and gravel in the mounds and low linear ridges, often with bifurcated crests (Fig.5). The latter probably

represent crevasse fillings in stagnant ice. Marshy hollows - kettle holes - occur among the kames and between glacifluvial and drumlinized forms. In at least one instance, a kame appears to have been deposited on a till hummock or drumlin (NY 271.219).

This assemblage of glacifluvial landforms indicates stagnant ice during deglaciation, and probably resulted from the confinement of bodies of thin, wasted ice between the drumlins and the valley side. Proximity to the valley side may also have ensured a plentiful supply of debris which would be carried by meltwater onto and into the melting ice. In other parts of the Keswick lowland, further from the valley sides, similar glacifluvial forms are absent.

7. REGIONAL SUMMARY

Reconstruction of ice movement across the area is possible by the combined use of erratics, till macrofabrics and drumlin crestline orientations. Traditionally, striations on bedrock have been used for the same purpose (Ward, 1876), but they are not widely available in the drift covered ground of this study.

The ice sheet which covered northern Britain during the last glacial maximum 18,000 years ago has been modelled by Boulton et al.,(1977), who show an ice-sheet surface at 1500 metres over the Lake District, inundating all high ground. However, such an ice sheet would not be a potent agent of erosion. Erosional conditions would be more prevalent during the valley glacier stage after deglaciation had commenced and it is probable that this stage is responsible for the evidence of ice movement presented earlier. Indeed, the survival of pre-Devensian deposits in areas such as Aberdeenshire (Boulton et al.,1977) and the Vale of Threlkeld (Boardman, 1980) may imply that the last ice sheet was cold based, at least in part, and therefore non-erosive.

Fig.7 assembles the evidence for the direction of ice movement. Macrofabrics, where reworking is suspected, have been omitted. The evidence is limited in quantity, but is consistent with the topography and the previous work of Ward (1876) and Smith (1959). The Thirlmere basin is the source area for ice moving NW and NE. A zone of divergence lies over the Naddle valley and the interfluve to its west. The role of ice passing south down the Glenderaterra valley from the Skiddaw Forest has not been explored but, following Ward (1876), it is assumed that this moved west to the Derwent valley and contributed little to the easterly flow up the Vale of Threlkeld.

This pattern of ice movement must relate to a late-stage of the Devensian glaciation when ice was thinning and its flow influenced by major relief elements. At the same time, minor relief elements, such as the low interfluve between Naddle and the Keswick lowland, had no control on flow direction. Flow up the

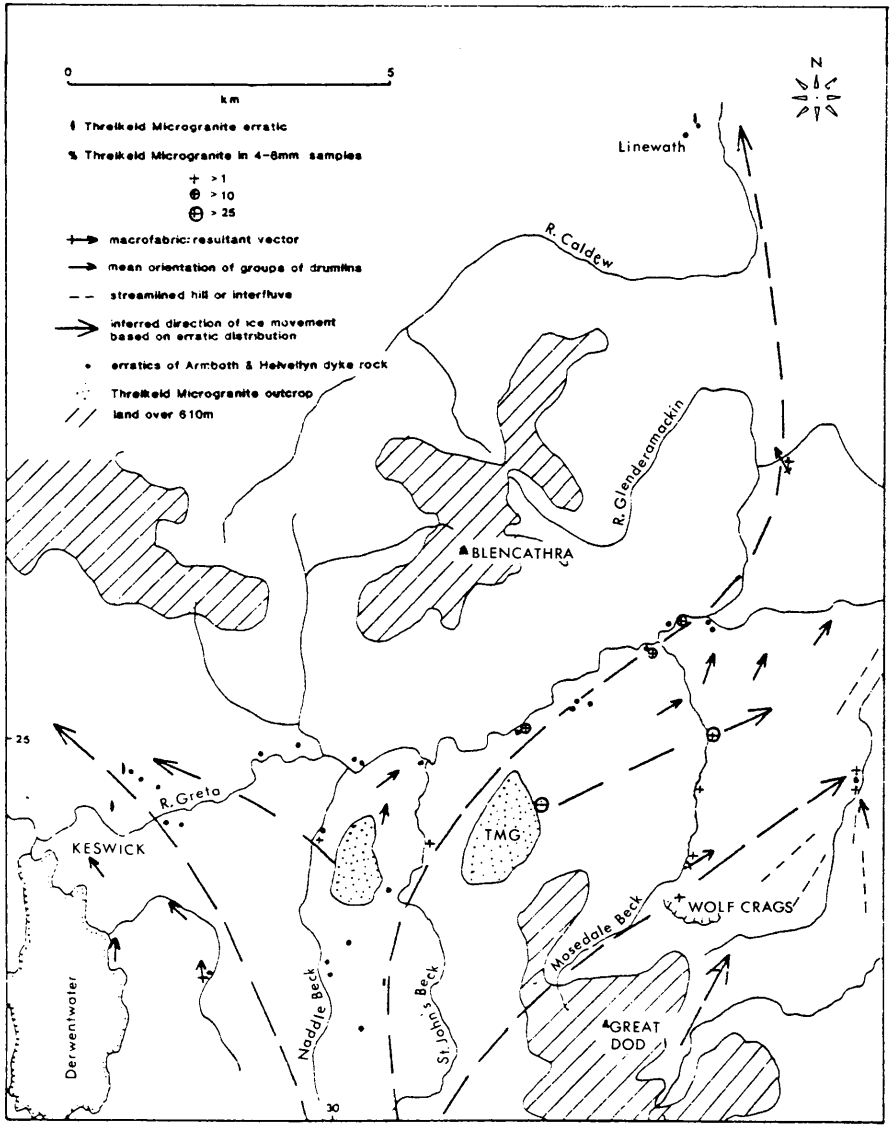


Fig.7 DIRECTION OF ICE MOVEMENT IN THE KESWICK AREA.

Vale of Threlkeld from the Thirlmere basin is indicated by streamlined landforms in the Burns Farm area and by the distribution of Armboth Dyke and TMG erratics northeast of Threlkeld.

The evidence of erratics, and in some areas streamlined interfluves and striations, has to be used with caution, since their age in relation to other events is debatable. Erratic distributions record aggregate events and are not snapshots of a particular time. Thus erratic distributions which are in conflict with the evidence of streamlined landforms and macrofabrics are likely to refer to an earlier phase of ice movement. Fig.7 records the distribution of two indicator erratic rocks in the Keswick area. This is part of a pattern that has been known for a long time (Ward, 1876) but has not previously been related to the landform evidence. Armboth Dyke rock and TMG is found in the vicinity of Keswick itself. Thus, ice from St. John's must at some time have moved NW across the area of the Burns Farm drumlins. There is therefore evidence for early NW-moving ice and later NE-moving ice over the same area, the source of the ice being in both cases the Thirlmere basin.

There is ample evidence for ice movement up the Vale of Threlkeld towards the east and Armboth Dyke and TMG erratics were transported to the north across the watershed near Mungrisdale, and eventually onto the Solway Plain (Leitch, 1884: Eastwood et al., 1968). At this stage meltwater flow would have been to the east and north in accordance with the flow-lines and the ice-sheet gradient. Ice thinning in the Threlkeld and St. John's area was accompanied by a change in the direction of the meltwater flow. The reason for this appears to be the stagnation of ice in the Vale of Threlkeld, the reversal of the meltwater flow being due to utilization of the lowest available exit, at Threlkeld, to the west. Cutting of the Greta Gorge may be partly the result of catastrophic drainage of an ice-dammed lake in the Vale of Threlkeld. Evidence for the lake is found at the eastern end of the vale, but its full westward extent is not known. Drainage to the west through the gorge was inevitable as no alternative route exists. The pre-glacial pattern of drainage was therefore re-established after having been interrupted by till deposition which appears to have filled a broad valley to the west of Threlkeld. There is also evidence in the orientation of the Low Rigg channels for a late-stage flow of meltwater to the NW.

With continued thinning of the ice-sheet and its break up in the valleys, kames, kettles, kame terraces, eskers and till hummocks formed among wasting blocks in the Naddle valley and in the Vale of St. John's. Meltwater escaped by the Greta Gorge and contributed to its deepening. Similar isolation and wasting of ice on the Keswick lowland led to the formation of kame and kettle topography among pre-existing drumlins. The mode of deglaciation, and the landforms resulting from the event, were considerably

influenced by existing topography, both pre-glacial and glacial.

The flat floors of the Naddle valley and of St. John's-in-the-Vale led Raistrick (1925) and Smith (1959) to suggest that these were the sites of lakes during deglaciation. Evidence has been presented which would suggest that they originated as large kettle-holes. Lakes may have succeeded the phase of ice wastage, though it is reasonable to assume that meltwater from the melting ice would have been partly responsible for the cutting of the channels through the till hummocks and kames. The present flat floors of the valleys are presumably a result of Late and Post-Glacial alluviation, in the case of St. John's-in-the-Vale no doubt controlled by the rock-bar in the channel at the foot of kame H, acting as a local base-level with respect to upstream areas.

8. AGE CONSIDERATIONS

The most recent regional glaciation of northern England was of Late Devensian age culminating about 18,000 years ago (Evans and Arthurton, 1973). A till sheet of this age, on which drumlins are the characteristic landform, is widespread in the Keswick area. Glacifluvial landforms and sediments clearly relate to the melting of the ice-sheet at this time. Pennington (1978) has shown that the Windermere basin, and by implication most of the Lake District, was ice-free by about 14,000 years ago. Thus events and landforms described here have their origin in the waning hemicycle of glaciation between 18,000 and 14,000 years ago.

A subsequent phase of corrie glaciation and widespread periglacial activity then occurred in the northern Lake District during the Loch Lomond Stadial 11-10,000 ago (Pennington, 1978, Boardman, 1978, Sissons, 1980). Solifluction features described in this paper probably relate to this event.

9. ACKNOWLEDGEMENTS

Permission to visit sites and consult borehole logs for the A66 Trunk Road re-alignment was kindly given by Mr.J.Dean, County Engineer, Cumbria County Council. Drs.N.Caine and C.Koteff and Mr. J.Rose are thanked for valuable comments on an earlier version of this article. Colleagues at the Institute of Arctic and Alpine Research, University of Colorado, provided hospitality and a stimulating academic environment while this work was completed.

10. REFERENCES

ANDREWS, J.T. & KING, C.A.M., 1968. Comparative till fabrics and till fabric variability in a till sheet and a drumlin; a small scale study. Proc.Yorks.Geol.Soc. 36. 435-461.

BOARDMAN, J., 1977. Stratified Screes in the Northern Lake District. Proc.Cumb.Geol.Soc. 3 (pt.4). 233-237.

BOARDMAN, J., 1978. Grèze Litées near Keswick, Cumbria. Biuletyn Peryglacjalny. 27. 23-34.

BOARDMAN, J., 1979. Pre-Devensian Weathered Tills near Threlkeld Common, Keswick, Cumbria. Proc.Cumb.Geol.Soc.4(pt.1).33-44.

BOARDMAN, J., 1980 Evidence for Pre-Devensian Glaciation in the Northeastern Lake District. Nature 286. 599-600.

BOARDMAN, J., 1981. Quaternary Geomorphology of the Northeastern Lake District. Unpublished Ph.D. Thesis. University of London.

BOULTON, G.S., 1971. Till Genesis and Fabric in Svalbard, Spitzbergen. In Goldthwaite, R.P., (Ed.), Till: a symposium. Ohio State Univ.Press, pp. 41-72.

BOULTON, G.S. & DENT, D.L., 1974. The Nature and Rates of Post-Depositional changes in recently deposited Till from South-east Iceland. Geog.Annlr. 56A. 121-134.

BOULTON, G.S., JONES, A.S., CLAYTON, K.M. & KENNING, M.J., 1977. A British Ice-sheet model and patterns of Glacial Erosion and Deposition in Britain. In Shotton, F.W. (Ed.). British Quaternary Studies: Recent Advances. Clarendon Press. pp. 231-246.

EASTWOOD T., HOLLINGWORTH, S.E., ROSE, W.C.C. & TROTTER, F.M.,1968. Geology of the Country around Cockermouth and Caldbeck. Mem.Geol.Survey. x plus 298 pp.

EMBLETON. C. & KING, C.A.M., 1975. Glacial Geomorphology. 2nd Edn. Vol.1. Edward Arnold. 573 pp.

EVANS, W.B. & ARTHURTON, R.S.,1973. Northwest England. In Mitchell, G.F. et al.(Eds.) A Correlation of Quaternary Deposits in the British Isles. Geol.Soc.Lond.Spec.Report.No.4 pp.28-36.

FITZPATRICK, E.A., 1956. An Indurated Soil Horizon formed by Permafrost. Jour.Soil Sci. 7. 248-254.

FLINT, R.F., 1929. The Stagnation and Dissipation of the Last Ice-Sheet. Geog.Rev. 19. 256-289.

HARTSHORN, J.H., 1958. Flow-till in South-eastern Massachusetts. Bull.Geol.Soc.Am. 69. 477-482.

JACKSON, D., 1978.The Skiddaw Group. In Moseley,F.(Ed.) The Geology of the Lake District.Yorks.Geol.Soc.Occ.Pub.No.3. pp.79-98.

LEITCH, J., 1884. Notes on the Geological Formation and Fossils of the Silloth New Dock. Trans.Cumb. & West.Ass.Adv.Lit. & Sci. 9. 169-174.

MANLEY, G., 1973. Climate. In Pearsall,W.H. & Pennington,W.,(Eds.) The Lake District. New Naturalist Series. Collins. 329 pp.

MILLWARD, D., MOSELEY, F. & SOPER, N.J., 1978. The Eycott and Borrowdale Volcanic Rocks. In Moseley, F.,(Ed.) The Geology of the Lake District. Yorks.Geol.Soc.Occ.Pub.No.3. 99-120.

NICHOLSON, H.A., 1869. Notes on the Geology of Derwentwater, Cumberland. Trans.Edin.Geol.Soc. 1. 274-278.

PATERSON, W.S.B., 1981. The Physics of Glaciers, 2nd Edn. Pergamon. 380 pp.

PENNINGTON, W., 1978. Quaternary Geology. In Moseley, F.,(Ed.) The Geology of the Lake District. Yorks.Geol.Soc.Occ.Pub. No.3. 207-225.

RAISTRICK, A., 1925. The Glaciation of Borrowdale. Proc.Yorks. Geol.Soc. 20. 155-181.

ROSE, J., 1974. Small-scale Spatial Variability of some Sedimentary Properties of Lodgement Till and Slumped Till. Proc. Geol.Ass. 85(2). 239-258.

ROSE, J. & LETZER, J.M., 1975. Drumlin Measurements: A Test of the Reliability of Data derived from 1:25,000 Topographical Maps. Geol.Mag. 112(4). 361-371.

SISSONS, J.B., 1958. Sub-glacial Stream Erosion in Southern Northumberland. Scott.Geog.Mag. 74. 163-174.

SISSONS, J.B., 1980. The Loch Lomond Advance in the Lake District, Northern England. Trans.Roy.Soc.Edin.Earth Sci. 71. 13-27.

SISSONS, J.B., 1981. Ice-dammed Lakes in Glen Roy and Vicinity: A Summary. In Neale, J. & Flenley, J., (Eds.). The Quaternary in Britain. Pergamon. pp. 174-183.

SMITH, R.A., 1959. Some Aspects of the Geomorphology of the Northern Lake District. Unpublished M.A. Thesis. Univ. of Manchester.

WARD, J.C., 1873. Glaciation of the Northern Part of the Lake District. Quart.Jour.Geol.Soc. 29. 422-441.

WARD, J.C., 1876. The Geology of the Northern Part of the Lake District. Mem.Geol.Survey. 12 plus 132 pp.

WARD, J.C., 1878. Unpublished 6" Geological Map. Cumberland Sheet 64. Inst.Geol.Sci.Library, South Kensington, London.

EXCURSION NOTES

EXCURSION TO THORNTHWAITE FOREST

SKIDDAVIAN TURBIDITES

Leaders: Mr. R. Orrell and Mr. T. Shipp

6th May, 1979.

A group of members gathered at the Whinlatter Visitor Centre (207.244) at 10 a.m. An initial briefing session was held in the Centre when Mr. Bob Orrell of the Forestry Commission spoke about aspects of forestry operations and management and illustrated his remarks with a short film. Members were impressed by the changes that had taken place over the years including the steps taken by the Forestry Commission to soften the visual impact of commercial conifer plantations and to cater for the needs and interests of visitors by providing way-marked trails with maps and information leaflets.

Mr. Tom Shipp then explained that the plan was to follow a route along the forest roads to investigate geological features revealed in the exposures provided by the various roadside cuttings. The rocks involved were the Kirk Stile Slates of the Skiddaw Group, and the excursion was planned to form the basis of a future Geological Trail on the lines of the existing Forest Trails.

The party set out along the forest road leading from the Visitors Centre to marker post 15, and branching uphill reached Locality A (209.246) shown on the sketch map (fig.1). Here there were outcrops of bluish, slightly micaceous mudstones weathering to a greenish brown colour. The bedding was noted to be vertical striking NE - SW, but there was also a moderately well-defined cleavage detectable dipping NW at about 10^{o}. Weathering acts along the bedding planes and the cleavage planes as well as opening the joints in the rock to produce a scree of sliver-like fragments which were seen for a further 200m along the track. Some of the weathered fragments showed load-casts in the bedding planes.

At Locality B (210.248) there was a change in the rock type with brown weathered sandstone overlying greenish mudstone. The blocky appearance of the sandstone contrasted with the flaky mudstone, and the brown staining was probably due to small traces

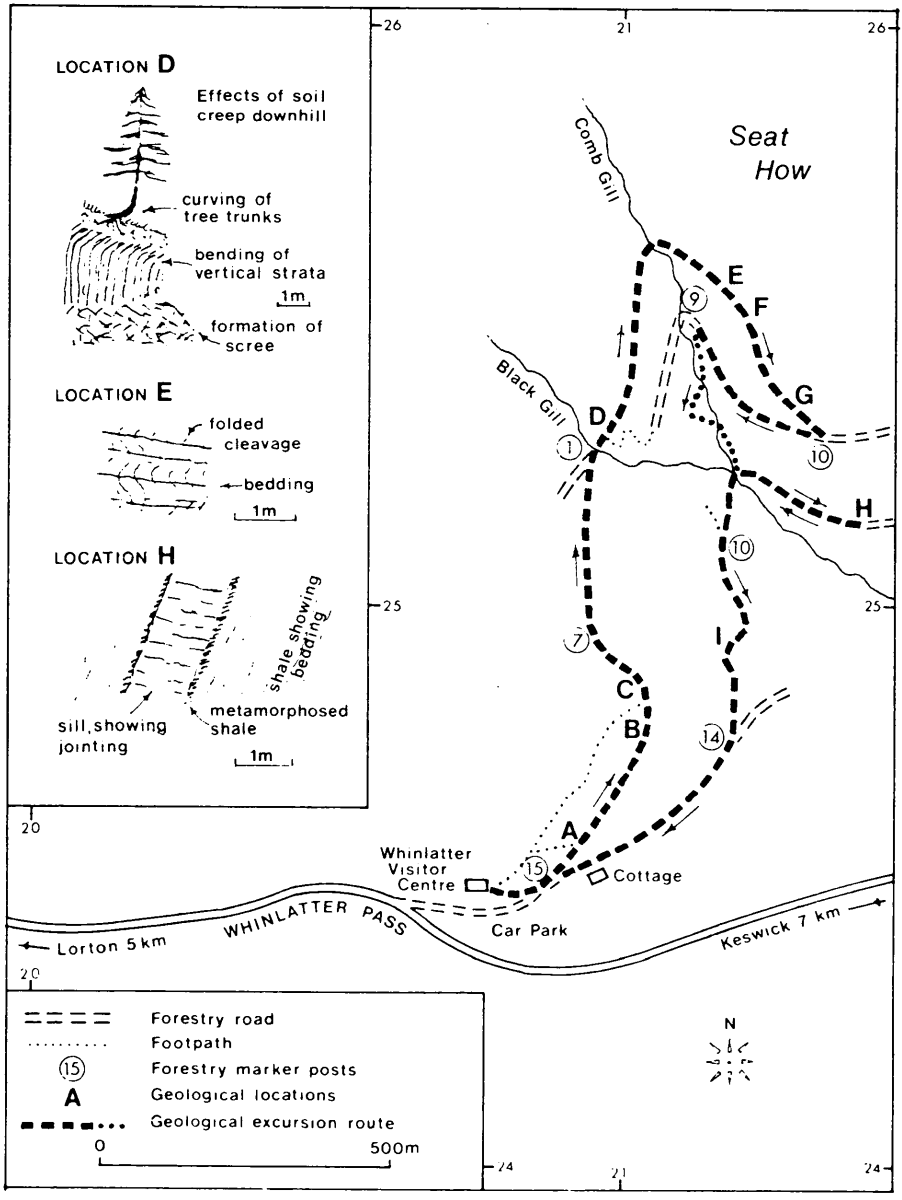


Fig. 1 SKETCH MAP OF THE GEOLOGICAL TRAIL FROM WHINLATTER VISITOR CENTRE.

of hydrated iron oxides.

The route now joined the existing Comb Forest Trail and 50 m further on up the hill at Locality C greenish, steeply dipping mudstones were seen and a large load-cast 0.5m across was identified. It was explained that this sedimentary structure could be used as a marker to indicate the original 'way up' of the beds.

The trail was followed some distance up the hill with few outcrops in evidence until shortly after passing marker post 1 Locality D (210.253) was reached just after crossing Black Gill. Here there were strongly folded and laminated green mudstones. The sedimentary origin of the rocks could be deduced from the occasional fossil trails and the odd graptolite present on the bedding surfaces. Minutely crinkled cleavage surfaces in the rock betray evidence of strains brought about by the enormous forces of former movements within the Earth's crust. Similar outcrops were found along the next 300m of the track and the effects of soil-creep on the growth of tree trunks and on the superficial portions of the vertical rock strata were noted (fig.1).

Crossing Comb Gill Locality E (212.255) was reached. Shales occur here with thin (15 cm) bands of sandstone which dip E at 35° and display an unusual folded cleavage. 50m further on at Locality F a small recumbent fold was noted and shortly after this a zone of intensely disturbed turbidites. These rocks are derived from underwater mudflows travelling down a former submarine slope, and at this locality consist of rapid alternations of mud-stones and sandstones.

At Locality G (213.253) there were a number of small landslips on an oversteepened scree slope and here too a gap in the trees afforded fine views of the glacially truncated spurs of Saddleback.

A little further on at marker post 10 (green on yellow) the route turned sharply to the right down a grassy ride where the exposed vertical rock strata were weathered into a spread of flat plates. Continuing down into Comb Gill the path followed a pleasant glade alongside the beck which was crossed by two foot-bridges. Boulders of white quartz and green volcanic rock were evident, some showing flattened striated sides indicating that they had been moved by glacier ice.

Reaching Lower Comb Road the party turned left to locality H (214.251) where a sill was seen intruded into the steeply dipping shale. This sill is about 1m in thickness and consists of quartz felsite. Narrow (5 cm) zones of thermal alteration are detectable in the adjacent country rock (see fig.1). Furthermore, character-istic 'top to bottom' jointing is visible within the sill itself. This intrusion is similar to one that can be seen on the roadside east of Bassenthwaite Lake at Long Close Farm (240.267), but is on a rather smaller scale.

The party now retraced their steps to the bridge over Comb Beck and followed the forest road to marker post 10 (white on green) at 212.251. At this point there is an outcrop of fine grained sandstone with blocky jointing, showing little trace of cleavage. About 100m further on at Locality I (212.249) the position of a distinctive vertical fault was marked by a narrow belt of pulverised rock. At the next small gill a recumbent fold in the mudstone was noted and a little further on a small roadside excavation revealed steeply dipping mudstones and here a few badly preserved graptolites were found after some searching. At this point too the leached soil profile (podsol) was pointed out where it was exposed at the top of the cutting. From this locality it was only a short distance back to the Visitor Centre and the completion of the route.

Finally Mr. Shipp mentioned that those seeking more detailed information about the rocks of the Skiddaw Group might be referred to the account given by Dr. Dennis Jackson in Chapter 7 of 'The Geology of the Lake District' published by the Yorkshire Geological Society in 1978. He also mentioned that the forest tracks followed by the party were for the most part gravelled with locally quarried material, but an area about 150m NE of the Centre was covered with spoil from a local mine tip. The footpaths and car park adjacent to the Centre had been spread with chippings of Threlkeld Microgranite.

PALAEOZOIC ROCKS OF THE ORTON AREA

Leader: Mr. R. V. Davis

9th June, 1979.

Some thirty members and friends met at Tebay for this excursion in the Shap area, which was led by Mr.R.V.Davis, the Warden of the Teachers Centre at Kendal. Mr. Davis was shortly to leave for a three year posting to Fremantle, Western Australia.

The first stop was to inspect the unstable, tightly folded and faulted Silurian sediments above the M6 motorway in the Tebay

Gorge. The leader drew the attention of his audience to the difference in fold styles between the weaker shales and the more competent fine-grained sediments. Tension gashes, often infilled by quartz and calcite were clearly seen. Multiple movements along small faults were imaginatively reconstructed.

The party then proceeded to the Shap granite quarry and later to the Blue quarry, to look at igneous features and the associated minerals. Xenoliths were very easily distinguished in the Shap granite either as dark fragments of recognisable country rock or as slightly altered patches in the intrusion. The search for mineral fragments was very rewarding. Extensive veneers of iron pyrites were found in cavities and on joint faces. Small quantities of chlorite and molybdenite were maddeningly easy to see, but difficult to extract.

Mr. Davis briefly explained the contact metamorphism responsible for the hornfels texture and the 'spotting' of the ashes in the Blue quarry. Specimens of many types of minerals were found. The excellent and common white and pink calcite crystals together with the occasional barytes and smoky quartz absorbed the members' attention so that the extensive epidotes and garnetiferous veins were relatively neglected.

After lunch the party moved to the unconformity at Shap Wells. The contact between the steeply dipping Brathay Flags beside the waterfall plunge pool and the almost horizontal basal Carboniferous conglomerate was very clear. The leader pointed out the significance of the feldspar fragments from the Shap Granite which formed pebbles in the conglomerate. The Granite, absent from the Brathay Flags was therefore post-Silurian, but pre-Carboniferous in age.

The final locality visited was a small abandoned limestone quarry on the B 6261 road near Orton. Huge assemblages of corals tentatively identified as Dibunophyllum beds were seen to have apparently been overwhelmed by shaly sediments and specimens were obtained. Patches of marl stone containing productid brachiopods and occasional spirifers were also found, as were one or two plant fossils. Interesting evidence of dolomitization with calcite and dolomite crystals within the same cavity were seen.

At the conclusion of a good day in the field, the leader, Mr. Vince Davis was sincerely thanked for his efforts and the members present wished him well for his sojourn in Australia.

EXCURSION TO THE LOWER CARBONIFEROUS

LIMESTONES OF FURNESS

Leader: Mr. D. Leviston

24th June, 1979.

Members of the Society met at the entrance to Greenscoe Quarry (219.757) where the leader, Mr. Derek Leviston, explained that the purpose of the field trip was to demonstrate the effect of variations in sea-level on the lithology of rocks as the environment of deposition changed.

The party made its way to Park Farm (217.755), passing exposures of Skiddaw Slates and intrusive volcanic agglomerates and andesites belonging to the Greenscoe Volcanic Complex. These rocks formed the basement onto which the Lower Carboniferous seas transgressed.

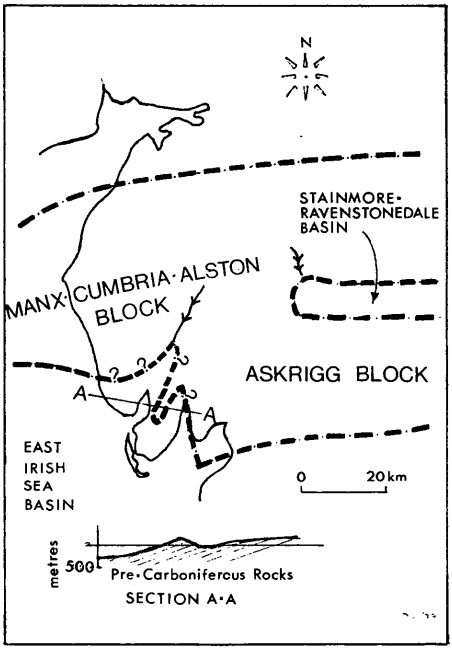
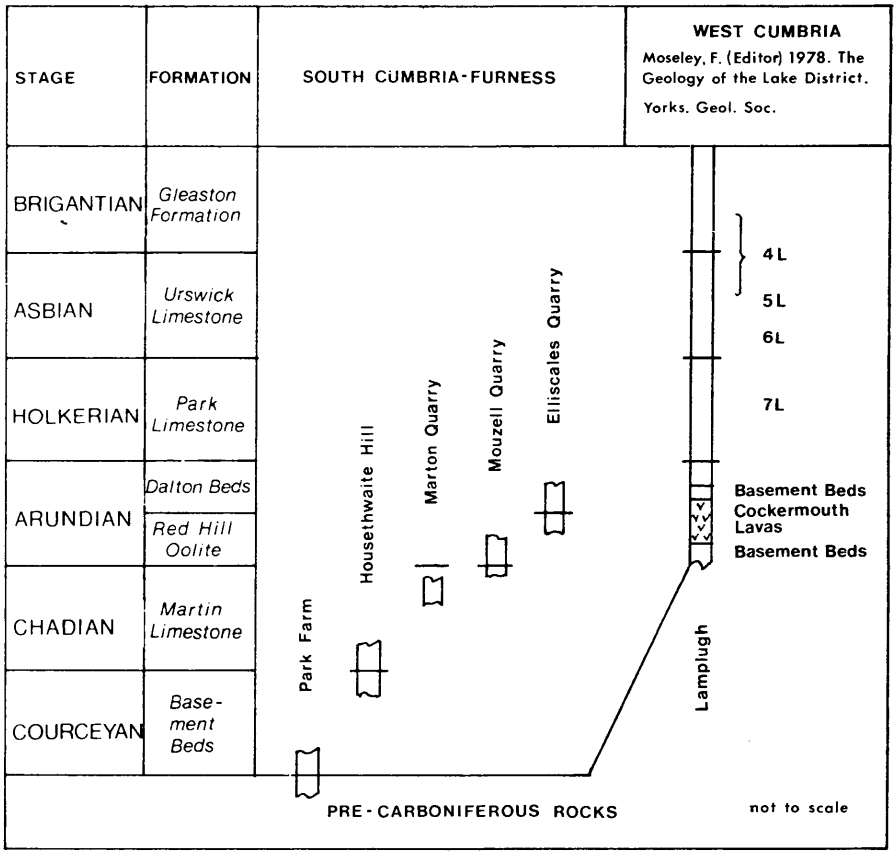


Fig.1 LIMITS OF THE ANCIENT 'DUDDON ESTUARY' AT THE CLOSE OF THE COURCEYAN STAGE (Based on information from Rose & Dunham, 1977).

In the shale pits the Carboniferous Basement Beds consisting of red conglomerates, purple shales and mudstones were seen lying unconformably on the Skiddaw Slates, although the actual contact was not exposed. It was explained that these terrigenous deposits were regarded as being the result of flash floods. (Rose and Dunham, 1977). The basement bed succession was then traced upwards in the woods behind Park Farm, where it was shown that the coarse deposits gave way to red mudstones and siltstones. This was interpreted as indicating that the water depth had increased as the sea transgressed onto the land, resulting in the source of terrigenous material becoming more distant, so that only

Table 1. RANGE CHART OF LOCALITIES IN FURNESS COMPARED WITH WEST CUMBRIA



finer material reached the area under discussion.

The old mineral tramway was then followed southwards to a sequence of dolomites and limestones with interbedded shale bands (220.753). It was explained that this section is of particular interest because it contains the boundary between the Basement Beds and the overlying Martin Limestones. (Rose and Dunham, 1977, p.45). More recent work by the leader and others yet unpublished has produced the diagnostic foraminifera Dainella sp. and the conodont Mestagnathus beckmanni from limestones below Rose and Dunham's boundary. These microfossils date the limestone as being of Chadian age, and it is suggested that the whole sequence be

assigned to the Martin Limestone. The limestones indicate that the depositional environment had changed from estuarine to more open sea conditions, although these were still restricted. Photomicrographs were passed around which demonstrated that frequent influxes of turbidites containing silt-sized quartz occurred. This, together with other palaeontological information suggests that the limestones are of Lower Chadian age, since no similar lithology is found in the limestones of Upper Chadian age in the area. (Leviston, 1979).

The party returned to their cars and then proceeded to Marton Quarry (243.769), which is the type section of the Martin Limestone. Here thinly bedded calcite mudstones, algal limestones and dolomites containing concentrated horizons of silicified Thysanophyllum pseudovermiculare, Syringopora sp. and Composita spp. were seen.

Following lunch, Mouzell Quarry (231.754) was visited, where a sequence of calcite mudstones, algal limestones and dolomitized, stromatolitic limestones, some with desiccation structures, were seen. These marked the boundary between the Martin Limestone and the overlying Red Hill Oolite of Arundian age. The desiccation structures indicated that there had been an emergence before the next transgressive phase which heralded the start of the Arundian stage and the deposition of the Red Hill Oolites. These latter limestones occupy the upper part of the quarry and consist of massive, crudely bedded, pellet limestones with current bedding. Details of this section are given in Leviston (1979).

The final locality of the field trip was Elliscales Quarry (224.747) where reef structures were seen within the Red Hill Oolites. The boundary between these limestones and the overlying Dalton Beds is considered to be where a change to more regular thin-bedded limestones occurs. Samples of Michelinea megastoma, Koninckophyllum praecursor and Zaphrentis sp. were found.

At the end of the day the members of the party expressed their appreciation of the way in which Mr. Leviston had pursued his theme and revealed to them so much of interest.

REFERENCES

LEVISTON, D., 1979. A study of four localities in the Martin Limestone (Lower Carboniferous, Dinantian) of Furness and Grange-over-Sands. Proc.Cumb.Geol.Soc., 4 (1), pp 3 - 20.

ROSE, W.C.C. and DUNHAM, K.C., 1977. Geology and Haematite deposits of South Cumbria. H.M.S.O.

CARBONIFEROUS LIMESTONE QUARRIES IN THE FRIZINGTON - KIRKLAND AREA.

Leaders: Mr. M. B. Dodd and Mr. T. Shipp

Two evening visits were made to limestone quarries in the Frizington - Kirkland area on 20th June and 4th July, 1979, under the leadership of Mr. Mervyn Dodd and Mr. Tom Shipp.

The first of these visits was to Yeathouse Quarry, near Frizington (039.169), and included a certain amount of site clearance work. The unconformity between the base of the Seventh Limestone and the underlying rocks of the Skiddaw Group was fairly easily identified. The tilted basement beds of the limestone consist of reddish conglomerates and pyritous shales, and these lie unconformably on the contrasting gently folded and much shattered Ordovician mudstones of Skiddaw Group rocks.

Exposures of the Fifth and Sixth Limestones and the associated shale bands in the quarry entrance are now scheduled as a site of Special Scientific Interest (S.S.I.) and these were identified and some clearance work carried out. The Chonetes Shale horizon was found and examined. This is an excellent example of a death assemblage of small brachiopods, and also includes many crinoid stems.

The second visit on 4th July, 1979, was to Kelton Head Quarry near Kirkland (067.183) now the site of a 'go-cart' racing track. 18 members and their friends attended and enjoyed one of the rare warm summer evenings of the year. This quarry was excavated in the Fourth Limestone, which dips at 15° on a bearing of 330°. The party found the stratigraphy difficult to decipher, because the well known marker bands could not be recognised with any certainty. However, the identification and collection of fossils and minerals was both easy and rewarding. A notably clean block of limestone on the eastern wall of the quarry provided clear casts of large productids, and solitary corals as much as 15 cm long and 5 cm across were seen. There were also smaller spirifers and colonial corals, and the President tentatively identified Caninia, Corwenia, Daviesiella, Aulophyllum and Phillipsi species. A fine reef structure measuring 3 m by 1 m was seen at the southern lip of the quarry.

Evidence of changes in the palaeoenvironmental conditions were also pointed out. In places resistant, well-jointed limestone overhung brecciated limestone which itself overlaid softer, badly weathered and heavily haematized shales which formed a small scree of very fine fragments. Splendid vugs containing fine aragonite needles occurred in rather dirty, soft, brown limestones

which had been heavily dolomitized. Small specimens of haematite and specularite were also present. A salmon pink barytes vein is exposed at one or two places at the foot of the southern wall of the quarry.

Solution features were also very evident. 'Pipes' in the limestone appeared to contain pebbles varying in type from volcanic lava and tuff to brown and red sandstone, and testified to an ancient land surface. Extensive spreads of dripstone curtain the eastern faces of the quarry, showing fine calcite crystals. Solution pits and small cave-like features were easily recognisable.

VISIT TO THE ELTERWATER SLATE QUARRY

2nd April, 1980

Eleven members of the Society visited the Elterwater Slate Quarry on 2nd April, 1980, by courtesy of the Burlington Slate Co. Ltd.

The slate is a fine andesitic volcanic ash deposited, in all probability, below water. Subsequent tectonic movements have imparted a cleavage to the rock at a steep angle to the bedding planes.

The quarry working methods and slate removal techniques were described and demonstrated to the party. Holes are driven below the slabs of rock and a steel hawser is continuously drawn through behind the slate to cut out the blocks using wet sand as an abrasive. The whole process is rather similar to the action of a wire cheese-cutter.

Faults in the slate are the greatest problem for the quarrymen. In some cases because of the cross-bedding it becomes necessary to abandon operations in favour of another plane, as at Spout Crag where a difficult horizontal band was encountered. The Elterwater slate is pale green in colour, but each of the six quarries operated by the Company yields stone of a slightly different colour, ranging from light green to blue-black.

A visit to the cutting and polishing sheds was made and

demonstrations of cleaving the slate blocks for roofing tiles and pavement stones were seen. The cutting of blocks by large diamond-edged wheels and by band saws and the subsequent large-scale polishing processes were also demonstrated. The slate quarries have provided building and facing materials for use throughout the world, including large structures in America, Australasia and Arabia, as well as the well-known fireplaces and cottages of the Lake District.

Thanks were expressed to Mr. Dixon, the quarry supervisor at Elterwater, for a very enjoyable and informative visit.

F.J.

EXCURSION TO STOCKHOW HALL LIMESTONE QUARRY

10th May, 1980.

This excursion was one of a series planned for 1979 and 1980 to various disused quarries in the Carboniferous Limestone of West Cumbria.

Stockhow Hall Quarry is situated at G.R. 066.176 about 500 m S.W. of Kirkland village. A fairly small party of members gathered at the rendezvous at Kelton Head (066.183) and approached the quarry by a circuitous route along a small dry valley examining the limestone outcrops on the way. The Potholes Formation of the Fourth Limestone was tentatively identified in some small eastward facing scars, with a variety of moderately well-preserved corals and brachiopods.

In the quarry itself the party found several small patches of delicate and well-formed calcite needles, although regrettably these had been savagely hammered by collectors. The Chonetes Shale, the marker horizon separating the Fifth and Sixth Limestones, is well exposed between the two sections of the quarry. Several good specimens of this small brachiopod were found after a little preliminary clearing had been undertaken. The weathering away of shale bands elsewhere in the quarry had led in some instances to pronounced undercutting of the massive limestone beds to such an extent that these overhung by three or four feet.

EXCURSION TO THE BUTTERMERE VALLEY

Leaders: Mr. M. B. Dodd and Mr. T. Shipp

18th May, 1980.

A fine day encouraged a good attendance for this excursion. Especially welcome were a number of friends from the Westmorland Geological Society.

The morning was devoted to an examination of the junction between the Borrowdale Volcanic Series and the Skiddaw Slates in the trough end of Warnscale Bottom. The localities visited are described in the article by Dr.F.Moseley in Part 3 of Volume 3 of these Proceedings, to which the reader is referred for more detail. After assembling at Gatesgarth car park (195.149) the party traversed the morainic material at the foot of Fleetwith Pike and noted the recent ill-drained alluvial in-fill at the head of Buttermere lake. The exposure of the B.V.S. - Skiddaw Slate junction in the bed of Warnscale Beck at G.R. 201.135 was first sought. Because of the amount of water in the beck the actual contact was elusive, but within the space of 25 metres a clear change was noted from the closely cleaved, colour banded Skiddaw Slates showing graded bedding, to the massive andesites of the Volcanic Series showing flow structures. From this view-point the leaders pointed out the trace of the junction from Fleetwith Edge round below Haystacks to High Crag. The multiple waterfalls and dramatic cliff scenery attributable to the resistant tuffs of the Volcanic Series were also noted. The party then moved over to inspect the analogous exposure of the junction in the bed of the nearby Black Beck (199.135).

After lunch the party moved down the valley a little way to Hassness (187.160) and the afternoon was spent examining exposures on the steep slopes leading up to Goat Crags. The rocks in this area are turbidites of the Skiddaw Group and have undergone severe deformation. An inverted succession of psammitic strata provided examples of first and second minor folds formed in relation to the major structures and the effects of pressure solution mechanisms were also pointed out. The elevated view-point provided an opportunity to observe a variety of interesting landforms. The Skiddaw Group rocks forming the relatively smooth south-west facing slopes of the valley were contrasted with the Borrowdale Volcanics on the opposite side which showed a much more rugged, broken topography with masses of exposed rock. The glacial corries of Bleaberry Tarn and Burtness Combe stood out and the leaders pointed out the variations in rock texture and colour which revealed the igneous intrusions on High Stile and the granitic stock underlying Red Pike.

EXCURSION TO THE FAULTED OUTLIER AT MOUSEGILL QUARRY, WILTON, NEAR EGREMONT

Leader: Mr. T. Shipp

21st June, 1980.

There was a good attendance of members for this afternoon visit to the down-faulted outlier of Carboniferous Limestone at Mousegill Quarry (048.110) near the village of Wilton.

The position of the major faults dropping down the limestone has to be inferred because of the absence of exposures, but some slickensiding was found along a small fault plane in the Skiddaw Group rocks to the west of Limekiln Lonning which runs past the quarry. The shallow open anticline in the limestone is faulted near its axis with pronounced brecciation. Fossils seemed very patchy in their distribution; a fine solitary rugose coral on a cliff face, some fine productid brachiopods and a strongly ribbed Daviesiella in a dry stone wall being the most striking finds. Several small corals and one or two rather poorly developed gastropods were also noticed.

The party leader, Tom Shipp, drew attention to a number of features of interest in the locality, including the prominent and well-preserved old limekiln. He also pointed out a local spring line, developing where a very fissile, pale coloured shale band underlies a much more massive limestone. On the hillside above the quarry there are characteristic features of limestone topography with an irregular surface and one actual swallow hole where a small stream disappears underground.

EXCURSION TO THE ORDOVICIAN INLIER OF TAYTHES BECK (CAUTLEY AREA, NEAR SEDBERGH)

Leaders: Messrs. A. S. Day and J. Wilson

6th July, 1980.

This was a Joint Field Meeting organised by the Westmorland Geological Society to the Cautley area between Sedbergh and Kirkby Stephen. The Editor is grateful to the Westmorland Society for permission to publish this account of the meeting which appeared in their Proceedings Vol. 2, No.4.

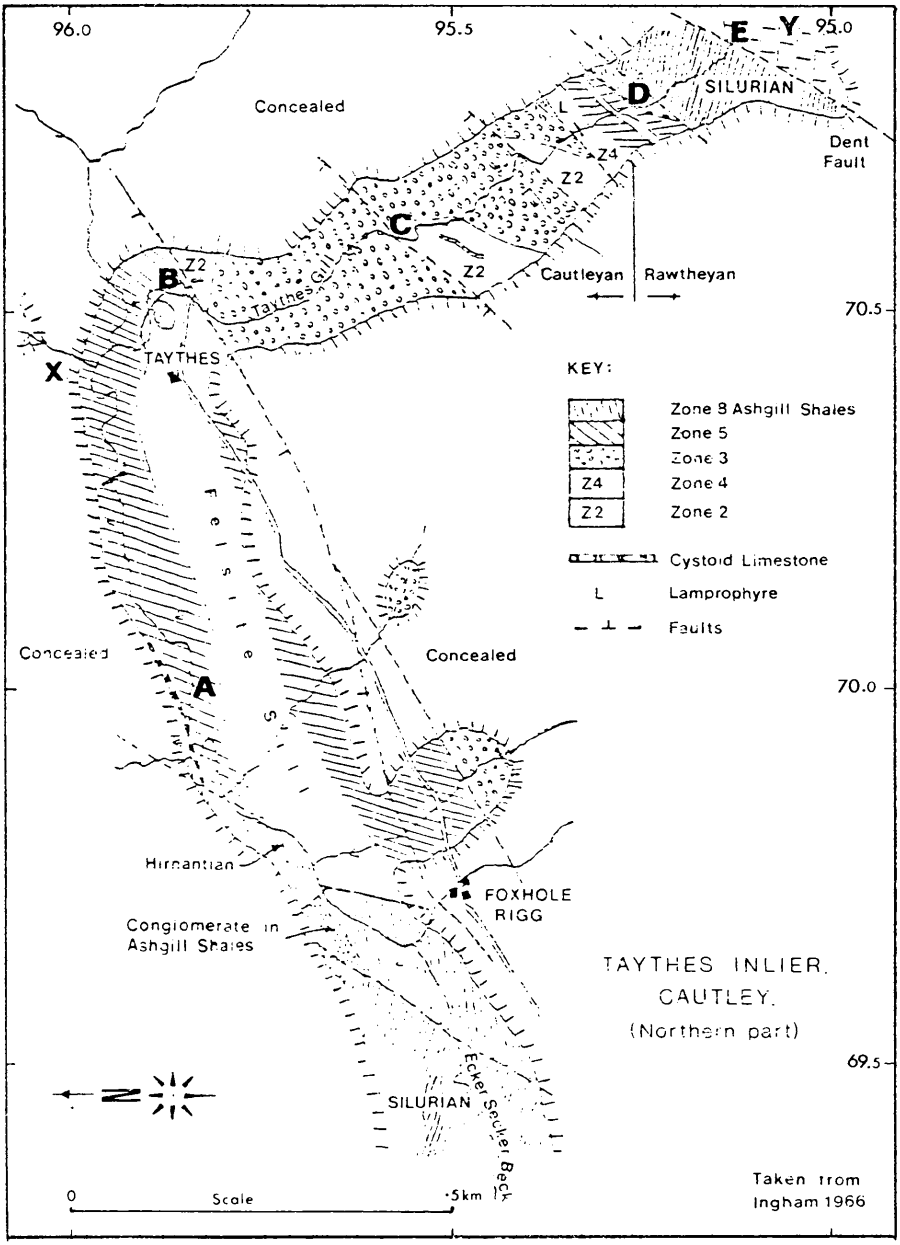


Fig. 1 TAYTHES INLIER, CAUTLEY, NEAR SEDBERGH

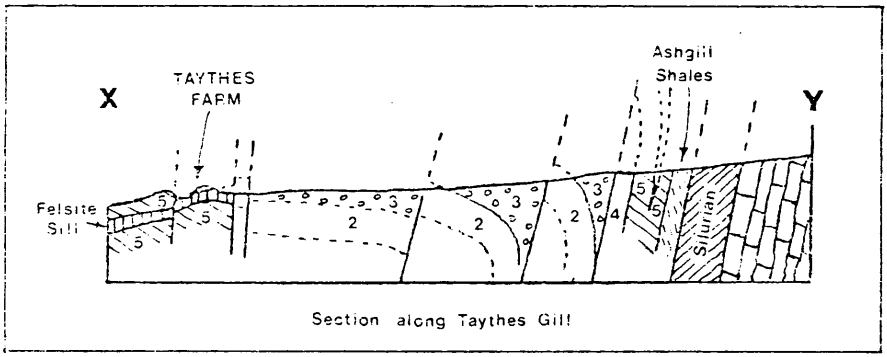


Fig. 2 SECTION ALONG TAYTHES GILL

The Taythes Inlier is one of the three large inliers of Ordovician age in the Cautley area. It lies almost wholly to the east of the Sedbergh - Kirkby Stephen road and is bounded on the eastern side by Lower Carboniferous rocks and on all other sides by Silurian rocks. The contact with the Carboniferous is a faulted junction along the Dent Line.

Structurally the inlier consists of an eroded dome within an approximately NE - SW axis. It is extensively faulted and is intruded by numerous felsite (microgranite) and lamprophyre sills and dykes of Devonian age, emanating from the Shap Granite intrusion to the north.

Lithologically the strata are a rather monotonous succession of cleaved, leaden-grey shales in the upper part (Ashgill Shales), passing downwards to nodular calcareous mudstones and shales in the lower beds. Under the old name of the Coniston Limestone Series they form a type section of the Upper Ordovician Ashgill Series. J.W.Ingham re-investigated the formation in the 1960's and established eight biozones based largely on the brachiopod and trilobite fauna. This fauna is rich in the lower zones and becomes restricted towards the top, indicating a general increase in water depth.

The zones present in the Taythes Inlier are 2 to 5, the upper part of 7 (Cystoid Limestone), and zone 8. Missing are zones 1, which appears to be faulted out, and zones 6 and 7 (apart from the Cystoid Limestone) which are absent because of non-deposition. Subsequently Ingham grouped the zones into major stratigraphical stages so that the Cautleyan Stage consists of zones 1 to 4, the Rawtheyan of zones 5 to 7, and zone 8 is the Hirnantian Stage.

A large party of about 40 members from the two Societies

assembled in the lay-by adjoining Foxhole Rigg Lane (693.953). The lane was followed for some 800 yards before a detour was made down the hillside to Taythes Beck, which here cuts through the northern part of the inlier.

A good section of the Cystoid Limestone, dipping west, is exposed in the stream bank at Locality A (700.958). This limestone is a conspicuous feature in most of the inliers and is found at the top of zone 7. It is an extremely hard, dense, calcitic mudstone which has a conchoidal fracture. The fauna consists mainly of cystoid plates with occasional fragments of trilobites. Although fossils are only apparent in the field on weathered surfaces, and this exposure is unweathered, their presence is easily detected in thin sections. Above the limestone are highly cleaved, fissile shales with very little calcareous material belonging to zone 8. Nodular limestones and squeezed shale of zone 5 lie unconformably below the Cystoid Limestone, and are well exposed in the north bank of the stream nearby.

The lane was rejoined and followed to Locality B where just beyond Taythes Farm the stream has cut a gorge through a massive felsite sill. It was possible to scramble into the gorge to examine, at about 10 feet above stream level, the contact between the top of the sill and zone 5 limestones and shales above. There is some baking of the shales.

Upstream of the gorge the beck follows the line of a considerable fault which runs almost parallel to the axis of the dome, and which throws down the sill against zones 2 and 3.

Leaving the stream, the party followed a footpath high above the eastern bank across a cover of thick drift to Locality C, where across the valley there can be seen an exposure of a large fault throwing down zone 3 against zone 2. Continuing along the path down to stream level again, another fault was seen also striking roughly along the dome axis and showing fault drag. At this point a stop was made for lunch.

After lunch the party continued to follow the beck upstream, passing several dykes in quick succession and then a thicker sill of felsite. Because of the steep dip of the country rock, on casual glance this sill may easily be mistaken for a dyke; there is a sharp contact between sill and country rock a few feet above stream level which suggests a faulted junction.

As the party approached the Dent Fault near the SE edge of the dome the steepness of the dips increased, and the zones, which are greatly attenuated because of compression and faulting, were passed in reverse order (Locality D). The Cystoid Limestone when seen again had become vertical and the dips were beginning to overturn.

A short section of Silurian strata (Stockdale Shales of Llandovery age) was seen faulted in, just before Locality E, east

of the Dent Fault. The main component of this complex fault line runs down a small gully trending SE. Red-stained Silurian Shales are exposed in the north side and Visean (Lower Carboniferous) dolomitic limestone in the south side of the gully.

Between here and the waterfall the limestone on the northern bank is brecciated on a massive scale, testifying to the compressive powers which caused the faulting. The beds in this section are inverted Arundian Stage limestone and they continue in this attitude until the eastern component of the Dent Fault is reached, where they are faulted against Lower Carboniferous limestones of the Brigantian Stage. The fault runs across the beck between the massive screen of steeply dipping, inverted limestone and the waterfall immediately behind. The Brigantian rocks are of typical Yoredale lithology; sandstones, limestones and shales, and are vertically bedded behind the fall. Further upstream the beck has cut a gorge through a long section of quite spectacular folded sandstones and shales, which suddenly level out to a horizontal attitude beyond the compressive effects of the Dent Line. Steeply dipping bedding surfaces, some inverted, expose a number of sedimentary structures, including ripple marks, rain pits and mud cracks.

Returning across the moor to Fairy Gill, a tributary of Taythes Beck near Taythes Farm, the party examined a classical fossiliferous section in the Ashgill Shales (Hirnantian) at 708.961. Several fine examples were found of the only trilobite indigenous to these shales, Mucronaspis mucronata, and also many small impressions of the brachiopod Eastropheodonta siluriana.

A.S.D. J.W.

REFERENCES

INGHAM, J.J., 1966. The Ordovician Rocks in the Cautley and Dent areas of Westmorland and Yorkshire. Proc. Yorks. Geol. Soc. Vol. 34.

INGHAM, J.J. and WRIGHT, A.D., 1970. A revised classification of the Ashgill Series. Lethaia. Vol. 3. pp. 233 - 242.

McNAMARA, K.J., 1979. The age, stratigraphy and genesis of the Coniston Limestone Group in the Southern Lake District. Geol. Jour. Vol. 14, Pt. 1.

THE MELL FELL CONGLOMERATE

Leader: Mr. J. W. Rodgers

20th July, 1980

The meeting place for this excursion to the Mell Fell Conglomerate was Pooley Bridge car park (471.244), from which the first locality on the edge of Ullswater could easily be reached. The conglomerate was well exposed on the lake shore around the jetty and in roadside cuttings, and was found to be a poorly sorted deposit with some boulders up to half a metre in size. Most of the pebbles and cobbles were composed of greywacke, very similar to the Silurian deposits to the south of the Borrowdale Volcanics. The frequent occurrence of calcite patches was noted.

One of the chief aims of the excursion was to show how the area of the conglomerate outcrop can be plotted on to a base map largely by feature mapping. The underlying rocks are either the black slates of the Skiddaw Group or Borrowdale Volcanics, and both of these give rise to characteristic topography when they are exposed. The conglomerates were shown to form the distinctive rounded low hills of the area, with the basal junction usually identified by a marked change in slope. After visiting other localities to confirm these observations, it was possible to draw in much of the conglomerate junction with the older rocks, especially on the south side of the outcrop area.

After examining some small basaltic intrusions in the flanks of Little Mell Fell, the group visited the northern edge of the conglomerate outcrop where it is overlain by Carboniferous Deposits, with limestone forming quite a prominent escarpment above Dacre (459.365). A descent of the scarp slope was made in an attempt to trace the base of the Carboniferous. A weathered pale conglomerate was found towards the foot of the escarpment, and this differed significantly from the much darker red conglomerate exposed in the opposite banks of the nearby Skitwath Beck. Although this darker material was of much finer grain size than the samples seen in the morning, it was taken to be the Mell Fell type of deposit.

Some time was spend considering the age of the conglomerate. The leader argued that a Devonian age was probable, the conglomerate representing the erosion products from the recently uplifted Caledonide mountains.

THE WATCH HILL GRIT AND THE IGNEOUS ROCKS OF THE EMBLETON AREA

Leader: Mr. T. Shipp

14th September, 1980.

For this late summer excursion members of the Society met at the car park of the Derwent School, Cockermouth, where the leader, Mr. Tom Shipp, outlined the geology of the area to be investigated.

Topographically, the 6 km by 6 km area of country north east of Cockermouth consists of three ridges of high ground separated by three E to W valleys. In the north, the Redmain-Sunderland ridge is composed of limestone and basalt lava flows of Carboniferous age. The Setmurthy ridge (Watch Hill-Elva Hill) is formed from the Loweswater Flags of the Skiddaw Group, consisting mainly of grits overlying shales, with dioritic intrusions. The Embleton (golf course) ridge is formed of Skiddaw Group shales capped by dioritic intrusions which thicken up to 120 metres at Close Quarry.

The broad valley south of Embleton which carries the A66 road along the line of the old railway, is clearly a misfit. J. E. Marr pointed out that it was choked with glacial debris and noted that the present course of the River Derwent in its deeply cut valley to the north was probably initiated in post-glacial times. The middle valley which carries the minor road from Derwent School to Higham Hall has some interesting terrace-like features which may have been produced in a temporarily ice-dammed lake towards the end of the glacial period.

The Skiddaw Group of the north western part of the Lake District has been intruded by a great many minor igneous bodies. These minor intrusions are generally of rocks classed as dioritic lamprophyres, containing relatively high proportions of the ferromagnesian minerals hornblende and biotite, with plagioclase feldspar as the dominant mineral. Free quartz is occasionally present in small amounts.

In the area under consideration the principal minor intrusions into the Skiddaw Group are to be found at:

Sale Fell (194.297)	-	minette
Between Watch Hill (150.319) and Elva Hill (173.319)	-	quartz diorite
Between Embleton Golf Course (156.307) and Close Quarry (175.319)	-	diorite
Slate Fell (143.303)	-	quartz diorite

All these intrusions are thought to be associated with Lower Palaeozoic igneous activity, and are similar to a suite of Caledonian lamprophyric dykes in the Lower Palaeozoic rocks of Kirkudbrightshire.

The first stop was made at the roadside opposite Greenlands Farm (148.314) from where, with the permission of the farmer, the party walked up the side of Watch Hill towards the prominent small quarry near the crest of the ridge. At the wire fence along the crest a conspicuous outcrop of coarse gritstone was seen showing blocky 'columnar' jointing. This exposure is shown on Plate II of Eastwood et al., 1968. The small quarry nearby (149.317) was found to be excavated in a very fine-grained, pink coloured igneous rock, sheet-like in form, extending along the ridge and approximately 10 m in thickness. This rock was seen to rest conformably on Skiddaw Group turbidites, and had an irregular upper surface on which were found pockets of conglomeratic material below the overlying Watch Hill Grit. Jackson (1978) recorded this as a

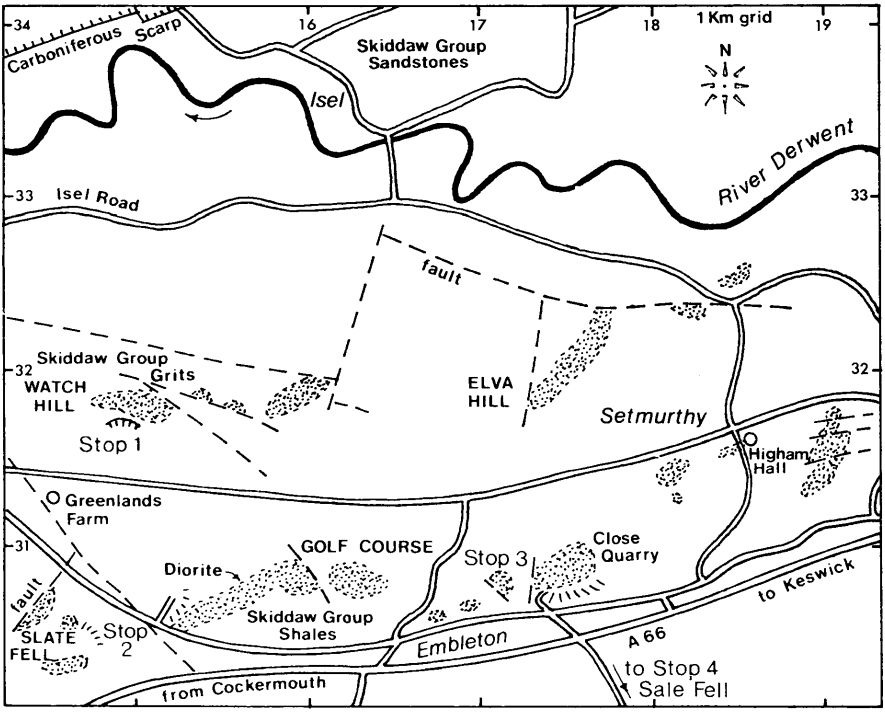


Fig. 1 DIORITE INTRUSIONS IN THE EMBLETON AREA.

felsite lava flow; the only record of contemporaneous vulcanicity yet found within the Skiddaw Group.

The second stop was made at the lay-by on the main road 1½ km SE of the Derwent School (148.306). The party walked across fields south of the road to inspect prominent outcrops on Slate Fell. Dioritic rock was seen intruded into highly fractured Skiddaw Group mudstones. Investigation and discussion ensued on the complex joint patterns, quartz veining and thermal metamorphism. An obvious fault was seen terminating the outcrop of the intrusion at the western end of the ridge.

The party now walked back to the lay-by and, crossing the main road at the 420' spot height on the O.S.map, continued NE up a green lane to some overgrown disused slate quarries. After noting the evidence of the close proximity of igneous rock and hardened mudstone, the conclusion was reached that the shale, thermally metamorphosed by the intrusion, had been quarried to provide roofing material or thin flagstones for the nearby town of Cockermouth.

The third stop was made at the small lane alongside the Wheatsheaf Inn (174.306), from which the party made its way uphill into the large disused Close Quarry, very little of which can be seen from the road below. The diorite was inspected for its mineralogy, jointing and variations in texture. Contacts were found with overlying and underlying Skiddaw Group rocks, confirming the sill-like form of the intrusion.

After a leisurely lunch in the garden of the Inn, a small number of the more energetic members of the group drove across the valley to Wythop Mill and set off up Sale Fell, noting the spectacular folding and quartz veining in the Loweswater Flags on the way. Their efforts were rewarded by finding near the summit the remarkable isolated intrusion of the beautiful Sale Fell 'Minette'.

REFERENCES

EASTWOOD, T. et al., 1968. Geology of the Country around Cockermouth and Caldbeck. Mem. Geol. Surv. x plus 298 pp.

JACKSON, D.E., 1978. In 'The Geology of the Lake District' (Ed. Moseley). Yorkshire Geological Society (Occasional Publication No.3), vii = 284 pp.

MARR, J.E., 1916. The Geology of the Lake District. Cantab. Univ. Press. xii plus 220 pp. Reprinted 1968 by Cedric Chivers Ltd., Bath.

THE ROCKS OF THE LANGHOLM AREA

Leader: Mr. I. Gray

10th May, 1981.

Some twelve members and guests braved a chill, damp and windy day to meet at Skipper's Bridge (372.835) just south of Langholm. Mr. Iver Gray, the leader, pointed out at this locality the faulted, unconformable junction separating the steeply dipping Silurian greywackes and shales from the Lower Carboniferous Birrenswark Lavas. The party examined the latter in detail, noticing the vesicles and possibly flow-banded amygdales in this hard, almost horizontally bedded olivine basalt.

The next place to be visited was an old quarry north west of Langholm, where greywackes and shales of Wenlock age showed very closely graded bedding. Sole and flute marks were seen besides a small thrust, but unfortunately no Monograptids were found.

At subsequent localities visited by the party the Carboniferous succession was followed. A pitching asymmetric syncline near Gilnockie Tower (329.785), exposed cyclothems in the Lower Carboniferous and typical fossil associations were seen in the Liddesdale Limestone; Gigantoproductids, Lithostrotion and Crinoids. A resistant dyke crossing the River Esk clearly showed spheroidal weathering.

The afternoon was spent in the eroded asymmetric anticline at Penton Linns (432.774), tracing the beds between the Penton and Harelawhill Limestones near the top of the succession. Erosion and weathering had delineated in spectacular fashion the less competent shaly beds from the more resistant limestones and sandstones. It was also fascinating to see how the course of the river had been influenced by the dip and strike of the strata. Productids, corals, crinoids and bryozoa were found easily enough, but the leader's expertise was needed to trace the cyclothems and to find the two or three thin coal seams within the limestone. At this point a fault brought in the characteristically current-bedded deltaic Millstone Grit.

Mr. Gray was warmly thanked for introducing members to an area new to many of them, but one which, geologically speaking, was reassuringly familiar.

EXCURSION TO CARROCK FELL AND BRANDY GILL

Leaders: Dr. F. J. Cockersole,
Mr. M. B. Dodd and Miss D. Slater.

14th June, 1981.

A group of about 25 members and friends assembled on a fine summer morning at the rendezvous just south of the hamlet of Mosedale (357.320). Two parties were formed; one to ascend the summit of Carrock Fell studying the petrology of the igneous complex, while the remainder moved on in the cars to the head of Mosedale to investigate the mineralisation in the area of Brandy Gill and the Carrock Mine.

The first party set out up the sharply rising shoulder of Carrock Fell immediately behind the village. The route commences over intensely folded and deformed Skiddaw 'Slates', and although in this locality they are outside the metamorphic aureole of the Skiddaw Granite the rock has nevertheless undergone a degree of thermal alteration, presumably from the proximity of the Carrock intrusion.

The path crosses the junction between the slates and the Carrock Fell gabbro at about the 1000 ft. contour at G.R.352.326, but the ground is heavily vegetated and only the change in the character of successive outcrops indicates the approximate line of the contact. From this locality the party obtained a very good view of the country to the east and south over Mosedale and Bowscale Fell and on towards Great Mell Fell in the distance. The effects of glaciation on the topography ere everywhere apparent, and the valley bottom traversed by the River Caldew below Mosedale had clearly at one time been a lake bed. The well-defined linear eastern cliffs terminating the Carrock Fell complex fall steeply towards the River Caldew, and are thought to mark the line of a major fault.

The party now followed a fairly direct line towards the summit over rough moorland terrain, sampling the outcrops and noting the variation in the texture of the gabbro. This is generally a hard, coarse-grained, speckled rock composed of feldspar and ferromagnesian minerals. The variations that occur are due to differences in grain size and in the proportions of the major minerals. The paler leucogabbros contain more feldspar, while in the darker melagabbros the mafic minerals predominate. The titanium-containing mineral ilmenite occurs in certain bands of the Carrock gabbro, but was not found on this occasion.

Approaching the summit of the fell the outcrops changed in appearance and fresh broken surfaces displayed the grey or pink colour of the granophyre. This is a medium-grained acidic rock of granitic composition with a characteristic 'graphic' texture derived from intergrowths between the quartz and feldspar crystals. Along the junction zones certain hybrid rocks occur where the gabbro and the granophyre grade into each other.

The leaders pointed out several items of interest to be seen from the eastern summit of the fell (343.337). These included the traceable outlines of the stone ramparts of an Iron Age hillfort, perhaps constructed rather hastily in response to the threat of Roman forces whose marching camps have been identified near Troutbeck, not far to the south. The view extended over the Carboniferous Limestone scarps in Greystoke Park and out beyond to Cross Fell and the Pennines in the distance. Around the summit erratic boulders of gabbro can be found several hundred feet above the level of the parent outcrops, indicating the uphill movement of ice over these slopes during the climax of the last major glaciation.

Lunch was taken on the northern slopes of the fell just below the main summit. Afterwards the leaders invited the party to reconstruct in their imagination the plate tectonic events associated with the closure of the Iapetus Ocean along the Solway line in Ordovician times. The subduction zone which is thought to have existed along the southern margin of the ancient sea could well have given rise to the deformed turbidites of the Skiddaw Group and to the andesitic volcanic rocks of the Borrowdale Series as well as the underlying granitic batholith of the Lake District basement. The genesis of the Carrock Fell igneous complex itself must also be related to these major tectonic processes.

In the afternoon the party traversed the high ground along the ridge to the west. This plateau area is thickly mantled with peat but is also studded with rocky outcrops. The granophyre is here in contact with diabase, an altered dolerite. This is a medium-grained, basic rock similar in composition to the gabbro. The evidence from the field relations of the different rock types in the complex, and from radiometric dating, is that the gabbro was intruded first about 468 Ma ago, shortly followed by the diabase. The granophyre came somewhat later about 421 Ma ago, while the main Skiddaw Granite was intruded some 25 Ma later still. The contacts along the ridge cannot be seen, but again the position of the junction zones can be inferred by identifying the rock types in the various outcrops.

The party reached the head of Brandy Gill (324.339) and descended towards the Carrock Mine. On the way they met the second group under the leadership of Miss Doreen Slater who had worked their way up the Gill studying the varied mineralisation

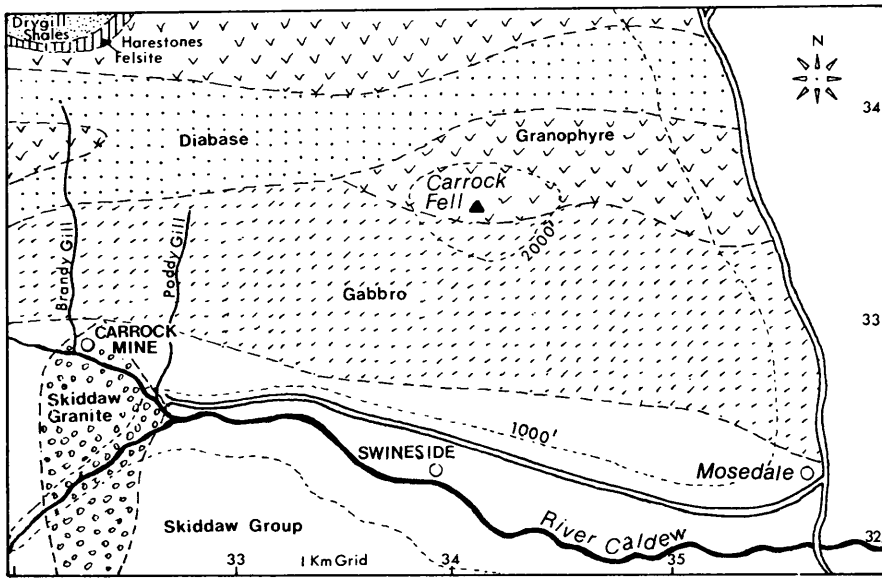


Fig. 1 GEOLOGICAL SKETCH MAP OF THE CARROCK FELL REGION

by sampling the old mine tips and investigating the stream bed exposures. Brandy Gill is roughly on the axis of several north-south trending veins which have been worked chiefly for their tungsten-containing minerals, wolfram and scheelite. Old adits can be seen at a variety of levels on both sides of the Grainsgill Beck, and some of these have been opened out recently for renewed exploitation of the veins. Apart from the wolfram, the metallic minerals that can be found in small amounts are mainly sulphides and include galena, sphalerite, pyrite, chalcopyrite, pyrrhotite, arsenopyrite and molybdenite. There is also a small group of bismuth-containing minerals, although these are rare. Of the non-metallic minerals, apart from the common quartz, calcite and dolomite, it is also possible to find small specimens of ankerite, apatite and fluorite. The tungsten-containing scheelite really requires an ultra-violet lamp to bring out its fluorescence in the dark. Towards the head of Brandy Gill, psilomelane, a black hydrated oxide of manganese, is not difficult to find, but the remainder of the extensive suite of minerals associated with this locality, including rare tungstates, molybdates and arsenates is elusive.

The day was concluded by passing through the Carrock Mine installations over to the south side of Grainsgill Beck. From here down to the bridge at G.R.328.326 the Skiddaw Granite has been

converted by metasomatism to a greisen consisting almost exclusively of mica and quartz. The exposure of the Skiddaw Granite in the bed of the River Caldew at G.R. 325.325 was examined and the members of the party then made their way in leisurely fashion down the Mosedale valley back to the cars, enjoying the pleasant summer evening and noting as they went the changes in the Skiddaw Slates relating to the various zones of the metamorphic aureole of the Skiddaw Granite.

EXCURSION TO NEWLANDS VALLEY MINES

Leader: Mr. J. D. J. Wildridge

27th June, 1981.

Just over 20 members and friends joined this excursion on a dry, chill afternoon. The leader, Mr. Denis Wildridge, gave an introductory talk referring to various features in the landscape and to old documents he had studied which provided the background picture of mining in this particular area in earlier days. He also described the technical methods available to the 'old men' of the mines.

Starting from Uzzicar Farm (234.218) he pointed out the three levels on Barrow Mountain, as well as the old shaft, the site of some bellpits and the position of the huge water wheel. The old mine tip provided samples of zinc-blende and galena with a little pyrites.

The party proceeded to Stoneycroft (232.213), where an old shaft in the stream bed and the site of another water wheel were pointed out. Also to be seen were the remains of the old dam and a number of 'leats'. After a rough scramble up a trial adit, cut with stope and feather, the party continued up the valley by Stoneycroft Beck to the site of an old smelt mill, where the tip provided varied and dramatic samples of vitrified furnace slag. The position of the long chimney flue running up the hillside was clearly seen.

Concluding an interesting afternoon, the leader mentioned that old estate papers had revealed that these smelt mills had used coal from Aspatria. He also mentioned the cobalt mine high up on Sail Crags in this vicinity.

THE GRANITE IN WASDALE

Leader: Mr. M. F. Burton

11th July, 1981.

The excursion party met at Strands village, Netherwasdale (125.040), at 10.00 a.m. and proceeded by car to the Flass (128.037). From here the cart track to the Wastwater pump-house was followed, where the cars were parked by kind permission of British Nuclear Fuels Ltd.

The party first climbed about 200m up the fellside towards the summit of Pens End (148.035), which comprises the lower northern slopes of Whin Rigg. Crossing the fell three small becks were encountered revealing an assortment of small boulders of pink granite and Borrowdale Volcanic rocks in their beds. Eventually a track was reached which proceeded upwards and bore much evidence of haematisation. The territory to the east of this track was found to be very broken and contained several lateral ridges and depressions which were filled with loose rocks, some heavily haematised. Keeping to the west of the track, the party reached a ridge of granite which was the first 'in situ' exposure encountered in this approach from the east. A compass bearing was taken along the general line of the small scarp and gave a reading of N 10^{o} W which could well be the general direction of the fault which in this locality provides the boundary between the Eskdale Granite and the Borrowdale Volcanic Series. Firman (1960) maps the boundary here as a dextral wrench fault trending NNW-SSE. Owing to the onset of bad weather with frequent rain showers, it was decided to abandon further exploration at this spot, and the party returned to their cars, noting some conspicuous water-worn exposed slabs of pink granite on the way down.

Haematisation appears to be a common feature in the normal pink granite, especially along faults and shears. It is not confined to the boundary areas, as a strong haematite vein is located in Great Hall Gill (143.034), the chasm of which could be plainly seen half a mile or so to the west.

The object of the second part of the excursion was to visit the exposure of granite at Wasdale Head, and to that end the party proceeded to the car park near the Wasdale Head Hotel. Dwerryhouse (1909) describes the Wasdale Head exposure of the granite as

extending from Down in the Dale (184.083) below the Hotel, up the valley to about half a mile above Burnthwaite (192.091), and having a dimension of one mile in length by half a mile in width, and a roughly elliptical shape. The familiar outcrops which the party visited lie in the bed of Lingmell Beck. The highest one lies near the junction with Gable Beck, and the pink of the granite was seen to stand out against the blues and greys of the Borrowdale country rocks.

The party crossed Lingmell Beck from the Sty Head track and proceeded downstream for several hundred yards noting the frequent outcrops of granite as they appeared in the stream bed. A brief examination of samples from the exposures showed a variation in texture and colour from different outcrops. Some appeared identical with the normal pink Eskdale Granite, whilst others had the appearance of granite porphyries and marginal granites and contained numerous black patches of chlorite or biotite. Some specimens had a light brownish-pink matrix.

Eventually the party reached the footbridge over the beck and returned to their vehicles where the leader was warmly thanked for his efforts.

REFERENCES

DWERRYHOUSE, A.R., 1909. On Some Intrusive Rocks in the Neighbourhood of Eskdale (Cumberland). Quat. Jour. Geol. Soc. Vol.65.

FIRMAN, R.J., 1960. The Relationship between Joints and Fault Patterns in the Eskdale Granite (Cumberland) and the adjacent Borrowdale Volcanic Series. Quat. Jour. Geol. Soc. Vol.116.

THE SCILLY BANKS OPENCAST COAL SITE

Leader: Mr. E. Lawrence

19th September, 1981.

Some 20 members assembled at the Scilly Banks opencast coal site near Whitehaven for a Saturday morning visit arranged by the leader, Mr. Eric Lawrence, Area Geologist with the Opencast Executive of the National Coal Board. Mr. Lawrence and the Site Engineer, Mr. Eric Thompson, gave the party a preliminary briefing talk in the site office at Round Close Farm (995.190).

Nationally there are some 90 opencast sites in the country, and six or seven of these are in Cumbria. This particular site is in two parts, the Moresby and the Keekle sections. Prospective drilling began as long ago as 1946, with further exploration in 1950 and a final assessment programme in the 1970s. Mr. Lawrence showed detailed geological sections indicating the stratigraphic levels of the measures being worked. Fig. 1 is a simplified section, based on the Whitehaven Memoir, not to scale, identifying the relationships of the chief seams. The leader referred to the typical sequence of coal measures strata consisting of sandstone grading up into mudstone and then the seat earth and the coal itself. On this particular site the general geology comprises strata dipping to the west or south west at inclinations varying between 1 in 8 and 1 in 5. The strata are cut by a large number of faults trending north-south or northwest-southeast. Numerous splinter faults occur off the main fault lines and throws vary from 1 metre or less to 50 metres or more. Some of the faulting may have been initiated in Carboniferous times, but most is the result of Tertiary movements. The faults throwing down the seams increase the difficulties of exploitation, as do the fairly frequent wash-out channels and the existence of old workings in the Main and Bannock Bands.

Research into old records and archives included those of Lord Lonsdale's Whingill Colliery dating from the seventeenth century and the party were shown some old mining plans of the Rhea pit in the 1800s.

On this site there are 16 seams, some of which are split into leaves with the result that 23 separate coal layers are being extracted. In contrast to deep mining, opencast methods can exploit seams as thin as 15 cm, but here they vary in thickness up to 2½ metres.

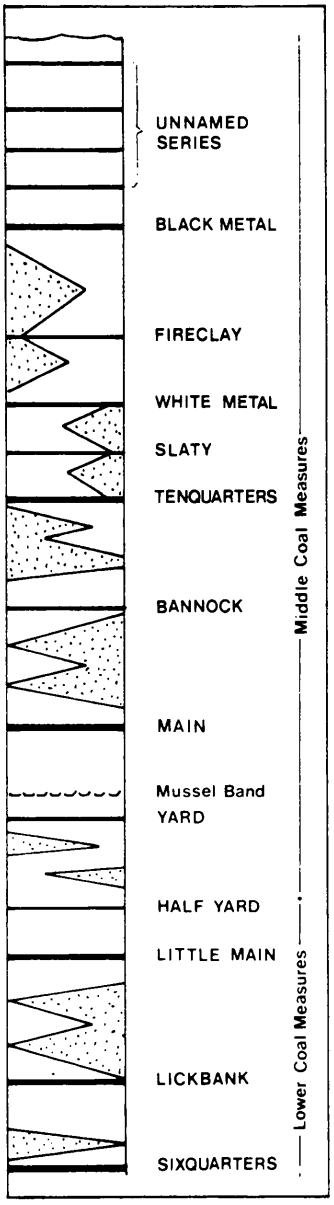


Fig.1 DIAGRAM OF SEAMS TO BE WORKED AT MORESBY AND KEEKLE SITE. (Not to scale)

A detailed drilling programme enables the tonnage of coal available to be calculated, but this has to be measured against the thickness of overburden that it is economical to remove. The contract for this site, let to Miller Mining Ltd., was based on the extraction of 1,045,000 tonnes of coal. Work began in November, 1980, and some 100,000 tonnes have been won so far. The maximum depth of excavation is 53 metres in the Moresby area and 78 metres in the Keekle part of the site. Although there has been previous underground working in the main seams, the old 'pillar and stall' methods that were employed have, in many instances, left worthwhile amounts of coal to be extracted by opencasting.

Mr. Thompson explained the methods of working to the party. On this site no drag-lines are used, only face shovels and dump trucks. This is possible because of the fragmented nature of the harder sandstone horizons which may have been fractured by settlement resulting from the old workings at deeper levels.

Another problem could arise from the suspended load of finely divided solid material in the run-off water from the site. Treatment in sedimentation ponds avoids contamination of the local streams.

The party was then conducted round the site and was greatly interested to see the various features and operations already described. At one vantage point on top of a heap of up-cast a long, vertical working face displayed the strata to perfection. Beyond this there was a dramatic view over Whitehaven with St.Bees Head in the background.

The whole constituted, in

effect, a full-size block section.

Mr. Mervyn Dodd, the Society's Excursion Secretary, at the conclusion of the visit expressed the thanks of the party to Mr. Lawrence and Mr. Thompson and to the National Coal Board for authorising the visit. He commented that the members were particularly appreciative of the opportunities afforded by occasions such as this to see the excellent, but temporary, exposures of the strata in their own locality resulting from the opencasting.

ROCKS AND FEATURES OF THE UPPER CALDER VALLEY

Leader: Miss D.Slater

3rd October, 1981.

Nineteen members and guests met by the cattle grid on the Cold Fell road (055.101) on a bright sunny cool afternoon in the midst of a very wet autumn. The leader, Miss Doreen Slater, set the scene by pointing out the features of the surrounding terrain. She also mentioned the difficulties presented by the area where contacts between puzzling suites of rocks were hidden by drift cover. Furthermore, the area badly needed re-mapping and re-interpreting.

The first exposure examined, by the side of the track down to the River Calder (062.102), revealed strongly jointed andesites reddened by haematite. Agate samples were seen in the amygdaloidal lavas in loose material at the base of the exposure. A little further on at Monk's Bridge (064.103) tuffs were exposed. These contained rounded to sub-angular clasts of over 2 mm in size, which stood proud from the weathered surface of the fine-grained matrix. It was suggested that the tuffs had been waterlain.

The party proceeded upstream along the east bank terrace of the River Calder. A small outcrop of highly cleaved and rather decayed but unfossiliferous slates was seen in the banks of the Latterbarrow Beck (068.109) and were thought by some to resemble Skiddaw Slates. Reaching the end of the Calder Gorge the party noted rapid changes in the sedimentary conditions; uniform grey quartzitic sandstones giving way to rocks containing boulder-sized,

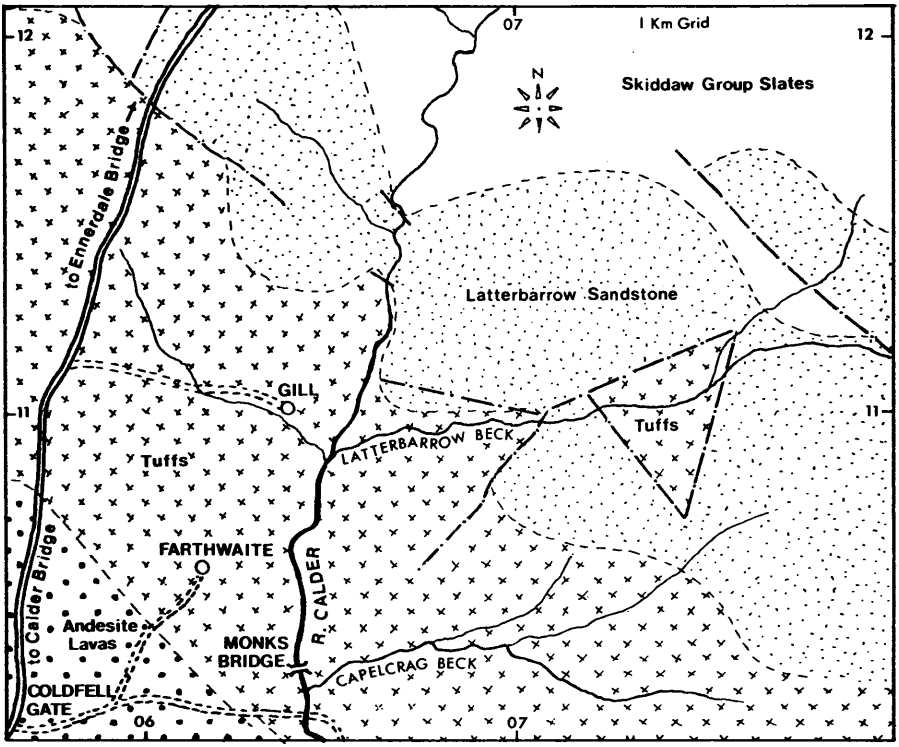


Fig. 1 GEOLOGICAL SKETCH MAP OF THE UPPER CALDER VALLEY

sub-angular, resistant, variegated and ill-sorted clasts.

An attempt to progress further upstream was halted by a spectacular example of contemporary erosion. Hundreds of tons of peat and drift had been washed down from the east terrace of the river by recent rains, forming a mud-flow partially damming the valley bottom and giving rise to a large morass in which two members sank to their knees. The intention had been to continue the excursion on the far bank of the river, but the Society well-nigh lost its President in his enthusiasm to cross, and a decision was made to beat a retreat back to the cars. On the way a characteristic outcrop of the Latterbarrow Sandstone was examined which showed marked reddening below the weathered edge.

As dusk fell a tired but happy group expressed their thanks to Miss Slater for conducting them over this intriguing and little known territory.

EXCURSION TO EDINBURGH

Leader: Dr. D. McAdam

16th October, 1981

Dr. David McAdam of the Lothian Division of the Institute of Geological Sciences was the leader of this expedition which was attended by ten members, and which took place in beautiful autumn weather.

The morning was spent at South Queensferry just below the Forth railway bridge, studying the Lower Carboniferous succession at this locality. The strata of shales and sandstones showed typical evidence of sedimentation in deltaic conditions. The sandstones were light in colour and showed current bedding, channelling and other sedimentary structures. They are used locally as building stone. The shales are more accurately described as oil shales for they contain petroleum residues showing up as brown streaks. These rocks are soft and react rather like paper when hammered. A distinctive, whitish, altered dolerite sill had apparently driven off the volatiles from an adjacent shale band. A small scale anticlinal fold structure was seen in which the sandstone beds showed faults and fissures at the apex, whereas the much less competent shales had been compressed into a sharp fold with steeply dipping limbs. The party succeeded in finding one of the highly fossiliferous estuarine beds, but the more diagnostic marine marker bands were not seen.

The afternoon was devoted to the volcanic rocks exposed in Holyrood Park. The route followed began on porphyritic basaltic lava flows and led on over ash deposits before ascending the volcanic plug of Arthur's Seat across its blocky agglomerates. On the way up the leader explained how the olivine basalts were classified on the basis of the included phenocrysts, and the party was able to identify some of the lava flows. The return route led past the spectacular columnar basalt of Samson's Ribs, very close to an agglomerate containing large volcanic bombs. By the roadside a small roche moutonnee was seen and within a few yards good examples of slickensiding were noticed. Finally the party stopped at Hutton's classic site where he proved the intrusive origin of sills.

Before setting out on the long journey home, Mr. Mervyn Dodd expressed the party's gratitude to Dr. McAdam for providing a full day of fascinating field geology.

OTHER EXCURSIONS

19th April, 1980	Carboniferous Limestone, Kelton Head Quarry. Leaders: Messrs. M. B. Dodd and T. Shipp.
2nd November, 1980	The Ennerdale Valley. Leader: Miss D. Slater. (This excursion had been planned as a week-end meeting, but in the event, for various reasons, it was limited to a single day).
5th April, 1981	Practical Geological Mapping, Blindcrake Area. Leader: Mr. T. Shipp.

SHORT EVENING EXCURSIONS

25th April, 1979	Lowther Park Forest. Leader: Mr. T. Shipp.
16th May, 1979	Opencast Coal Mining, Low Close, near Broughton Moor. Leader: Mr. E. Lawrence.
23rd May, 1979	Geological Site Clearance, working party at Bigrigg.
13th June, 1979	The Barrowmouth Unconformity. Leader: Mr. T. Shipp.
11th July, 1979	Igneous Intrusions on Irton Fell. Leader: Miss D. Slater.

LECTURE REPORTS

EARLY PALAEOZOIC SHELF SEDIMENTS IN PRINCE OF WALES AND SOMERSET ISLANDS, ARCTIC CANADA.

Dr. J. Dixon

A meeting of the Society was held on Friday, May 18th, 1979, at the West Cumbria College, Workington. The speaker was Dr. J. Dixon of the Institute of Sedimentary and Petroleum Geology of the Geological Survey of Canada who spoke on 'Early Palaeozoic Shelf Sedimentation in Prince of Wales and Somerset Islands, in Arctic Canada'. About twenty members of the Society attended.

Dr. Dixon, a native of Maryport and on holiday in this country, commenced his lecture by locating Prince of Wales and Somerset Islands as lying N. and N.E. respectively of the Boothia Peninsula, very close to the North Magnetic Pole. In terms of distance this was some 2500 km north of Calgary and 3500 km north of Montreal. Such distances, coupled with a harsh climate and difficult terrain, meant that the geologist had to adjust his life-style very dramatically. Dr. Dixon showed colour slides of the types of light planes and helicopters used in the region as well as scenes of interest in the small settlement of Resolute Bay, with its bright orange buildings, fuel stores and above-ground sewerage system, built in this way because of the perma-frost.

The rocks of the region are largely composed of flat-lying carbonates, with some folding at the margins, giving good strike sections. Their ages range from late Precambrian (Proterozoic) to Lower Devonian. The age of the base of the sequence is indicated by a diabase sill within the Proterozoic strata which gives a K/Ar radiometric age of 702 $\pm$ 25 Ma. Above this lies the Hunting Formation, approximately 1200 m of sandstones, dolostones and cherty dolostones. There appears to be a widespread unconformity, with the Lower Cambrian missing. Carbonate sedimentation appears to have been relatively uninterrupted from Middle Cambrian to Middle Silurian and the lecturer went on to describe some of the faunal and depositional features that he had investigated.

In describing the facies, Dr.Dixon showed a stylised cross-section of the edge of a shallow sea. (Fig.1).

He then went on to show with the aid of colour slides, evidence for deposition within the various facies. The carbonate rocks showed a great variety of stromatolites (fossilised algal growths), which were relatively abundant in Lower Palaeozoic times

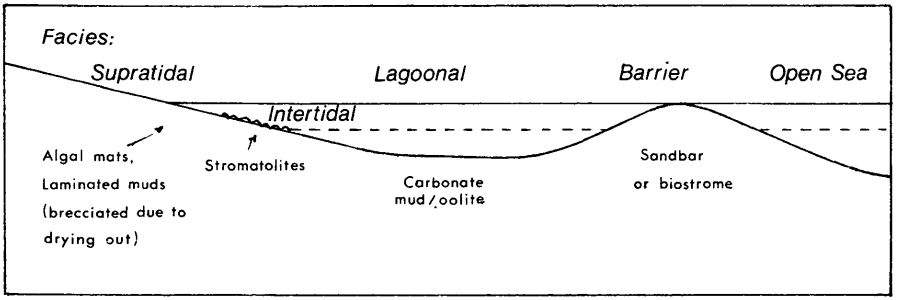


Fig. 1

perhaps because of the absence of gastropods which graze on algal growths. Well displayed were features such as normal and cross laminations, ripple markings and contemporaneous brecciation probably due to desiccation above the high tide line.

An interesting feature developed in some of the carbonate rocks in the region is a 'patterned' texture. This has been attributed to the deposition of carbonate and sulphate evaporite muds, probably in tropical or sub-tropical seas, which covered vast areas of N.America and Europe in Lower Palaeozoic times. Diagenetic changes in this material resulted in the diasolution of nodules of gypsum and its replacement by dolomite with some of the sulphate material remaining, chemically altered, as finely disseminated pyrite. The patterning varies in appearance. Sometimes it looks remarkably like worm-burrowings, but it has been interpreted as being of non-organic origin, best displayed in fine-grained carbonates or laminated dolostones which have been deposited in an intertidal or supratidal zone.

In thanking Dr. Dixon for his talk, Mr. Mervyn Dodd commented that it was fascinating to see evidence of deposits laid down in ancient tropical seas yet now to be found so near to the present North Pole; clear evidence of a fairly massive drift of the continents.

The Society wishes to thank Dr. Dixon for copies of the following papers that he has written about his work and which will be deposited in the Library:

'Revised Stratigraphy of the Hunting Formation (Proterozoic), Somerset Island, North West Territories.'
Canadian Journal of Earth Sciences. Vol.11, No.5. 1974.

'Ordovician and Silurian Fossils from the Lang River and Allen Bay Formations of Prince of Wales and Somerset Islands, North West Territories.'
Bull.Can.Pet.Geol. Vol.23,No.1, pp 172-184. 1975.

'Patterned Carbonate - a Diagenetic Feature.'
Bull.Can.Pet.Geol. Vol.24, No.3, pp 450-456. 1976

'Corallite Increase and a New Corallite Type in Upper Ordovician Cateniform Corals.'
Jour.of Palaeontology Vol.50, No.5, pp 916-921. 1976

THE PERSISTENCE OF MAN

Dr. T. A. Whitworth

The first lecture of the 1979 - 1980 winter programme was held at the West Cumbria College, Workington, on Wednesday 3rd October, 1979. About 25 members and their guests attended. The speaker was Dr.T.A.Whitworth of Hatfield College, Durham, and he entitled his talk 'The Persistence of Man'.

Dr.Whitworth first described his interest in what he termed human palaeontology tracing the origin and development of man from the other primates. He reflected that as well as morphological development at some stage in the story less tangible characteristics must have appeared such as the capacity for reflective thought and a sense of responsibility.

The antiquity of man has not always been accepted but the fossil record shows the emergence of the Hominidae among the primates in the Lower Pleistocene Period perhaps as long as 4.5 Ma ago. Their evolution is characterised by increasing cerebral capacity and evolving man can be classified conveniently into three chronological groups - Ape-like man, Neanderthal man, and Sapient man.

Ape-like man is represented by a number of types. Of these Australopithecus seems to be the earliest and most basic form. Both skeletally and in brain development Australopithecus falls midway between the gorilla and modern man. He is known from cave breccias in Bechuanaland and other South African localities. Appearing in the Lower Pleistocene Australopithecus walked upright and had a human type of dentition and may have used fire and tools.

At this point Dr. Whitworth spoke about the discoveries of Dr. Leakey and his family in the Olduvai gorge in East Africa. This is an area of thick dissected lake deposits today forming an arid plain with a calcrete surface layer. The strata exposed

have produced a mass of information on hominids from the Lower Pleistocene onwards. Together with other sites in the area and in Ethiopia the remains of 50 - 60 individuals are known.

Other types of ape-like hominids such as Pithecanthropus from Java and Sinjanthropus from China are all regarded as developments of Australopithecus and all can be grouped into perhaps two genera. The more advanced forms transgress up into the Middle Pleistocene.

Dr. Whitworth's second group, Neanderthal man appeared in the Middle Pleistocene and has also been found widely distributed in Europe, Palestine, Africa and Java like the earlier ape-like man but forms a fairly well-defined taxon. These people were powerfully built but with a fairly short stature. They had a brain case approaching that of modern man in size though the brain was less sophisticated. They had a more upright carriage, a low forehead and prominent supra-orbital ridges. They certainly used fire and possibly were cannibalistic and left evidence of ritual burial. The name is derived from the Neanderthal valley near Dusseldorf where remains were found in 1856 eight years before the celebrated controversy on the origin of man between Charles Darwin and Thomas Huxley and Bishop Wilberforce.

The third group, Sapient Man, developed in Upper Pleistocene times and is virtually indistinguishable in fossil remains from modern man. These were the people associated with cave-paintings from which we know they possessed the skills of hunting, shooting and fishing and they may well have followed religious practices. They had large capacity sophisticated brains with thin cranial walls. Recognisable races of sapient man emerged in the Upper Pleistocene such as the physically powerful Cro-Magnon stock and the Grimaldi races who were of shorter stature and with distinctly negroid features. Other races had Esquimaux-like affinities and there were the Bushmanoid types.

In drawing some general conclusions Dr. Whitworth pointed out that the evidence indicates similar sequences of hominid development in widely separated geographical localities. This suggests early wide dispersion and regional overlap during the development period. New discoveries and technology as we have seen have already pushed back the origin of man to perhaps 4.5 Ma ago and the whole picture becomes ever more complex. A recent idea to emerge is that the different types of early man that have been described overlapped chronologically to a much greater degree than had been supposed. There are increasing instances where different types seem to have existed contemporaneously side by side. Perhaps the persistence of earlier forms by interactions aided the development of later more sophisticated types. The speaker concluded by suggesting that these studies might provide a clue as to the nature of future human development.

DAM GEOLOGY

Dr. M. S. Money

A meeting of the Society was held on November 7th, 1979, at the Derwent Centre, Cockermouth. The speaker was Dr. M. S. Money of the Department of Engineering Geology of the University of Newcastle-upon-Tyne. Some 35 members and their guests were present.

Dr. Money opened his talk by referring to some general aspects of Engineering Geology. This branch of geology is forward-looking in nature in that predictions have to be made for example on the behaviour of rocks and rock structures under different loads and stresses. Another example is the prediction of the wearing properties and other characteristics of rock materials used in road construction. The problem of the disposal of radio-active waste materials involves making such predictions perhaps many centuries ahead.

Dam Geology is a specialised branch of Engineering Geology and contractors employ specialists in the field. The consequences of error may be serious and there have been numerous examples of dam failure. The speaker referred to the Bradfield disaster of 1854 involving the loss of 200 lives, and there are records of 77 major dam failures in this country alone since 1800.

Dr. Money illustrated by means of slides some of the causes of failure. Seepage can occur round or under a dam and seepage paths once established tend to enlarge silently. There is also the problem of the soil and rock stability of the side slopes of the reservoir site itself; an example being the Frejus disaster in Italy where a huge land slip caused a gigantic wave over the dam. The present day safety of dams built in the last century also occupies the attention of engineering geologists. There are about 2000 dams in this country and Safety Acts of 1930 and 1975 have not yet been fully implemented.

Turning to the various types of construction that can be used for dams Dr. Money said that the choice depended both on the topography and the geology of the site. Given a rock foundation a gravity dam depends for its stability on its weight and cross-section. Fissures in rock below a dam require to be grouted and some dams contain access tunnels which allow grout holes to be inserted subsequently. Large masses of concrete however are very expensive. Glacial valleys are popular reservoir sites but there are often buried channels filled with till. The Thirlmere dam, though small, required an unusually deep excavation. If there is

less overburden a lighter form of construction can be used such as the buttress type of dam. An example is seen at Haweswater where the dam is composed of a series of concrete arches.

The topography and geology of the reservoir site must also be suitable. Deep narrow valleys with sound rock are ideal but many British dams are earth embankments with a clay core, and can be built on a variety of base materials. A rock-fill dam is an embankment dam using quarried rock as a core, and one of the tasks of the geologist is to find sources of building material as close to the construction site as possible. One advantage of this type of dam is that construction can be carried on all through the year whereas concreting requires special aggregates and suitable weather conditions. In the case of the Kielder dam rock material for the dam site was obtained from quarrying Tertiary dykes within the catchment area of the reservoir.

The Cow Green reservoir and dam in Upper Teesdale is of interest in that the dam is in part built across a deep pre-glacial buried river channel cut in the Whin Sill and now filled with sand and gravel. A composite form of construction was used; that part of the dam based on the solid rock was built of concrete whereas the section over the buried channel is an earth embankment. The contained reservoir is situated in porous limestone strata including many old mine workings and it was prophesied that it would not be watertight. The water is retained, however, because of the high level of the local water table.

This interesting talk stimulated a number of questions about the safety and life of various dam structures and about seismicity induced by reservoir contruction.

A cordial vote of thanks was proposed on behalf of the Society by Mr. Eric Lawrence.

BRITISH CARBONIFEROUS VOLCANOES AND THEIR ORIGINS

Professor E. H. Francis

The Society was honoured on 5th March, 1980, by a visit from Professor E. H. Francis of the University of Leeds. The meeting was held at the Derwent Centre, Cockermouth and 43 members and their friends assembled to hear the lecture on the origins of vulcanism in Britain in Carboniferous times.

Professor Francis began by referring to the geographical distribution of land and sea in the Carboniferous System and pointed out that the greater part of Northern Britain at that time was receiving sediment which accumulated to many thousands of feet in thickness. Vulcanism was not dominant during this period but the local Cockermouth Lavas for example are mainly of Dinantian age. Tuffs, where they occur, are generally later in date, being Namurian or Westphalian in age. The lavas, however, form the greatest bulk of extruded material and are found mostly in Scotland and the majority are alkaline basalts. In plate tectonic terms they were produced under continental structural control as a result of the closure of the Iapetus ocean. Still later a different suite of basalts appeared as intrusives only - the Whin Sill and its equivalents. Early in Permian times yet another group of basalts were formed under different structural control.

Dealing with these different phases of vulcanism in turn the speaker mentioned that the first phase basalts formed the Campsie fells in Scotland and had also been identified in bore-holes in the East Midlands. There is controversy as to whether they are 'flood' basalts or volcanic cones, but they show horizontal stratification over wide areas.

The second phase tuffs were outpourings of ash now to be seen in Fife, Ayrshire and in Nottinghamshire. Many small volcanic cones seem to have been formed which were rapidly buried by fresh sediments and later exhumed by erosion revealing stock-work and pipes. In Fife cinder cones are seen which look as if the sediments have been stripped off leaving the cones as such exposed but this interpretation is probably misleading. Contemporary examples of cinder cones are formed of loose, unstable material which is unlikely to resist erosion. The material slips down leaving structures what are not more than a few hundred metres high at most. The Carboniferous tuffs, however, do not present this appearance. There are igneous bombs in fine material with alternating layering. The probable modern equivalent is to be seen on Tenerife and another example is the recent Surtsey

eruption off Iceland. Magma coming up through wet, recent sediments picks up water and escapes with explosive force. The eruption is very violent and phreatic in nature with high particle fragmentation and ash spreads out over a wide area. Concentric rings of ash are deposited depending on particle size and succesive eruptions result in the appearance of graded bedding. A characteristic feature is the formation of palagonite - an unstable glass decaying to chlorite and other minerals. As the vulcanism dies away subsidence in the conduit can amount to as much as 1000 feet and peripherally ring faults are prone to develop. Slaggy lava, a surface phenomenon can therefore be found at some depth in the plug. The shore lines of the Firth of Forth at St. Andrews show these structures.

The speaker showed a slide of a map of Iceland on which had been plotted contours showing the thickness of the deposit of modern explosive eruptions. As well as revealing the prevailing wind direction at the time the maps showed that the thickness and coarseness of the deposits increased towards the site of eruption. Similar structures of Carboniferous age have been mapped from bore-hole evidence for example in Nottinghamshire. Fine grading of the ash deposits provides evidence sometimes of water settling. Such sediments in this context may have been altered to carbonates and are therefore difficult to identify but occasional sherds of volcanic glass provide the clue. Similar evidence is now revealing details of vulcanicity in Jurassic and Cretaceous strata.

Alkali dolerite sills are associated with the tuffs and tend to occur in structural basins. The tuffs are always found above the sills and a possible explanation is that as the Carboniferous wore on the accumulating sediments provided such a load of overburden that at a certain stage the less-dense magma column was constrained to spread laterally as sills. This provides an explanation too for the early lava sequences being followed later by sills and tuffs as the sediment pile thickened - a sediment controlled type of vulcanism with structural controls operating at depth.

The lecturer turned to a consideration of the relevance of plate tectonics in these concepts. After the suturing of the Iapetus the continent lay astride the equator. To explain the Hercynian orogeny a new fracture zone is required and various models have been proposed. All the Carboniferous basalts have the geochemical affinities of continental vulcanism and perhaps the modern African rifting mechanism is a better parallel for what happened than the subduction concept. One idea is that Devonian granite plutons gave buoyancy in some areas causing crustal fracturing as the plate moved over an ellipsoid earth.

Dr. Francis also referred to other mechanisms that may have had a controlling influence on the situation and type of volcanic

activity. Vulcanism occurring at the margin of a depositional basin may be induced by peripheral fracture zones. The Ardross fault in Fife may be an example of this in that volcanic plugs exhumed by erosion occur along the line of the fault. In the Canary Islands there are examples of recent cinder cones distributed along fault lines.

The third phase of vulcanicity in the Carboniferous occurred with the injection of the Whin Sill complex at the end of the Westphalian (circa 295 Ma ago). The sill cuts across all other strata and is associated with a series of east-west fractures. Similar formations in the Midland Valley of Scotland may all be part of the same large complex. Tholeiitic lavas of identical petrochemical composition are found in Sweden and are of the same age.

After the lecturer had answered a number of interesting questions prompted by this stimulating talk a vote of thanks was proposed by Mr. Mervyn Dodd.

THE STRATIGRAPHY OF THE YORKSHIRE DALES

Dr. A. A. Wilson

A meeting of the Society was held on Wednesday 2nd April, 1980 at the West Cumberland College, Whitehaven, when Dr. A. A. Wilson of the Institute of Geological Sciences at Leeds, gave a talk entitled 'The Stratigraphy of the Yorkshire Dales'. 26 members and their friends were present.

Introducing his subject Dr. Wilson explained that in broad terms the geology of the Dales consisted of flat-lying Lower Carboniferous strata with boundary faults outlining for example the Askrigg and Alston Blocks. Millstone Grit sequences occur to the south east of the area and also cap the highest outcrops in the Dales themselves. Around Ingleton and north of Settle folded pre-Carboniferous Ordovician and Silurian rocks are exposed in the valley bottoms. There is still some uncertainty about the age of these Ingletonian beds. They are unfossiliferous and even micro-palaeontology has not provided a positive answer.

The speaker referred to the nature of the underlying foundation rocks and showed a slide of a gravity anomaly map of the area. A negative anomaly centred in Wensleydale indicates a large granite mass and a similar foundation has been proved by the

well-known Rookhope bore in Weardale. Both granites are Caledonian in age similar to the Shap Granite.

Aero-magnetic surveys have shown a belt of magnetic anomalies flanking the southern margin of the concealed Wensleydale Granite. The I.G.S. have undertaken a drilling programme to investigate this and a borehole at Beckermonds Scar at the head of Langstrothdale has revealed a siltstone beneath the Carboniferous strata with a high content of magnetite. These sediments may have been derived from some ancient, possibly Precambrian land mass. These basement rocks have been shown to contain microfossils (acritarchs) which give a probable Arenig age, and if they can be related to the Ingletonian rocks it may be possible to attribute the latter to the Lower Ordovician.

Dr. Wilson next turned to the Carboniferous limestone itself and illustrated some of the characteristic features by referring to the exposures at Malham Cove. Here the lower levels were formed of closely jointed material which had broken down into scree while the overlying Asbian limestones were well bedded and massive and had given rise to steep cliffs and to the shelf and scar topography so characteristic of the region. The jointing systems coupled with the soluble carbonate rock were also responsible for the 'clints and grikes' of limestone pavements and for the underground cavern systems of the area.

Referring again to the I.G.S. boreholes Dr. Wilson said they had also provided information about the Carboniferous horizons above the basement. At Ingleborough 200 m of Asbian (D_1) and Holkerian (S_2) beds overlie the basement but over the granite the beds thicken to the north and Arundian limestones come in. The interpretation is that there is a depositional belt in Ravenstonedale showing classical onlapping characteristics and forming the Stainmore trough with the strata thinning to north and south over the blocks.

The next formations up the succession in the Dales are the Yoredales of Brigantian age. These are the well-known cyclical sequences of limestones with mudstone,siltstone and sandstone above them. The sandstone horizons show sedimentary structures such as deltaic channels, ripple marks, and bioturbated sediments. It is noteworthy that the proportions between the different elements of the cycles are not constant. Northwards the sandstones tend to thicken and predominate whereas they peter out to the south. The beds between the limestones thicken in total towards the middle of the trough.

Siliceous limestones, or cherts, occur in the Lower Namurian horizons just above the main Dinantian (Lower Carboniferous) limestones. There are three or four horizons of the Richmond chert mostly found in Swaledale and some of the exposures have been found in the 'hushes' of the old ore-miners. Isopachyte mapping of the

chert shows centres around Richmond itself. The cherts are surprisingly unfossiliferous but this may be due to the activity of annelids whose trace markings are present and who may have consumed all other organic matter. Further south the cherts are more amorphous. Discussing the environment of deposition and subsequent changes the speaker mentioned the possibility that much of the silver previously mined in the area may have been 'fixed' by bacterial action.

Concluding his talk Dr. Wilson spoke about the Millstone Grit capping the highest land. This must have been deposited in the distributive delta of a great northern river. Feldspathic sandstones were laid down on a gigantic scale. The strata are correlated by goniatites which tend to diminish southwards. Ending on a topical note the speaker mentioned that the goniatite Gastrioceras cumbriense is found in most of the Yorkshire Dales.

Proposing a vote of thanks to Dr. Wilson Mr.Stan Gate said that the lecture had given new insights into the geology of an area that was not unfamiliar to many members of the Society.

Note. The attention of readers is drawn to the tables on pages 4 and 66 of Part 1 of Volume 4 of the Proceedings which may be helpful when reading this report.

THE MINERALIZATION OF THE PENNINES

Sir Kingsley Dunham

On September 10th, 1980, the Society was privileged to welcome for the second time as its speaker Sir Kingsley Dunham, one-time Director of the Institute of Geological Sciences. Despite bad weather some 50 members and their friends assembled at the Derwent Centre, Cockermouth, to hear him talk on the subject of Mineralization in the Pennines.

Sir Kingsley had recently returned from a professional trip to Zimbabwe and prefaced his discourse with a few impressions of his visit which were of great interest to his audience in view of the recent political changes in that country.

In view of Dr. Wilson's recent talk to the Society reported elsewhere in this issue, Sir Kingsley avoided a detailed description of Pennine stratigraphy but pointed out that the Askrigg and

Alston Blocks, because of their elevation, had received only 1 - 1½ km of sediment in the Carboniferous compared with perhaps 4 - 5 km in the Bowland Trough area and again north of the Stublick Fault in Northumberland. To the south in the northern part of Derbyshire the sediments thinned out again.

Lead mining in the area went back to Roman and possibly pre-Roman times. Working continued through the Dark Ages and German miners, notably Daniel Hochstetter, were brought into the Keswick area by Queen Elizabeth and as a consequence some Pennine ore veins have German names. Possibly as much as 8 - 9 million tons of lead was extracted in total from the area. The speaker described some of the visible industrial relics of this activity.

Sir Kingsley referred to some of the characteristic features of Pennine mineralization which help to explain its nature and origins. Mineralization is of the vein type and is restricted to the Carboniferous strata although there are extensive barren areas suggesting that the origin is not within the system itself. The veins have a definite though complicated tectonic pattern and are virtually limited to the block features, and it has been cogently argued that the fissuring is related to the up-doming of the blocks. The inclination of the fractures and fissures varies according to the competence of the strata - low inclination in shales and near vertical in hard limestone. The overall picture is one of a system of channels through which mineralizing solutions have risen from depth to the surface.

The Whin Sill is a feature of the Alston Block. It steps up in the succession in every direction centred on Teesdale. The sill must have been intruded before the Permian brockram 280 - 290 Ma ago. The mineralization occurred after that, however, because the veins penetrate the sill. The sill was intruded when the Alston Block was undergoing gentle folding into a dome.

The primary mineralization is based on galena and zinc blende, fluorite and the barium minerals. In the 1930s the speaker plotted every vein over the Alston Block and demonstrated a zoning of mineralization. It seemed as if hot solutions had risen in the centre of the area and spread out sideways, giving rise to lateral zones as opposed to the vertical zoning seen in the Cornish tin mining area. Fluorite marked the central area with some copper, while the outer zone contained the lead. On the Askrigg Block instead of a prime fluorite zone there is a mixed fluorite-barytes zone.

The concept at that time, based on the findings, was that the mineralization derived from juvenile hydrothermal fluids arising from a deep source and by analogy with other areas the source could be a granite mass under the Pennines.

At this stage of his career Sir Kingsley went to Durham where

two geophysicists, Masson-Smith and Bott were seeking opportunities to test new portable gravimetric equipment. Surveys over the Pennine area showed gravity 'lows' centred on the fluoride zones and the anomalies were similar to those obtained over known granites elsewhere.

In the late 1950s research funds became available and the Weardale Granite was proved by the Rookhope deep bore. Surprisingly the contact between the basement conglomerate of the Carboniferous and the granite showed that the latter was certainly pre-Carboniferous and possibly Caledonian in age. The relation of the granite cupolas to the centres of mineralization in the limestone still had to be explained, however, and perhaps it had to be assumed that fractures in the granite somehow linked up with the channels in the Carboniferous strata. Did the hydrothermal fluids have to be thought of as arising from the mantle itself or was there a second granite below the first? Or was the juvenile hydrothermal hypothesis itself due for revision?

At this time deep oil well bores were encountering hypersaline fluids thought to be concentrated sea water trapped at depth in the sediments below hydrocarbon accumulations. Enormous volumes of these fluids exist and it is now thought that these hot brines form the solvent which mobilises, transports and deposits the various minerals in the vein systems. The hypersalinity may be related to the solution of evaporite deposits. Many of the minerals concerned while soluble in hot concentrated brine are readily precipitated out when cooled and diluted by meteoric water near the surface.

These hydrothermal circulations require a heat source to drive them and this could possibly be a hot spot in the mantle while tectonic movements give rise to the fracturing and fissuring necessary to provide channels to the surface. In the Pennine context it is most probable that these movements were Hercynian in origin.

Much can be learnt about the geochemistry of the mineralization processes and the temperatures at which they took place from the study of fluid inclusions trapped in the crystal structures. It has been shown for instance that some fluorite crystals contain fluid similar in composition to the concentrated brines referred to above and that temperatures of 200° C were reached implying origins at great depth or close to an intrusion. Sulphur isotope studies have also contributed to confirming the details of the overall picture of mineralization occurring, perhaps in late Carboniferous times, through the agency of hypersaline hydrothermic circulations bringing minerals up from the deep basement rocks and depositing them near the surface in the vein system. Sir Kingsley's talk stimulated many questions and Mr.Stan Gate expressed in his vote of thanks the Society's appreciation of the interest that the speaker had always shown in our activities.

THE GEOLOGY OF NORTH CUMBRIA AND THE BORDERS

Mr. Iver Gray

A meeting of the Society was held on 1st October, 1980, at the West Cumbria College, Workington, at which Mr.Iver Gray, a member of the Society, gave a talk on 'The Geology of North Cumbria and the Borders'. About 20 members and their friends attended.

The speaker explained that a basement of folded Silurian greywackes and slates of Wenlock age, inverted in places and occurring in blocks separated by major NE - SW trending faults, extended from Langholm eastwards towards Hawick and the Berwickshire coast. Characteristic sedimentary structures such as flute marks, load casts and graded bedding are seen and the chief fossils are graptolites.

Overlying this basement, principally in the Tweed and Jedburgh areas, are the almost horizontal Upper Old Red Sandstones and siltstones representing the flood plain deposits of a river system draining from Galloway to the Jedburgh cuvette. In the Cheviot area, Lower O.R.S. andesitic lavas, with their rounded, grass-covered hills, intruded by the Cheviot Granite, form the massif of the North West Northumberland border country.

The Lower Carboniferous System follows the Upper Old Red Sandstone almost conformably, with a variety of facies. In the west, the Birrenswark Lavas are olivine basalts, comparable to the Kelso or Cockermouth lavas, and form the base of the succession, followed in the Langholm area by the deltaic White Sandstone. In the case of Liddesdale and Bewcastle the environment seems to have been like that of the Arabian Gulf of the present day, with sabkha or algal limestones, forming the 'Cementstones' in an area periodically overwhelmed by deltaic river incursions of sand from the north and north-east. The crags of Christianbury in Bewcastle and the Otterburn and Fell sandstone country of the Rothbury area are the dramatic expressions of these events.

The Roman Wall area and the Northumbrian coast portray the subsequent Limestone Groups with their well developed cyclothems including workable coals, sandstones and marine limestones. These constitute the thick sequence of the Northumberland Trough compared with the purer limestones of the Alston Block.

The general structure of the Carboniferous strata is of a gentle regional dip towards the south-east in Northumberland. This is modified by localised asymmetrical anticlines in the Bewcastle and Liddel valleys, and in the area east of the Cheviot mass, caused by pressure from the south-east against the rigid older

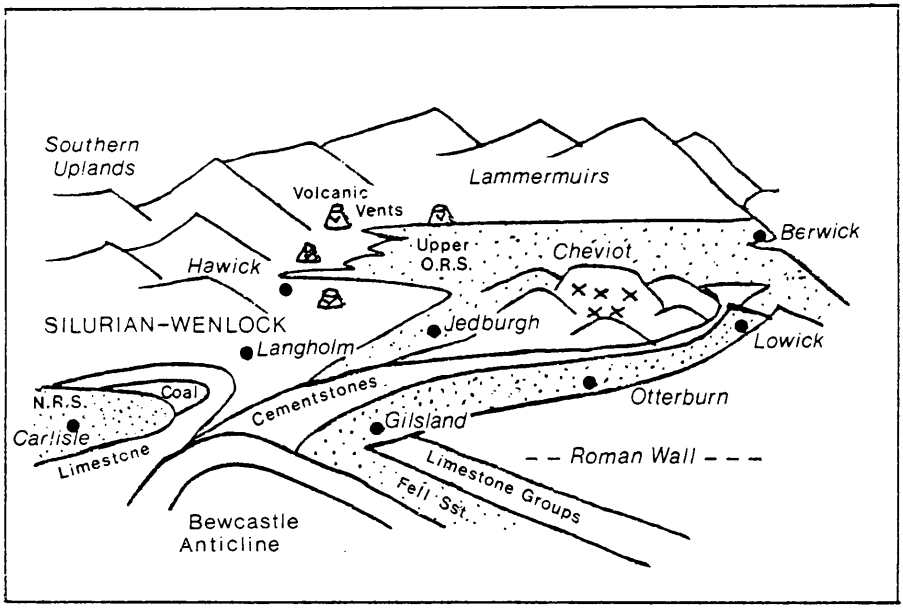


Fig. 1 SCHEMATIC REPRESENTATION OF THE TOPOGRAPHY AND GEOLOGY OF THE BORDERS.

basement. Tear faulting accompanied this movement.

Later deposits such as the Coal Measures occur in down-faulted blocks in the Canonbie area, and workable coals may exist beneath the Barren Red Measures. The New Red Sandstone, consisting of Brockrams, shales of possibly Permian date, and sandstones containing both waterlain and aeolian levels occur in the Carlisle and Annan basins, and are well exposed in the Esk and Lyne valleys.

Boulder Clays and outwash material occur extensively in the Tweed valley and in lower Eskdale, overlain in places by the widespread peat deposits of the Solway Moss, Spadeadam, Bewcastle and the Cheviot areas. Scaleby Moss near Brampton has been a site of classic study. River terraces are well developed in several valleys, particularly between Longtown and Langholm.

Mr.Gray concluded his talk by referring to the Carlisle earthquake of Christmas 1979 with its epicentre close to his place of residence at Longtown. This might serve to remind us, perhaps, of the ancient basement junction between Palaeozoic Scotland and England lying along the Border.

EARTHQUAKE ACTIVITY IN NORTHERN BRITAIN

Dr. C. W. A. Browitt

On 12th November, 1980, a meeting of the Society was held at the Derwent Centre, Cockermouth, attended by 44 members and their friends. The President introduced the speaker Dr.C.W.A.Browitt from the Edinburgh office of the Institute of Geological Sciences, who chose as his subject 'Earthquake Activity in Northern Britain'.

Dr. Browitt began by explaining the significance of the sometimes misunderstood terms magnitude and intensity in relation to seismic shocks. Magnitude is an instrumental measurement used for the last 40 years and indicates the amplitude of ground motion. Intensity is a term indicating the amount of shaking at the earth's surface and is related to depth as well as distance from the focus. The speaker illustrated by the use of slides that over the globe as a whole earthquake epicentres were mostly concentrated in narrow belts which in modern terms define plate boundaries. There are exceptions, however, and in Britain earthquakes do occur though we are quite remote from contemporary plate margins.

Historical reports of British earthquakes derived from archival studies go back to the early centuries A.D., but little reliance is placed on first millennium data. Since then, however, there is evidence that epicentres have been widespread. Major events were centred on Inverness in 1816 and 1901. In the mid-1800s earthquake swarms were experienced at Comrie. The greatest amount of damage recorded in Britain, on the other hand, was at Colchester in 1884. This may have been a deep-focus earthquake related to the base of the crust whereas most British seismicity is intra-crustal. In more recent times the Dogger Bank earthquake with a magnitude of 5.1 could have damaged oil pipe lines had they existed at the time. In 1974 earthquakes in Gwent may have signified cracks in the plate. In 1975 the focus of an earthquake at Portree was found to be at a depth of 10 - 15 km.

Dr. Browitt next referred to the recent Carlisle earthquake of 26th December 1979. The epicentre was near Longtown and Kirklinton and the intensity on the modified Mercalli scale was 6. This scale indicates the amount of shaking and consequent damage at a particular locality. For example at an intensity of 4 - 5 pictures are displaced and pendulum clocks are stopped and there may be slight cracking of plaster. In this country there is rarely more damage than this although in a few instances chimneys and roofs have been damaged. The intensity falls off with distance from the epicentre and in the case of the Carlisle earthquake the intensity at Aberdeen was only 2 - 3 and at this level the shaking was only noticed by people lying awake in bed. In

Northern Ireland and in Edinburgh the intensity was 4.

The speaker turned to the question of modern research into seismicity in Britain saying that knowledge of those earchquakes that are unrelated to plate boundaries is still quite restricted. On the technological side modern seismometers are relatively small instruments employing a magnet delicately suspended on coil springs. Movement of the magnet induces an E.M.F. in a surrounding coil which is electronically recorded. These instruments are highly sensitive and will react to movements in trees, water and traffic and suitable sites are not always easy to find. The recorded data is transmitted by wire or radio and networks or arrays of instruments can be fairly rapidly set up. Processing of the results is facilitated by multichannel electrical recording.

The arrival of 'P' or pressure waves is recorded to within 0.01 sec. 'S' or surface waves follow after an interval. The accurate timing of first arrivals at two or three stations permits identification of the focus.

Dr. Browitt turned to the problems of earth movements induced by mining, particularly mentioning the investigations centred on Stoke-on-Trent in recent years. A macroseismic survey indicated the area of activity into which a closely spaced array of seismometers was installed. Energy release plots showed minimal activity on Saturdays and Sundays and during holiday periods when the pits were closed. These earth movements are of very shallow focus and therefore of small magnitude and result in little damage. A similar pattern of events has been found in the Midlothian coalfield. The picture could be more complicated, however, because a very recent earthquake at Kidsgrove in Staffordshire might well not be related to the mining.

Modern seismometers also record some events identified by slow propagation in air. One such source was supersonic aircraft.

In closing Dr. Browitt said that modern research could provide a great deal of information but more instrumentation to provide more comprehensive cover for all areas was required. The financial resources however were not at present available. This talk stimulated a number of questions particularly in relation to mining-induced earth movements, several members having personal experiences to recount. Mr. Alan Line proposed a vote of thanks on behalf of an appreciative audience.

THE BRITISH ANTARCTIC SURVEY

Mr. F. Anckorn M.Sc.

A meeting was held in the British Legion Hall at Workington on 3rd December, 1980. 32 members and their friends attended. At very short notice Mr. F. Anckorn at present working with the N.C.B. Opencast Executive gave a splendidly illustrated talk on his experiences over a period of three years as a geologist with the British Antarctic Survey.

Mr. Anckorn explained that he joined the Survey shortly after graduating and first attended introductory courses not only on the geology of Antarctica but also on the general problems of living and working in low temperature environments.

The outward journey to Antarctica itself contained much of interest. The Canary Islands were seen to be rugged and mountainous and of volcanic origin with little vegetation and vertical cliffs 2000 feet in height. After calling at Montevideo the expedition stopped at the Falkland Islands still used as a base for Antarctic exploration vessels. Moving southwards the Little Orkneys consisted of bleak moorland terrain with much quartzitic rock. The possibility of oil-bearing strata in this area explains the interest shown by the Argentinian Government in these islands. South Georgia was reached entering sub-antarctic latitudes and this territory was noted to be a continuation of the submarine ridge south of Cape Horn. Abundant animal life was seen, fish, whales, seals and many species of birds all dependent on a food chain beginning with the planktonic krill.

The Antarctic Peninsula was reached at Graham Land, the approach being through a sea-way consisting of a late Tertiary faulted trough. The speaker described the various types of ice formation encountered by the ship and showed slides of the Barrier Ice of the Antarctic cap which flows off the mainland and out over the sea with large ice-bergs forming by fragmentation at the periphery.

Mr. Anckorn went on to show pictures of the establishment of the expedition base camp using pre-fabricated huts. Particularly impressive were his shots of Emperor penguins and Minke whales in the vicinity.

Describing his work as a geologist to the expedition the speaker explained that in Antarctica over an Archaean basement all subsequent geological periods are represented. Ancient orogenic belts and subduction zones have been plotted and the plate tectonic history of the area is complex. Active volcanoes occur on the Antarctic Peninsula extension of the Andean chain. Plutonic intrusions of Cretaceous age have been mapped.

The expedition had teleprinter and radio-telephone contact with its London base while H.M.S. Endurance provided a British naval presence and also carried out survey and rescue functions. In the summer seasons traverses of up to 500 miles from the base were made but during the winter only short range work could be undertaken. 1972 was the last season in which dogs were used, subsequent work being carried out using mechanized transport. Two-man teams consisting of one climber and one scientist were organised and each team had nine dogs. Important back-up and support facilities were provided by light aircraft. An initial 5000 ft. climb had to be made up onto the plateau and each team had a 40 square mile area to study. Topographical and geological mapping, including the investigation of all outcrops and supplemented by aerial survey, formed the basis of the work. In addition geophysical traverses were made making magnetic and gravimetric measurements to correlate with the surface surveys.

At this point the lecturer showed a ciné film illustrating the survey, mapping and sampling procedures and the study of exposed rock. Part of the film was taken behind a dog-team in action showing the response of the leader to voice commands. Air-temperatures at sea-level were in the region of -15°C and much lower further inland, -40°C being regarded as very cold. Snow temperatures were about -5°C, but the dry atmosphere made the low temperatures more tolerable.

Concluding a most interesting talk the speaker commented that economic minerals were looked for but in their area nothing was found apart from some copper mineralization. Some evidence was found pointing to some retreat of the ice at the present time.

A vote of thanks was proposed by Mr. Eric Lawrence who said that Mr. Anckorn had been too modest about his own contributions to the scientific and other work of the expedition for which he had been awarded the Polar Medal.

THE GEOLOGICAL RECORD OF PLEISTOCENE CLIMATIC CHANGES

John Boardman B.A.,B.Sc.

This meeting of the Society was held at Whitehaven in the Chase Hotel. 25 members and their guests braved the most inclement weather to attend. Mr. Mervyn Dodd, acting as Chairman for the evening, introduced the speaker. Mr. John Boardman from Brighton Polytechnic was already well-known to many members as a

contributor to Proceedings and as an excursion leader, and he entitled his talk 'The Geological Record of Pleistocene Climatic Changes'.

Mr. Boardman explained that the Pleistocene Period lasted roughly for 2 Ma and in Britain is also known as the Quaternary. The Pleistocene was characterised by frequent climatic changes which distinguish it from other periods of geological time. The use of the name Anthropogene has been advocated by the Russians but the climatic changes are rather more characteristic than the advent of man. A recognised magnetic reversal at 1.63 Ma ago - the Olduvai event - might be taken to mark the beginning of the Pleistocene.

The speaker reviewed the various types of evidence which have been used to identify palaeoclimates starting with landforms. The main geological evidence for the glaciation of Britain was accumulated in the last century but the whole concept was not fully accepted until about 1900. The main glacial units show four boundaries identifying the Devensian, Wolstonian, Anglian and Beestonian glacial periods. The most recent glaciation, the Devensian, reached its maximum 20,000 years ago. The succeeding post-glacial phase has lasted about 10,000 years and it has been estimated that for 90% of the last 120,000 years the average July temperature has been in the range of 10° - $12^{\circ}C$ compared with the present day figure of $17^{\circ}C$. This alone justifies the study of cold climate landforms. The study of sculptured rock, roches moutonnées, striations and fluvio-glacial deposits and erratics has enabled a model of the Devensian ice-sheet to be constructed in terms of extent, flow-lines and thickness. Other landforms such as solifluction lobes testify to seasonally frozen ground. Ice-wedges are known to form in contemporary environments with average annual temperatures of less than $-6^{\circ}C$. Pingoes are formed by a growing mass of ice within sediments fed by ground water. A raised structure is formed and these are common in areas of discontinuous permafrost.

A study of sedimentary deposits also provides evidence of palaeoclimates. Tills and boulder clay relate to glacial periods while fossil soils generally indicate warm interglacial conditions with a stable vegetated land surface. Radiocarbon dating can be carried out on these soils at least for the most recent deposits. Mottled soils with the formation of haematite indicate a warm climate of Mediterranean type with appreciable rainfall. Such conditions were present in the area of the Yorkshire Moors in the last interglacial which must have been on average 3° - $4^{\circ}C$ warmer than the present day. Palaeosols therefore provide important evidence for interglacial climatic change. A local example is Dodd Wood scree which was formed in periglacial conditions but is now covered by superimposed soil.

Mr. Boardman next spoke about the biological evidence of

climatic changes. Vegetable matter converted into peat can be analysed for plant pollens which indicate the particular plant communities which existed when the deposit was laid down. Each interglacial period has its characteristic pattern. More recently other organic material has been used in the same way, particularly the identification of individual species of beetles known to exist only in climatic conditions with specific temperature ranges.

Oxygen isotope analysis of narrow horizons in deep sea sedimentary cores has recently produced much evidence of widespread climatic changes. ^{16}O is preferentially trapped in glacial ice so that the sea water is relatively enriched in ^{18}O. This is taken up by foraminifera which preserve the record in the deep sea cores. From this oxygen isotope curves can be constructed which indicate changes in the total ice volume which reflects climatic change. The record can be dated by magnetic reversals. This and other evidence now seems to be identifying eight cold periods in the Pleistocene instead of the four usually mentioned.

Finally Mr. Boardman mentioned that evidence of this type had been used to forecast future climatic changes by extrapolation. One interpretation was that the next glacial period would occur about 23,000 years hence.

The meeting concluded with an interesting series of questions from the audience and the speaker was warmly thanked for his efforts by Mr.J.F.Yearsley on behalf of all those present.

GEOLOGY AND ANCIENT MAN

Mrs. Jean Ward, M.A., B.Litt.

For the final meeting of the 1980/1981 season the Society met at the Derwent Centre, Cockermouth, to hear a lecture entitled 'Geology and Ancient Man'. This was given by Mrs. Jean Ward, who, in her capacity as Tutor in the Extra-mural Department of Newcastle University has been particularly associated with this area for many years. 31 members and their friends attended.

The speaker was introduced by the Chairman for the evening, Mr. Derek Allen. Mrs. Ward introduced her subject by pointing out that since the time of his emergence about 1.5 Ma ago Man has inevitably been closely involved with the geological basis of his environment. He has used rocks, minerals and ores as building materials and to fabricate tools and weapons and he has used caves and other geomorphological features for special purposes.

Early man with primitive hands, a shambling gait and

relatively limited cerebral development was concerned with survival and food supply. The first tools and weapons were suitable stones used as 'bashing' implements - an activity seen in chimpanzees today. Man carried useful stones about with him as is shown by the occurrence of 'foreign' stones in association with early human remains in Africa. A later, more sophisticated, development was the shaped stone hand-axe. The edge was used for chopping or striking and a variety of cherty or flinty rocks were utilised. Later still with the arrival of Homo sapiens, physically superior and with a larger brain capacity, more refined stone tools were produced - spears mounted on shafts, scrapers, burins (borers) and many others. By this time, too, Man had migrated up from Africa into Europe.

Mrs. Ward next spoke about the use of caves by ancient man. In the Pyrenees and in the Massif Central there are cave systems which were used as dwellings and for religious or ritual purposes. Occupation rubbish has been found at the mouth of the caves, but in the deeper recesses wall paintings show representations of different animals such as mammoth, deer and bison. Did ancient man draw these animals to catch their spirits or perhaps to practice throwing spears at the paintings? Naturally occurring pigments such as ochre were used. The paintings have retained their fresh look through being sealed off under a layer of carbonate in the limestone caverns. The development of stalagmites in relation to the paintings has been used as an indication of their antiquity.

About 9000 B.C. the Neolithic age saw the introduction of sophisticated polished stone axes which were a sufficiently effective tool for forest clearance. The most perfect examples may have been used ceremonially. Shallow mining operations with short galleries were undertaken to obtain better flints. Sites are known in Belgium and Suffolk as well as the renowned Grimes Graves in Norfolk. Here the flints are concentrated in three horizons and were mined to a depth of sixty feet. Artificial light from small oil lamps was used and knapping was done at the surface. Mrs. Ward described the Stone Axe 'factories' in the Lake District in Langdale and around Scafell. Other sites are known in Argyll and Northern Ireland and elsewhere. Axes from these sites were distributed widely in this country and in Europe and finds have led to identification of prehistoric trade routes.

The next phase was the transformation of stone (ore) into metal by heating. Copper smelting may have been discovered from observation of the changes occurring in 'slips' in firing pottery. Copper working spread from Anatolia about 7000 B.C., but only reached Britain some 4000 years later. From copper harder alloys such as bronze were developed. Some contained lead as well as tin. Mining for metalliferous ores was stimulated and trade was fostered.

Mrs. Ward went on to mention the use of stone in public monuments starting with circles such as Stonehenge and Avebury which indicated the existence of an organised social structure to transport and erect such huge stones. Later developments in the same vein include the Pyramids, Scottish brochs, castles and so forth.

The use of iron as a material may have begun with the discovery of meteoric iron, but as the processes of heating, annealing, and re-working the metal were mastered, iron implements became common-place.

Luxury goods ultimately became a possibility in the developing human economy and the use of gold and silver and precious stones such as garnet, lapis lazuli and so on should be noted in this context.

Finally the speaker referred to the use by man of other geological features. Caves had already been mentioned, but human settlements were often established along spring lines, a local example being the ancient occupation sites on Aughtertree fell near Ireby. Prominent defensible features have been used for Iron-age hill forts, and castles in more recent times. Special soils have also been exploited by man. Weathered volcanic material provides a very fertile soil and bands of loess across Central Europe have attracted human settlements.

In proposing a vote of thanks to the speaker Mr. Tom Shipp said that Mrs. Ward's talk had been of particular interest in that members had been presented with a refreshingly different perspective of geology.

THE LATE-GLACIAL PERIOD

(15,000 - 10,000 years ago)

Mrs. T. G. Tutin (Dr. W. Pennington)

A meeting of the Society was held at the Derwent Centre, Cockermouth on 9th September, 1981, at which Mrs.T.G.Tutin (Dr. Winifred Pennington) spoke about 'The Late-Glacial Period in Cumbria'. 38 members and their friends attended.

Mrs. Tutin opened her talk by speaking about her long-standing family connections with Cumbria and how much of her research, involving the study of Quaternary deposits and the development of

pollen analysis, had been done in the Lake District. In her talk she proposed to describe some of the evidence for climatic changes in this part of the world during a relatively brief but interesting period of geological time from about 15,000 to 10,000 years B.P. This span of time occurred at the very end of the last main, Devensian, glaciation and is known therefore as the Late-glacial period or sub-stage. During this time conditions overall became much warmer and those parts of Britain covered by ice were deglaciated. At about 10,000 years B.P. the present Flandrian inter-glacial warm period began.

During the 5,000 years of the Late-glacial period there were, however, considerable fluctuations of mean temperature and climate which are now becoming better understood. In comparison with the major glacial and interglacial stages these minor climatic oscillations are termed stadial and interstadial periods. The distinction between an interglacial and an interstadial warm period is that during the former the climate becomes warm enough for deciduous forest as opposed to birch forest to become established.

With the aid of colour slides of scenes in present day arctic environments, Mrs. Tutin went on to describe the climatic conditions existing in Britain 20,000 years ago. Ice covered the country down to the South Midlands. Periglacial tundra-like conditions extended over most of Europe and forest lands surrounded the Mediterranean. Starting at about 18,000 years B.P. the climate gradually began to improve. The ice margin retreated northwards leaving bare rock and drift cover. In this hostile environment pioneer vegetation such as dwarf willows and mountain sorrel were the first to gain a foothold. Further amelioration of the climate saw the establishment of Highland Birch Forest which was widespread by 10,000 years B.P. Equivalent sequences can be seen in parts of Scandinavia at the present day where there is evidence that the valley glaciers are still retreating.

In a periglacial environment the sediments laid down in lake bottoms and in peat accumulations preserve much evidence of the climatic changes. Varved clay sediments, which are the annual deposits from seasonal melt waters and contain no organic matter, are laid down in lakes and tarns in the catchment areas of retreating glaciers. As vegetation spreads over the deglaciated ground organic matter appears in the sediments and the progress of colonisation by successive plant communities can be traced by pollen analysis. At Blelham Tarn, a kettle hole near Windermere, the oldest organic matter has been dated, by radio-carbon methods, to about 14,500 years B.P. The warm period to which this change is attributed lasted over 2,000 years and is now known in this country as the Windermere Interstadial. The climate was warm enough for birch forest to become established at least on lower ground. In Scandinavia there is evidence that this interval consisted of two warm periods, the Bølling and the Allerød Inter-

stadials with the Older Dryas colder interval in between. In Britain, however, there is only very slight evidence of this additional oscillation.

Lake bottom cores from a good number of localities in Cumbria show an upper sequence of varved clays laid down about 11,000 years ago indicating a temporary deterioration in the climate and the reappearance of permanent ice correlating with the Younger Dryas period in Scandinavia. This has been termed the Loch Lomond Readvance in this country because much of the evidence for the re-establishment of a permanent ice-sheet has been derived from Western Scotland. In the Lake District the Readvance seems to have been marked by the reappearance of corrie glaciers which left characteristic moraines at the heads of many valleys, of which Ennerdale is a good example. All lakes with corries in their catchment areas show this upper varved clay and the number of annual couplets is consistently between 400 and 450 which gives an indication of the duration of the climatic reversal.

Mrs. Tutin spoke of the contribution that botanists had made to the study of palaeoclimatology, particularly through pollen analysis, and delighted her audience with some humorous recollections of the difficulties experienced in the early coring of lake bottom muds in Windermere in which she was involved as early as 1937. Plant pollens, and especially tree pollens are highly species specific and remarkably resistant to decay. The scanning electron microscope has led to an even better understanding of the subject and the speaker showed some impressive slides of different pollen assemblages from lake deposits. These were again linked to illustrations of corresponding present day environments thus giving the audience a visual impression of our locality at different stages of the retreat of the ice.

More recently the work of Dr. Coope at Birmingham University has shown how the identification of the remains of characteristic species of beetles in the organic deposits can also be an indicator of changing environmental temperatures. Insect populations respond more rapidly to temperature changes than the vegetation which colonises the deglaciated ground relatively slowly. The evidence from this source indicates an earlier date for the onset of the Windermere Interstadial than that derived from pollen analysis.

Mrs. Tutin went on to describe in some detail various localities that have provided important evidence about Late-glacial climatic changes in Cumbria. At St.Bees, for example, there is an exposure of a Late-glacial sequence with organic deposits between two glacial tills. These organic deposits contain beetle remains and the various horizons have been reliably dated by radio-carbon methods. At 12,500 years B.P. the species identified were those of a temperate climate, but within the space of no more than 500 years these had all been replaced by arctic or sub-arctic species

indicating a very rapid deterioration in the climate at the end of the Windermere Interstadial.

In conclusion Mrs. Tutin emphasised that by drawing together the evidence from all the sources and by comparing the sediments and pollen profiles from a variety of lakes and tarns at different altitudes and with different catchment areas, it was possible to build up a fairly detailed picture of Cumbria in Late-glacial times. Birch and shrub woodland covered the lower levels during the Windermere Interstadial, with arctic-alpine grass sedge heath vegetation above this up to about the 1600 foot contour. The higher land was probably bare but the corries were free of ice, though snow accumulations would persist for much of the year. During the Loch Lomond Readvance many corrie glaciers became re-established, and it has been possible to construct quite detailed maps of the location and extent of the ice cover. Finally there was the evidence of rapid down-melting in situ at the very end of the period.

The lecture stimulated a number of questions particularly on Mrs. Tutin's own subject of pollen analysis and the Chairman expressed the audience's appreciation of a most interesting exposition on this, the speaker's second visit to the Society.

CAMBRIAN GEOLOGY OF THE NORTHERN INTERIOR PLAINS OF CANADA

Dr. J. Dixon

A lecture meeting was held at the West Cumbria College, Workington, on 23rd September, 1981, when 22 members gathered to hear Dr. Jim Dixon of the Institute of Sedimentary and Petroleum Geology, in Calgary, Canada, talk about 'The Cambrian Geology of the Northern Interior Plains of Canada'. The Society is grateful to Dr. Dixon for offering to give up time on a family vacation in Britain to come and talk for a second time to members about his work in the North West Territories.

By means of maps, diagrams and colour slides, Dr. Dixon built up a picture of the stratigraphy and tectonic history of a large area extending northwards from the Great Bear Lake to the Arctic Ocean, and bounded on the west by the strongly folded Franklin and McKenzie Ranges. The speaker showed how a major early Cambrian marine transgression across a Precambrian shield area had been inferred from the investigation of NNW - SSE trending outcrops of

sandstones, overlain by dolomitic shales and evaporites which extend through the Great Bear Lake region.

The basal layer is the Mt. Clark Sandstone composed of up to 95% quartz grains with up to 5% feldspar and occasional glauconite. The strata show bioturbation in the form of 'scolithos-like' tubes up to 25 cm long and there is the occasional trilobite. Cross-bedding and the occasional channel fill is seen and there is marked bimodality of grain size. All the evidence seems to suggest deposition in a shallow marine environment, with tide-dominated beaches and lagoons. The transgression probably resulted in a semi-enclosed marine basin, and the overlying rocks of the Mt. Cap Formation show a facies change from shale to dolomitic limestone to sandstone across the area explored. Earth movements during the Middle Cambrian resulted in uplift of the area followed by further deposition of evaporitic shales of the Saline River Formation in a semi-enclosed basin centred NW of the Great Bear Lake.

Dr. Dixon then went on to discuss the cementing minerals that had been investigated in the Mt. Clark Sandstone with a view to establishing its diagenetic history. This investigation had been undertaken in order to assess the importance of this formation as a potential reservoir for hydrocarbons. The original sandy sediment of the Mt. Clark Sandstone must have been very porous. This porosity was diminished firstly by the mobilisation and re-precipitation of quartz as overgrowths on the original grains (as with the Penrith Sandstone in Northern England), secondly by the precipitation of illite (clay) between the grains, and thirdly by the crystallisation of dolomite cement, which completely replaced the clay and the quartz overgrowths. By this time most of the original porosity of the rock had vanished, but a secondary porosity was created by subsequent removal of the dolomite or by a leaching out of the feldspar grains. Some of the dolomite appears to have been replaced by calcite crystals which grew and crushed the surrounding grains. This reversed the usual sequence of diagenetic change and was probably caused by some sort of chemical saturation of the rock. The presence of bitumen in the present Mt. Clark Sandstone shows that hydrocarbons did migrate into this formation, but the lecturer explained that earth movements in the Tertiary probably fractured this potential reservoir rock allowing the petroleum residues to escape.

Dr. Dixon's lecture provoked a number of questions from his audience, including the origins of hydrocarbons in Cambrian and Precambrian rocks, the palaeolatitude of the region in Cambrian times and the environmental issues of industrial activities in a fragile tundra region. Finally the Chairman of the meeting, Mr. Eric Lawrence, in thanking Dr. Dixon, remarked that the Society was much indebted to him for an interesting talk on aspects of his investigations and to PetroGeology, Canada, for allowing him to make public his observations and conclusions.

THE MORPHOLOGY OF AN ACTIVE PLATE BOUNDARY

Dr. R. Sibson

A meeting of the Society was held on 4th November, 1981, at the Whitehaven branch of the West Cumbria College of Science and Technology. The speaker was Dr. Richard Sibson of the Royal School of Mines, at Imperial College, and he chose as his topic 'The Morphology of an Active Plate Boundary'. 27 members and guests were present.

Dr. Sibson chose the State of California and the adjacent State of Nevada to illustrate some features of the tectonic activity associated with an active plate boundary. First of all he reminded his audience of the various types of plate boundary that are recognised. The Atlantic type is characterised by a spreading axis, rifted continental margins and heavy off-shore sedimentation. The related Andean and Island-arc types of margin are associated with crustal subduction zones, trench systems and batholith formation. Finally there is the Californian type with massive strike-slip motion between the plates occurring sub-parallel to the continental margin.

The speaker displayed some splendid and colourful United States Geological Survey maps of the areas he was to talk about and the lecture was illustrated with excellent colour slides.

In the general area of the western sea-board of North America all the different types of plate margin have been present at some time or another. In the Palaeozoic there was shelf sedimentation, while in Cretaceous and Lower Tertiary times there was an Andean type of subduction zone. At present, however, the area was the classical example of strike-slip movement between two plate margins and was full of interest for the geologist.

The magnetic anomaly pattern of the sea-floor off the Californian coast enables the events of the last 30 Ma to be re-constructed. The geometry is complicated, but there was an Andean type margin convergent with an off-shore spreading ridge. Sub-duction of crust proceeded at a faster rate than production at the spreading axis so that the ridge system ultimately impacted with the continental margin and the present slip movement was initiated.

Today in California this mobile plate boundary is marked by the San Andreas fault system. The tectonic mechanisms vary in different sectors, but in addition to the strike-slip movement there is also thrusting and extensive tensional normal faulting. In Northern California the disastrous 1906 earthquake was

associated with rupture along 450 km of the San Andreas fault and great damage was caused in San Francisco. In addition to sudden rupture, however, a more stable form of movement known as fault creep occurs. Up to 3 cm or 50% of the average annual movement along the fault zone takes place in this manner. Many small seismic shocks are recorded instrumentally in areas of creep, but the 1906 rupture zone is at present aseismic.

In Southern California the pattern is rather different with multiple small ruptures and little evidence of fault creep.

The picture emerges of a range of earthquakes of different magnitude and a relationship can be established between this and the frequency of occurrence. Thus the more severe earthquakes with large, sudden, damaging displacements occur only at long intervals, while at the other end of the scale minor slips are recorded much more frequently. It is only earthquakes of magnitude 5 and above that give rise to surface ruptures which can be studied in detail.

Dr. Sibson referred at this point in his talk to the subject of earthquake prediction. The large financial investment in an area like California has stimulated a great deal of research, and some interesting points have emerged. For example, the time scale involved is well illustrated by a particular fault which has been shown to have undergone a total of 110 km of dextral movement since the Miocene, yet today houses are built across it. In Diablo Canyon a nuclear reactor has been built in a area which has now been shown to be a fault zone.

Only about half the total movement occurs along the San Andreas fault itself, the rest is accommodated in smaller parallel faults. In predicting what is likely to happen at a key site such as Diablo Canyon several approaches are possible. Individual faults can be classified on the basis of their recurrence interval into those with, for example, an average movement of, say, 10 cm a year that might be expected to produce severe slips of 1.0 m in magnitude every 10 to 100 years, while at the other end of the scale a fault moving less than 1 mm a year might produce a similar event only once in 10,000 years.

The central sector of the San Andreas fault shows an off-set and in this area in 1960 near Los Angeles the Palmdale Bulge was recognised by sensitive instrumentation. A large area bulged up by about 25 cm and this may be an indication that a severe movement is imminent.

Further information has been derived from one locality where recent deposits of layered peat occur in a fault zone. The disturbance of the stratification has preserved the seismic history, and carbon dating has enabled the earthquake frequency to be traced back for 2,000 years. It was calculated that at this particular site a major rupture could be expected every 200 - 275

years. Dr. Sibson showed a slide of a diatomite quarry to the west of Los Angeles where in a similar way a fossilised record of earth movements had been preserved in the bedding.

Dr. Sibson now turned to the consideration of another area, this time in Nevada, about 500 km to the east where, nevertheless, there was evidence of major tectonic activity related to the plate boundary. This is an area of 'basin and range' topography. The scenery is impressively beautiful with long parallel snow-capped mountain ranges separated by wide flat-bottomed valleys. NE - SW extension of the crust appears to have caused extensive normal faulting and given rise to this 'horst and graben' configuration. The whole complex is interpreted as very large scale 'en echelon' tear faulting secondary to the strike-slip movement at the plate boundary to the west. In such an active zone there is much evidence of recent fault traces. Displacements of several metres show up over long distances at the bases of the hill slopes. Detailed study of these features, including estimates of the rate of weathering and degradation of the fault slopes has enabled deductions to be made about the frequency of the movements. In this area too it had been observed that the heat generated by friction in fault movement can sometimes lead to the formation of a glass, which might be termed a pseudo-tachylite. This can flow into joints and fractures in the rock, providing a record of the earthquake that produced it. Finally, the lecturer mentioned that some of the valley bottoms in this area were below sea level and might at some future time become ocean floor.

This lecture stimulated a number of questions, after which the Chairman for the evening congratulated Dr. Sibson on covering so much interesting material in a most lucid manner before thanking him warmly on behalf of those present.

GEOLOGY AND WINE

Mr. R. J. Whittaker

On 4th December, 1981, one of the more memorable meetings of the Society was staged at the British Legion Club in Workington. Over thirty members and their friends attended what was both a social and educational occasion. The subject was 'Geology and Wine', the speaker and organiser being Mr. Richard Whittaker of the Joint Matriculation Board, a member of the Wigan and District Geological Society, and an enthusiast in the appreciation of wine.

After being introduced by Mr. Derek Allen, the Chairman for the evening, Mr. Whittaker explained that his double interest in

wine and geology had led him to consider the effect that the solid geology and the drift cover of a locality might have on the quality and character of the wine produced. He suggested to the audience that investigations of this nature combined well with holidays and field trips on the Continent.

It had to be admitted, however, that there were many factors which influenced the final character of a wine apart from the soil. The most significant was probably the type of grape involved, Muscat, Riesling, Sauvignon, Traminer or Gamay. Other factors were the climate and the methods used in cultivating the grape and processing the juice. The influence of the soil was not at all easy to define. Natural soils can be altered by fertilisers, and the effect of transport by wind and ice may mean that a soil has not been derived primarily from the rock beneath it. However, some general statements can be made and Mr. Whittaker identified various soil types as being possibly significant.

(i) Loess soils. Many wine growing areas in Europe, such as the Rhine, the Danube, the Hungarian Plains and Croatia had wind-blown soils with much sand, silt and a variety of mineral content.

(ii) Pure sandy soils. These will support the vine which is undemanding in its requirements, and have an advantage in that the damaging phylloxera aphid cannot survive in sand. However, no really distinguished wines are produced on a purely sandy substrate.

(iii) Clay soils. World wide, the full bodied red wines are generally derived from soils with a high clay content, but such soils tend to drain badly.

(iv) Limestone soils. Much European wine is grown on thin limestone soils, and often on little more than bare rock hillsides. The roots of the vine can penetrate the cracks in the rock which also reflects the sunlight onto the grapes. Pebbles covering the soil also conserve heat from the sun and radiate it back to the grapes during the night hours.

(v) Chalky soils. Chalk predominates in some areas and is said to impart sharp clear characteristics to wine grown on it.

(vi) Slaty soils. These soils have an effect rather like limestone and are said to give a steely taste to the wine, as in the Mosel region.

(vii) Granites, gneisses and schists influence the wine chiefly through the variety of their mineral content.

(viii) Volcanic rocks give rise to dark fertile soils and give a distinctive fragrance to the wine. This applies particularly to the Muscat grape.

With this introduction Mr. Whittaker invited the audience to sample a dozen different wines, six white and six red, that he had chosen to illustrate some of the points he had made. The wines were presented in groups as follows:

I. White Wines.

Group A. The Riesling grape from different soils.

A Yugoslavian Riesling wine from North Croatia, grown on loess soils was compared with Lieser Niederberg from the middle Mosel region of Germany. This wine is grown on thin, mineral rich, soils derived from frequently exposed Devonian slates. The speaker suggested that here was an instance where any difference between the wines might fairly be attributed to the soils.

Group B. The Sauvignon grape from different soils.

Three examples of wines derived from this grape were presented. Bergerac Blanc from the Dordogne region of France is grown on a mixed sand and clay soil, whereas Monbazillac from the same immediate area is derived from vineyards on the slopes of a limestone hill. The third example was Sancerre, a wine of the Loire district grown on chalky limestone. This wine has a bouquet technically described as 'gunflint'.

Group C. A product of volcanic soil.

The example chosen was an Italian wine, Lacrima Christi del Vesuvio, grown on the seaward-facing slopes of Vesuvius itself. It is produced from a mixture of lesser known varieties of grape. The soils derived from volcanic ash and weathered basalts are very rich in a variety of minerals and the wine has distinctive flowery fragrance.

II. Red Wines.

Group D. Two red wines from Italy.

These wines, Bardolino and Valpolicella, both from the Veneto region near Lake Garda are grown within 30 km of each other. They are produced from an almost identical mixture of grape varieties. The Bardolino, however, is derived from a light, sandy, stony soil, whereas the Valpolicella is grown on heavy, predominantly clay, soils, which seem to give it more colour, depth and flavour.

Group E. The Gamay grape from different soils.

Beaujolais Villages is a wine from the northern part of the Beaujolais district where the soils are mainly derived from granitic rocks. The second example of the Gamay grape was from the lower reaches of the river Loire - Gamay Val de la Loire. The thin soil is derived from ancient metamorphic rocks, mostly schists, and is very rich in potassium and magnesium.

Group F. Fuller-bodied red wines.

The two examples chosen were Chateau Grand Abord, a red Graves from Bordeaux, and Domaine de Bel Air, from the Côtes du Rhône. The Graves comes from a gravelly, well-drained mineral-rich soil, one type of which is termed 'alios' and

consists of sand grains cemented by a blackish ferrous material. In the southern part of the Rhône valley the soils are mostly clays with some limestone outcrops and much pebbly alluvial drift.

As the speaker had intended, the meeting rapidly became converted into a most pleasant informal social occasion which was ultimately drawn to a conclusion at a relatively late hour by the Chairman, who thanked Mr. Whittaker for all the work he had put in to make the evening a success, and congratulated him on the originality of the topic and the form of its presentation.

A PRACTICAL APPROACH TO GEOLOGICAL FIELDWORK

Dr. I. M. Simpson

A meeting of the Society was held on 13th January, 1982, at the Derwent Centre, Cockermouth. About 20 members and their friends attended and Mr. Eric Lawrence, the Chairman for the evening, opened the proceedings by introducing the speaker, Dr.I.M. Simpson, Senior Lecturer in Stratigraphy in the University of Manchester. The title of his address was 'A practical approach to geological field-work'.

Dr. Simpson said he wanted to emphasise the continuing value and importance of basic observational and interpretive stratigraphical field-work in geology. This was still true in an age when new technological methods were often available to complement the older standard techniques.

Illustrating his comments with excellent colour slides the speaker described the information to be gleaned from a number of favourite localities in the Hebrides and Derbyshire to which he took university students on field work courses. In his experience it was very often this basic aspect of geology that served to fire the imagination of professionals and amateurs alike. In some ways it was rather unfortunate that many useful exposures now tended to be over-protected by well meaning public bodies such as the National Park Planning Boards. It could be argued that sometimes restrictive measures to make sites inaccessible could be counter-productive.

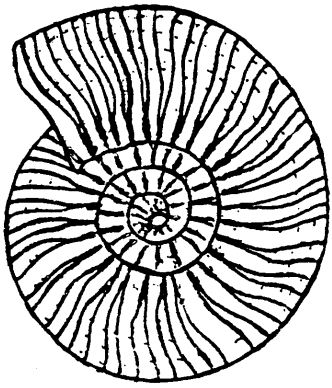
Dr. Simpson then went on to talk in some detail about two particular sites where detailed study occasioned by the teaching of field work methods had led to important and unexpected discoveries. The first of these was the well-known beauty spot

of Winnats Pass near Castleton in Derbyshire. Here, near horizontal Lower Carboniferous limestones are separated from onlapping Millstone Grit measures by a 30^{o} - 40^{o} slope which has been described as an apron reef front. A well known amateur geologist P.Parkinson in the early years of this century postulated the somewhat unlikely idea that this slope represented the original dip, but because of the uniform cover of turf over the scarp it has been difficult to prove the point. Dr. Simpson showed how the question has been resolved by a close study of such exposures as there were, coupled with exploiting to the full a fortuitous Local Authority excavation made to enlarge a car park. It was shown that the slope was formed of fragmented limestone blocks deposited by some contemporary process of erosion. Brachiopods and other fossils showed partial in-filling of their cavities with carbonate mud, the surface of which provided in effect a fossilised spirit level. Detailed study and measurements showed that of the 35^{o} of existing dip, 27^{o} was primary and only 8^{o} attributable to subsequent tilting, thus justifying in large measure the original views of Parkinson.

The second locality described by Dr. Simpson was an abandoned brickworks quarry in the vicinity of Wigan, also used by the Manchester students for field work exercises. There is a good Lower Coal Measures succession with cyclothems. Coals pass up into carbonate shale and are succeeded by a whole series of 50 to 60 well defined, alternating, bands of shale and sandstone. The layers vary a little in thickness, but average a few centimetres each. Intrigued to know the meaning of this feature one of the students was inspired to study the sequence in detail and found that the undersurface of each sandstone bed was covered with nodules a centimetre or two in size, while the upper surface showed corresponding depressions. Vertical sections through the sandstone flags showed apparent bioturbation markings passing through the thickness of the beds. These did not seem to be the usual type of burrows or feeding channels, and it was finally concluded that they were the marks of Carbonicola organisms struggling to escape from their habitat in the silt up through a flood deposit of sand. Extensive search through many blocks revealed the occasional individual that had not succeeded and had been fossilised in situ. The environment of deposition that emerged, therefore, was one of very rapid sedimentation in a restricted lagoonal basin. There must have been alternating dry and wet seasons with devastating monsoonal flooding. Other evidence of extremely rapid accumulation of sediments in coal measure sequences is provided by instances of erect tree stumps fossilised in situ.

A number of questions were provoked by this interesting talk and the speaker was cordially thanked by the Chairman who commented on the entertaining manner of presentation which had underlined so effectively the message about the fundamental importance of field observation.

GASTRIOCERAS CUMBRIENSE



Readers of the Proceedings will have noticed that with the publication of the last issue the decoration on the front cover was changed to indicate the beginning of a new volume. The figure chosen to characterise Volume 4 is a representation of the Carboniferous goniatite Gastrioceras cumbriense. As the name implies, this is a fossil of considerable local interest and significance.

The Goniatites were a family of coiled, free-swimming, marine, cephalopod molluscs belonging to the Ammonoidea. They evolved in Lower Palaeozoic times from the Nautiloidea, some species of which have persisted to the present day and so provide us with good evidence of the natural history of this type of organism. In the Devonian and Carboniferous Periods, like the better known Ammonites of the Mesozoic Era, the Goniatites underwent rapid evolutionary changes, and this characteristic, together with their wide marine distribution, makes them very good bio-stratigraphic marker fossils.

In the Upper Carboniferous (Millstone Grit and Coal Measures) almost every marine transgression had its characteristic goniatite which can be used for stratigraphic correlations.

In our own area, interest in this connection centres on the Namurian strata which, in Northern England, are the approximate equivalent of the Millstone Grit, lying between the Carboniferous

Limestones and the Coal Measures. In West Cumbria the Limestone succession is overlain conformably by the Hensingham Grit. Above this lies a series of shales, impure limestones and thin coal seams lithologically indistinguishable from the superimposed Coal Measures themselves. These horizons, together with the Hensingham Grit, are collectively known as the Hensingham Group. In the type locality near Whitehaven they have a thickness of no more than 50 metres, but this increases considerably to the north and west beyond Workington and Maryport and towards Cockermouth.

For a long time there was considerable uncertainty as to where in this local succession the stratigraphic boundaries should be drawn. On the one hand the Hensingham Grit had fossil affinities with the upper beds of the Carboniferous Limestone, while on the other the upper part of the Group on lithological grounds seemed to belong to the Coal Measures.

In the 1920s the goniatite zones of the Namurian strata in Northern England were painstakingly worked out by W.S.Bisat, and the results published in a comprehensive paper in the Proceedings of the Yorkshire Geological Society in 1924. The author generously acknowledges help he received from many sources, but in particular he records in the following terms (p. 65) how he received specimens from Mr. Charles Edmonds, co-founder and first President of our Society:

> 'Mr. Edmonds has kindly forwarded me goniatites from the Bigrigg goniatite shale. The dominant goniatite is a Gastrioceras which I provisionally keep separate under the name Cumbriense.'

In the same article on page 121 Bisat gives a definitive description of the fossil to which readers are referred for details. Bigrigg has become the type locality of the species.

This work led to a resolution of some of the problems already mentioned. It is now established that the Namurian succession in our area begins at the base of the First Limestone, which is the equivalent of the Great Limestone of the Alston Block. Above this all the beds of the Hensingham Group are Namurian in age, but in all except the top few metres the goniatite fauna belongs to the earliest part of this period of time ($E_1 E_2$ age, Eumorphoceras zone). The very uppermost beds, however, contain Gastrioceras cumbriense, now known to characterise the very end of the Namurian Stage. The intermediate strata are all missing so that there is a non-sequence which is only detectable on the basis of the fossil evidence. Dr.W.H.C.Ramsbottom, writing in 'The Geology of the Lake District', has identified in other parts of Northern Britain eleven major marine transgressions and regressions in the Namurian (N_I - N_{II}) and it is only the first and the last of these incursions of the sea that reached West Cumbria. This is regarded as evidence that for the greater part of Namurian times the Lake

District massif remained above sea-level. The increase in the thickness of the Hensingham Group towards Maryport and Cockermouth could indicate either increased deposition or the presence of some or all of the intervening strata missing round Whitehaven. This uncertainty, however, has not yet been elucidated.

Gastrioceras cumbriense in its well developed adult form can reach a diameter of 40 - 50 mm, but most known specimens are less than half this size and are usually found in a crushed and fragmented state. In obtaining an authoritative drawing of the organism, the Editor gratefully acknowledges the assistance of Dr. Ramsbottom and the Leeds Office of the Institute of Geological Sciences. The Editor is also indebted to Mr.E.H.Shackleton, the Society's Honorary President, who, in providing much assistance in the preparation of this note, recalled his own long association with Charles Edmonds who contributed so much to the knowledge of the geology of our area.

REFERENCES

BISAT, W.G., 1924. The Carboniferous Goniatites of the North of England and their Zones. Proc.Yorks.Geol.Soc. 20. 40-124.

RAMSBOTTOM, W.H.C., 1978. Chapter 12 in 'The Geology of the Lake District', Ed. Moseley. Yorks.Geol.Soc. Occasional Publication No.3. viii + 284 pp.

ANNUAL DINNERS

1980

The 1980 Annual Dinner was held on Friday 25th April at the Hundith Hill Hotel, Cockermouth, the Guest of Honour being Dr.N.J. Soper of Sheffield University.

The occasion was also marked by the award, in absentia, of a citation of Honorary Membership of the Society to the President, Mr.E.H.Shackleton, who was not able to attend because of illness. Following the proposal of the loyal toast the General Secretary addressed the gathering in the following terms:

'Mr. Vice-President, Dr.Soper, Ladies and Gentlemen, I had been asked to say a few words prior to presenting our President with a memento of his election to Honorary Membership of the Cumberland Geological Society.

Unfortunately Mr. Shackleton is at present in hospital, but I can say that his illness is not as serious as we had feared, and he should be convalescing very soon. He telephoned me from the hospital earlier this evening to express the hope that this dinner would be a happy occasion for those attending. In the event, I am going ahead with my few words about our President, even though the presentation will have to be made on a less suitable occasion later.

Edgar Shackleton was born in 1903 at Great Harwood in Lancashire. His interest in geology was kindled at the early age of seven when his father took him down the Cock Pit coal-mine. Because of the war he left school to start work at twelve, and at fourteen commenced apprenticeship in engineering. He attended evening classes at Blackburn Technical College where his favourite subjects were geology and botany. He reached Inter-B.Sc. standard, but due to staffing difficulties at the College, matriculation was not possible, so an external degree was denied him. How different he would have found things had he had more recent educational opportunities. He was greatly influenced at this time - in the early 1920s - by his tutor at Blackburn, John Ranson, who introduced him to the art of lecturing and excursion planning in geology. Ranson introduced him to R.L.Sherlock, an officer of the Geological Survey who was working in East Lancashire in the 1920s. Sherlock enlisted Mr. Shackleton's help in the investigation of several localities. It was also

Sherlock who suggested that the group of keen geology students in East Lancashire should form the first regional group of the Geologists' Association. This was done and Mr. Shackleton became the first group secretary.

Soon after this, during the mid-1920s when the economic life of the country was in the doldrums, Edgar married Doris Pilkington and they moved to Bowness-on-Windermere where he earned a modest living as a rock-climbing guide and lecturer, keeping very much in touch with the geology of his beloved Lakeland.

In 1934 an opportunity arose for him as a local representative with Hoover Ltd., and he soon became an area supervisor, covering the region from Whitehaven to Penrith.

After the outbreak of the Second World War he was drafted to the Royal Ordnance Factory at Drigg manufacturing nitric and sulphuric acids for explosives. With the coming of peace Edgar remained in West Cumberland and joined United Steels, officially as an instrument mechanic and perhaps less officially as a geological adviser on such matters as faulting in the local mines, drainage and the mineralogy of imported ore supplies from which he collected and documented several rare manganese minerals.

It was about this time that he met up with the late Charles Edmonds, whose expertise on the Lower Carboniferous was unrivalled. Together they instituted Workers' Educational Association classes in geology, and such was their enthusiasm that they attracted a group of youngsters who were to go through University to careers in geology - Tony Dickson, Dennis Jackson, Clive Nicholas, Patrick Rook and Brian Waugh. In the latter half of the 1950s the West Cumberland Geology Group was formed, with such stalwarts as Bob Hewitt, Herbert White, Herbert Bland, Teresa Murray with Bob Pearson as secretary, and under the leadership of Edmonds and Shackleton.

This group inaugurated the Cumberland Geological Society in 1961, and such has been the esteem in which Mr. Shackleton is held that he has been President for most of its period of existence.

Mr. Vice-President, whilst we miss the presence of our President and his wife on this occasion, I consider it an appropriate time to record his career as an amateur geologist, and to link it with the rise of the Cumberland Geological Society to which he has given so much. If this has sounded like a 'This is Your Life' programme, then we should remember with gratitude that so much of Mr. Shackleton's life has been spent helping and encouraging others to appreciate and understand the geological wonders of this uniquely beautiful

corner of Britain.

We should also recall that Mr. Shackleton is only the second person to be given the Society's Honorary Membership, the first being his old friend Charles Edmonds.

I am sure that, disappointed perhaps that he is not with us this evening, you would all wish to rise and join me in the toast:

'Edgar Shackleton, and his speedy recovery'.

These comments were received with acclaim by all present and the Vice-President, Mervyn Dodd, was charged with conveying the illuminated address to Mr. Shackleton together with an account of the proceedings and an expression of the good wishes of the Society with their hope for his speedy recovery.

After an adjournment Dr.J.Soper addressed the company. He spoke about his field experiences in the Arctic territories, particularly in Greenland, over eight seasons. His talk was built around a series of the most superb colour slides which gave a vivid impression of the topography and geology of the area. Dr. Soper concentrated on three localities. Starting on the extreme northern coastline of Greenland he remarked on the extent of exposed rock and relative lack of snow and ice. The reason for this is the low precipitation combined with strong anticyclonic winds round the North Pole which tend to blow the snow away. There is no accumulation to form a thick ice-cap such as covers most of Greenland to the south. Satellite pictures showed the weather pattern, while the distribution of pack ice indicated the oceanic circulation. Currents from the Pole caused the piling up of ice in impressive pressure ridges against the northern coastline.

Dr. Soper was with an expedition of the Danish Geological Survey and the party travelled inland using skidoos hauling trains of small sledges. Some topographical surveying was done to provide datum points for aerial mapping. Geologically an east-west Caledonian fold belt was mapped with metamorphic rocks thrust up over Tertiary volcanics. Animal life in the area was represented by arctic foxes and musk oxen, and white hares were seen running erect on their hind-legs. Pictures of fox cubs were shown showing no fear due to lack of previous contact with man.

The party climbed up onto a plateau consisting of a carbonate platform sequence Pre-Cambrian to Silurian in age. An interesting structural anomaly was seen where the high ground was formed of more resistant rocks hardened by compression in synclinal folds while the lower ground and valleys were the result of erosion acting on less competent rock material which had suffered tensional fragmentation in the corresponding anticlines. Evidence of poly-phase folding similar to that seen in the Lake District rocks was noted and the tightly folded carbonate rocks of Lower Cambrian age

were sampled for micropalaeontological studies.

Turning to another locality this time on the East Greenland coast further to the south the speaker described the famous Skaergaard intrusion of layered gabbros. Dr. Soper referred also to the Tertiary basalts erupted when Greenland and Europe split apart with the opening of the Atlantic. Dating of these basalts might enable a precise date to be allocated to the onset of the rifting and provide a fixed datum in plate tectonic evolution. Slides were shown of icebergs ploughing through pack ice and also mile-high cliffs of basalt from the measurement of which it had been deduced that successive lava flows had occurred at average intervals of 14,000 years. Further pictures were shown of exploration of the Skaergaard intrusion which required a high standard of rock, ice and snow climbing.

Dr. Soper's third locality was also on the East coast a little further to the north again. Jurassic sandstones here were the equivalent of the reservoir rocks of the Brent and Forties oil fields in the North Sea, here available for examination at outcrop. Ordovician limestones were likewise the equivalent of the Durness limestones of Scotland, but here were very much thicker. These strata were overlain by Devonian sandstones with a beautifully exposed major unconformity.

Finally Dr. Soper showed slides of exposures showing continuous deposition in Pre-Cambrian and Cambrian times with evidence of a fossilised boulder clay providing evidence for a widespread episode of glaciation at that time.

Mr.B.D.Allen wound up the proceedings by proposing a vote of thanks to Dr. Soper for his splendid contribution to another successful annual celebration.

1981

The 1981 Annual Dinner of the Society was held on Saturday 9th May at the Hundith Hill Hotel, Cockermouth. Under the chairmanship of Mr.E.H.Shackleton some 42 members and their guests welcomed the Guest of Honour, Dr.G.A.L.Johnson of Durham University together with Mrs. Johnson.

After an excellent meal and after the Loyal Toast there was a brief adjournment while the room was re-arranged for Dr. Johnson to address the company. He entitled his talk 'Tours in Laurasia'.

Dr. Johnson started by explaining that Laurasia was the name given to one of the three major continental masses which existed in Upper Palaeozoic times. The approximate dispositions of old land masses are known from palaeomagnetic, stratigraphical, palaeoclimatic and palaeontological studies. Laurasia dominated the equatorial regions and was composed of what are now the continents of Europe and North America together with Greenland. On this Old Red Sandstone continent land plants and fresh water organisms developed extensively and by the end of the Devonian there was a comprehensive flora and fauna. The diversification and migrations of these plant and animal species is preserved in the fossil record and is important evidence in reconstructing the sequence and timing of plate movements. Dr. Johnson referred particularly to the tetrapods, the first land animals composed of amphibians and later reptiles. These developed in the coastal wet-lands of Laurasia and being unable to exist in marine conditions have provided evidence of the formation of land bridges either by continental collision or falling sea-level.

Laurasia, lying astride the equator and surrounded by wide shelf seas, contained an extensive tropical and sub-tropical climatic belt giving rise to comparable depositional environments and faunal provinces. This belt can be traced today in localities which have been widely separated by subsequent rifting and fragmentation of the continents in the Mesozoic.

With these introductory remarks Dr. Johnson proceeded to describe a number of geological localities in what had once been the old Laurasian continent which he had had occasion to visit at different times in the course of his work. His descriptions were beautifully illustrated by excellent colour slides.

Starting in the western part of the old continent present-day Nova Scotia was seen from the air. This territory was a micro-continent that had joined the main Laurasian land mass in mid-Devonian times. The position of the suture line was seen and an impression gained of continental mobility.

Part of the southern shore of western Laurasia is now Kentucky. Here the Devonian - Lower Carboniferous boundary is marked by good stratigraphic fossils and the limestones have all the characteristics of our local North British sequences. The Pennsylvania coalfield lies above sandstones showing deltaic features and they now contain natural tar. They are in fact fossilized reservoir rocks with petroleum residues. The coal seams are worked by open-cast methods and the whole scene has many parallels with our own area and with other localities in the Laurasian equatorial belt.

Turning to Spitzbergen, which was originally in northern Laurasia, the conditions were rather different. The speaker referred to the continuous rock successions covering long periods of geological time. Current research in the area is concerned

with periglacial phenomena. Dr. Johnson showed slides of beautiful fish fossils in the Devonian strata. Further up the succession in the Lower Carboniferous continental conditions prevailed with evaporite basins rather than open marine facies which, however, took over in the Upper Carboniferous and persisted through into the Permian. Before leaving Spitzbergen the speaker referred to the coal seams worked in the Tertiary strata.

Returning to the southern boundary of the old continent Dr. Johnson described the geological complexities in what is now mid-European territory - Czechoslovakia, Austria, Hungary and Romania. It is considered that there must have been an east-west sea-way through this area which closed in Carboniferous times as a result of micro-plate collisions from the south. Shelf deposition occurred on both the northern and southern margins of the sea-way but the sequence south of the line shows continuous deposition through the Carboniferous-Permian boundary whereas the northern shore is characterised by coal measures such as those of the Donetz basin matching the sequence in Kentucky and Britain. The evidence of late-stage tetrapod migration from north to south suggests a late Carboniferous date for the closure.

Dr. Johnson concluded by referring to the friendliness and international accord he had encountered in his travels between geologists of widely differing cultures.

A vote of thanks was proposed by Mr. Derek Leviston who commented that Dr. Johnson's contribution to the evening had been a most worthy addition to the talks given by the sequence of distinguished guests that had graced our Annual Dinners in recent years.

19th ANNUAL GENERAL MEETING

The nineteenth Annual General Meeting of the Society was held at the West Cumbria College of Science and Technology, Whitehaven, on the 13th February, 1980, with the President, Mr.E.H.Shackleton, in the Chair.

GENERAL SECRETARY'S REPORT

Membership

Numbers have remained steady during 1979. 18 new members were elected, whilst 21 have either resigned or been removed from the list for non-payment of subscriptions. The various numbers and categories of members for 1979 are:

Ordinary	158
Husband and Wife joint	26 x 2
Associate	26
Institutional	13
Total	249, a net loss of 3

Meetings

The Society has held the following indoor meetings during 1979/80:

1. The Annual General Meeting held on Wednesday, February 14th, 1979, at the West Cumbria College, Whitehaven. This was followed by a showing of the films 'African Quest' and 'Out of the Blue'. 16 members attended.

2. A lecture on 'Radiocarbon dating and the last Glaciation' by Dr. Lewis F.Penny of the University of Hull. This was held at the Derwent Centre, Cockermouth, on Wednesday 7th March, 1979. 21 members and 5 guests attended.

3. A lecture on 'The British Continental Shelf' by Sir Peter Kent, F.R.S. This was held at the West Cumbria College, Whitehaven, on Wednesday 28th March, 1979. 35 members and 4 visitors attended.

4. A lecture on 'Early Palaeozoic Shelf Sedimentation in Prince of Wales and Somserset Islands, Arctic Canada' by Dr. Jim Dixon of the Geological Survey of Canada. This was held at the West Cumbria College, Workington, on Friday 18th May, 1979. 17 members and 1 visitor attended.

5. A lecture on 'The Persistence of Man' given by Dr.T.A. Whitworth of Hatfield College, Durham. This was held at the West Cumbria College, Workington on Wednesday 3rd October, 1979. 22 members and 2 visitors attended.

6. A lecture on 'Dam Geology' by Dr.M.S.Money of the University of Newcastle-upon-Tyne. This was held at the Derwent Centre, Cockermouth on Wednesday 7th November, 1979. 31 members and 4 visitors attended.

7. A 'Members' Evening' was held at Distington Junior School on Wednesday 5th December, 1979. There were exhibitions of thin sections and photographs (F.Jones), gemstones and ornaments (P.R.Wallace), trilobites (E.H.Shackleton), corals (F.J.Cockersole), local fossils (boys of Whitehaven Grammar School), colour slides of Etna and Lipari (M.F.Burton), and a talk on site recording and conservation (S.Drinkwater and M.Barratt). About 20 members attended.

8. A Film Evening was held on Wednesday 9th January, 1980, at the West Cumbria College, Whitehaven. The films 'Volcano - birth of a mountain' and 'Heartbeat of a Volcano' were shown. 28 members and 12 guests attended.

During past years the Society has enjoyed the benefits of accommodation hired from the Cumbria Education Authority at its Further Education Centres in Whitehaven, Workington and Cockermouth. Uncertainties about the future of these centres, due to cuts in the County education budget, have led your Council to consider contingency plans. It may be necessary, possibly at short notice, to bring meeting times forward to 7 p.m. and to change our venues. In the event of such change I shall endeavour to give Members adequate warning, by circular letter, or via the media.

As will be seen from the above figures, average attendance at meetings has been 27 (compared with 32 in 1978/9). This may be a reflection of increasing cost of transport, or a less than attractive programme of events. From the point of view of your General Secretary who is trying to book lecturers of high calibre, to obtain films which reflect the excitement and interest of geology, and to prod members into a more active participation, the variable attendance is disappointing and baffling. My first question is one which will no doubt be repeated by the Excursion Secretary: 'What do members want?'. At the moment requests and negotiations for lecturers for next year are being handled, and with last year's attendances in mind I am tempted to wonder, during the composition and typing of tactful letters, the telephoning of arrangements, and the heart-stopping panic of coping with the last-minute crises that sometimes occur, 'Is it worth it?'. What is it going to take to shake some of our more sedentary members out of

their armchairs to support the Society at meetings?

The Annual Dinner

The Annual Dinner was held at Hundith Hill Hotel, Cockermouth, on Saturday 28th April, 1979. Guests of Honour were Dr. and Mrs. Frank Moseley of the University of Birmingham. Dr. Moseley was presented with the Charles Edmonds Prize and gave an amusing and informative talk on some of his field experiences. The success of the dinner is due in no small measure to the behind-the-scenes work done by Mr. Dodd, Mr. Shackleton, and the Bennett brothers.

The Council

Council has met five times, hospitality being provided by the Cockersole, Dodd and Shipp households. The Editorial Sub-Committee has met twice. Apart from planning the Society's activities and dealing with administrative and correspondence matters, the main subject of importance to be carried forward into the 1980s is an active concern with the recognition, recording and conservation of sites of geological interest and importance in Cumbria. The Society, and I hope this means a good number of its individual members, is firmly committed to participating in the National Scheme for Geological Site Documentation.

Correspondence during the year has ranged widely, from the normal inter- and intra-Society exchanges of information, requests about the Society and its activities, requests for geological information, requests from various political pressure groups seeking the Society's support against certain allegedly earth-shaking changes, and requests from the media for comments on certain other earth-shaking events (the Longtown Earthquake, December 26th, 1979). Among the foreign correspondence, surely the strangest letter was one in a quaint phraseology from a Moscow professor seeking information on geological emblems. I replied suitably, but not in Russian, quaint or otherwise!

Conclusions

Despite my earlier reservations about attendances, I am confident that the Society has enjoyed a year of interesting activity and progress. I am very grateful for the advice and assistance received from the Officers and the Council. To end this report on a high note, I am very pleased to announce that, in recognition of his long and unselfish service to the Cumberland Geological Society, Council has elected our President, Mr.E.H. Shackleton, to Honorary Membership. A presentation to mark this event will be made at the Annual Dinner. I am sure that we shall all wish to congratulate Mr. Shackleton, and assure him of members' continued affectionate regard for him.

Tom Shipp, B.Sc., M.I.Geol., F.G.S.
General Secretary.

11th February, 1980.

HONORARY TREASURER'S REPORT

Funds in hand at the end of 1979 stand at £738, a nett decrease during the year of £198, which, taking into account the high printing costs that we have incurred of £677, is a very satisfactory result for the Society.

Subscription income has increased, although this is mainly accounted for by payments in advance for 1980. Our bank interest has almost trebled at £121. This, together with the Income Tax Refund of £53, has significantly added to our income for the year. Sale of publications at £127 is at its lowest level since 1973, although Part 1 of Volume 4 of the Proceedings was not available until November and will not yet have had a significant effect on our income.

Expenditure on postages, telephones, stationery, room hire, films and lecture expenses has been contained during 1979 despite inflation in costs. This is mainly due to intensive efforts to hand deliver letters and reduce the number of receipts issued. The annual dinner incurred an unexpected loss of £21 owing to revised costs from the Hundith Hill Hotel.

The increase in subscription rates this year, together with an excellent financial start to the new decade should enable the Society to counter further inflation and cope with the high cost of publications when required.

I would conclude by expressing the Society's thanks to the Honorary Auditor for his time and efforts in checking these accounts.

S. R. Alexander.
Honorary Treasurer.

The following Officers and Members of the Council were elected to serve for the year 1980:

President	E.H.Shackleton, F.G.S.
Vice-President	M.B.Dodd, M.A.
General Secretary	T.Shipp, B.Sc., M.I.Geol., F.G.S.
Treasurer	S.R.Alexander
Membership Secretary	B.D.Allen
Excursions Secretary	Miss D.Slater
Publications Secretary	E.Lawrence, B.Sc., M.I.Geol., F.G.S.
Editor	F.J.Cockersole, F.R.C.O.G.
Librarian	M.F.Burton
Members of Council	R.Bennett
	F.Jones
	J.D.Hinde
	A.P.Rook, B.Sc., F.G.S.
Honorary Auditor	T.J.Dawson

INCOME AND EXPENDITURE ACCOUNT

INCOME:	£	1978 £	EXPENDITURE:	£	1978 £
Subscriptions					
Arrears for 1978	11.50	2	Publications	676.55	22
1979	257.50	261	Lectures & Excursions		
Advances for 80/81	94.25	6	Lecturers' Expenses	27.00	37
Sale of Publications	127.19	172	Hire of Films	5.29	16
Inland Revenue Refund	52.82	56	Hire of Rooms	2.40	12
Other Income			Subs. to other Societies	3.00	3
Donations	11.13	17	Loss on Annual Dinner	20.92	-
Refund of bank charges	.36	-	Administration		
Bank Interest	120.65	46	Stationery & Materials	58.22	54
	675.40	560	Telephone	10.07	9
			Postages	68.55	69
Surplus for the year	-	338	Refunds	1.25	-
Bal. forward from 1978	935.84	599		873.25	222
Bal. forward as Revenue	737.99	937	Deficit for the year	197.35	-

THE CHARLES EDMONDS MEMORIAL FUND

INCOME:	£	1978 £	EXPENDITURE:	£	1978 £
Years Interest 3½% War Stock	5.10	5	Prize presented 1979	20.00	-
Bank Interest	2.58	1		20.00	-
	7.68	6			
Decrease in fund	12.32	(6)			
Bal. forward from 1978	24.50	18			
Bal. forward to 1980	12.18	25			

BALANCE SHEET: 31st December, 1979.

CAPITAL EMPLOYED:	£	1978 £		£	1978 £
Assets					
Equipment (nom. value)	12.00	12	Accumulated Funds	2799.59	1739
Stock of Publications	1946.00	1142	Deficit for year 1979	197.85	-
Deposit A/c at Bank	579.48	870	(Surplus for year 1978)	-	338
Current A/c at Bank	755.56	60			
Cash in hand	.45	6			
Cheques in hand	54.70	-			
	3348.19	2090			
Less liabilities					
Creditors	652.20	7			
Subs. in advance	94.25	6			
	746.45	13			
Total Net Assets	2601.74	2077		2601.74	2077

These accounts have been re-cast in the form used from 1980 onwards to facilitate comparison.

20th ANNUAL GENERAL MEETING

The twentieth Annual General Meeting was held on 11th February 1981 at the Royal British Legion Club, St. John's Court, Workington, under the Chairmanship of the President, Mr.E.H. Shackleton.

GENERAL SECRETARY'S REPORT

Membership

There has again been little change in numbers of members during 1980. 16 new members were elected, whilst 12 have either resigned or been deleted for non-payment of subscription. The various numbers and categories for 1980 (1979 numbers in brackets) are:

Ordinary	157	(158)
Husband and wife joint	29	(26)
Associate	25	(26)
Institutional	13	(13)

Meetings

The Society has held eight indoor meetings during 1980/81, as follows:

1. The Annual General Meeting held on Wednesday, February 13th, at the West Cumbria College, Whitehaven. This was followed by the showing of the films 'Cornish Venture' and 'Our Mineral World'. 26 members and 1 visitor attended.
2. A lecture on 'British Carboniferous Volcanoes and their Origins' was given by Professor E.H.Francis on Wednesday, March 5th at the Derwent Centre, Cockermouth. 32 members and 11 visitors attended.
3. A lecture on 'The Stratigraphy of the Yorkshire Dales' was given by Dr.A.A.Wilson on Wednesday 2nd April at the West Cumbria College, Whitehaven. 20 members and 4 visitors attended.
4. A lecture on 'The Mineralisation of the Pennines' was given by Sir Kingsley Dunham on Wednesday 10th September, at the Derwent Centre, Cockermouth. 32 members and 16 guests attended.
5. A lecture on 'The Geology of North Cumbria and The Borders' was given by Mr.I.Gray on Wednesday 1st October at the West Cumbria College, Workington. 15 members and 4 visitors attended.
6. A lecture on 'Earthquake Activity in Northern Britain' was

given by Dr.C.W.A.Browitt on Wednesday 12th November at the Derwent Centre, Cockermouth. 32 members and 12 visitors attended.

7. The advertised lecturer for the December 3rd meeting withdrew at very short notice. We are grateful to Mr. Fergus Anckorn of the N.C.B., who saved the situation by giving a lecture and film on 'Geological Exploration in the Antarctic'. The meeting was held at the Royal British Legion Club, Workington.

8. A film evening at which 'Remote Sensing - a new angle on the World', 'The Bay of Mont St.Michel', and 'Motorway through the Lune Valley' were shown on Wednesday January 14th, 1981, at the West Cumbria College, Whitehaven. 28 members and 2 visitors attended.

The experiment of bringing meetings forward by 15 minutes has been favourably received and we have had none of the anticipated difficulty over obtaining accommodation for meetings. Attendances have at last taken an upturn from an average of 27 per meeting in 1979 to 33 last year. However, it is still disappointing, having gone to considerable trouble and expense in obtaining lecturers of high calibre, to see what a small proportion of our members in West Cumbria is willing to turn out to meetings.

Council has met on four occasions in members' houses. The Editorial Sub-Committee has met once.

The Annual Dinner

This was held at the Hundith Hill Hotel on Friday 25th April. About 50 members and guests were present. Guests of Honour were Dr. and Mrs.N.J.Soper of the University of Sheffield. Dr. Soper spoke of the joys and hazards of geological exploration in Arctic Greenland. Once again we are indebted to a number of members working behind the scenes to make the function run smoothly and successfully.

The President

At the Annual Dinner the Society's President, Mr.E.H. Shackleton, F.G.S., was presented in absentia (due to his illness) with an illuminated address recording the award of Honorary Membership of the Society in appreciation of his contribution to the furtherance of geological science and of his support of the Society over many years. Towards the end of the year it was disclosed that Mr. Shackleton was to be further honoured by the Geological Society of London, which intended to award him the R.H.Worth Prize for 1981.

Towards the end of 1980, Council regretfully accepted Mr. Shackleton's wish to be relieved of the Presidency of the Society. He has held the office for nearly twenty years, taking it up soon after the inception of the Society early in 1962. We shall all, I

have no doubt, wish him well in his retirement from Office, and hope that it will be active in the affairs of the Society.

Publications

The Editor considered that there was insufficient material to publish Proceedings during 1980. Matters have not been entirely dormant on the Publications front, for at the suggestion of the Publishers, George Allen & Unwin Ltd., a number of our members have been prevailed upon during the year to produce detailed accounts of geological excursions in Cumbria. The thirteen excursions written up have been carefully edited to iron out style differences, and together with introductory and explanatory chapters are being prepared for printing in 1981/2. The book will be one of a series of regional fieldwork guides for the British Isles being produced by Allen & Unwin. The first two volumes 'The Weald' and 'Snowdonia' are in an advanced state of preparation.

Site Documentation

The Society has continued to involve itself in site documentation matters under the regional scheme centred at Brockhole.

Conclusion

It has been a busy year again for your General Secretary. May I thank fellow Officers, Council Members and Ordinary Members for their assistance and advice in the running of the Society during 1980.

T. Shipp, B.Sc., M.I.Geol., F.G.S.
General Secretary

10th February, 1981.

HONORARY TREASURER'S REPORT

Increased subscription rates, record sales of publications and high interest rates have all resulted in a very satisfactory financial position for the Society. It should now safely bear the anticipated high cost of future publications and meetings.

We have achieved an excess of income over expenditure of £638 during the year and carry forward into 1981 a balance of funds in hand of £1376.

Total income for the year stands at £1093 (compared with £675 for 1979) and is made up of Subscriptions £424, Sales of Publications £416, Refund from Inland Revenue £78, and Bank Interest, Donations etc. of £175. It should be said, however, that this could have been better still if members had all responded to the request for increased subscriptions. We still have a number of Banker's Orders being paid at the old rates, and expenditure has been incurred (in postage, bank charges and lost interest) in chasing many that did not respond to our initial

request.

Total expenditure for the year stands at £455 (compared with £873 in 1979). This relatively low figure is due to the fact that we have not had any large publishing costs. Publication expenditure for the year includes a number of geological books that have been bought for sale to our membership, and stands at £170. Other expenditures incurred were the costs of Lectures and Excursions £49, Subscriptions to other Societies of £3 and a total Administrative and General Expenditure of £233. This includes a fairly hefty increase in postage costs from £69 in 1979 to £107 in 1980 despite the many savings obtained by hand delivery of circulars by officers and members of the Society. The other major expenditure in this area was for Stationery and Materials (including membership cards) which increased from the 1979 level of £58 to £93 in 1980. We have had to pay Bank Charges to find out who did (and who did not) change their Banker's Orders since many of the part payments appeared on our Bank Statements in the first instance as unidentified 'Bank Giro Credits'.

The Charles Edmonds Memorial Fund account shows a total income of £7.12, with no expenditure. The balance carried forward to 1981 stands at £19.30.

I would conclude by expressing my grateful thanks on behalf of the Society to the Honorary Auditor Mr.T.J.Dawson for his services in verifying my accounts.

S.R.Alexander
Honorary Treasurer

The following Officers and Members of Council were elected to serve for the year 1981:

President	No nomination
Vice-President	Miss D.Slater
General Secretary	T.Shipp, B.Sc., M.I.Geol., F.G.S.
Treasurer	S.R.Alexander
Membership Secretary	B.D.Allen
Excursions Secretary	M.B.Dodd, M.A.
Editor	F.J.Cockersole, F.R.C.O.G.
Publications Secretary	E.Lawrence, B.Sc., M.I.Geol., F.G.S.
Librarian	M.F.Burton
Members of Council	R.Bennett
	J.D.Hinde
	F.T.B.Lawton
	A.P.Rook, B.Sc., F.G.S.
Honorary Auditor	T.J.Dawson

INCOME AND EXPENDITURE ACCOUNT

INCOME:	£	1979 £	EXPENDITURE:	£	1979 £
Subscriptions			Publications	169.90	677
Arrears for 1979	1.00	12	Lectures & Excursions		
1980	393.50	257	Lecturers' expenses	21.00	27
Advances for 81/82	29.75	94	Hire of Films	24.37	5
Sale of Publications	416.30	127	Hire of Rooms	4.00	2
Inland Revenue Refund	77.74	53	Subs. to other Societies	3.00	3
Other Income			Administration		
Donations	11.75	11	Stationery & Materials	92.71	58
Cheque re Dinner A/c	9.50	-	Telephone	13.01	10
Bank Interest	153.91	121	Postages	106.93	69
	1093.45	675	Refunds	2.25	1
			Bank Charges	8.41	-
Surplus for the year	638.37	(198)	Cheque re Dinner A/c	9.50	21
Bal. forward from 1979	737.99	936		455.08	873
Bal. forward as Revenue	1376.36	738			

THE CHARLES EDMONDS MEMORIAL FUND

INCOME:	£	1979 £	EXPENDITURE:	£	1979 £
Years Interest 3½% War Stock	5.10	5	No prize presented 1980	-	20
Bank Interest	2.02	3		0.00	20
	7.12	8			
Increase in fund	7.12	(12)			
Bal. forward from 1979	12.18	25			
Bal. forward to 1981	19.30	12			

BALANCE SHEET: 31st December, 1980.

CAPITAL EMPLOYED:	£	1979 £		£	1979 £
Assets					
Equipment (Nom. value)	8.00	12	Surplus for year 1980	638.37	(198)
Stock of Publications	1916.32	1946	Accumulated Funds	2622.76	2800
Deposit A/c at Bank	1307.58	579			
Current A/c at Bank	57.87	756			
Cash in hand	6.41	-			
Cheques in hand	5.50	55			
	3301.68	3348			
Less liabilities					
Creditors	10.80	652			
Subs. in advance	29.75	94			
	40.55	746			
Total Net Assets	3261.13	2602		3261.13	2602

21st ANNUAL GENERAL MEETING

The twenty-first Annual General Meeting of the Society was held at the Royal British Legion Club, Workington, on the 10th February, 1982, with the Vice-President, Miss Doreen Slater in the Chair.

HONORARY LIFE PRESIDENT CITATION

The Vice-President opened the proceedings with the following announcement:

> 'Following representations from a number of members during 1981, the Council of the Cumberland Geological Society at its meeting on 2nd Decem c, 1981, resolved to make Mr.E.H.Shackleton, F.G.S., Honorary Life President of the Society.
>
> Council members were very mindful of Mr. Shackleton's wish, on his retirement from the Presidency, to be relieved of the strain of active leadership of the Society. Council has therefore declared that this honorary post shall carry no incumbent duties to the Society.
>
> Mr. Shackleton, it may be recalled, was awarded the Society's Charles Edmonds Memorial Prize in 1973, and was made an Honorary Member in 1980.
>
> I hope that fellow members will join with me in endorsing this further mark of esteem for a co-founder of our Society, who has served as its Vice-President and then its President for a span of nearly twenty years.'

GENERAL SECRETARY'S REPORT

Membership

There has been little change in numbers of members during 1981. 30 new members were elected during the year, set against 29 who have been taken off the membership list. The various numbers and categories for 1981 (1980 numbers in brackets) were:

Ordinary members	158	(157)
Associate members	20	(25)
Joint husband and wife members	30	(29)
Institutional members	16	(13)

Henry Mayson, one of the Society's founder members, died during the year.

Meetings

The Society held 9 indoor meetings during 1981/82, as follows:

1. The A.G.M. held on Wednesday February 11th at the Royal British Legion Club, Workington. This was followed by a Members' Evening, with displays of members' geological work. 21 members and 3 visitors attended.

2. A lecture on 'The Geological Record of the Pleistocene Climatic Changes' was given by Mr. John Boardman on Wednesday March 4th at the Chase Hotel, Whitehaven. 23 members and 3 visitors attended.

3. A lecture on 'Geology and Ancient Man' was given by Mrs. Jean Ward on Wednesday April 1st at the Derwent Centre, Cockermouth. 25 members and 6 visitors attended.

4. A lecture on 'The Late-glacial Period in Cumbria' was given by Dr. Winifred Tutin on Wednesday September 9th at the Derwent Centre, Cockermouth. 31 members and 7 visitors attended.

5. A lecture on 'The Cambrian Geology of the Northern Interior Plains of Canada' was given by Dr. Jim Dixon on Wednesday September 23rd at the West Cumbria College, Workington. 22 members attended.

6. A lecture entitled 'The Geological Story of the Lake District' was given by Mr. Tom Shipp on Wednesday October 7th at the West Cumbria College, Whitehaven. 25 members and 8 visitors attended.

7. A lecture entitled 'The Morphology of an Active Plate Boundary' was given by Dr. Richard Sibson on Wednesday November 4th at the West Cumbria College, Whitehaven. 20 members and 7 visitors attended.

8. A lecture and wine tasting entitled 'Geology and Wine' was provided by Mr. Richard Whittaker on Friday December 4th at the Royal British Legion Club, Workington. 32 members and 5 visitors attended.

9. A lecture on 'A Practical Approach to Geological Field-work' was given by Dr. Morven Simpson on Wednesday January 13th, 1982, at the Derwent Centre, Cockermouth. 20 members and 1 visitor attended.

With one more meeting than last year, attendances have dropped to an average of 29 per meeting. This is disappointing, in view of the travelling distance, time, trouble and expense that lecturers undertake on the Society's behalf.

Council has met on four occasions in members' homes. A rule-revision sub-committee met once at the home of Mr.G.S.Gowing.

The Annual Dinner

This was held at the Hundith Hill Hotel on Saturday May 9th. About 45 members and their guests attended. Guests of Honour were Dr. and Mrs. G.A.L.Johnson of the University of Durham. Mr. Shackleton took the Chair. The Society is indebted to Mr. Dodd, the Bennett brothers, and the proprietor and staff of the hotel for a successful function.

Publications

Publication of the Society's Fieldwork Guide to the Lake District is now imminent. Eight members of the Society contributed 13 very varied excursion schedules. The General Secretary provided the introductory chapter and glossary, and co-ordinated the exercise with the publishers, George Allen and Unwin Ltd.

In conclusion, it has been a busy year once again for your General Secretary, who has coped with more correspondence than ever. Organisation of the Society's lecture programme, publicity, links with other Societies and requests for information all take up an increasing amount of time and effort. May I express grateful thanks to fellow members who have eased this burden for me from time to time. Whilst I am willing to continue as General Secretary for 1982, if elected, I shall be reluctant to go further. The task has lost its freshness for me, and I would like more time to do some active geological work of my own, instead of organising it for others.

Tom Shipp, B.Sc., M.I.Geol., F.G.S.
General Secretary

10th February, 1982.

HONORARY TREASURER'S REPORT

I can report that 1981 has been a successful year financially for the Society. We have achieved a balance of income over expenditure of £288 despite having a significantly reduced income from the sale of publications, and moderate increases in expenditure in some areas. We carry forward to 1982, in readiness for the costs of our next publication, a total of £1665, being the balance of funds in hand.

Total income for the year was £930 (£163 down on 1980). This was made up from £507 Subscriptions, £91 Sales of Publications, £88 Refund from Inland Revenue re-covenanted subscriptions, £8 Donations, £72 income from the Geology and Wine lecture, and a total of £164 Bank Interest received. Subscriptions are up by £83 although taking into account advance payments for 1981 received in 1980, and arrears for 1980 received in 1981, the true comparison

shows an increase of £103. Sales of Publications shown in the accounts are at their lowest level since 1972 at £91 (compared with £416 for 1980), although this modest income is very useful in a year when no new publications have been printed.

Expenditure for 1981 totals £642 and comprises £86 for typing and photo-copying, a total of £248 for cost of lectures and excursions, £5 subscription to the Cumbria Naturalists' Trust, £100 for materials and stationery (including membership cards), £63 general council expenditure, £5 bank charges payable, £27 telephone calls and £108 postal charges. The major increase of expenditure is as shown in the hire of rooms and lecturers' expenses. It should be mentioned that included in the £174 shown is a sum of £78 being the costs incurred in the Geology and Wine evening, exclusive of room hire. Lecturers have, in 1981, been more inclined to accept the Society's offer of reimbursement of expenditure on rail fares and petrol, reflecting the inflationary times in which we live.

The Charles Edmonds Memorial Fund Account shows a total income of £7.35, with no expenditure and the balance carried forward to 1982 stands at £26.65.

I would like to conclude my report by expressing on behalf of the Society and myself thanks to the Honorary Auditor, Mr.T.J. Dawson, for his services in verifying my accounts.

S.R.Alexander.
Honorary Treasurer.

The following Officers and Members of Council were elected to serve for the year 1982:

President	M.B.Dodd, M.A.
Senior Vice-President	E.H.Shackleton, F.G.S.
Vice-President	Miss D.Slater
General Secretary	T.Shipp, B.Sc., M.I.Geol., F.G.S.
Treasurer	S.R.Alexander
Membership Secretary	B.D.Allen
Excursion Secretary	M.B.Dodd, M.A.
Publications Secretary	E.Lawrence, B.Sc., M.I.Geol., F.G.S.
Editor	F.J.Cockersole, F.R.C.O.G.
Librarian	M.F.Burton
Members of Council	J.D.Hinde
	F.T.B.Lawton
	T.P.Loftus
	A.P.Rook, B.Sc., F.G.S.
Honorary Auditor	T.J.Dawson

INCOME AND EXPENDITURE ACCOUNT

INCOME:	£	1980 £	EXPENDITURE	£	1980 £
Subscriptions			Publications	86.30	170
Arrears for 1980	15.50	1	Lectures & Excursions		
1981	481.50	393	Lecturers' expenses	174.47	21
Advances for 1982	10.00	30	Hire of Films	-	24
Sale of Publications	90.70	416	Hire of Rooms	73.75	4
Inland Revenue Refund	87.61	78	Subs. to other Societies	5.00	3
Other Income			Administration		
Donations	8.33	12	Stationery & Materials	99.62	93
Cheque re Dinner A/c	-	9	Telephone	27.17	13
Income from Geol.& Wine	72.00	-	Postages	108.22½	107
Bank Interest	164.39	154	Refunds	-	2
Total Income 1981	930.03	1093	Bank Charges	5.06	8
			Cheque re Dinner A/c	-	9
Surplus for the year	288.33½	638	Council expenses	62.50	-
Bal. forward from 1980	1376.36	738			
Bal. forward as Revenue	1664.69½	1376		641.69½	455

THE CHARLES EDMONDS MEMORIAL FUND

INCOME:	£	1980 £	EXPENDITURE	£	1980 £
Years Interest 3½% War Stock	5.10	5	None	-	-
Bank Interest	2.25	2			
Increase in fund	7.35	7			
Bal. forward from 1980	19.30	12			
Bal. forward to 1982	26.65	19			

BALANCE SHEET: 31st December 1981.

CAPITAL EMPLOYED:	£	1980 £		£	1980 £
Assets					
Equipment (Nom.value)	8.00	8	Surplus for year 1981	288.33½	638
Stock of Publications	1866.55	1916	Accumulated Funds	3240.91	2623
Deposit A/c at Bank	1575.78	1308			
Current A/c at Bank	117.29	58			
Cash in hand	.42½	6			
Cheques in hand	6.65	5			
	3574.69½	3301			
Less liabilities					
Creditors	35.45	11			
Subs. in advance	10.00	30			
	45.45	41			
Total Net Assets	3529.24½	3261		3529.24½	3261

A NEW PUBLICATION

Members of the Society will be interested in a new geological field guide which is to be published by George Allen and Unwin this spring. The book is entitled 'The Lake District' and is one of a series of similar regional guides produced by this publisher.

The authors are a group of eight members of our own Society, and the preparation of the material has been the work of our General Secretary, Tom Shipp, who has contributed several sections and acted as the editor.

The book consists of 160 pages and is fully illustrated with over fifty maps, diagrams and photographs. There are 13 self-contained itineraries, and the contents are as follows:

Preface

Part 1 The Geological Background

Part 2 Field Excursions:

1 The Shap Granite
2 Permian Rocks of the Eden Valley
3 The Mell Fell Conglomerate
4 The Armboth Dyke, Thirlmere
5 The Skiddaw Granite in Sinen Gill
6 The Carrock Fell region
7 The Carboniferous Limestone between Caldbeck & Uldale
8 Borrowdale
9 The Buttermere Valley
10 The St. Bees Headland
11 The Granite of Lower Eskdale
12 Ordovician & Silurian Rocks of the Appletreeworth area
13 Greenscoe Quarry: an Ordovician Volcanic Vent

Appendixes:

I Bibliography and References
II Museum facilities in Cumbria
III Glossary of Geological Terms

Index

The book will be on sale in bookshops and through the Society at the price of £3.95.

VOLUME 1 (8 parts)

1962	part 1	32	pages
	" 2	24	"
1963	" 1	34	"
	" 2	36	"
1964	" 1	36	"
	" 2	30	"
1965	" 1	32	"
	" 2	26	"

VOLUME 2 (4 parts)

part 1	1966	58	pages
" 2	1967	46	"
" 3	1968-69	38	"
" 4	1969-70	56	"

£1.00 per part + 50p p & p per part.
Index to volumes 1 & 2 20p each (includes postage).

VOLUME 3 (4 parts)

part 1	1970-71	56	pages
" 2	1971-72	68	"
" 3	1973-74	70	"
" 4	1975-76 (includes index)	104	"

£1.00 per part + 50p p & p per part.
(first copy to new members .75p plus p & p).

VOLUME 4

part 1	1977-78	100 pages
part 2	1979-81	132 pages

£1.50 + 50p p & p.
(first copy to new members £1.00 plus p & p).

£2.00 + 50p p & p.
(first copy to new members £1.25 plus p & p).

SPECIAL PUBLICATIONS OF THE CUMBERLAND GEOLOGICAL SOCIETY

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