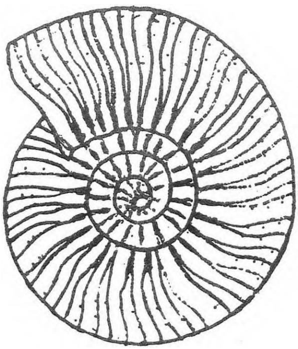
THE CUMBERLAND GEOLOGICAL SOCIETY



PROCEEDINGS

Volume 4 1982-83 Part 3

THE CUMBERLAND GEOLOGICAL SOCIETY

Honorary Life President:
E. H. Shackleton, F.G.S.

PROCEEDINGS
1982-83

Volume 4 **Part 3**

Published by the Cumberland Geological Society. May 1984

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EDITOR'S NOTE

The typing, art-work and page arrangements have again been carried out by Mr.J.D.Hinde, to whom I extend thanks on behalf of the Society.

I also thank all authors, lecturers, excursion leaders, note-takers, and friends in the Westmorland Society, who have made these Proceedings possible.

S.H.G.

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A VOLCANIC VENT AT COLT CRAG NEAR CONISTON, CUMBRIA.

C. R. Watson, M.Sc.

SUMMARY

During a re-survey of the area west of Coniston, Cumbria, a volcanic vent has been found within the succession of the Borrowdale Volcanic Group. It is located at Colt Crag and Crowberry Haws and is composed of vent agglomerate intruded near to the junction of the Yewdale Bedded Tuffs and the Tilberthwaite Group. The agglomerate is uniform and consists of andesite fragments partially fused together with intervening areas filled with feldspar. Only a few other examples of volcanic vents are known cutting the Borrowdale Volcanic Group. This new example gives a source of extrusion for at least part of the volcanic pile in the Coniston region.

1. INTRODUCTION

The volcanic vent lies 2 km to the north west of Coniston village on the eastern flank of the Old Man in Coppermines Valley (Fig. 1). Outcrops of the agglomerate are seen at SD 2800 9800 and SD 2830 9810 and may be reached by leaving Coniston by way of Dixon Ground Farm (SD 2996 9765) and following the footpath towards the Old Man. The prominent cliffs of Stubthwaite Crag and Crowberry Haws form part of the agglomerate outcrop and are clearly seen ahead when an old quarry track is encountered at SD 2845 9809.

Coppermines Valley is a favourite fieldwork locality of undergraduate and postgraduate students of geology and the Ordovician rock successions have thus been closely scrutinised. Original geological mapping was carried out by the Geological Survey in about 1877 - 82. Later the region was studied by Dr.G.H.Mitchell and a paper was published covering the Coniston and Tilberthwaite Fells (1940), this being the only readily available work on the area.

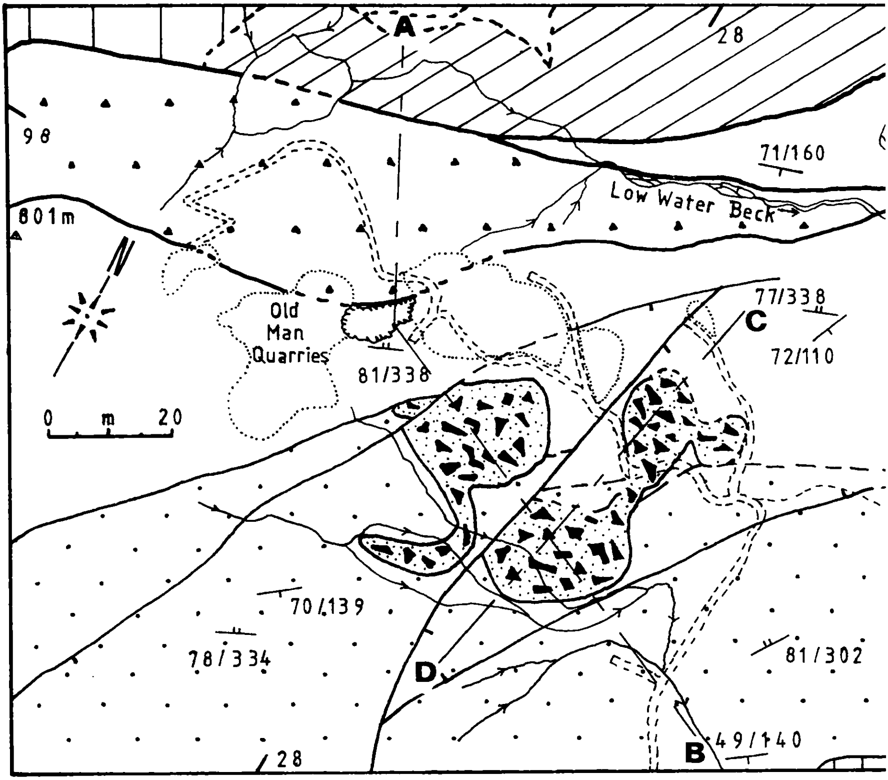
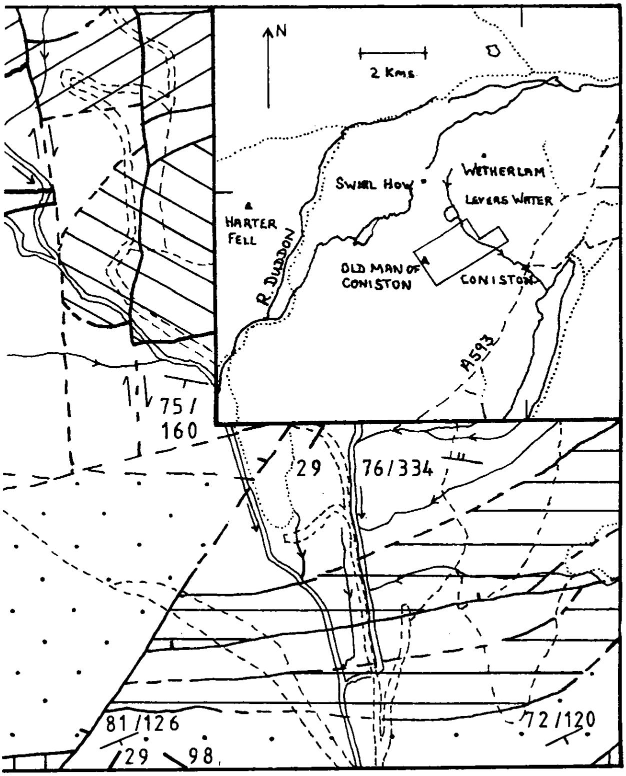


Fig.1 GEOLOGICAL SKETCH MAP OF THE COLT CRAG VENT, INSET SHOWING THE RELATIONSHIP WITH THE SURROUNDING AREA. (for key see Fig.2)

The Ordovician rocks of the Lake District range in age from Arenig to Ashgill and are believed to represent the products of a volcanic island arc adjacent to a south easterly dipping subduction of Iapetus oceanic crust. The succession around Coniston (Table 1) is part of the Borrowdale Volcanic Group, a thick pile of dominantly calc-alkaline lavas and tuffs, whose age is post-late Llanvirn (Didymograptus murchisoni Zone), pre-Ashgill (probably pre-Longvillian.

The Caledonian Orogeny produced the structural features in the area, the majority during the main phase of this orogeny, at the end of the Silurian or earliest Devonian, caused by continental collision after the closure of the Iapetus Ocean. However, folding of the group on a large scale was probably initiated before the Caradoc and Ashgillian marine transgression and is, according to



Soper and Moseley (1978), primary compressional buckling which affected the whole of the volcanic pile. These folds were also affected by the end-Silurian deformation to produce the structures we see today. Folding on this large scale is not observed in the area of study, although the region lies in the steeply dipping southern limb of the Wrynose - Nan Bield Anticline. The suggestion of isoclinal folding of the Borrowdale Volcanic Group reported with reservations by Mitchell (1940) but apparently abandoned by him after further study in an adjoining area (Mitchell, 1983), is confirmed as being absent by the present work.

The succession of the Borrowdale Volcanic Group in the Coniston area is a conformable sequence of tuffs and lavas, down at least as far as the Kidson How Tuffs, which dips steeply to the south east.

2. COUNTRY ROCK

The outcrop of the vent agglomerate occurs within the area which was mapped by Mitchell (1940) as part of the Wrengill Andesites and is approximately at this horizon. The Colt Crag Vent has pierced the succession of volcanic rocks which is outlined

Table 1 THE STRATIGRAPHICAL SUCCESSION OF THE CONISTON FELLS, CUMBRIA.

System	Series	Group/Formation	Thickness in metres
SILURIAN	Wenlock	Brathay Flags	150+
SILURIAN	LLandovery	Stockdale Shales	170
ORDOVICIAN*	Ashgill	Coniston Limestone Group	45
	u n c o n f o r m i t y		
ORDOVICIAN	Caradoc and Llandeilo	Borrowdale Volcanic Group including	4440+
		The Yewdale Breccia	450+
		The Yewdale Bedded Tuffs	350 - 100
		The Wrengill Andesite	120 - 0
		The Tilberthwaite Group	3520+
	b a s e n o t s e e n		

* The location of the Ordovician - Silurian boundary is in debate, but is here taken as the base of the Stockdale Shales.

in Table 1 and intersects the surface topography near to the conformable junction of the Yewdale Bedded Tuffs and the Tilberthwaite Group Tuffs. Both sets are waterlain, finely-bedded tuffs with a well-developed cleavage.

The Tilberthwaite Tuffs display collapse and flame structures as well as laminar and fine-scale ripple cross-bedding. These features are particularly clearly seen on the riven surfaces of the Old Man quarry tips. Ash-fall accretionary lapilli of a blue colour, as opposed to the grey-green of the main body, may be seen at various horizons, also indicating a shallow water depositional environment. The Yewdale Bedded Tuffs are lithic, dark green, medium-grained tuffs.

On the opposite (eastern) side of the valley to the tuffs the Wrengill Andesite is seen and occupies a position in the succession between the two sets of tuffs (Fig. 1). Near Low Blue Quarry at SD 2948 9857 a small clean face exhibits the basal contact of the

Wrengill Andesites:-

Flow banded grey-green andesite

30m nodular flow brecciated andesite

5m pillowed andesite

Cleaved Tilberthwaite Group Tuffs

The pillows indicate flow into water. The base of the set of flows is seen to burrow into the underlying tuffs, producing rafts up to thirty metres long and fifteen metres thick. The joint plane surfaces of the main body of andesite display fine ridges indicative of flow lamination. In thin section the andesite is seen to consist of small sparse feldspar phenocrysts and occasional larger chlorite filled vesicles in a fine-grained to glassy groundmass showing perlitic texture.

3. AGGLOMERATE

The outcrops of the agglomerate form Colt Crag, Stubthwaite Crag and Crowberry Haws (Fig.1). At Colt and Stubthwaite Crags the agglomerate is bounded by steep cliffs to the north, east and south, producing a prominent upstanding area. It is approximately elliptical and is about 220 by 160 metres in size. An agglomerate 'dyke' extends from the south towards the south east, and curves clockwise. It is about 250 metres long, and probably represents a large fissure in the adjacent tuffs. The other outcrop forms Crowberry Haws and areas to the south and east, descending in that order as ellipses connected by thin waists. The overall length is about 500 metres.

The agglomerate is intruded into the Yewdale Bedded Tuffs and Tilberthwaite Group Tuffs. The boundary between these tuffs may be followed with a good degree of certainty except in two places. Between the two outcrops there is a shallow valley along which lies a fault. To the west of this fault the tuff boundary is uncertain, as it also is to the east of Crowberry Haws where it is overlain by boulder clay and peat deposits.

The agglomerate boundary is quite certain, and it is easily traced around the foot of cliffs up to thirty metres high, whilst elsewhere it is easily distinguished from the surrounding tuffs. On weathering, the grey-green andesite fragments recede behind thin prominent ridges of feldspar, producing a network of white lines. The subangular to angular fragments vary in size from half to four centimetres across, and are well packed with feldspar infilling any remaining spaces.

In thin section the agglomerate reveals additional phenocryst phases to those of the Wrengill Andesite and also lacks quartz. These phenocrysts, mostly of plagioclase, but also of olivine, chlorite, calcite and occasional altered pyroxene are contained in a fine groundmass. Non-porphyritic areas up to five millimetres in diameter of a more coarse groundmass, and with indistinct boundaries, make up about a third of the rock. The presence of these areas indicate that the material has flowed at some stage.

A comparison of the Wrengill Andesites and the vent agglomerates provides several points of interest. They both consist of similar andesitic material and occur at the same position in the succession; however, the Wrengill Andesite is nowhere overlain by the Tilberthwaite Tuffs, whereas the agglomerates lie such that the Tilberthwaite Tuffs do outcrop stratigraphically above them, and some Yewdale Bedded Tuffs below them. As the set of tuffs appear to be conformable it is hard to envisage any lava flow capable of being extruded both before the end of the deposition of the Tilberthwaite Tuffs and yet after the beginning of the deposition of the Yewdale Bedded Tuffs. The pillows and burrowing features of the Wrengill Andesites are absent in the agglomerate. If the outcrops at Colt Crag are highly flow-brecciated lava flows a geometric reconciliation between flow behaviour and the outcrop shapes, even allowing for the strain caused by the cleavage, seems to be impossible. Major problems in such an attempt are the narrow areas between the main areas of andesite and the thin 'dyke', both being features which cut across the strike of the tuffs. Such a geometric reconciliation is simple if it is concluded that this body of andesitic material at Colt Crag is intrusive in nature.

The double outcrop is thought to be caused by faulting so that two sections of the main body are seen. The narrow areas between the main outcrops of the vent indicate that the body is bifurcating at this horizon, (see Fig.2). The dip of the vent is not known, but is shown dipping at a shallow angle to the north east in Fig.2a, as this seems the most likely configuration. The vent appears to terminate on the section (Fig.2a) as the line of section is oblique to the direction of dip of the body for part of its length.

Comparison of these outcrops with descriptions of vent agglomerates found in the Borrowdale Volcanic Group by Oliver (1961), Mitchell (1963) and Clark (1964) is favourable. This agglomerate is peculiar among these in the relative smallness of the fragments and the uniformity of the included material. It is worth noting, however, that it would be equally surprising for a series of flows not to contain clasts of the tuffs picked up from what would have been a most remarkable and precipitous topography.

If the whole of the Borrowdale Volcanic Group succession was extruded by the small number of vents presently recorded in the literature then the broad rationale is left quite unsatisfied. There must be more vents; but because of the high intensity of study of the Lake District rocks it is unlikely that the

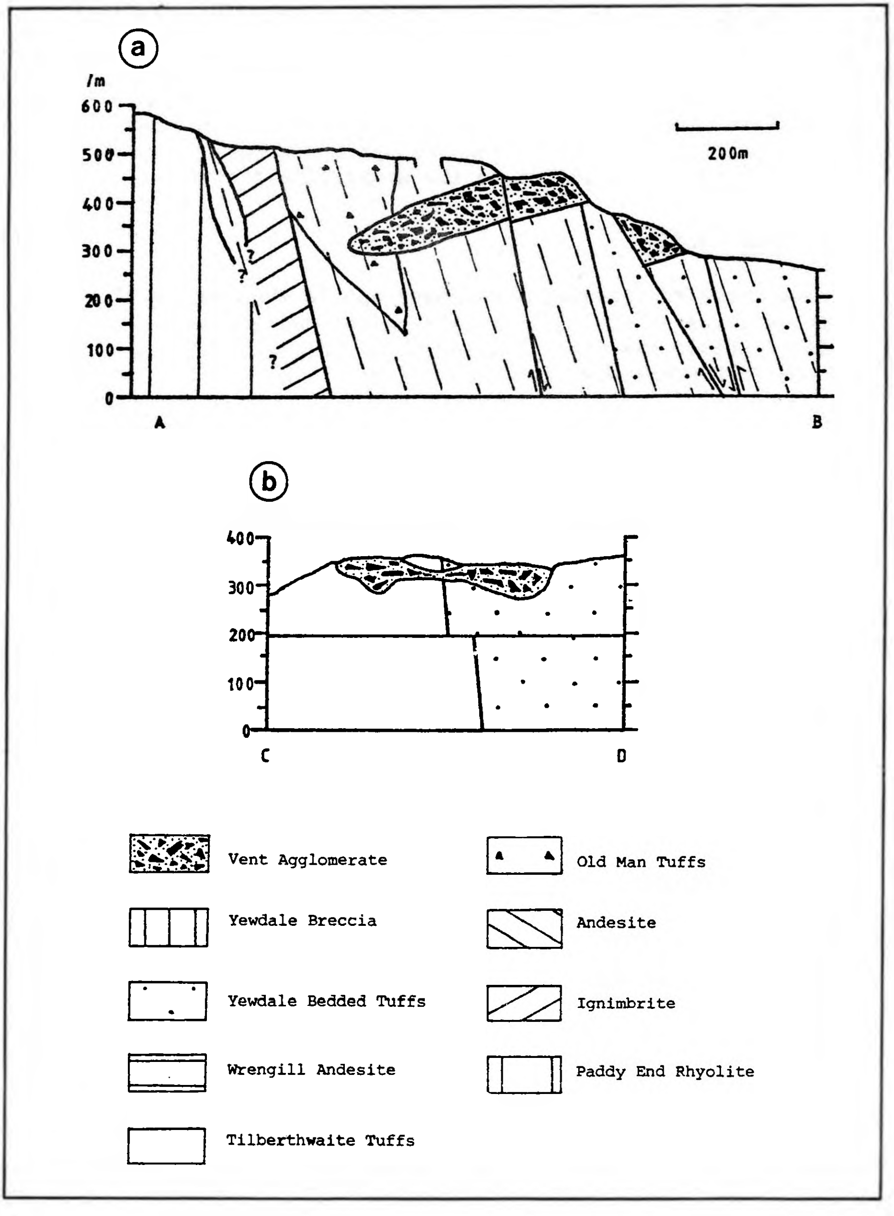


Fig.2 SECTIONS THROUGH THE COLT CRAG VENT. SECTION (a) IS OBLIQUE TO THE VENT AND THUS SHOWS CLOSURE IN DEPTH. SECTION (b) SHOWS THE VENT IN CROSS-SECTION.

undiscovered examples are in any way obvious. They must be cryptic features of the Borrowdale Volcanic Group with internal composition similar to the surrounding extrusive country rocks. It is therefore proposed that, despite a similarity with highly flow-brecciated lava flows, the outcrops of andesitic rock at Colt Crag are agglomeritic in nature, forming the upper regions of a vent which extruded material similar to the Wrengill Andesite.

4. ACKNOWLEDGEMENTS

I have cause to remember those many people who, during the course of my research, in various ways helped and guided me. In particular I should like to acknowledge the help of Dr.G.A.L. Johnson and Dr.C.H.Emeleus of Durham University.

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THE PHILOSOPHY OF STREAM SEDIMENT EXPLORATION AND INDICATIONS OF MINERALISATION FROM A STREAM SEDIMENT SURVEY IN THE WESTERN LAKE DISTRICT

A. Buckley, Ph.D.

SUMMARY

This paper presents a brief appraisal of the scientific background to stream sediment surveys as applied to mineral exploration. Using such techniques a number of base metal anomalies were found in the western Lake District; of these only two were considered to be related to previously unrecorded mineralisation. In comparison with the rest of the Lake District there is little known base metal mineralisation in this area, and few significant geochemical anomalies were observed. In view of this, and the lack of any apparent relationship between the geochemical dispersion patterns and the presumed shape of the underlying granite, it is suggested that the older intrusive bodies of the western Lake District exerted less influence on the location of base metal mineralisation than the succeeding Lower Devonian intrusions.

1. LOCALITY

The survey was carried out over the Lower Palaeozoic strata of the western Lake District (Fig.1) as an extension of the work of McAllister (1979, 1981). The geology is described in Moseley (1978) and is summarised on Fig.1. Briefly, a sequence of more than 3000m of strongly deformed Arenig sediments, the Skiddaw Slate Group, is overlain by 4000 - 8000m of Llanvirn - Llandeilo volcanics (The Borrowdale Volcanic Group). This succession is intruded by the Ennerdale Granophyre. Although the area is beyond the main region of Lakeland base metal mineralisation there are some minor occurrences and the hematite mineralisation is not insignificant. The former is indicated in Fig.1, the latter is not amenable to detection using the methods applied in this survey.

2. THE RATIONALE OF STREAM SEDIMENT SAMPLING

Since the early 1960's the chemical analysis of stream sediments has been used in mineral exploration surveys over much of the world. The primary importance of the technique is that it is possible to locate areas of anomalous metal concentrations in a region of mineral potential, the latter being identified by geophysical techniques, geological inference or records of past mining activity. It is based on the assumption that the products of weathering and erosion are channelled into the drainage system, and that the sediment's composition reflects the distribution of the minerals in the rocks and soils of the catchment; albeit subject to some modification by weathering processes. As the drainage system can provide a composite sample from a large catchment, the 'target area' is increased. Consequently the expense of a sediment survey is considerably less than that of many alternative methods, as fewer samples need to be collected and analysed to achieve the same coverage of an area.

If the ore minerals present are relatively resistant to weathering, anomalous metal concentrations in the sediments may be caused by detrital material. In such circumstances the analogy can be drawn between the analysis of sediment samples and the visual inspection of the heavy mineral concentrate produced by panning. Conversely, many minerals are readily oxidised on weathering and the resulting solutions can be dispersed by runoff or groundwater movements. This is particularly applicable to sulphides, such as are found in many of the Lakeland veins.

The base metal concentrations present in such solutions are too low to be conveniently determined by chemical analysis. However, many of the cations present are readily adsorbed by materials in the stream sediments. The resulting scavenging and concentration of base metals allows the dispersion patterns to be identified by chemical analysis of the sediments. Clay minerals and colloidal organic material are efficient adsorbers of base metal ions, but of more significance are the hydroxides and hydrous oxides of Fe and Mn which respectively form the brown and black coatings seen on many cobbles and finer sediments in stream channels. These coatings are produced by the oxidation of groundwaters and precipitation of their Fe and Mn content on entering the stream system; they are particularly well developed at the sediment/water interface.

As a consequence of this, stream sediment anomalies can be formed by the action of groundwater on mineralisation which is not directly intersected by the surface drainage system, and the contrast between background and anomalous metal concentrations is often enhanced. Furthermore, some elements occurring in minor minerals associated with a mineralised body may be particularly strongly adsorbed by these scavengers, so producing a larger

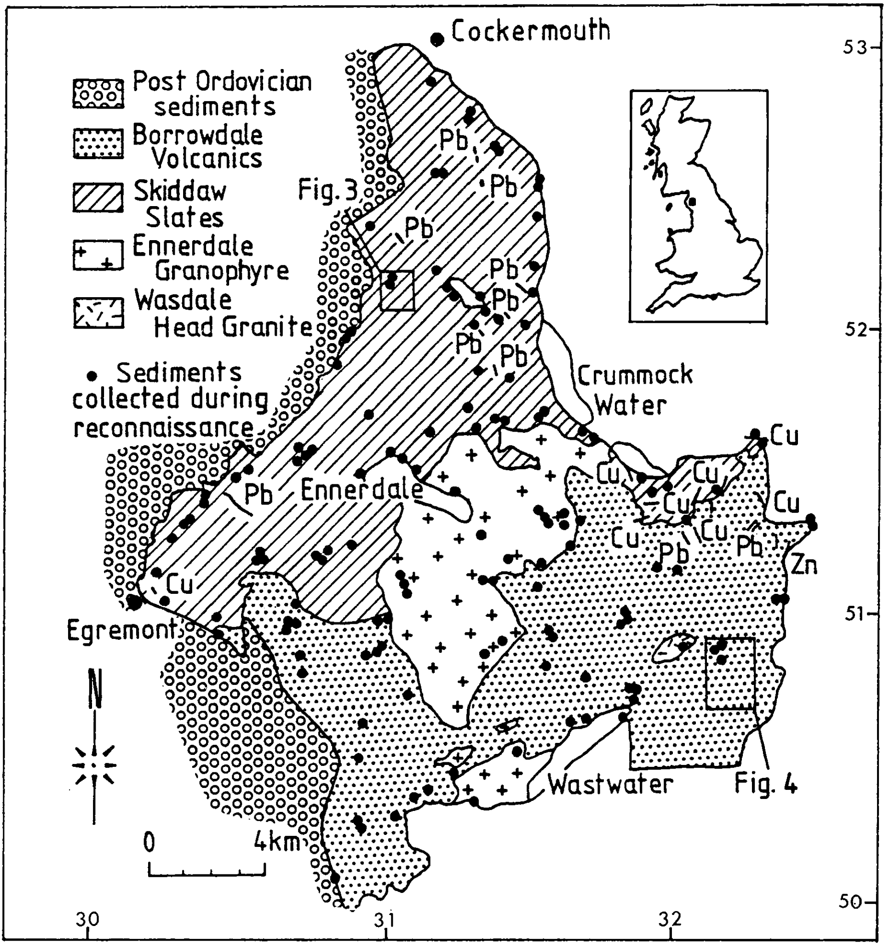


Fig. 1 GENERALISED GEOLOGICAL MAP OF THE SURVEY AREA SHOWING SITES OF RECONNAISSANCE STREAM SEDIMENT SAMPLES (•) AND LOCATION OF BASE METAL MINERALISATION. Data drawn from Ward (1876), Eastwood (1921), Dixon (1928), Eastwood et al. (1928), Strens (1962), Moon and Wildridge (1963) and Moseley (1978). Dominant base metals in veins indicated by Pb (lead), Cu (copper), Zn (zinc).

anomaly than the element of primary interest. An example of such a 'pathfinder element', specific to the Lake District, is arsenic. This has a low concentration in the igneous and sedimentary rocks of the area, but does occur in many of the sulphides and is strongly adsorbed by scavengers. A problem caused by the scavenging of metals is that under certain conditions 'false anomalies' (unrelated to mineralisation) may be formed by the concentration of background levels of trace elements at sites particularly rich in secondary Fe/Mn oxides. In order to make allowance for this the elemental abundance of Fe and Mn in the stream sediments should be determined in addition to that of any other metals of interest.

3. SAMPLING AND ANALYSIS

Numerous sampling techniques have been applied to stream sediment surveys: many of these are discussed by Levinson (1974) and Rose et al. (1979). The unifying feature is that, in an attempt to reduce sample variability, a specific grain size fraction of the sediment is analysed. In the case of this work about 2 kg of -2mm sediment was collected from the central part of the stream channels using a stainless steel scoop. This was dried in the laboratory and sieved in stainless steel sieves to -150μm (approx. 100 mesh ASTM). This powder was then ground in an agate disc mill and pressed into pellets for analysis by X-ray fluorescent spectrometry (Norrish & Chapell, 1977). Ti, Mg, Fe, Ca, K, Mn, P, Ba, Ce, Cu, Zn, S, Rb, Pb, Zr, Y, Th, U, Co, Ni, Cr, Sb, Mo, Bi and As were determined for 139 sediment samples from the 320km^2 area studied during the reconnaissance survey. More than 120 rock samples were also analysed in order to determine the background concentrations of the elements. Follow-up of anomalies found entailed the collection and analysis of a further 140 sediment samples.

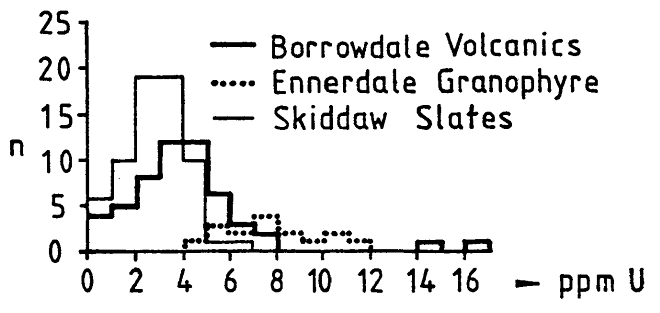
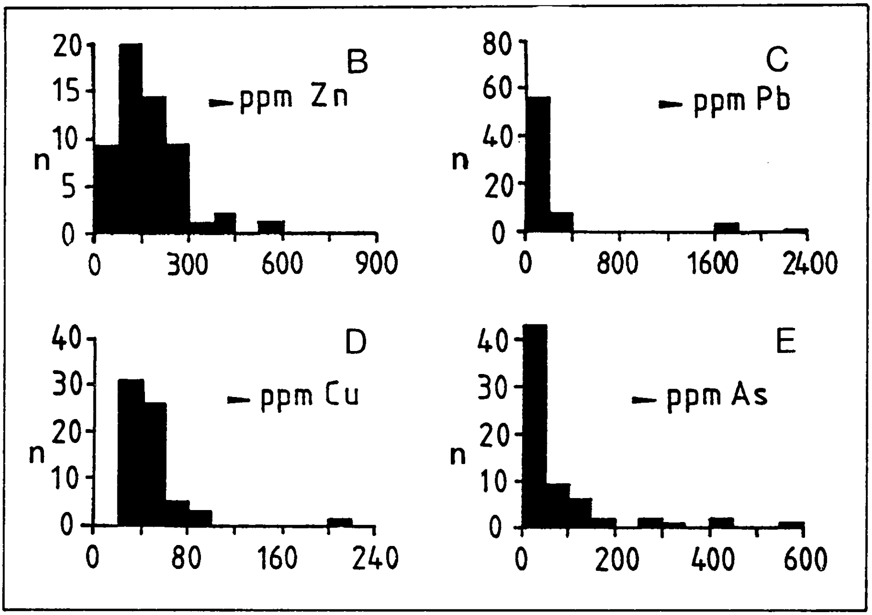


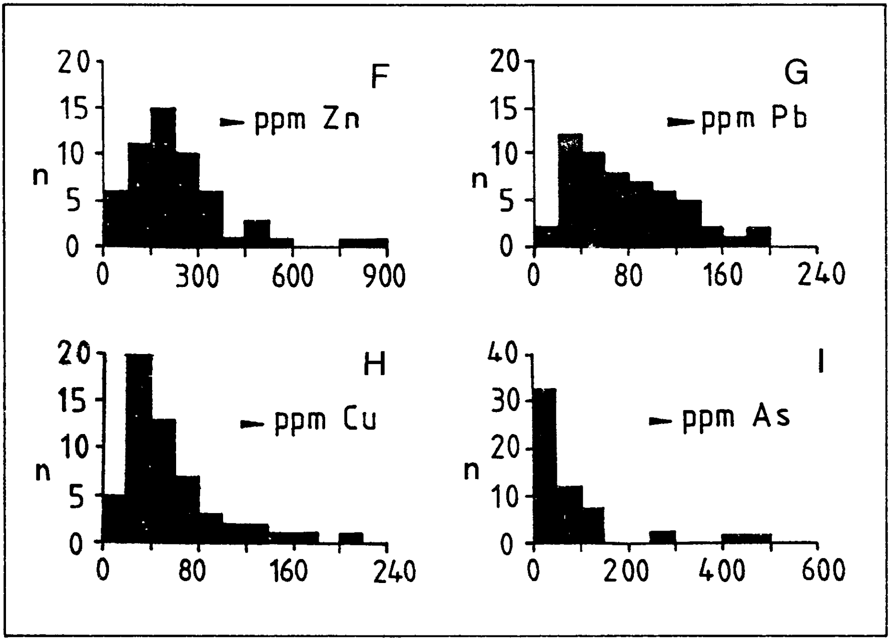
Fig.2A DISTRIBUTION OF URANIUM CONCENTRATIONS IN THE GROUPS OF STREAM SEDIMENTS DRAINING EACH OF THE PRINCIPAL LITHOLOGIES OF THE AREA (ALL RECONNAISSANCE SAMPLES PLOTTED). (n = number of samples having a particular concentration).



Figs.2(B)-(E). DISTRIBUTION OF Zn, Pb, Cu AND As IN ALL OF THE RECONNAISSANCE STREAM SEDIMENT SAMPLES COLLECTED FROM STREAMS DRAINING THE SKIDDAW SLATES.
(N.B. The data plotted on histograms 2(B)-(I) includes samples from sites of known mineralisation such as the old mines of Dale Head (NY 2216), Loweswater (NY 1421) and Wath Brow (NY 0414). In view of the strongly skewed nature of many of these histograms statistical parameters such as the mean and standard deviation are not presented).

4. DATA TREATMENT

Sampling and analysis of the area's three main lithologies revealed that the background levels of many elements varied from one lithology to another; furthermore, it is likely that some lithologies are more susceptible to leaching of particular elements than others. The latter point is well illustrated by the fact that, for many elements, the abundance in the sediments collected from the streams draining the Skiddaw Slates is similar to the lithogeochemical abundance: this is not so in the case of the Borrowdale Volcanic or granophyre derived sediments. A likely explanation of this is that the Skiddaw Slates have already undergone one cycle of erosion and re-deposition during which many of the less stable minerals were broken down.



Figs.2(F)-(I). DISTRIBUTION OF Zn, Pb, Cu AND As IN ALL OF THE RECONNAISSANCE STREAM SEDIMENT SAMPLES COLLECTED FROM STREAMS DRAINING THE BORROWDALE VOLCANICS.

In view of these considerations the sediment samples were separated into three groups on the basis of the lithology drained by the streams; as an example of this Fig.2A shows the distribution of uranium in the three groups of stream sediment samples.

5. ANOMALIES DETECTED AND THE RESULTS OF FOLLOW-UP INVESTIGATIONS

All of the known base metal occurrences in the area were identifiable from the reconnaissance data with the exception of the copper mineralisation reported by Eastwood et al. (1931) at Egremont. The latter is at some depth and is very close to the edge of the survey area. A number of anomalies which were unrelated to known mineralisation were also observed; two of these are described below. In addition to these the reconnaissance data pointed to the presence of a barium anomaly in the Skalderskew area (NY 0807). Further examination revealed that this was a false anomaly, produced by a high background barium content in the underlying Borrowdale Volcanics.

(a) Black Beck, Lamplugh (NY 103 223)

The sample distribution and geology of the area (the latter as recorded by Eastwood et al., 1931) are shown on Fig. 3A. The reconnaissance samples from Black Beck and Meregill Beck were separated by only 100m and the streams drain the same area of fellside; however, the abundance of Pb and As in each sample was found to be vastly different. The nearest known sites of mineralisation are at Sosgill (NY 104 236), Highnook (NY 123 201) and Whiteoak Beck (NY 130 199), all more than 1km away. Pb mineralisation is dominant at these localities but, from a consideration of the topography, none is likely to be the cause of the Black Beck anomaly.

The stream drains an area of marshy land and the sediments were rich in Fe and Mn. There are a number of springs on the fellside which have been utilised for water supply. Possible causes of the anomaly are:-

i contamination by water board activities, e.g. pipework,

ii strong accumulation of Pb and As by Fe and Mn oxides,

iii mineralisation in the area.

It seems unlikely that the anomaly is due to contamination as there are similar water board installations in the neighbouring Meregill Beck; furthermore, soil sampling across the pipework revealed no anomalies.

The results plotted on the maps of Figs. 3(B)-(E) can be compared with the data on the histograms of Figs. 2(B)-(E) which show the corresponding elemental abundances in all of the stream sediment samples collected from the Skiddaw Slate drainage during the reconnaissance survey.

The Pb content of the sediments from this locality is in excess of that from known sites of Pb mineralisation in the Lake District, and far in excess of that found at sites of strong Fe/Mn scavenging. Elements such as Co, Zn and Cu have not formed marked anomalies despite the fact that they are readily accumulated by the hydrous oxides of Fe and Mn, and are found at observed sites of strong scavenging in the Lake District. In addition the background level of As in the Lake District is low (the mean As content of the Skiddaw Slates is <20 ppm) and it is rare that false anomalies of this element occur. For these reasons it is unlikely that scavenging of Pb by Fe/Mn precipitates is solely responsible for this anomaly.

Follow-up sampling showed that the anomaly could be traced to an area of marshy ground draining into Black Beck (Fig. 3(C)). No outcrops are present in the immediate area but the drystone walls around the field contain an unusual abundance of quartz-rich

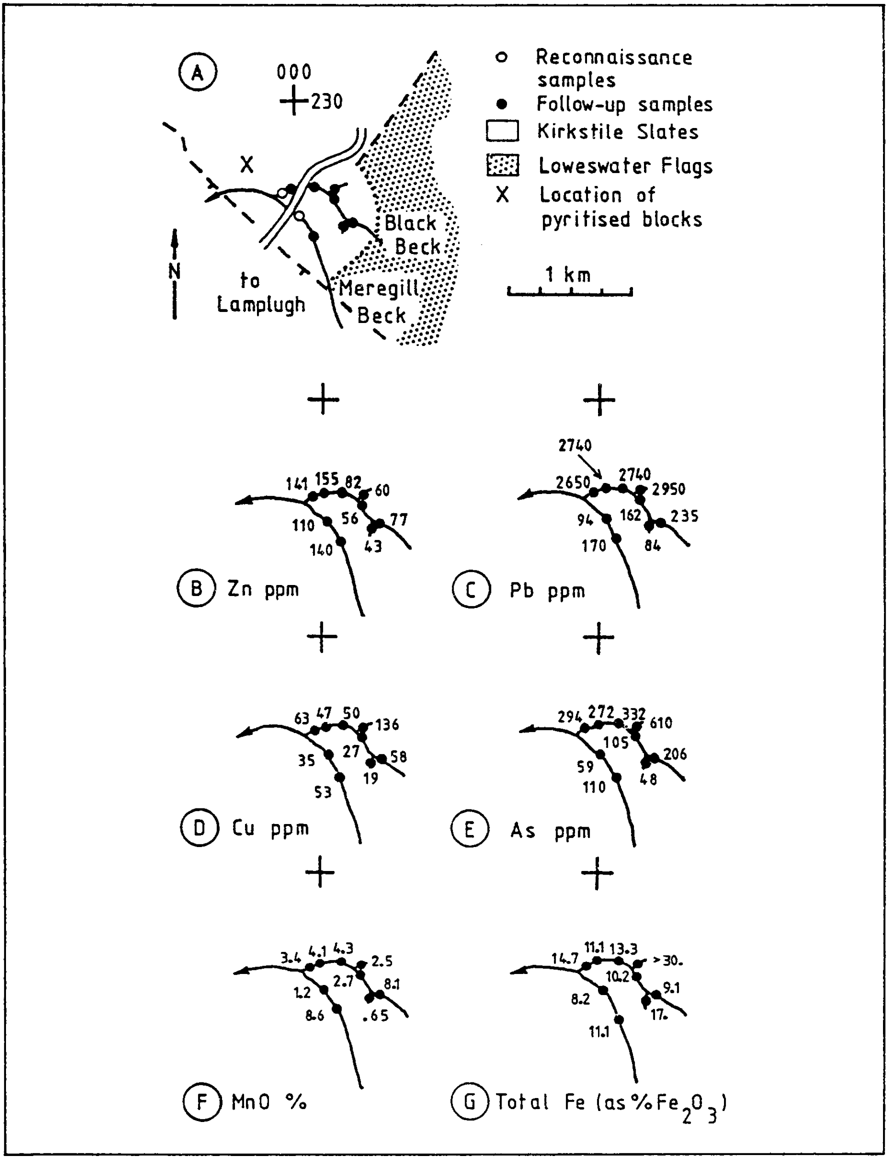


Fig. 3 (A) SAMPLE SITES AND GEOLOGY OF BLACK BECK AREA, after Eastwood et al. (1931).

(B)-(G) DISTRIBUTION OF ELEMENTS IN STREAM SEDIMENTS AT BLACK BECK.

boulders and a number of strongly pyritised quartz blocks were found in the drift a short distance downstream of this site (NY 098 223).

These observations suggest that the anomaly is derived from concealed mineralisation in the area. In view of the lack of exposure in the area it is not improbable that the NE/SW trending fault shown on Fig.3(A) actually extends further to the SW and that there is mineralisation located therein - most of the Lakeland mineralisation is fault controlled. Furthermore, the fault would bring Loweswater Flags into contact with the less competent Kirkstile Slates, the former being the best host rock for mineralisation in the Skiddaw Slates.

Any further exploration in this area would be best conducted using geophysical techniques.

(b) Piers Gill, Scafell (NY 2108)

The geology of the area (after Oliver, 1961) and the distribution of samples are shown on Fig. 4(A). The rocks comprise a sequence of Borrowdale Volcanics cut by a number of NW/SE faults and lie near the axis of the Scafell syncline. The nearest known base metal mineralisation is close to Seathwaite, more than 3km to the north (NY 2312).

Examination of Figs. 4(F) and (G) shows that the Mn and Fe abundances are generally low. Comparison of the data shown on the other maps of Fig. 4 with the histograms of Figs. 2(F)-(I) reveals that both As and Zn are fairly abundant at some sites, particularly in Piers Gill, Spouthead Gill and Girla Gill; there are also some sites showing above average levels of Pb and Cu in these streams. Both Girla Gill and Piers Gill are fault guided, as are many of the streams hereabouts; there is extensive calcite veining (up to ½m in width in Piers Gill) and pyrite and chalcopyrite can be found in association with calcite strings, particularly in Girla Gill. Thus there is definite evidence of base metal mineralisation in the area and it is highly likely that there is concealed mineralisation in the vicinity of Spouthead Gill.

The mineralisation of Piers and Girla Gills occurs particularly within the more acidic rocks of the Borrowdales (especially the 'massive rhyolites' and 'hornstones' of Oliver's (1961) succession) rather than in the immediately underlying andesitic material. The former are often silicified and brittle, hence more conducive to the formation of voids when fractured; because of this such lithologies are preferentially the host rocks for a number of the significant Lakeland veins, e.g. the Coniston copper veins (Mitchell, 1940; Dagger, 1977). As the sampling indicates that the Spouthead Gill anomaly has its origin in the upper part of the drainage, where the stream is fault guided, it is

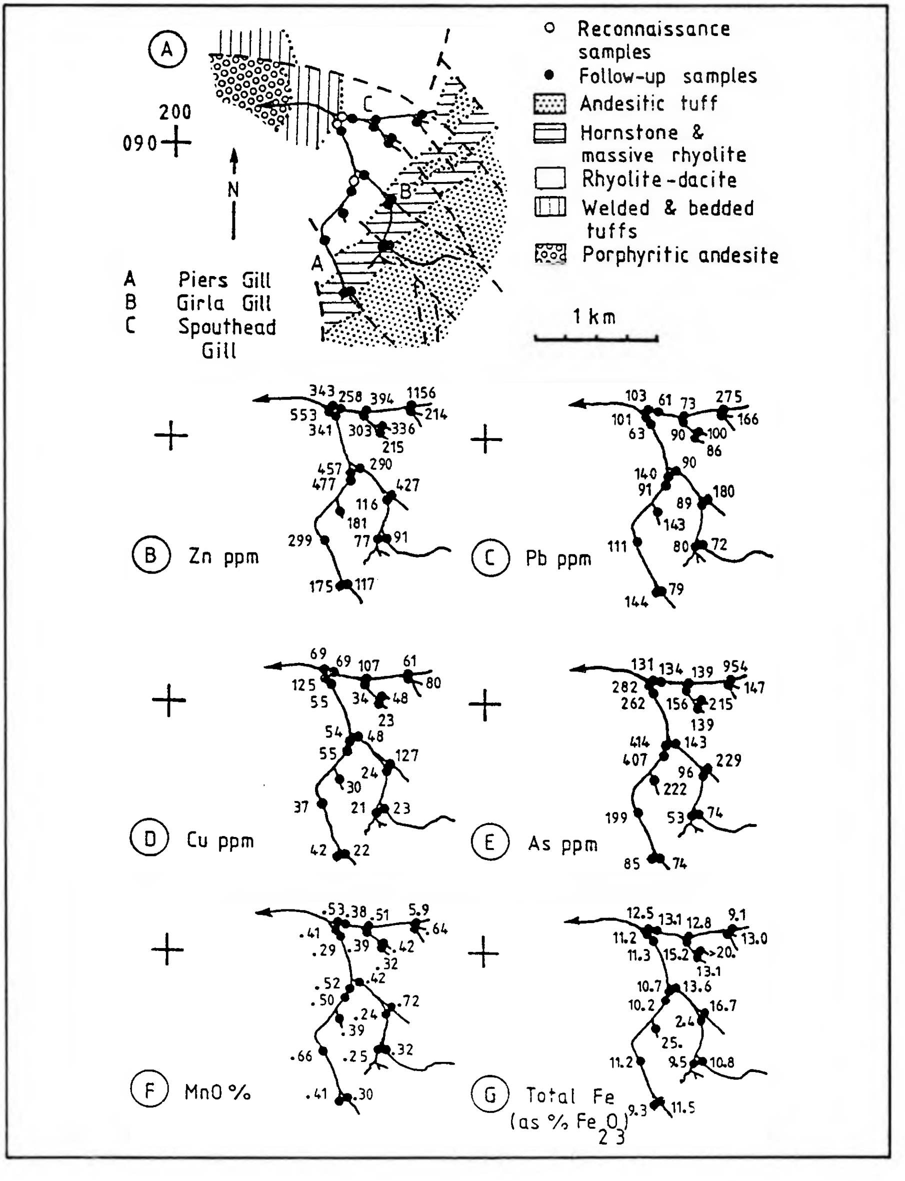


Fig. 4 (A) SAMPLE SITES AND GEOLOGY OF PIERS GILL AREA, after Oliver (1961).

(B)-(G) DISTRIBUTION OF ELEMENTS IN STREAM SEDIMENTS IN PIERS GILL AREA.

likely that this mineralisation is present in a similar horizon.

It appears probable that the mineralisation is virtually stratabound and, as is often found in the Lake District, of very variable tenor. Furthermore, the locality overlies part of the negative Bouger anomaly of the Eskdale Granite (Bott, 1974, 1978) which is not an area renowned for the abundance of its non-ferrous mineralisation.

6. CONCLUDING REMARKS

On the basis of this geochemical survey Piers Gill and Black Beck were the only sites, other than the areas of known mineralisation, which could be considered genuinely anomalous. Although it cannot be categorically stated that there are no other base metal occurrences in the area, the fact that only two significant anomalies were located over about 320km^2 suggests that the early miners were thorough in their prospecting; they were no doubt aided by the considerable degree of exposure over much of the area. Furthermore, there is little geochemical expression of the numerous mineral deposits which Cruzat and Meyer (1974) forecast on the basis of a statistical examination of a series of geological and geochemical parameters. In this respect the results are similar to those of McAllister (1979, 1981) who found only two significant base metal anomalies, unrelated to previous mining activity, in an area extending from Wastwater to Black Combe and Coniston.

In order to relate this work to the overall distribution of mineralisation in the Lake District it must be borne in mind that most of the known copper mineralisation is located above the ridges in the roof, or along the walls around the body of granitic material indicated by Bott's (1974, 1978) gravity survey of the Lake District. This, and the occurrence of varied base metal mineralisation in and around some of the granitic intrusions of the Lake District has led many workers to consider that the underlying granitic bodies have exerted some control over the location of the area's base metal mineralisation - especially the copper veins. For example, these bodies may have provided a source of heat which initiated a system of convective circulation, or their intrusion and later isostatic uplift may have resulted in the development or re-activation of fracture systems. However, it is now clear that the 'Lake District Batholith' is actually a composite body which has developed in a number of stages (Rundle, 1979, 1981), and the present survey has highlighted the sparsity of significant geochemical anomalies or base metal mineralisation in the vicinity of the Upper Ordovician intrusions of Rundle (1979) - particularly the Eskdale Granite and the Ennerdale Granophyre. This contrasts with the presence of mineralisation in and around the two main Lower Devonian bodies, the Shap and Skiddaw Granites. Furthermore, the geochemical dispersion patterns in the western Lake District show little relationship to the presumed shape of the underlying granitic intrusions. As both of these chronologically distinct groups of granites cut essentially similar lithologies it would appear that the earlier intrusions have had a less positive influence on the location of base metal mineralisation in Lakeland.

Despite recent studies on both a general level (e.g. Wheatley, 1971; Firman, 1978 and Stanley & Vaughan, 1982a) and on a more local scale, (e.g. Stanley & Vaughan, 1982b), it has as yet proved impossible to clearly define the controls acting on the Lakeland mineralisation and hence produce a predictive model. In view of this consideration, and the possibility that there may be small mineral deposits concealed elsewhere in the Lake District, geochemical prospecting must be regarded as one of the more useful techniques available for exploration in this area.

7. ACKNOWLEDGEMENTS

The work described in this paper was undertaken as part of a Ph.D. study at the University of Nottingham and was supported by a NERC research studentship, which is gratefully acknowledged. The author wishes to thank colleagues at the Department of Geology, particularly Dr.R.J.Firman, for discussion and critical comments.

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CLASSIFICATION, AGE AND ORIGIN OF THE CUMBRIAN HEMATITE.

Sir Kingsley Dunham F.R.S.

SUMMARY

The hematite deposits of West and South Cumbria have been classified in a United Nations Report with the Bilbao type in which the protore is ferriferous carbonate. This is demonstrably incorrect for the Cumbrian ores, in which the hematite is primary in a gangue of dolomite and quartz, with calcite from the limestone wallrock. The total quantity of all other minerals (blue fluorite, baryte, chalcopyrite, pyrite) represents less than 0.001 per cent of the ore as a whole. Geochemically these ores could hardly be more different from the Bilbao-type iron hydroxide/ carbonate ores of the northern Pennines, or from the non-ferrous deposits of that orefield and the Lake District. The geological facts, including the presence of epigenetic hematite ore in Sherwood (St. Bees) Sandstone wallrock favour a post-Triassic age, but in direct conflict, palaeomagnetic observations by El-Nikhely and Evans, following earlier work by DuBois are interpreted as indicating a Permian date. There is evidence from the Brockrams that pre-Permian hematite existed but there must be serious doubt as to whether it had been concentrated into multi-million tonne deposits. The state of genetic controversy as the hematite orefield disappears under the green fields of Cumbria for ever is briefly reviewed.

1. INTRODUCTION

The occasion of the joint visit of the Cumberland and Yorkshire Geological Societies to Florence, the last remaining active hematite mine in the county celebrated during the past century for its output of high-grade, low-phosphorus iron ores was a suitable one for a sober review of established geological facts and the interpretations placed upon them. Soon the workings will have been obscured totally by land restoration, save perhaps for the little lakes in the subsidences over the larger sops in Furness, and before long no living geologist with first-hand personal knowledge of the underground detail of these remarkable deposits will remain. This short paper is based upon an invited lecture to the Societies at Whitehaven on the evening of 16th July, 1983. The geological background, familar or accessible to all, will not be described; instead, areas of agreement and of disagreement will be indicated.

2. CLASSIFICATION

It is pertinent first to inquire how the Cumbrian iron ores stand within the worldwide family of metalliferous ores. Firstly, we can all agree that they are epigenetic, that is, introduced into their wallrocks after these had become lithified. No-one to my knowledge has suggested a sedimentary or syngenetic mode for these deposits for such a position could not be maintained in the face of the clear evidence of emplacement in faults as veins, in joints as ginnels, and of metasomatism of limestone so complete that fossils are preserved in hematite or quartz, and shale beds or lines of chert nodules pass through the flat orebodies (Kendall, 1875).

All should also agree that the classification of the Cumbrian hematites as Bilbao-type in the United Nations Report of 1968 is fundamentally mistaken. The Bilbao type consists of deposits formed by the oxidation of underlying iron carbonates. There is not a scrap of evidence that Cumbrian hematite originated in this way. Systematic collection of the carbonates associated with the Furness orebodies (Rose & Dunham, 1977, p.83) and subsequent optical and XRD determination by R.K.Harrison and B.R.Young showed that only dolomite ($MgCO_3.CaCO_3$) and calcite are present and there is no evidence of any kind to suggest in situ oxidation of siderite ($FeCO_3$) or ankerite ($Mg,FeCO_3.CaCO_3$). The discovery by Brian Young (this volume, page 267) of a few late siderite crystals at a West Cumbria mine dump in no way changes this conclusion, as he is the first to agree. The generally oxide rather than hydroxide character of the ores is a marked distinction from the hydroxide/carbonate iron ore of Weardale and Alston Moor (and of Ardale and Dun Fell on the Pennine Escarpment), which are unquestionably oxidation products of epigenetic ankerite and siderite (Dunham, 1948, p.108).

In all the deposits, hematite predominates, usually greatly, over the other constituents, among which only a manganese oxide mineral, quartz, dolomite and calcite occur in more than trace or minor amounts. While the beautiful small blue fluorite crystals, found lining cavities with specular hematite, baryte and quartz at Florence - Beckermet and a few other mines have been much prized by mineral collectors, it must be remembered that their total bulk cannot have reached 0.001 per cent of the ore as a whole. The absence of sulphides, almost total save for Anty Cross in Furness, where an earlier body of copper sulphides had become engulfed by hematite, is remarkable. In Furness, no fluorite was found, but very rare pseudomorphs or epimorphs in hematite might perhaps represent its former presence. Trace-element analyses of typical hematite (Rose & Dunham, p.86) showed the metals Cu, Ni, Pb and Zn to be present in amounts mainly less than normal continental background. Only As was found to be anomalously high (up to 1820 ppm). How different, geochemically, from the non-ferrous ore deposits of the Lake District Lower Palaeozoics, where all the sulphide-forming elements listed above are strongly represented, and where baryte is an important gangue mineral. Of course, hematite veins occur in Skiddaw Slates and Eskdale Granite beyond the eastern margin of the West Cumbria Carboniferous, but it is noteworthy that the mineralogy of these offers no evidence of transitions to the non-ferrous suite, nor do any of the non-ferrous veins carry hematite, only the hydroxide goethite. The contrast between the Cumbrian hematite deposits and the epigenetic ores of the Pennines is still greater. Goldring & Greenwood's (1977) discovery of fluoritized limestone at Florence fails to provide an acceptable transition.

The Cumbrian hematite ores thus deserve a category of their own, as epigenetic, anhydrous, low-phosphorus, low-sulphur iron oxide ores in limestone environments. Curiously enough to those of us who take for granted the Cumbrian scene, there are few parallel cases worldwide, though one small one will be mentioned below.

3. AGE

It is well known that hematite of pre-Upper Permian age exists in northern England, from the evidence of pebbles of the mineral found, albeit in very small numbers, in the Brockram flood-breccias. They are easier to find in the Vale of Eden, for example in quarries near Hoff and Kirkby Stephen, than in West Cumbria. There is also widespread evidence that a period of intense lateritization occurred under the hot, humid conditions of latest Carboniferous times, leaving its imprint in the form of a deeply reddened zone affecting the rocks immediately underlying the land surface of the time (Trotter, 1939; Anderson & Dunham, 1953). Hematite was produced by these palaeolaterite soils and could have provided the pebbles in the Brockrams. Hard hematite is a common constituent of modern laterites, and it does not appear necessary to accept Trotter's (1945) suggestion that the pebbles were hematized *in situ* in the breccias. While it is more than probable that the weathering of these laterite soils provided the skins of hematite covering the grains in the Upper Permian Marl and the St. Bees Sandstone (Dunham, 1953), it is very difficult to picture how the iron concentrated during laterization could be further concentrated into the great orebodies of hematite in the Carboniferous.

Four lines of evidence point to orebody formation as a late - or post - Triassic event:

(i) In all three iron orefields (West Cumbria, Millom and Furness) the dominant direction of the vein oreshoots is north-west. This, according to Eastwood, Dixon, Hollingworth & Smith (1931), well supported by later observers, is the direction of post-New Red Sandstone faulting and indeed some veins have been emplaced in faults that cut Permian and Triassic rocks. By contrast, the proved pre-Permian ('Hercynian') fault set trends north-east and very seldom carries mineralisation; it must be assumed to have been closed during the post-New Red Sandstone tensional period. J.D.Kendall (1882, 1920) eventually favoured a pre-Permian age, thus involving more than one period of movement on the north-west faults, but on this, Eastwood et al. (1931, p.20) say that this conclusion cannot be maintained; with very few exceptions, it is difficult to find any evidence to support it.

(ii) The great Yarlside orebody, east of Furness Abbey, was worked against a hangingwall of St.Bees Sandstone along the Park - Yarlside Fault. Bernard Smith (1923) speculated upon the possibility that the sand was piled up against a cliff of Carboniferous Limestone containing the orebody, but the bedding in the sandstone and the tectonic setting are both against any such conclusion. The St.Bees Sandstone for some distance from the wall of the hematite had been softened by leaching of the quartzose matrix, presumably by the mineralizing fluids (since this effect is not seen elsewhere in the St.Bees Sandstone). The sand was worked for moulding sand as the hematite was mined, both destined for the Barrow foundries. Boreholes south-west of Egremont showed (Trotter, 1945) ore with red sandstone on both walls, clearly indicating mineralisation post-dating St.Bees Sandstone.

(iii) The large sops of the Park and Roadhead mines had central cores made up of large jumbled blocks of St.Bees Sandstone, lithologically perfectly recognisable but bleached of most of their grain-covering hematite. The sops are major karst features, originating like swallow holes but receiving hematite mineralisation during the first two-thirds of their development. It is possible that the karstic processes started on the pre-Permian surface but not very likely, otherwise there would be sand at the bottom of the sops and direct observation showed that this was not the case.

(iv) The absence of hematite orebodies beneath the Coal Measures, or underneath St.Bees Shales indicates that a direct connection from the highly permeable sandstone into the limestone was a condition of formation. This is well attested by the work of the Cumberland Unit of the Geological Survey (Smith, 1923; Eastwood et al., 1931; Trotter & Rose, 1937) and the primary survey in Furness (Rose & Dunham, 1977) supplied striking confirmation. Whether the mineralizing fluid was seen as meteoric water, juvenile-hydrothermal fluid or resurgent connate brine, the role of the St.Bees Sandstone as a reservoir from which fluids descended into karstified limestone appears to be a necessary one. In support of the descent into the limestone, it may be noted that all the large hematite flats have formed in the bottom parts of the limestone unit in which they occur, resting on shale beds or partings. This contrasts markedly with the non-ferrous mineral flats in the Northern Pennines, where the favoured position is the 'High Flat' or a comparable horizon.

4 A CONFLICTING VIEW

Palaeomagnetic dating of seven oriented specimens from Florence Mine and three from Beckermet by A.M.Evans and A.El-Nikhely (1982) has led to a quite different conclusion. After demagnetisation, pole positions for the specimens were plotted on a polar wandering curve based upon the best available data, giving ovals of confidence not on the curve, but nearer the Permian than the late Triassic points. While the Permian and Triassic positions are not regarded as the most reliable points on the European polar wandering curve, and the number of measured samples is small, the results are far removed from the Tertiary position or even a late Jurassic ('Cimmerian') position that would seem most probable from the geological evidence.

5 DISCUSSION

The palaeomagnetic results are therefore in direct conflict with most if not all interpretations of the geological evidence, at any rate since J.D.Kendall's time. To resolve the problem, the palaeomagnetic result may be queried on the basis of the possibility of longitudinal error, and perhaps more appropriately because the Lake District block may have rotated as a whole since the Florence orebody was formed, for example in connection with the opening of the Atlantic Ocean. A large rotation is generally accepted for the whole Iberian Peninsula while in Southern California it is now becoming necessary to introduce a 'microplate' concept to explain numerous anomalies in palaeomagnetic results. Several writers on North of England structural geology have postulated rotation of the Pennine fault-blocks. Rotation of the Lake District against the Pennine-Dent fault-system and against a conjugate system that may join the Craven faults to the Stainton Fault in Furness is one that should be checked by independent palaeomagnetic evidence.

Should it eventually be established that the Florence and

Beckermet orebodies are in fact Permian in age, then (a) more than one period of hematite ore emplacement might be proposed, but this is unlikely to meet easy acceptance; (b) post-ore movement must have occurred on all or most of the north-west veins, though it is strange that in a century of geological investigation, this has gone unrecorded; (c) the apparent connection between the absence of argillaceous, impermeable strata (Westphalian or St.Bees Shale) separating permeable sandstone and karstified limestone, and the origin of the orebodies, will become invalid.

This last has important industrial implications, for it would follow that orebodies might be expected to occur beneath the Whitehaven Coalfield, or under the offshore extension of the district south-west of Egremont, or beneath the two large areas of Triassic outcrop north and north-east of Barrow-in-Furness. Some capital was invested in deep drilling of certain onshore areas during the great developmental days in Furness, and it was a particular disappointment that no trace of ore was found south of the St.Bees Sandstone onlap at Park and Roanhead, where the feather-edge of the St.Bees Shale comes on. Ought more prospecting to be done, or is a pre-St.Bees Shale age for the hematite illusory?

Whatever the conclusion of this may be, I would reinforce Shepherd's (1973) view that the mineralising fluid was warm hyper-saline brine, not of juvenile origin as Evans & El-Nikhely imply; and to appeal for experimental work on chloride-iron complexing in which virtually no other metals are leached.

I conclude on a personal note. Several years before I was assigned by Tommy Eastwood to the primary survey of the Furness iron ore field, I had made an investigation, in collaboration with its Bureau of Mines, of the mineral deposits of Dona Ana County, State of New Mexico, U.S.A. The principal igneous centre here in the Sierra de los Organos, where quartz-monzonite intrudes lime-stones from Cambrian to Pennsylvanian, has a staggering array of non-ferrous metal ores associated with it. Far remote from this centre, limestones of the Carboniferous Magdalena Formation at Iron Hill on Robledo Mountain are cut by veins and replaced by flats of hematite which streak as red as that of Cumbria, and with quartz as almost its sole associate. The overlying red Abo Sandstone (Permian) seemed, and still seems, the only reasonable reservoir for concentrated Fe_2O_3 at hand (Dunham, 1935, 1980).

6. ACKNOWLEDGEMENTS

It is a pleasure to acknowledge the important work done by my collaborator of Furness days, Mr.W.C.C.Rose, but he should not be held responsible for all the views expressed here. Dr. Ronald Girdler of Gray College advised me on geophysical aspects, and my seminarist Mark Kitching took an independent look at the problem.

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SIDERITE FROM THE WEST CUMBRIAN HEMATITE DEPOSITS

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(Short communication)

Siderite occurs locally in very small quantities as a gangue mineral in the West Cumbrian hematite deposits. Kendall (1893) and Smith (1924) refer to the occurrence of 'iron carbonate' in vugs in the orebodies, and Trotter (1945) described siderite encrusting kidney-ore at Crowgarth Mine (NY 0140 1530), Cleator Moor. As no specimens from these occurrences are known to have survived it has not been possible to confirm that the minerals described were, in fact, siderite rather than ankerite or dolomite. More recently Shepherd (1973) observed that siderite was rather more common in the Lamplugh, Eskett and Yeathouse areas than elsewhere in the orefield, though no description of the mineral or its paragenesis is given. Despite a careful search neither siderite nor ankerite were identified in the hematite deposits of South Cumbria and Furness (Rose & Dunham, 1977).

Specimens collected recently by the writer from the dumps of two mines in the Frizington area have been confirmed as siderite. At Windergill Mine (NY 0524 1746) siderite (refractive index n_ω>1.795) forms crudely botryoidal, fawnish-brown crystalline masses up to 10 mm thick, the surfaces of which display curved rhombic faces up to 2 mm. The siderite encrusts large (up to 25 mm) colourless, bi-pyramidal quartz crystals, which in turn locally encrust kidney-ore. At the nearby Postlethwaite's Eskett Mine (NY 0546 1716) pale fawn siderite (refractive index n_ω>1.795), forms compact crystalline masses up to 30 mm thick encrusting kidney-ore. Small drusy botryoidal surfaces similar to those at Windergill, occur locally. The siderite here is overgrown by a rather coarser-grained, pale fawn carbonate (refractive index n_ω<1.735) considered to be a ferroan dolomite. The siderite from both localities shows brown oxidised outer surfaces.

In all these occurrences siderite post-dates hematite and is clearly a late-stage gangue mineral which cannot be regarded as a protore of the hematite mineralization.

Refractive index determinations by Dr.N.J.Fortey are gratefully acknowledged.

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GEOLOGY AND HISTORY OF

NAB GILL MINE, ESKDALE, CUMBRIA

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INTRODUCTION

Within the Eskdale Granite many small mines have been worked and trials made on hematite veins. Of these the Nab Gill Mine at Boot (NY 1755 0120) was by far the largest both in the extent of the workings and in total ore production. Brief accounts of the mine have been given by Smith (1924), Hibbert et al. (1940) and Davies (1968).

1. GEOLOGY

The Eskdale Granite, which forms the country rock of the Nab Gill deposit and most of the other Eskdale hematite veins, forms part of the extensive granitic batholith which underlies much of the Lake District (Bott, 1974 & 1978).

Much of the northern part of this intrusion consists of coarse-grained, pink, quartz-rich, perthitic granite. Fine-grained microgranites occur and recent mapping by the author has shown that these crop out widely in the Boot area (Fig. 1). These microgranites are of very similar mineralogical composition to the coarse-grained granite, though they exhibit variable textural characteristics and include non-porphyritic and porphyritic varieties.

Rundle (1979) has obtained Rb-Sr and K-Ar ages of 429 $\pm$ 4 ma, which indicates an early Silurian age for the Eskdale Granite (Harland et al. 1982).

In the Boot area N - S trending faults are common and these frequently carry hematite mineralisation. The Nab Gill Vein is developed along one such fracture which strikes approximately NNW and dips to the east at between 65^{o} and 90^{o} with a downthrow to the east. Several minor branches diverge from the vein. The vein filling consists of brecciated granitic wall-rock and hematite, with the payable ore in two shoots separated by barren ground (Hibbert et al. 1940, p.82) (Fig. 2). The mineralogy of the vein is outlined in the following section. Contemporary reports indicate that the vein was widest near the fell top where widths of up to 6.1m were recorded, though this figure included up to 3.4m of 'horse' or 'rider' of granite: the average width was between 0.76 and 1.06m (Smith, 1924). In the deepest levels the vein had narrowed to as little as 0.15m immediately prior to the mine's final closure.

2. MINERALISATION

In common with other hematite veins in the Lake District, the Nab Gill Vein consists almost entirely of hematite with only minor amounts of other minerals. Of these quartz is the commonest and occurs both massive and crystallised: the latter form typically displays turbid crystals up to 5mm with well developed prism and pyramid faces. Dolomite is found locally on the dumps as pale yellowish-fawn cleavable masses. A little 'nail-head' calcite may also be found in places. Manganese oxides, which occur mainly on the dumps from the workings on the fell top, are present both as soft earthy masses and harder botryoidal aggregates. Botryoidal material from one of these upper dumps (NY 1728 0149) has been shown by XRD to be romanechite (Fortey, personal communication).

Most of the hematite is present as 'kidney ore' and much of it displays varying degrees of brecciation. The most intensely brecciated ore shows disorientated 'kidney ore' or 'pencil ore' clasts in a matrix of earthy hematite. Inclusions of granite are common. Good specimens of 'kidney ore' may be collected locally, notably on the west side of the gully above No. 1 level (NY 1731 0139) and on a dump from old shaft workings to the north of this (NY 1728 0149). A little massive hematite is also found and the stalactitic variety known locally as 'ring ore' has been recorded by Smith (op. cit. p.211). Specularite appears to be absent.

There are few exposures of the vein today, though typical ore specimens are abundant on the dumps. Nab Gill Vein itself may be seen as a hematite-stained granite breccia in the opencut above No. 1 level (NY 1731 0142). The branch vein may be seen in the open stopes (NY 1726 0146) on the fell top to the west of this. Here 'kidney ore' forms bands parallel to the vein walls. A more accessible exposure of this vein may be examined in the opencut a few metres to the north (NY 1725 0148) where brecciated 'kidney ore' is exposed on the west wall of the vein. The finest exposure is to be seen adjacent to the collapsed portal of No. 2 level (NY 1738 0133). Here several narrow branch veins on the west side of Nab Gill Vein display parallel bands of 'kidney ore' in which the botryoidal surfaces face the centre of the veins. Much

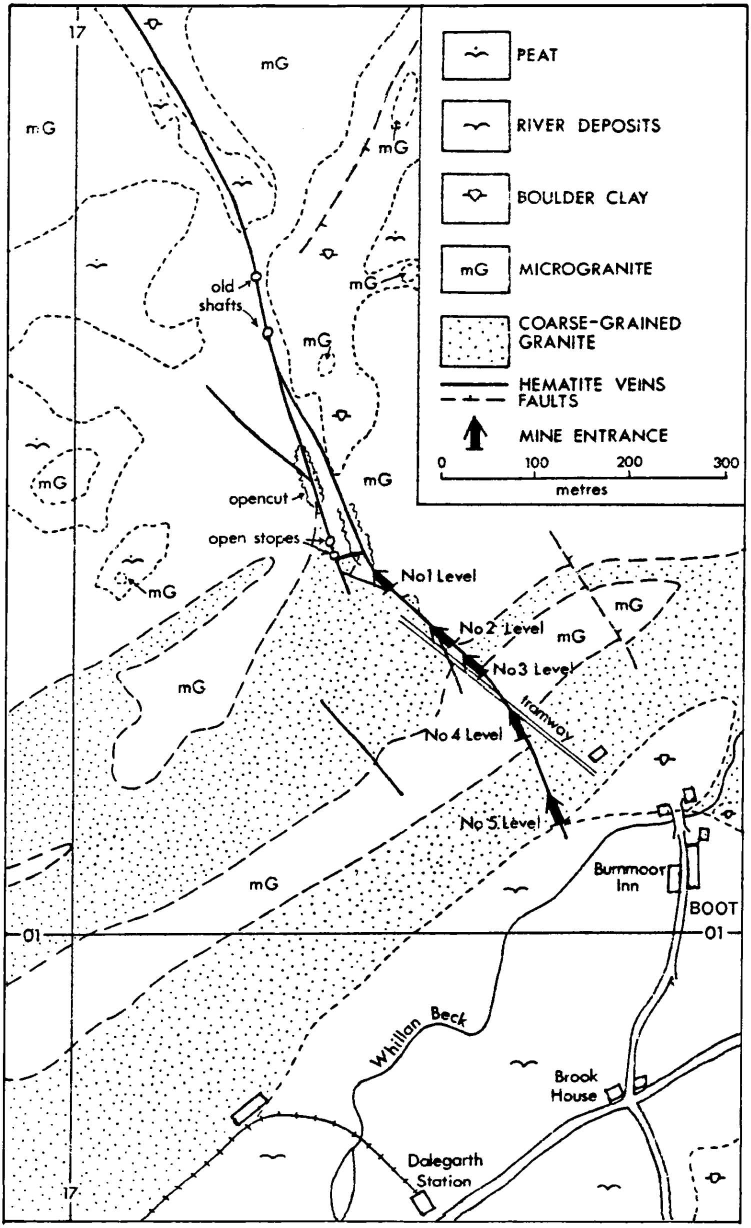


Fig. 1 GEOLOGICAL SKETCH MAP OF NAB GILL MINE.
(Geologically surveyed by B.Young, 1982)

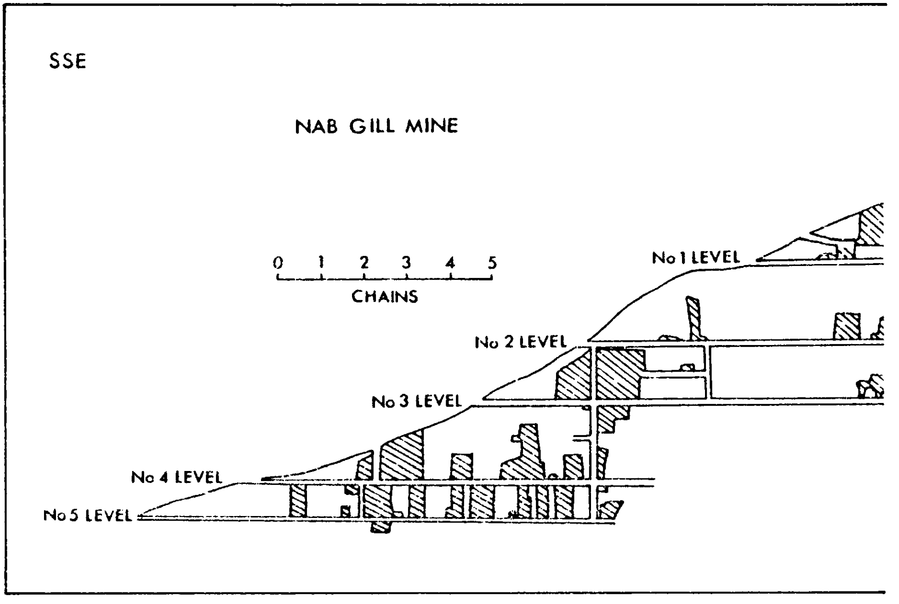


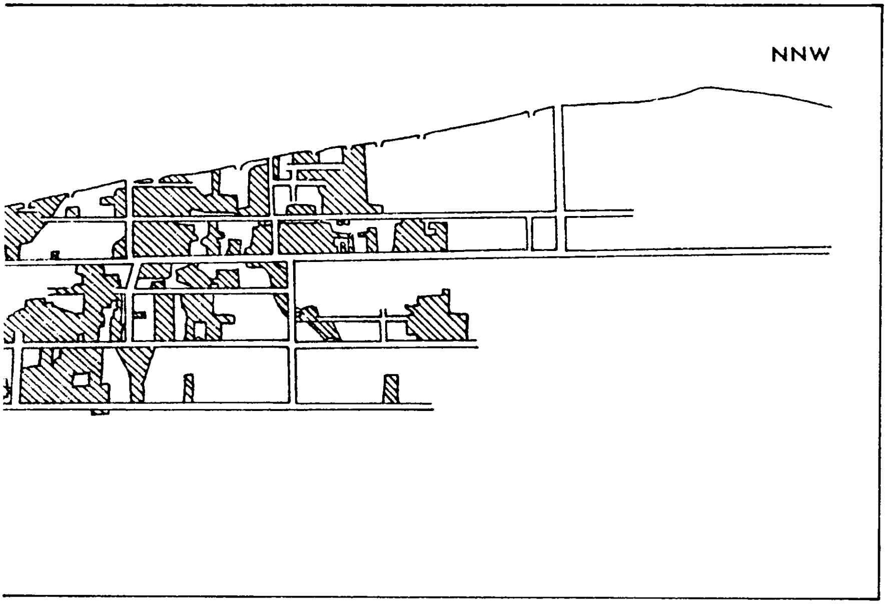
Fig. 2 SECTION OF NAB GILL MINE SHOWING AREA OF STOPING.

of the ore is slightly brecciated and a few granite clasts are present.

The origin of the West Cumbrian hematite deposits has long been the subject of speculation. However, the two most recent studies are those of Shepherd (1972) and Rose & Dunham (1977).

In the first of these Shepherd proposes that late-stage alteration of constituents of the Eskdale Granite released iron which was locally precipitated as free hematite. Red earthy hematite commonly replaces micas in the granites and micro-granites. Coarse-grained specular hematite has been found recently by the author as disseminations and segregations in parts of the Devoke Water Greisen (SD 1492 9678), a marginal variety of the Eskdale Granite. Re-mobilisation of this scattered hematite by circulating subsurface brines then deposited hematite at higher levels as the epigenetic deposits seen today as the Lake District veins and the replacement bodies of West Cumbria and Furness.

Rose & Dunham (1977, p.91) favour a model of the West Cumbria and Furness deposits whereby hypersaline brines leached iron from the St.Bees Sandstone of the Irish Sea basin. These fluids were then forced up dip and deposited their contained iron as replacements in the Carboniferous Limestone. This mechanism could also explain, at least in part, the origin of the hematite veins



in Eskdale. However, the presence of hematite veins, albeit fewer in number, elsewhere in the Lake District as far east as Grasmere, perhaps suggests some contribution of iron leached from parts of the Lake District batholith.

Shepherd (op. cit.) produced evidence for a middle or late Trias age for the mineralisation whereas Rose & Dunham (op. cit. p.92) advanced arguments for a Cretaceous-Tertiary age.

3. MINING HISTORY

It is possible that iron working in Eskdale dates back to Roman or even earlier times and patches of iron slag at various localities suggest mediaeval working, though sites of the iron ore mines are unknown. The first known working of the Nab Gill deposit dates from the first half of the nineteenth century when a man called Lindow carried out exploration both here and at Ban Garth (NY 1535 0084) near Eskdale Green. The Nab Gill trials were unsuccessful and were abandoned (Davies 1968, p.14).

A new incentive to exploration came in about 1870 with the increasing demand for home-produced iron ore resulting from the Franco-Prussian war. A company known as the 'Whitehaven Iron Mines Ltd.' was formed in January, 1871, to exploit the Nab Gill Vein. The mine at this time was known as the Whitehaven Iron

Mine. Ore was found in payable quantities and over the next few years the mine was worked from five levels, driven on the vein, and from shafts and opencuts on the fell top. The best quality ore was found in the higher workings and an inclined tramway was built to lower the ore to the foot of the fell. Transport of ore from the mine was a problem from the earliest days of the company and as early as 1872 it was resolved, at a meeting of shareholders, to promote a Parliamentary Bill for the construction of the 'Ravenglass and Eskdale Railway' to carry ore to the main line at Ravenglass. The railway, subsequently to become known locally as 'La'al Ratty', opened in May, 1875.

Production figures for the first years of the mine are incomplete, though 5432 tons were recorded for 1873. In 1876 some 9135 tons were raised. The Leconfield Estate records (held by the Cumbria County Records Office) show a more or less steady decline in production from this date, though 1880 saw a temporary increase in output to 7812 tons. By 1882, the year in which the Whitehaven Company went into liquidation, the output had fallen to 4189 tons, though this figure may include some ore from nearby mines at Ban Garth (NY 1535 0084) and Blea Tarn (NY 1672 0070). A company variously known as 'The Eskdale Haematite Iron and Mineral Co.' or 'James Wingate and Co., Steamship Owners and Brokers', continued the lease and produced 1954 tons of ore in 1883, but this company also surrendered its lease early in 1884.

The mine lay idle until about 1908 when a Glasgow-based syndicate took over the mine and carried out a little work in the lowest (No. 5) level, though only a little ore was raised.

Contemporary records state that in 1909 the forehead of this level was in barren ground. A 15.24m shaft was sunk near the mouth of No. 5 level from the base of which short levels were driven north and south along the vein, which was found to be 0.91m wide but poor in the northern drive, and only 0.4m wide in the southern drive. An inclined drift provided a second access to these trials. By 1912 exploration had reached 27.43m below the No. 5 level, but showed only a little ore 'very much mixed with stone': the mine was again abandoned.

In 1917 four men are known to have been employed in the No. 5 level producing up to 8 tons of ore per week. Pumping out of the flooded deeper workings was contemplated, but was not carried out and the mine closed in 1917.

Surface remains visible today include the bed of the inclined tramway, a large sheave wheel from which lies on the fellside a short distance NW of the foot of the tramway. The roofless office, blacksmith's shop and change house stand at the foot of the tramway adjacent to the old loading bays and remains of Boot Station. Most of the level portals are now obscured, but on the fell top are open stopes and shafts.

4. ACKNOWLEDGEMENTS.

The assistance of staff of the Cumbria County Records Office, Carlisle, and the Egremont Estate Company, Cockermouth Castle, is acknowledged with thanks. The figures were drawn by Miss S. Galliers. This paper is published by permission of the Director, British Geological Survey (NERC).

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EXCURSION NOTES

DEGLACIATION FEATURES NORTH AND SOUTH OF ENNERDALE

Leader: Mr.T.Shipp

27th March, 1982.

Having parked their cars at Mockerkin Tarn lay-by (083 233), the party found a vantage point at Ullock road-end (084 236). Looking west, part of the Mockerkin-Kirkland kame belt and a possible crevasse-filling were seen. Foulknott Hill (082 237) is a conical kame 1 km north of Mockerkin Tarn (which is a kettle-hole). A feature south of Mockerkin Tarn mapped by Huddart as an esker looked more like a continuation of a flat-topped kame; its slope facing the tarn consists largely of small sub-angular boulders, probably of fluvioglacial origin, and its form either an ice-contact slope or trimmed by outwash. Cogra Moss to the south is a combe feature with a moraine-dammed tarn, now enlarged into a reservoir. Water-cut notches show on the fellside.

The side of Kelton Fell (088 180) provided a good point from which to view the Ennerdale valley. Mr. Shipp in discussing the topography said that the Survey had supposed that the valley had been blocked off by Irish Sea ice, with the result that when the valley ice melted 'Glacier-Lake Ennerdale' was formed, the melt-water at successively lower levels cutting across cols on the southern side of the valley.

Huddart disagrees with this, suggesting that most of the meltwater was moving within the ice which still choked the valley. This view is supported by the discontinuous nature of the notched meltwater channels and the existence of 'humped' channel profiles which can only be envisaged as forming under pressure, enclosed by a cover of ice. It was also supposed that a general southerly movement of meltwater within the ice, or along its margins, southward from the Cogra Moss and Loweswater regions, spilled over into Ennerdale. Dixon et al. suggested that the valley-side deltaic forms to be seen today along the north slopes of lower Ennerdale could be linked to successive levels of a glacier lake, but the level delta tops do not seem to be linked by connecting beach deposits. Huddart suggests that all these deltaic forms can be explained as subglacial features, formed when the sediment-laden subglacial streams reached the englacial water table.

The party proceeded to examine the railway cutting near the former Kirkland Iron Ore Mines (086 181). This cutting exploits a meltwater channel leading down from higher ground. There is a suggestion of a humped profile.

From Kirkland village (073 177) there are views of a magnificent series of gashes cut north-south down the hillside leading to two lobes of deposited sediment at High Starbank and Hawes.

After taking lunch at Kirkland, the party proceeded to Cold Fell and followed the route described in Proceedings Volume 3, part 4, page 25. At the conclusion the party thanked Mr. Shipp for this extensive coverage of glacial landforms of the area.

(Excellent maps and discussion of the glacial features are included in Dr. Huddart's paper, Proceedings Volume 2, part 2, pages 63-75, and in Excursion Notes in Proceedings 1963, No.2, pages 14-15, and Proceedings 1964, No.2, pages 10-12).

EXCURSION TO BORROWDALE AND LANGSTRATH

Leader: Mr.K.W.Bond

18th April, 1982.

About 15 members and friends met on a beautiful spring day at Stonethwaite Church where the leader explained that the itinerary would be divided into two parts. The morning would be devoted to glacial and fluvioglacial features of the floor of Borrowdale, and later in the afternoon part of the Borrowdale Volcanic Group succession at the foot of Langstrath would be examined.

All around and continuing more extensively to the north was a broad, remarkably flat valley floor, the result of a vanished meltwater lake probably formed about 12,000 years ago when the 'Jaws of Borrowdale' were blocked by moraine material.

Moving westerly the party traversed three ridges of moraine, some care being needed to distinguish these from other glacial

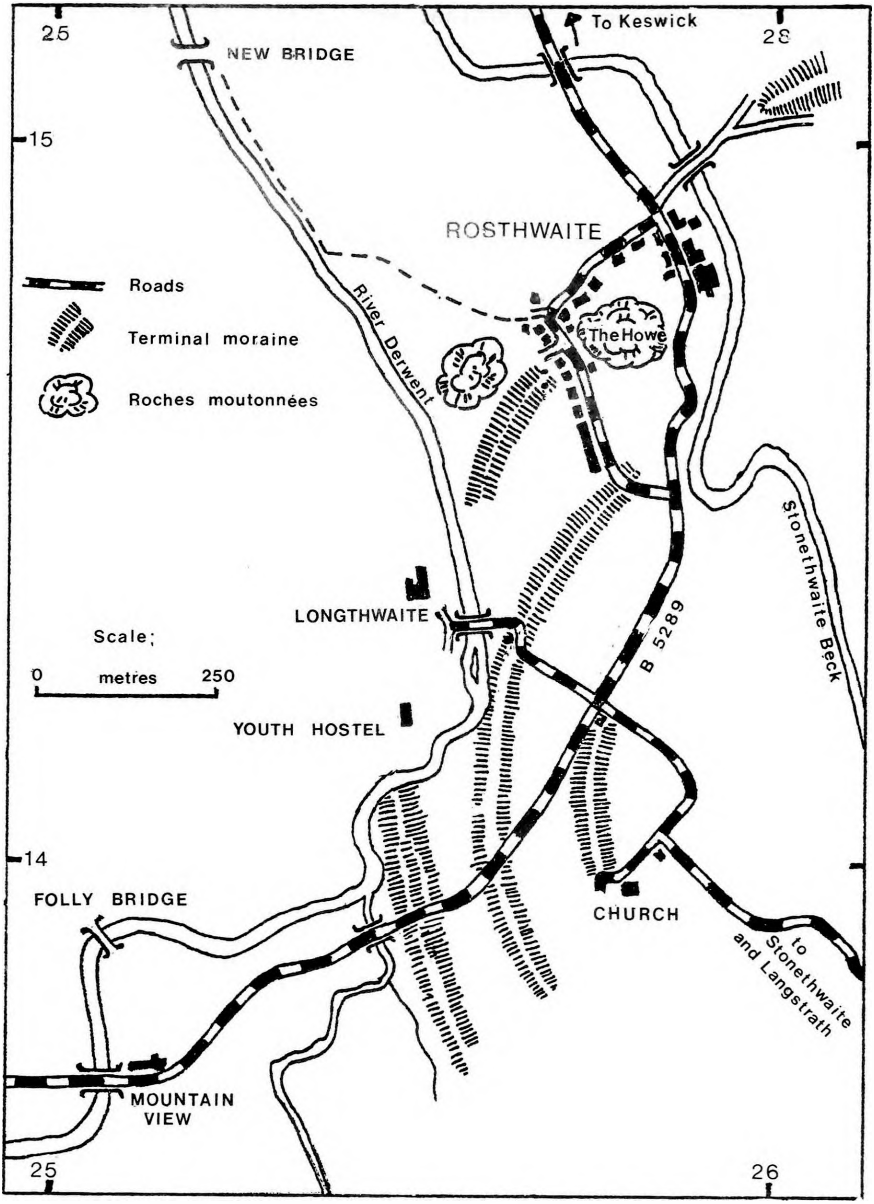


Fig. 1 ROSTHWAITE AND SURROUNDING AREA SHOWING GLACIAL FEATURES

debris. Their shape and disposition, particularly in relation to the Stonethwaite and Seathwaite valleys were noted, and their correlation and origin discussed. There are three concentric arcs of terminal moraine, concave towards Stonethwaite, marking three stages in the retreat of the Stonethwaite glacier which had for some time dammed back meltwater from the earlier-melting Seathwaite glacier. That meltwater overflowed eventually between the west valley side and the glacier, cutting a marginal channel.

Crossing Folly Bridge, the path was taken towards Longthwaite Youth Hostel, so following the marginal channel. The Derwent has cut down through the moraine, but the earlier meltwater overflow is marked in the rock of the north-west bank by pot-holes 3 - 5m above present river level. The opposite bank cuts the outermost terminal moraine containing unsorted Borrowdale Volcanic Group boulders, some of the rocks showing fiamme (streaky) structure.

North of the hostel the Derwent was re-crossed and the path to Rosthwaite followed, passing between parts of the two outer moraine arcs, so enabling confirmation of their shapes.

Approaching Rosthwaite, examples of roches moutonnees were examined, their southern sides smoothed and striated, their northern sides quarry-like. Their position a little above valley level and their sheltering effect explains the siting of the hamlet in Norse times.

After lunch, following the path to the bridge over Stonethwaite Beck, another dissected part of the outer moraine arc was seen to form the eastern bank of the stream. South-easterly towards Smithymire Island, Borrowdale Volcanic Group lavas and tuffs are exposed, and while viewing the latter the difference between bedding planes, joints and cleavage was explained. Galleny Force and its plunge-pool occupy a belt of weakness on a fault-line, though the direct evidence of this fault (displacement of beds on opposite banks of the stream) was not located on this occasion.

At the foot of Langstrath the stream runs along a bedding plane. Details of the Airey Bridge ignimbrite and rhyolite textures were clear along the channel margins.

Mr. Bond, after being warmly thanked, had to return in mid-afternoon for business reasons, leaving some of the more energetic members of the party to continue up the valley.

(The reader may like to know that further information on Borrowdale and Langstrath is presented in the Society's 'The Lake District' and in Mr.E.H.Shackleton's books 'Lakeland Geology' and 'Geological Excursions in Lakeland'. An article by P.Wilson on page 239 of Volume 3, part 4 of these Proceedings also deals with the Rosthwaite Moraines).

VISITS TO THE ANHYDRITE MINE, WHITEHAVEN

15th April, 1982 & 13th April, 1983

This mine came into production in 1955, operated by Solway Chemicals Ltd., a subsidiary of Marchon Products Ltd., for the production of anhydrite used in the manufacture of cement and sulphuric acid. It reached an output of 250 tonnes per hour, the highest for any mine in Europe. The process involved kilning a powdered and carefully metered mix of anhydrite, coke and St. Bees shale, the latter being quarried nearby. However, about six years ago it was decided that sulphuric acid, the more important product, could be made more economically from imported sulphur. Today the mine, though not working, is maintained dry, ventilated and regularly inspected.

The parties on each occasion were welcomed, equipped and taken underground by Mr.M.Fox. Access is by two drifts running in for 1000m at about 7^{o}, one for personnel, using cable-controlled man-riders (in which our members rode), the other housing the product conveyer belts. The drift seen was steel-arched and concreted as it ran through the St. Bees Shale, except for a small length at the beginning where wooden lining between arches is now rotting after 29 years.

At 61m below sea-level our members walked along part of the mine's 112km of roadways, first to see the electric pumps and the dammed-off underground reservoir into which they deliver about 9000 litres of water a minute. Other pumps then discharge this at the surface. It was pointed out that this mine-water is corrosive, and a supply of local tap-water had been piped in for such purposes as filling vehicle radiators.

Roadways and workshop areas are usually 9m wide and 4.3m high, the workings being developed on a pillar and stall system, leaving about 40% of the anhydrite as roof-support. The anhydrite is massive, the best grade being pale blue, another pink, and a third cream-coloured, with nodules thought to be due to secondary crystallisation. Occasional gypsum, shale or marl partings were seen. This particular anhydrite bed is up to 24m thick; there is another mine district below the one seen. The only geological structural complications seem to be a monocline and a small fault. In some areas of the mine there has been some methane seeping from the underlying coal measures and appropriate precautions were observed during working.

A thorough explanation was given of working methods, equipment and its repair. Two large air compressors and a crushing-mill were seen, and a variety of huge diesel-powered tractors, trailers (of 14 tonnes capacity) and loaders. A twin-drill rig has been custom-built onto a Chase-side chassis; this could be directed to drill shot-holes at any height and angle needed. The visitors were able to look up the air-intake shaft which stretches 126m to the surface near Sandwith, and has permanently-fixed steel ladders for emergency use (and also a continuous shower of water descending it). Adjacent was the huge fan and its equally huge electric motor, power for which has to be switched in from Sandwith village. It is used one day a week.

On returning to the surface Mr.J.Telfer, the mine manager, discussed the mine and produced operational photographs and a copy of the plans. The local strata in downward sequence is sub-soil, 1 to 2m; St.Bees Sandstone, 60m; St.Bees Shale, 60m; anhydrite (with shale partings), up to 24m; Brockram. The area considered to contain Permo-Trias anhydrite extends south beyond Barrow, west under the Solway and, probably with restricted continuity, east of the Pennines.

Our members who toured the mine felt well pleased with their visit and expressed their thanks to Mr. Fox and Mr. Telfer before leaving.

EXCURSION TO THE THRELKELD MICROGRANITE

1st May, 1982.

Sixteen members and friends met on a bright cold afternoon in the Threlkeld Quarry of Amey Roadstone Ltd. Although the quarry had not been worked since autumn, 1980, good specimens of the micro-porphyritic variety of the microgranite were found, the plagioclase feldspars being especially clear. Freshly broken specimens contained chlorite, tourmaline and much-altered micas all around 2mm in size. In the west end of the quarry there is much variation in the spacing of the joints, which in places are as little as 5 - 10cm apart. Mineralisation along the joints has produced some strikingly coloured bands usually of very friable amorphous material, but with a few well-formed quartz crystals. The microgranite-Skiddaw Slate contact in the east of the quarry is very clear, the tongue-like projections of the microgranite showing up well. Graptolites were found in the very soft Skiddaw Slates in a loose scree very close to the contact, which has caused little if any metamorphism. The horizontal extension of the microgranite is also easily visible.

The party proceeded to the Bram Crag exposure in the more sheltered St.Johns-in-the-Vale. The granite here was seen to be much less porphyritic, particularly where close to the much steeper Skiddaw Slate contact by the southern entrance, and in general seemed more massive and uniform in appearance. The more or less horizontal fault plane, with its frequent quartz stringers, was the dominant feature. There were many pieces of Borrowdale Volcanic Group rocks on the quarry floor, especially the purple breccia, and porphyritic andesite with augite crystals. However, the microgranite - B.V.G. contact high above the quarry face was neither accessible nor obvious. In approaching Bram Crag the stepped topography of the lavas and ashes of the B.V.G. on High Rigg, and the old lake bed of the Naddle valley floor were clearly seen.

EXCURSION TO DRYGILL AND DRIGGETH MINES

Leader: Mr.D.Wildridge

22nd June, 1982.

17 members and friends met at Carrock Beck ford (350 350) some two miles to the south of Hesket Newmarket, on a cool, grey day. Mr.D.Wildridge in his introductory talk on the mines of the area mentioned that lodes extended to Drygill from the more substantial Carrock End Mine. On reaching Drygill Orthid brachiopods were found in the Drygill Shales, and the main lode was seen as a 3m wide quartz vein by the well-preserved main adit at stream level. An old sluice, several leats and a probable dressing floor were found. Very large quartz pyramids up to 3 - 5cm across were common. Excellent barrel-shaped yellowish campylite crystals were found, and a little mimetite.

Manganese staining and spherical crystals of pyrolusite were common. Mr.Wildridge described the changes in height of the lode due to three faults before pointing out the present vandalised stopes, rich in barytes. Traces of the unusual highly coloured lead ores were seen.

The party then crossed the fellside by the mine-road to the relatively new and more extensively worked Driggeth Mine, first looking at the dangerous shaft leading down to the 12 fathom cross cut before searching successfully for mimetite and pyromorphite in the very old opencast working on the fell top running in the direction of the old Sandbeds Mine. The deeply rotted Harestones Felsite and a wide barytes vein were noticed. The leader related the history of what he believed was the oldest adit, which opened up the original 30 fathom workings. The modern dressing floor and older washing boxes were seen. On the nearby tips good specimens of galena, blende (sometimes in disseminated form), copper pyrites, barytes and possible malachite were obtained.

Mr.D.Wildridge, an expert on metalliferous mining, was accorded grateful thanks for imparting so much information and making possible the collection of so many good specimens.

THE CARBONIFEROUS SUCCESSION AROUND THE LEVENS ESTUARY

Leader: Mr.D.Leviston

18th July, 1982.

Derek Leviston welcomed the 20 or so members and friends who met on a warm summer's day at the picnic site just east of Greenodd. His main aim was to demonstrate the Carboniferous succession around the Levens Estuary. In the broader setting the Carboniferous beds formed the lowland, ice etched and flooded by the post-glacial rise in sea level; the Silurian the gently rolling hills, and the Borrowdale Volcanic Group the rugged hills from High Street west to Coniston Old Man. The Silurian shales dipped west and were upthrown along the north-south fault near Stribers. The Levens Estuary has become heavily silted since the railway viaduct was built, with the demise of Greenodd as a port.

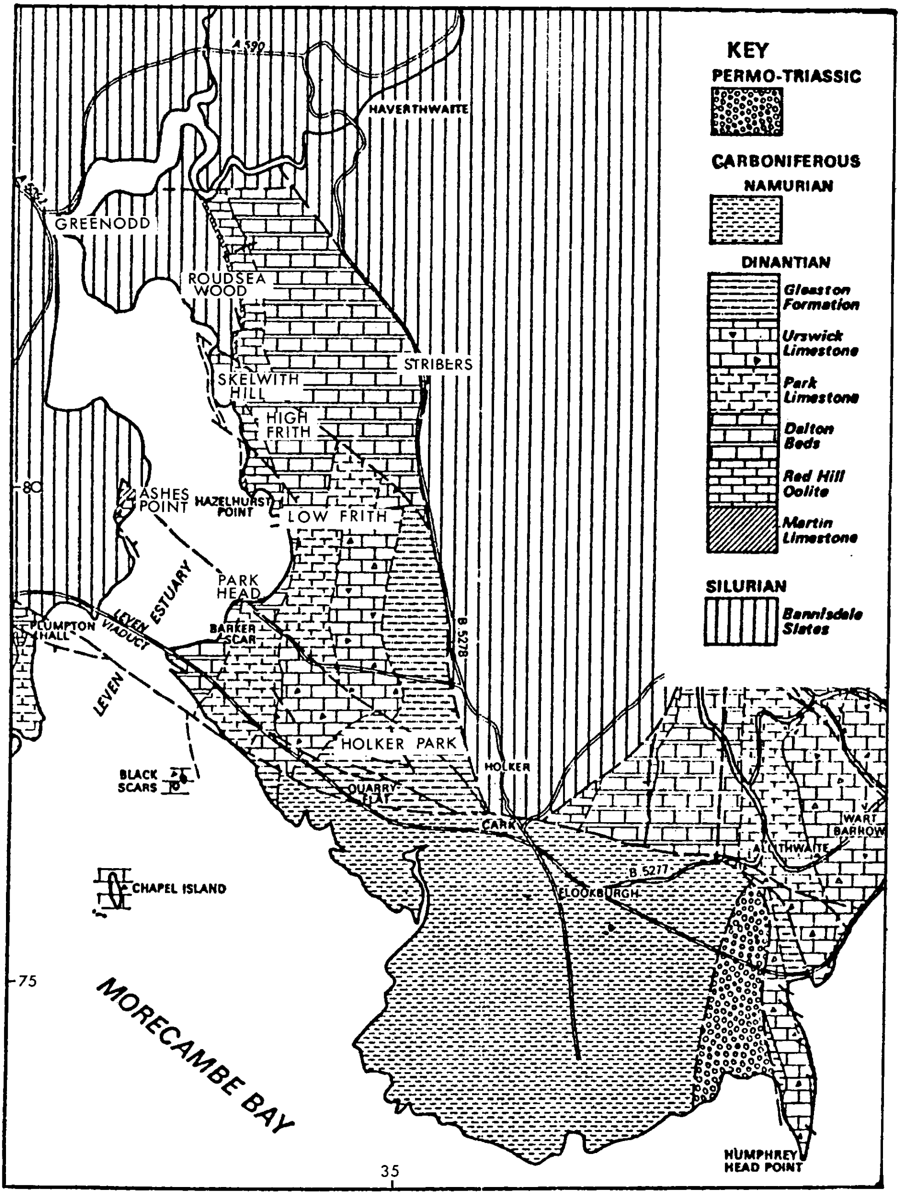


Fig. 1 GEOLOGICAL MAP OF THE LEVENS ESTUARY.
(Based on Fig. 8 in the Geological Survey of Dunham and Rose, and reproduced by permission of the Director of the British Geological Survey).

The first stop was near Ashes Point to examine the basal Martin Limestone. This is a fine-grained, finely-bedded calcite mudstone indicating deposition in calm water. This was overlain in the late Chadian* stage by the Red Hill Oolite, separated by a local undulating disconformity produced by the planing off of the uppermost Martin Limestone beds. The Red Hill Oolite is coarser, with rubbly beds at the base, being interpreted as a re-worked limestone, formed on a more exposed site with calcrete palaeosols indicating a minor still-stand or regression. Solution weathering of the Red Hill Oolite was very striking.

By kind permission of the Nature Conservancy the party visited Roudsea Wood and Mosses, very precious to the botanist. Badger setts and damage by roe deer were pointed out by the warden. Mr. Leviston indicated the terrace-like junction of the Martin Limestone and the Silurian shales, which he considered was due to the limestone being deposited on a very uneven surface rather than to a fault as the Nature Conservancy suggests. Details of the succession were difficult to trace in the coppiced oak wood.

After lunch the Martin Limestone - Red Hill Oolite junction was inspected at Skelwith Hill on the edge of the Levens estuary. Here the calcrete was easily visible as laminar bands in the rubbly beds. Organic root-like traces in the rod-like calcite crystals gave way upwards to grape stones. Calcite pseudomorphs occurred. The overlying Red Hill Oolite was more fossiliferous, containing gastropods, brachiopods and <u>Palaeosmilia</u>.

On returning the party looked at the overlying, more uniform, open sea deposited Dalton Beds of the Arundian stage with their corals, crinoids and the easily identified marker fossil <u>Delepinea carinata</u>, a brachiopod. These lower beds were near High Frith. The upper beds near Low Frith are even more fossiliferous in the shale bands, with additional zoophycos (trace feeding tracks), syphonella corals and trilobite trails. A rubble bed near High Frith marked the Arundian/Holkerian regression.

The final visit was to the type section of the Arundian/Holkerian boundary at Park Head, where the numbered beds and the core sampling points for palaeomagnetic investigation were very clear. It was difficult to find good examples of the marker fossil <u>Ecclesiophyllum multisepta</u>, a fasciculate coral of the top of the Dalton Beds, but the 'shelf' separating the two stages was obvious.

Members thanked Mr. Leviston for a very full and rewarding visit to a locality outside the Society's normal range.

* See diagram on pages 304 and 305 of these Proceedings.

GEOLOGY FROM 'LA'AL RATTY

Leader: Mr.F.Jones

3rd September, 1982.

About 14 members and friends met in the 'Ratty' car park at Ravenglass on a grey September day for an excursion into Eskdale, using the miniature railway as the means of transport.

While travelling up the valley features of interest and exposures of Eskdale Granite and of the Borrowdale Volcanic Group were pointed out, and, when the terminus was reached, a summary of the structure and glacial history of the valley was given, using the Boot station waiting room as a 'classroom'. The old Nab Gill Iron Ore Mine was then visited and its history was briefly reviewed after making the short steep ascent to the first two levels. Good specimens of kidney ore and calcite were found along the line of the old tramway. Near the second level the vertical outcrop of two parallel high quality hematite veins up to half a metre thick were noted. A fuller account of this mine is given in an article by Mr. Young on page 269 of these Proceedings.

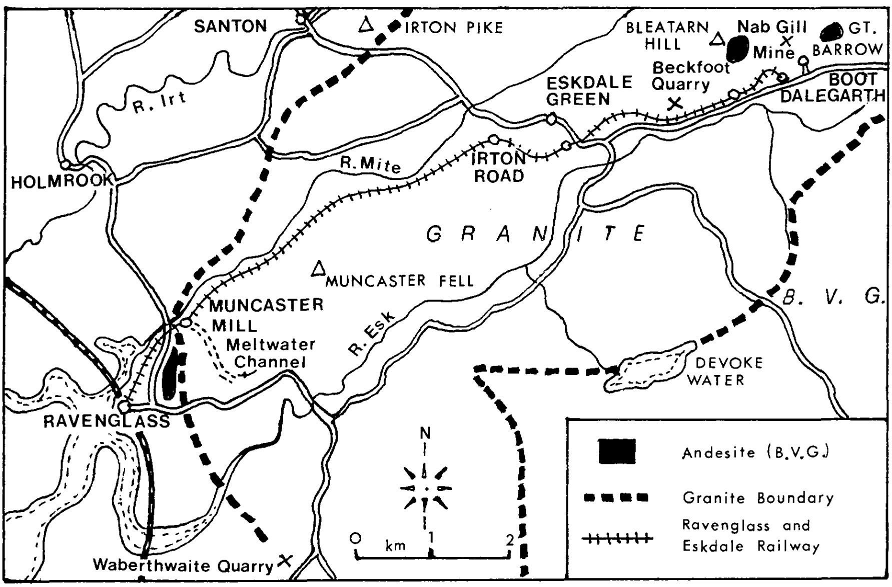


Fig. 1 SKETCH MAP OF LOWER ESKDALE.

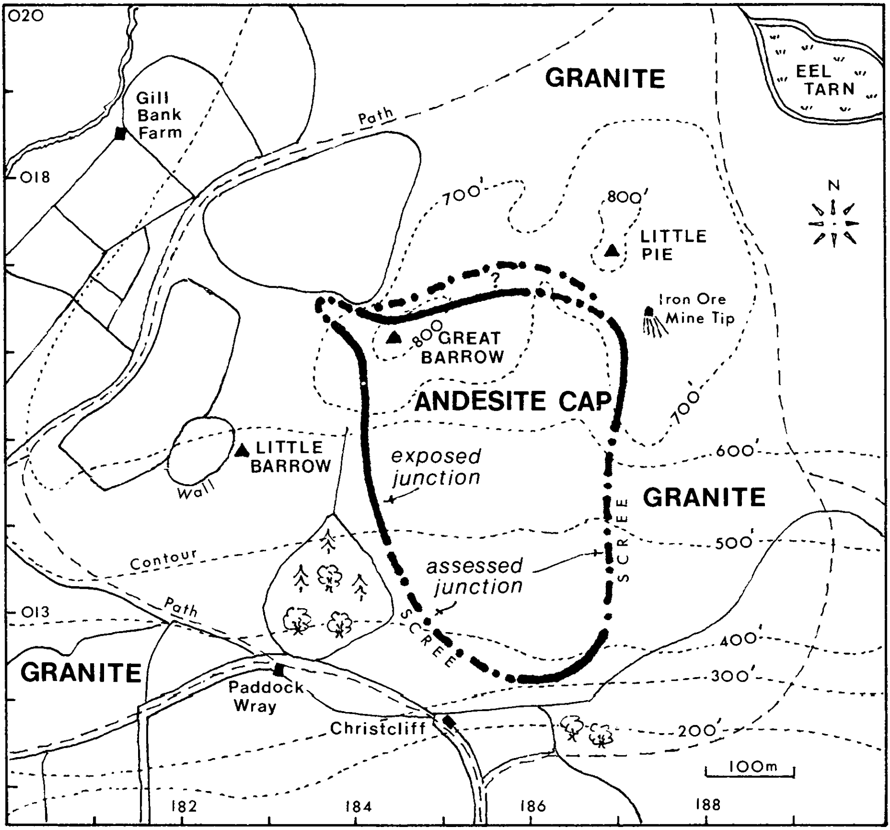


Fig. 2 SKETCH MAP OF THE RESULTS OF THE BRIEF SURVEY.

After lunch the party proceeded to Great Barrow to look for the Eskdale Granite/Andesite junction, which was found initially near the summit on the west side facing Little Barrow. Contrasts between the coarsly crystalline Eskdale Granite, the very resistant baked margin of the andesite and the deeply rotted more normal andesite were noted.

Variations in the nature of the andesite, more massive just above the junction, and markedly banded higher up with what appeared to be thin lava and tuff layers, showed up well. The party split to locate the junctions around the crest of the hill and in the hour or so available found the andesite capping to be much thicker on the north and south flanks forming a thick wedge, and perhaps of more complicated form than the literature suggests. The accompanying sketch map shows the results of the brief survey, for which the Society is grateful to Mr.Jones.

EXCURSION TO THE GILSLAND AREA

Leader: Mr.I.Gray

26th September, 1982.

This joint meeting with the Northern Group of the Institute of Geologists was attended by 25 or so members and friends meeting at Gilsland on a fine autumn day.

First visited was the exposure of the King Water fossil trees in Spadeadam Waste. Walking along the King Water a finely bedded calcareous sandstone was seen, with rectangular joints and current bedding. Several fossil trees were found in situ along the burn course. Cellular patterns, trunk flutings, cell structures and growth rings were recognised in the specimens which were up to 2.4m in diameter. The I.G.S. memoir suggests that the rocks originated as an impure gannister partly covered by sediments through which limy solutions then percolated. This horizon separates the Middle and Upper Border Groups, well down in the Viséan succession, thus showing the early onset of deltaic sedimentation in the Borders.

The party proceeded to the Crammel Linn waterfall in the Irthing Gorge. The fault-guiding of the waterfall was recognised by the flexing of the beds bear it and the fault gouge material. In the Crammel Linn Sandstone (lowest of the Upper Border Group) were bioturbation traces, probably of gastropods; burrows were very marked. The succession passes into the Cottering Sandstone and Millerhill Limestones, rich in echinoids. A thin and much weathered coal seam was also found. Rock thicknesses are very variable in this horst and graben area where there is much lensing of the deltaic sandstones.

Lunch was taken at Gilsland Spa - in the car park! Some of the more energetic members of the party descended to the fault, guided by the truly evil-smelling sulphur spring.

Most of the afternoon was spent following the lower part of the Namurian succession in the valley of the Haltwhistle Burn. The Great Limestone, marine but sparsely fossiliferous, wavy-bedded but very consistent in its outcrop, was the base of a series of cyclothems. Just above it, in a shale, tiny Crinoid stems and small Productids were found, as were unidentified burrows and infills in more micaceous rocks. A particularly fine gastropod trail was collected from a flaggy sandstone higher in the succession. Load casts and near-vertical feeding traces were

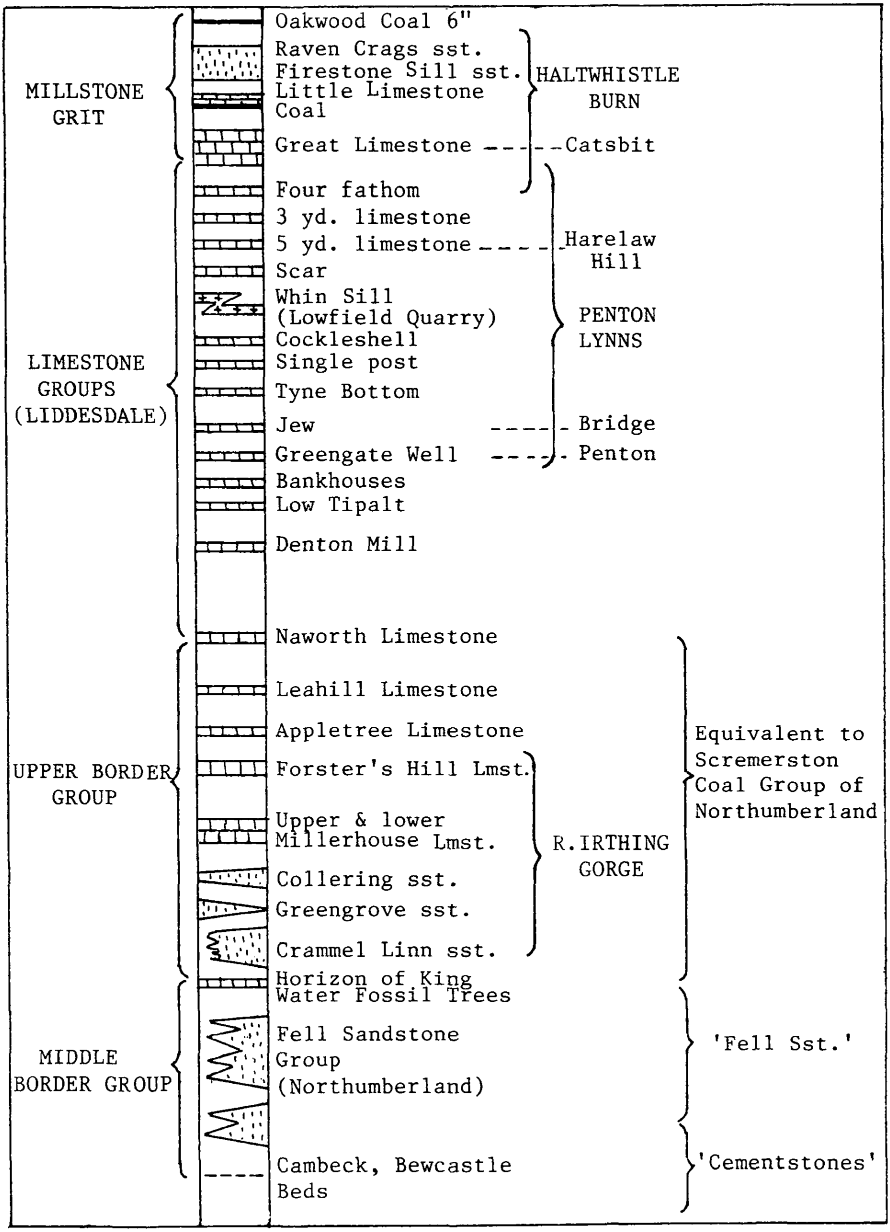


Fig. 1 SKETCH SECTION, CARBONIFEROUS SEQUENCE - ROMAN WALL AREA.

noted in the shaly sandstones and more massive sandstones above. The route passed the well-preserved remains of a mine (probably drift) working a coal at the base of the Little Limestone, in which were quite large Productids. The massive cliffs of the heavily wooded Raven Crags Sandstone made quite a feature by the Haltwhistle Burn.

The final stop was at Caufield Quarry, where the columnar jointing in the Great Whin Sill, strikingly yellow-buff in colour, showed up dramatically. Its rubbly nature at its chilled edges, now tilted to near vertical angles, showed up well, but energy was lacking to search for the contact after a full day.

Mr. Gray was thanked for providing a varied, interesting and memorable excursion, enhanced by the skill of members of the Institute of Geologists in identifying trace fossils and sedimentary structures.

GEOLOGY OF THE EASTERN FELLS AROUND RENWICK

Leader: Mr.R.S.Arthurton

22nd May, 1982.

This was a joint excursion with the Westmorland Geological Society and the following account is taken, with permission, from that Society's Proceedings, Volume 3, No. 2.

A group of W.G.S. and C.G.S. members assembled at Renwick (596 436) about 4 miles north of Melmerby in N.E. Cumbria for an excursion to the environs of the Pennine Fault and its associated rocks.

Shortly after leaving the village in the direction of Outhwaite the leader stopped at a convenient vantage point to summarise the geological history of the area. The Pennine Fault is Hercynian in age. In southern England and South Wales the Hercynian orogeny caused folding and faulting along east-west axes. In northern England the folding of Carboniferous rocks was on north-south lines along the Pennine axis from Derbyshire to the Craven Faults with folding along oblique lines, mainly NE-SW, affecting the thick basinal sequences around the south Pennines.

In the northern Pennines the orogeny caused an east-west compression which re-activated major crustal units established in late Caledonian times. The rigid low-density cores of the Devonian Weardale and Wensleydale granites, underlying the Alston and Askrigg Blocks, enabled the blocks to resist these pressures so that there was little folding within the block areas. Deformation was concentrated along the block margins where, along their western edges, faulting and tight folding took place on generally N - S axes to form the Pennine and Dent lines.

Under continuous compression this tight folding of the Carboniferous rocks developed into an eastwards facing monocline with thrust faulting in places. The intrusion of the Whin Sill appears to have closely followed this compressive phase.

As the compressive forces died away, because of the buoyancy of the underlying granites, the blocks retained their stability as positive areas whilst the region to the west subsided causing a further phase of faulting along the Pennine and Dent lines, but this time the movement was down to the west. This subsiding Vale of Eden area became an elongated intermontane basin in which (Penrith) desert sandstone and wadi breccias of Permian age accumulated. Throughout the Permian the western edge of the Alston Block formed an escarpment which was gradually buried by the desert sands and was probably finally covered by the fluviatile sandstones of the Permo-Triassic St. Bees Sandstone. This is a fine-grained chocolate red sandstone with local yellow layers as a result of variations in water level during deposition.

Mr. Arthurton concluded this introduction by commenting that the St. Bees Sandstone was not particularly interesting and very little of it would be seen during the excursion.

Topographical details to be seen included a quarry to the south cut in the Cleveland/Armathwaite Dyke. This belongs to the Mull Dyke Swarm of Tertiary times and is therefore associated with the opening of the present day Atlantic Ocean. The surrounding countryside was modified during the last glaciation by deposits of drift coupled with the cutting of channels by sub-glacial melt-water streams. There appears to have been a considerable stream system underneath the ice sheets whereby a complex of channels became incised in the underlying land surface: they cut into both solid rock and drift deposits and are typically steep-sided with flat bottoms. Some have humped longitudinal profiles indicating uphill flow of water under hydrostatic pressure. Many begin and end abruptly and although some contain present day streams many are now dry. These observations suggest that the channels were cut sub-glacially and not by successive stages of overflow from ice-dammed lakes as was previously thought. This drainage system had a dendritic pattern converging on and emptying through the Tyne Gap.

The party continued to Outhwaite initially over St. Bees Sandstone and then across the Pennine Fault. Across the valley of Raven Beck could be seen a glacial meltwater channel with dumps of sand and gravel resting on boulder clay. The gravels had been cemented by immersion in calcareous waters. Just beyond the farm buildings small exposures by the track showed tight folding in Carboniferous Limestones immediately to the east of the Pennine Fault.

The folding became more open a little further from the fault in Raven Beck and diminished almost entirely as the beck was followed upstream to an exposure of the Whin Sill. The Sill, exposed along the valley sides, formed a waterfall where it crossed the stream (617 438). Whin Sill is a quartz dolerite consisting of labradorite, hypersthene and augite with a quartz-feldspar intergrowth as groundmass. This intergrowth is confined to the coarser middle part of the more massive parts of the Sill and was not seen in this exposure which was relatively thin at 6m overall.

Stratigraphy provides an approximate age for the Sill between Middle Coal Measures and Lower Permian, for the highest beds intruded by the Sill are Westphalian rocks of N.E. England and pebbles of the whinstone occur in the Lower Brockram near Appleby. Intrusion of rocks to the west of the Pennine Fault seems to have been prevented by rocks of the Cross Fell inlier which was brought against the Carboniferous Limestone by faulting. No trace of the Sill has been found to the west of the Pennine Fault where it should, if present, occur in Lower Palaeozoic rocks of Pre-Carboniferous age.

The party returned downstream, noting a small anticline at stream level which exposed a typical Yoredale cyclothem of limestone, shale and sandstone, and then turned into Loo Gill at 614 435. Tight, almost isoclinal folding with axes parallel to the Pennine Fault was well exposed in the gorge-like section of lower Loo Gill. More Yoredale cyclothems were noted and the trace fossil zoophycus examined on a wall of vertical Tynebottom Limestone.

Upstream in more open ground, a short search revealed a small exposure at stream level of the Armathwaite Dyke, just above a footbridge (622 430). This rock is a tholeiite distinguishable in the field from the Whin Sill by its porphyritic character with phenocrysts of plagioclase feldspar and pyroxene set in a dark, find-grained groundmass. The variable character of the country rocks near the Pennine Fault has broken the continuity of this dyke into a series of pod-like sections.

After lunch the party continued upstream noting Giganto-productids and Lithostrotion in slabs of Lower Little Limestone. At 622 428 a mass of cemented Pleistocene gravel rested on boulder clay and at stream level a thin coal seam overlying a seat earth concluded another Yoredale cyclothem.

At 628 426 a track over the moor was followed northwards, cutting down into upper Raven Beck after a mile and a half. Eight miles to the west the conical outline of Barrack Fell denoted an outcrop of the Armathwaite Dyke. Across the moor coal levels have been driven underneath the Four Fathom Limestone. Numerous shakeholes have sunk into the quite thick drift alongside the track.

A scar on the slopes of Renwick Fell marked the site of a catastrophic mud flow on 13th August, 1966. Following prolonged rainfall a mass of water accumulated in the spongy peat cover until it could no longer be contained and it flowed downhill as a slurry scouring away all vegetation. (A similar smaller peat flow blocked the M 62 in June of this year, 1982).

In upper Raven Beck at 620 443 Whin Sill of more typical thickness was exposed along the valley sides and again formed a waterfall. This was really a continuation of the exposure lower down the beck where the Sill has been stepped down by faulting.

The track on Greenrigg was reached at 612 442 and followed down to Renwick, noting a fine esker in the valley below in the vicinity of Fellgate.

REFERENCE

ARTHURTON, R.S. & WADGE, A.J., 1981. Geology of the Country around Penrith. Memoir of the Geol. Survey.

EXCURSION TO PICA OPENCAST COAL SITE

Leader: Mr.E.Lawrence

3rd July, 1982.

By kind permission of the National Coal Board, Opencast Executive, a Saturday morning visit to the Pica Working Site was organised and guided by the Area Opencast Geologist, Mr. Eric Lawrence.

Members gathered at the site which is situated half a mile south-west of the village of Pica within the Copeland District of

Cumbria, and were given an introductory talk in the site office where the general geology and method of working the site were explained, with the aid of geological plans and cross-sections. Following this talk the party walked to the working excavation to study the exposed strata and geological structure of the site.

After competitive tender, work was commenced on the site by the Board's Contractor, W.J.Simms Sons & Cooke in November, 1980. The site is scheduled to produce 560,000 tonnes of coal from four main seams by completion date in 1985.

The strata exposed on the site comprises a Middle Coal Measure sequence of sandstones, mudstones, coal seams and seat earths, with a general dip to the east. The site is limited to the north by a large fault trending north-west to south-east, with a downthrow of at least 45m to the north-east. Another major fault forms the southern boundary of the site: this has a similar trend but the downthrow is to the south-west, again of at least 45m.

Three of the seams to be worked on the site, the White Metal, Slaty and Tenquarters outcrop between these two faults within the site boundary. The fourth seam, the Bannock, does not outcrop within the site, but will be worked in a box cut below the Tenquarters. The seams do not outcrop at ground surface, however, as the site is covered by a superficial deposit of boulder clay. The shallowest excavation depth to the coal outcrop is around 4m while the maximum depth of excavation down dip will be approximately 85m.

The party was shown the complex nature of the three seams currently being worked, the White Metal, the Slaty and the Tenquarters, all being split into separate leaves, some allowing a working thickness of almost 1m, others being as thin as 15cm. The method of working an opencast site allows the production of clean coal for direct conveyance to the Board's disposal plant at Maryport.

Collections of the various rock types were made by members and some plant fossils were found, though the site is not as fossiliferous as others in the county. The northern major fault was well exposed, and also numerous small faults with throws of 2 or 3m, where usual fault features such as slickensided surfaces and distortion of strata could be examined. Small washout features were pointed out and it was explained how these were expected to prove more extensive in the lower seam, the Bannock.

The tour finished at the site office where some restoration features were pointed out, the Board's aim being to restore the site to agricultural use, with improved drainage and land form.

All who attended appreciated the opportunity of seeing these features of the Coal Measures, and of having them so well explained and correlated.

VISIT TO THE FLORENCE MINE, EGREMONT

15th March, 1983.

Ten members, some gaining a new experience, others with some nostalgia, took the opportunity to see the only remaining working hematite mine under the guidance of Mr.G.Finlinson, the Managing Director of the Egremont Mining Co. He showed a three-dimensional model of the area immediately to the south of Florence Mine illustrating the occurrence of the ore. It lies, always associated with faults, in parts of the Lower Carboniferous Limestone; the 6th and 7th Limestones in this part of the ore field. Below the limestone at this point lie beds of Skiddaw Slate, but towards Beckermet rocks of the Borrowdale Volcanic Group form the base of the limestone, which drops southwards, from Florence to Beckermet, about 600m, mainly due to a series of faults.

The Permo-Trias normally overlies the limestone: where, in mining, the Brockram has been cut, problems have arisen due to its flowing.

Equipped with helmets and lamps, the party descended by cage the 57m shaft, and were taken into the workings originally driven by the separate but adjacent Ullcoats Mine. The walls, at first in St. Bees Sandstone gave way, by faulting, to limestone showing a shale parting and in places fossil shell sections. There was then a gradual patchy change over a few metres from limestone to hematite.

Passing the now disused and very wet Ullcoats Number 1 shaft, a rise took the party into an area mined at the turn of the century. In following the sloping ore body the miners had broken into sub-surface sand, causing a major problem only solved by sealing off that working. The rest of the area will have its pillars 'robbed out'. The ore body being worked is approximately 26m thick, de-watered by two pumps delivering a total of 900 litres per minute. Workings in the south of the ore field are now flooded.

Most of the hematite is massive, bluish, relieved by occasional small vugs with barytes and calcite. Bedding plane relicts were pointed out at one site, and, very unusual here, a bus-sized empty natural lough. Kidney-ore development was found to be of restricted occurrence.

Present policy is to market very high grade ore (it can reach 90% purity) for specialised steels, and to exploit the high density of iron ore by selling it to make 'heavy weight' concrete used under-water by the oil industry.

The party was shown a scraper and loader in use, and on the return walk to the shaft had to make way for the electric locomotive taking tubs of ore to the shaft bottom.

The visit concluded at the mine office with a brief look at mineral specimens available for sale.

EXCURSION TO THE LITTLE KNOTT PICRITE

Leader: Mr.K.W.Bond

17th April, 1983.

Some 13 members met at Castle Inn on a bright chill day, the leader taking the place of Dr.Cockersole, whose professional duties compelled his absence. Having parked their cars on the Highside road (236 311) the party walked up the steep ridge to an exposure (probably an old quarry) on the Watches. On the way several tight folds and brecciations were noticed in the Skiddaw Slate.

At the old quarry the picrite was easily identified by its well jointed massive blocks. Detailed examination showed the picrite to be hard, brittle and flinty with prominent hornblende phenocrysts showing striation under the lens. Mineralogical investigations reported in the literature show the rock to be 80 - 90% hornblende, with a little chlorite. Nearby in the Skiddaw Slates a probable Orthograptid and a trace fossil were found.

The walk continued to Little Knott and observation suggested a sill-like form to the intrusion. Specimens of spotted slate were found along the contact where Skiddaw Slate has been metamorphosed. A group of boulders of picrite resting on Skiddaw Slate bedrock, suggested a glacial or periglacial mechanism for their transport.

In the afternoon various features adjacent to the main Bassenthwaite to Keswick road were examined. The first stop was near Little Crosthwaite where a newly widened forest road meets the main road. The newly cut exposure showed an undulating surface of till with ill-sorted boulders succeeded by a bedded deposit of angular coarse material whose long axes pointed down slope. 'Water-lain', 'talus', 'periglacial' were suggested origins.

A dyke outcrop was then visited on the dangerous bend by Longclose Farm. The dyke rock is fine grained, pale, silica-rich, with slate xenoliths, and small pyrites crystals. It formed a slight ridge 3 - 5m wide rising above the softer shales, with fluvio-glacial sands deposited in its shelter. A rather larger dyke outcrop 50m to the north had been quarried. The Longclose area offers an excellent view of the post-glacial alluvial infill and hydroseres at the south end of Bassenthwaite Lake, and of the drumlin family towards Crosthwaite Church.

Mr. Bond was warmly thanked for his guidance, and for taking over the leadership of the excursion.

(Further information on this area is given in E.H.Shackleton's 'Geological Excursions in Lakeland').

EXCURSION TO DOBB'S LINN

Leader: Dr.E.N.K.Clarkson

8th May, 1983.

13 members of the Society and 9 members of the Newcastle branch of the Institute of Geologists met at the Grey Mare's Tail car park some nine miles to the north-east of Moffat, southern Scotland. Dr. Clarkson then led us to Dobb's Linn, the classic site Lapworth had examined in detail in his 1878 paper. He reminded us of the stamina, fieldwork skills and intellectual virtuosity Lapworth had shown. It was only in very recent years that the ground had been critically re-examined and alternative interpretations developed by staff and post-graduate students from Glasgow University. The main differences suggested were that the two isoclinal folds Lapworth had mapped are now interpreted as local and minor rather than the overall structural controls, which are now held to be thrust and strike faults.

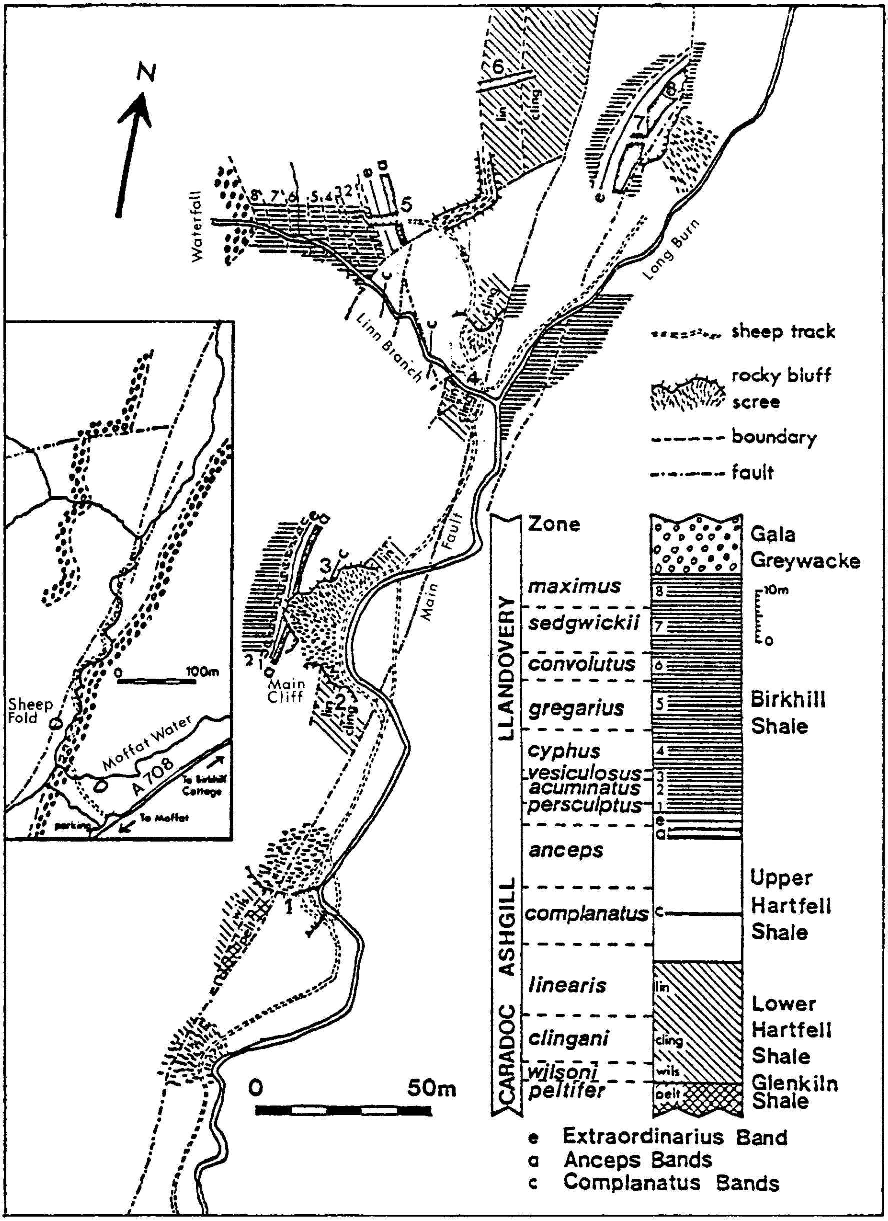


Fig. 1 THE ORDOVICIAN AND SILURIAN SUCCESSION AT DOBB'S LINN

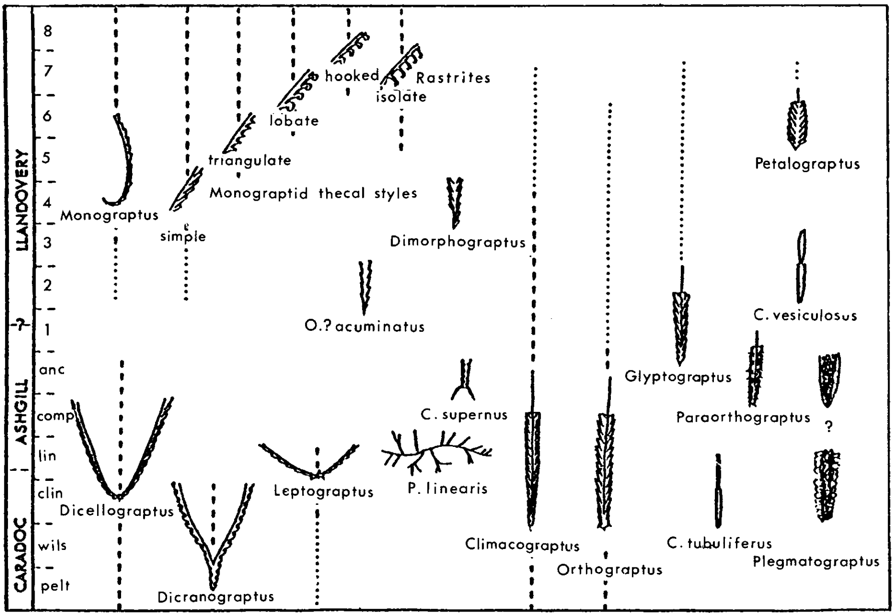


Fig. 2 THE GRAPTOLITES OF DOBB'S LINN

The succession at Dobb's Linn extends upwards from the Caradocian of the Upper Ordovician into the Wenlock of the Mid-Silurian. It is a typical condensed sequence deposited well out to sea far from the then shore line near Girvan. The basal members, the cherts of the Glenkiln Shale's peltifer zone (see the map on the previous page) and the wilsoni zone of the Lower Hartfell Shale are poorly exposed.

Specimens were more plentiful, better preserved and easier to recognise than our members expected. The first stop for collection was in the clingani zone on the steep hillside (locality 6 on the map) west of the Long Burn where an over-fold and fault had led to inversion. Specimens of the characteristic Dicranograptus, Dicellograptus and Climacograptus species were plentiful and some of our members were successful in identifying all three! Time prevented an attempt to look for the much rarer planktonic brachiopods and blind trilobites recently discovered by research workers.

The group then proceeded up the succession to locality 5, through the complanatus and anceps zones, finding good samples of Pleurograptus linearis and the characteristic V-shaped Dicellograptids, the uppermost fossils before the barren grey mudstones at the top of the Ordovician. The absence of graptolites at this horizon is attributed to the lack of algae, possibly due to a glacial episode.

The party lunched just below the main cliff and spent some time looking for the *anceps* zone and the overlying Silurian zones to try and pinpoint the boundary. This was easier to appreciate in the trench dug across the boundary by research workers just north of the Linn Branch. Most of the afternoon was spent in the Birkhill Shales of the Lower Silurian, both north of the Linn Branch and also by walking up the steeply inclined strike of these beds south of the very impressive waterfall. The darker shale beds are especially rich in graptolites, mainly from zones 4 to 7 (*cyphus* to *sedgwickii*). Many fine specimens of the easily recognised *Monograptus sedgwickii* and the biseral *Petalograptus* were found. Contortions in the greywackes are clearly seen near a pronounced east-west fault.

Members who attended felt that this was one of the best excursions for some years despite the long journey involved and the rather grey weather. They expressed their enthusiasm for the interest-arousing leadership Dr.Clarkson had given.

EXCURSION TO THE DUDDON VALLEY

Leader: Mr.H.Kellett

5th June, 1983.

25 Members and friends met at Ulpha Bridge on a fine warm breezy day, and at once proceeded to Hall Dunnerdale (215 955) where Harry Kellett gave a brief introduction to the geology of the Duddon area. He described the upper Duddon valley as an alternation of narrow, steep, V-shaped gorge-like sections and wide open straight stretches of markedly U-shaped cross-section. The rocks east of the Duddon showed the typical Caledonian strike especially in the waterlain Ordovician tuffs. Their dip was very variable in amount (from 15° to 90°), but generally to the south-east. Most were brecciated tuffs with the fragments protruding from the matrix. Two sets of folds could be seen, the pre-Caradoc movements and the main Caledonian folds, plate movements

being responsible for the underthrusting.

Investigations began at a copper vein, just east of Hall Dunnerdale, showing brecciation near an old trial working. A little further along the green track were the remains of the small Hall Dunnerdale copper mine, where the vein seemed to be both poor and narrow, with a few small pyrites crystals. The mine closed in 1890. The old low, narrow entrance is still visible, as are traces of the water wheel position. The vein continues to the south.

The party continued along the valley of Old Park Beck, which follows, approximately, the shatter zone of the Great Longmire Fault, with its very big throw and hematite-reddened rocks near the fault plane. Outcrops of lava, probably andesite, show joints and flow banding. From a distance small rhyolite flows were seen, distinguishable by their slightly 'blonde' colour, one of which was worked in Cow Quarry, on the hillside above.

To the north a volcanic agglomerate to the west of the track leading to Seathwaite Tarn was pointed out, recognisable from a distance by its different relief.

After lunch a call for liquid refreshment gave opportunity to examine the fine-grained cleaved flagged floor of the Newfield Inn, providing a good illustration of graded bedding, slumping and earlier shattering followed by later cleaving. Walking on the field path to Turner Hall farm, roches moutonnées were seen where cleavage and bedding were almost parallel and with glacial striae still recognisable and with siliceous ribs standing proud. The finely bedded rocks at Turner Hall contained several oval-shaped features up to 1m in length, with onion-skin patterns. They were fairly uniform in shape and size, but some had bedding running through the features, and others had it curving around. Some seemed to be softer than the rock around, whilst others had raised rims. Two origins were suggested: nodules of chemical origin, or volcanic 'bombs'.

The return journey was along the foot of Wallabarrow Crag, noting the bedded tuffs south of the fault, and rhyolite flows on Wallabarrow immediately overlooking the Duddon, and the andesite further west. Thick peat has infilled the postglacial whirlpool site at the foot of the Crag. The outcrop of quartz porphyry dyke in Rake Beck valley was found, aided by previous sight of its striking red colour and almost freestone properties when used in the walls of the farm buildings at High Wallabarrow. This dyke has a very narrow chilled edge and hardly alters the rocks around, but can be traced as far as Whicham and Ambleside. There was discussion as to whether is was of Caledonian age.

The leader was warmly thanked for providing such an extensive and instructive tour of the area.

CARBONIFEROUS LIMESTONE OF BLACKSTONE POINT, ARNSIDE

Leader: Mr.M.Mitchell

9th July, 1983.

This was a joint excursion with the Westmorland Geological Society, and the following report is reproduced with their kind permission:

The six regional stages of the Lower Carboniferous of Britain are based on six major cycles of transgression and regression which have been recognised in the limestones, each stage corresponding to one major transgressive-regressive cycle. The cycles are of widespread occurrence throughout Britain and are believed to be the result of eustatic (worldwide) changes in sea level.

The Arnside foreshore is a classic locality for exposures of the Dalton beds, part of the Arundian Stage of the Lower Carboniferous. The Dalton beds are divided into three parts; a lower unit of well-bedded limestone, a middle unit of thin limestone beds with shale partings and an upper massive-bedded sandy unit.

The Arnside limestones form one of the easterly dipping faulted blocks found on the southern fringe of the Lake District between Millom and Kendal. The Arnside beds show moderate folding and faulting probably connected with the major structural disturbances around Trowbarrow where beds are vertical, in contrast to the gently dipping undisturbed limestones of Meathop across the estuary. It is the less competent thin limestones and shales of the middle Dalton Beds which have buckled under the compressive forces to become folded and faulted.

A large party of about forty members of both Cumberland and Westmorland Societies assembled on the promenade at Arnside on a hot, sunny morning, and ambled slowly along the foreshore to reach Blackstone Point in time for lunch.

Thin bedded limestones with shale partings of the middle Dalton Beds are exposed just beyond the boatyard. These beds were included by Garwood in his *Michelinia grandis* zone and several examples of this zone coral were found in loose material below the small cliffs. The trace fossil *Zoophycus* was noted on the underside of bedding planes. Moving further along, and down the sequence into more massive limestones of the lower Dalton Beds, weathered examples of the large brachiopod *Delepinea carinata* were seen on the well trodden slabs of the foreshore. Arnside is the

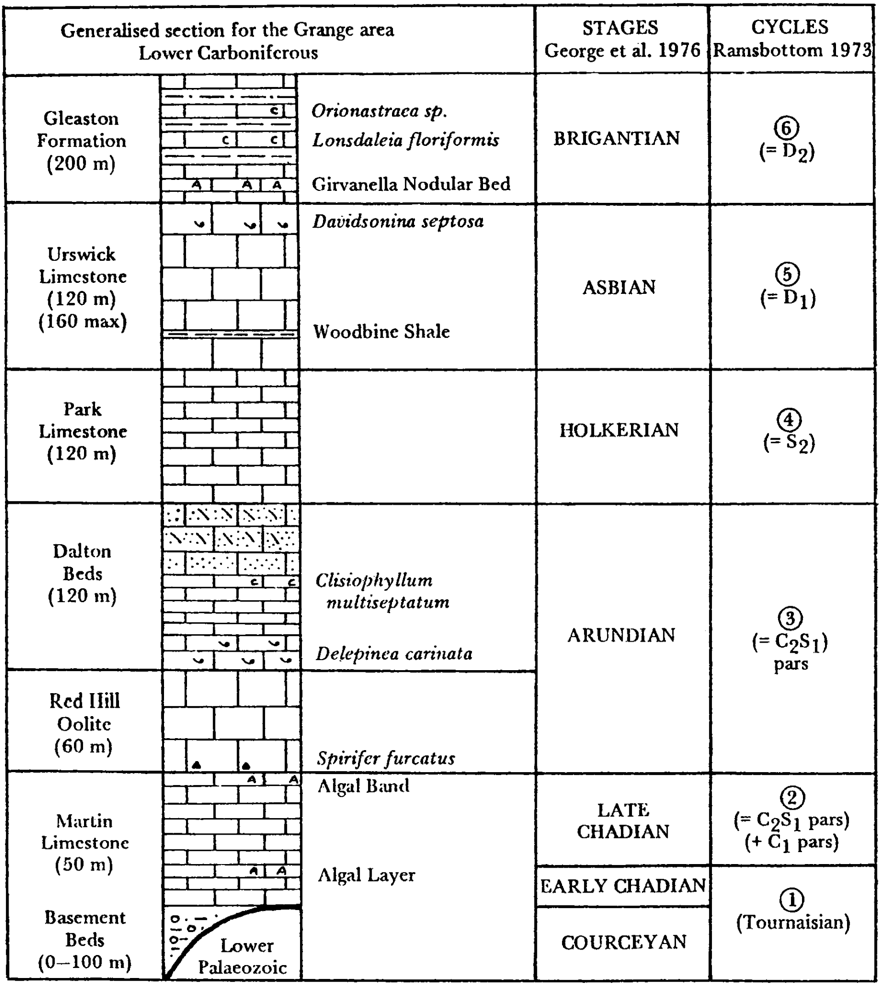


Fig. 1 DIAGRAM OF THE LOWER CARBONIFEROUS SUCCESSION.

type locality for this brachiopod which is confined to the bottom five to ten metres of the Dalton Beds. It is also found in South Wales, Weston-super-Mare and Ireland, although because of a gap in the Lower Carboniferous sequence in the Avon Gorge it is absent from that section. The widespread distribution and narrow vertical range of Delepinea carinata make it invaluable as a zonal fossil in correlating Lower Carboniferous rocks. Several

GARWOOD 1913	Some characteristic fossils
Upper *Dibunophyllum* Subzone	*Dibunophyllum bipartitum* *Diphyphyllum lateseptatum* *Lonsdaleia floriformis* *Palaeosmilia regia*
Lower *Dibunophyllum* Subzone	*Axophyllum vaughani* *Palaeosmilia murchisoni* *Dibunophyllum bourtonense* *Lithostrotion spp.*
Nematophyllum minus Subzone *Cyrtina carbonaria* Subzone	*Linoprotonia corrugatohemispherica* *L. ashfellensis* *Lithostrotion minus*
Gastropod Beds *M. grandis* Zone: *Chonetes carinata* Subzone	*Composita spp.* *Palaeosmilia murchisoni* *Michelinia megastoma* *Siphonophyllia garwoodi* *Haplolasma subibicina*
M. grandis Zone: *Camarophoria isorhyncha* Subzone	*Palaeosmilia murchisoni* *Koninckophyllum praecursor* *K. ingletonense*
Seminula gregaria Subzone *Solenopora* Subzone	*Axophyllum simplex* *Carruthersella compacta* *Thysanophyllum pseudovermiculare*

fragments and one excellent specimen were found amongst loose rock on the foreshore.

A low cliff just above high water mark contained a rich coral fauna and examples of gastropods.

Moving on past New Barns the party walked to Blackstone Point for a leisurely lunch stop. The limestones of Blackstone Point are near the top of the middle Dalton Beds. This is a most fossiliferous locality and includes Garwood's Clisiophyllum multiseptatum band.

After lunch it was suggested to the party that they might exert themselves instead of basking in the sun and collect as wide a variety of fossils as could be found. The subsequent accumulation of corals and brachiopods were set out on a convenient slab and it then became clear that only the corals were really required. The true object of the exercise proved to be the testing of a taxonomic key designed by the leader, with which it was possible to identify, down to genus level, a range of Carboniferous corals.

The party ambled back to Arnside and dispersed.

For some of the Cumberland members this excursion was part of a weekend programme that continued on the next day with an excursion over Yewbarrow and Whitbarrow also under the leadership of Mr. Mitchell, a repeat of the W.G.S. excursion of 1981.

EXCURSION TO THE CARBONIFEROUS LIMESTONE

OF YEWBARROW AND WHITBARROW

Leader: Mr.M.Mitchell

10th July, 1983.

15 members and guests assembled by the A 590 road at Witherslack Hall lane end (436 859) on a very hot Sunday. The leader outlined the area's structure and stratigraphy. The two north-south blocks of Carboniferous Limestone forming Yewbarrow and Whitbarrow are fault bounded on their eastern sides with the basal limestones resting unconformably on the Silurian Bannisdale Slates on the western flanks. These Carboniferous Limestones in the Furness and Cartmel areas are much thicker and more complete than those of West Cumbria.

At Cat Crag Quarry on Yewbarrow were fine exposures of the Red Hill Oolite of Arundian age, a very pure limestone with little shale, and with characteristically wavy weathered surfaces. It is a pelleted high energy sediment producing rolling landscapes of gentle dip and scarp features. By the Holy Well the Red Hill Oolite/Martin Limestone junction outcrops, a shale parting between producing a cavern. The Martin Limestone is a fine grained dolomitised rock with many shale partings.

A raised peat bog has developed on the recent alluvium which covers the Bannisdale Slate in the south of the Winster Valley. The slates form rock ribs moulded north to south by ice. Slate Hill is an east-west rock bar which ponds back a small tarn. Near Halecat Quarry an unconformity between the highly contorted Bannisdale Slates and the gently dipping Martin Limestone forms a noticeable break in slope. Near the Martin Limestone of Chadian age are exposures of a cemented Quaternary periglacial scree deposit.

The Martin Limestone makes a good building stone with its regular joints and bedding picked out by the frequent shale partings. Mr. Mitchell suggested that limestones from this quarry may have been used to build parts of the nave of Cartmel Priory.

The party climbed to St. Paul's Church, Witherslack, sited on a shelf in the Lower Dalton Beds of Arundian age. The basal beds contained a very large brachiopod, Delespinea carinata, but the junction with the Red Hill Oolite is not very obvious, mainly a change to darker rocks with more shale partings. The Middle Dalton Beds, also of Arundian age, show alternations of shale and limestone, but the late Arundian Upper Dalton Beds are the main scarp former. The eastern slopes of Yewbarrow follow the dip of these beds as far as the fault near Lawns House. This fault with its westerly downthrow of about 150m, is picked out by calcite veining on the track and a small north to south bank running through the woods.

A descent was made to Witherslack Hall, near which lies a former lake basin now filled with sediments which have been investigated by pollen analysis.

Before climbing Whitbarrow's scarp face the junction of the Middle and Upper Dalton Beds was seen. The ascent brought underfoot the Park Limestone, of Holkerian age. This weathers into dark platey blocks which 'rang' melodiously when walked on. The rhythms of the Asbian age Urswick Limestone showed up in a series of prominent dip and scarp features, separated by beds of shale which were not exposed.

The anomalous Argles Tarn is probably held in by a shale band slightly thicker than usual. The unexpected patches of heather growing in the north-south aligned hollows on the top of Whitbarrow are on lime-free loess blown uphill when Morecambe Bay was a tundra area following the retreat of the Lake District glaciers.

The pavements which developed on the Urswick Limestone on the eastern flank of the hill dip east at 20 - 30^{o} and are formed by rocks of the same age as most Northern England limestone pavements. The limestone cycles are related to variations in sea level. Rhythms of sedimentation of perhaps half a million years duration have formed bands about 5m in thickness. The basal deposits are cross-bedded high energy limestones followed by thicker bedded limestones formed during calmer conditions. A prominent master bedding plane usually occurs at the top of the limestone part of the cycle and a shale layer rests on its surface. The shale is partly composed of atmospherically-derived volcanic dust. These master bedding planes are usually the site of the main limestone pavements.

At the conclusion of the excursion all present conveyed their appreciation to Mr. Mitchell for an excellent weekend which had enabled them to see exposures of most of the Dinantian succession in this area.

THE ROCKS OF THE EDEN VALLEY

Leader: Mr.J.Rodgers

3rd September, 1983.

The party of 9 was taken by minibus to the vicinity of Penrith Beacon where Cowrake Quarry was visited (540 309). Here the Penrith Sandstone is well displayed in a SE facing escarpment. Mr. Rodgers explained the origin of the sandstone in desert dunes, and the rounded aeolian sand grains, with later quartz overgrowths, were easily seen under a hand lens. Bedding planes dipping at 25 - 30^{o} NW were followed across the face of the quarry, whilst in the upper part, thin flaggy partings dipping NE at 5^{o} were seen. These were formerly in demand as roofing flags. The principal feature in the quarry is a magnificent fault plane with horizontal slickensiding, interpreted as a dextral tear fault.

Some three miles SE of Penrith beacon the party visited another quarry in Salter Wood, near Cliburn (584 264). A set of truncated dunes could be seen, although an overall appreciation of them was rather obscured by coniferous trees.

By kind permission of the owners, the group then visited a river bank exposure in the grounds of the Winderwath Estates. Here could be seen gypsum of the fibrous variety interspersed with rather nodular pink and orange alabaster, protected by the overhanging banks of the Eden. Mr. Rodgers explained that the Eden Shales hereabouts were probably formed in a playa-lake bed in an arid environment. Four phases of playa-lake evaporation had been recognised, and the gypsum was being mined not far away for the manufacture of plaster and plasterboard.

Lunch was taken at Hoff, near Appleby, and the party then visited the classic exposure of Brockram at Burrells (676 180). The coarse breccia, showing characteristic imbrication, was interpreted as having formed in alluvial fans on the edge of a Permian desert basin. The clasts in the Brockram were mainly of Carboniferous Limestone, with characteristic fossils, and sandstones.

A short drive brought the party to Hilton beck (720 207) where, due to recent heavy rain, it was impossible to investigate the stream bed. However, the leader pointed out the position of the Belah Dolomite, interpreting it as a marine incursion on to Permo-Triassic coastal flats. The adjacent micaceous sandstones yielded ancient ripple marks and carbonised traces of plants, as well as trace fossil trails.

Having explained and demonstrated the environments of deposition of the Permo-Triassic rocks around Penrith, Mr. Rodgers took the party a few miles north, to Armathwaite, where a magnificent Tertiary dolerite dyke, some 10 - 15m wide, crosses the River Eden (504 453). An interesting end to a full day's geology was provided by the spectacular dune-bedding features in the sandstone river-cliffs, and the potholes and other erosional features of the river bed.

REFERENCE

'The Lake District: a geological field guide', 1982. Cumberland Geological Society. Unwin Paperbacks.

EXCURSION TO THE THREE SHIRES STONE

Leader: Dr.P.Allen

17th September, 1983.

Thirteen members and friends met on a grey windy day at the Three Shires Stone on the summit of Wrynose Pass (278 027). In introducing the day's activities, Dr. Allen explained the distinction between the Lower Borrowdale Volcanic Group with its andesitic lava flows, and the predominantly pyroclastic Upper Borrowdales. He emphasised the importance of fault control within the sequence.

The morning was spent between the Three Shires Stone and Black Crag (275 037) on the southern slopes of Pike O'Blisco. Andesitic lava flows of the Lower B.V.G. were examined, each forming steps of limited lateral extent. Their bases are brecciated, their centres massive, some with compositional layering and flow jointing. Their upper parts are also brecciated, with laminated sediments filling the gaps between the blocks which are up to 0.5m in length. The volcaniclastics separating the lava flows are unfossiliferous, fine grained, and were probably deposited in lacustrine conditions. Outcrops of sediments show many minor contemporaneous faults, slumps or slides, and sinuous breccias which Dr. Allen interprets as pebble dykes marking the passage of hot springs. The frequent small contemporaneous faults he attributed to minor seismic events such as those preceding the recent Mt. St. Helens eruption.

Further up the hill slope was an ash flow at the base of the Upper B.V.G., easily recognisable by its flattened and weathered-out pumice fragments. This is an extensive unit, but present here only as a faulted wedge of no great lateral extent. Overlying this unit are coarse grained tuffs and thinly bedded volcaniclastic sediments showing excellent slump structures.

Continuing upwards towards Black Crag and crossing a major fault led to a different Upper B.V.G. sequence. Near its base is an ash flow tuff with pink nodules, diagnostic of this hard splintery rock. The nodules, which could originally have been gas filled bubbles, have blade-like central hollows containing quartz and epidote crystals, surrounded by a pink bleached zone similar in composition to the host rock.

Epidotisation, which affects much of the Borrowdale Volcanic Group, is well exhibited in tuffs overlying this nodular tuff on Black Crag. This Crag consists of a great depth of thin ash flows of very variable thickness, and bedded volcaniclastic sediments.

After lunch the hummocky drift near Red Tarn (268 036) was crossed onto the eastern slopes of Cold Pike (263 036) where an andesitic lava flow was traced from its frontal end. Overlying it is a very thick and extensive quartz andesite flow which in places is massive, but elsewhere is brecciated, locally incorporating blocks of foreign material.

On the eastern slopes of the Gaitscale Gill near Gaitkins Crag (258 032) was found an island of Lower B.V.G. andesitic lava within Upper B.V.G. volcaniclastics and ash flows. Its shoreline is marked locally by overstepping volcaniclastics.

On the return journey outcrops of garnetiferous dacite were seen on the steep banks of one of the east bank tributaries of Gaitscale Gill (260 228). Further east in the bed of a smaller tributary (263 230) the nodular tuff is exposed, with the large nodules in the stream emphasising the dramatic colour variations in the rock.

The leader was thanked for demonstrating and interpreting the sometimes subtle features of these volcanic rocks.

THE WEST CUMBERLAND HEMATITE OREFIELD

15th - 17th July, 1983.

For this weekend excursion the Cumberland Geological Society was host to the Yorkshire Geological Society and some thirty of the members of that Society stayed in or near Whitehaven for the occasion.

Friday evening 15th July

The weekend began with a welcome by officials of the Cumberland Society to their Yorkshire guests in the conference room of the Chase Hotel, Whitehaven. Mr.T.Shipp gave a talk on the stratigraphy of the area, mentioning in particular that hematite occurred in most local rocks, including granite, Skiddaw 'Slates' and Carboniferous Limestone. Much information on these rocks, especially the Limestone, had been gathered in prospecting for hematite orebodies, found to be associated with faults.

Saturday morning 16th July

Nearly 20 of the Y.G.S. members started their day with a visit to the Daniel Hay Library, Whitehaven, to see books and maps relating to the hematite mines.

Later a party of 30 descended the shaft of the Egremont Mining Co.'s Florence Mine (019 102) by kind permission of their Managing Director, Mr.G.Finlinson. The party walked into the Lonely Heart workings, crossing at a fault from Permo-Trias St. Bees Sandstone into the 7th (lowest) Limestone where goniatites replaced by micaceous specularite were pointed out. Mr. Finlinson showed the visitors a 2m wide outcrop of botryoidal kidney ore in which there were incipient 'pencils'. He then led the party into an area where stoping of an irregular body of ore approximately 25m in vertical thickness had taken place from several levels. Good hand specimens of kidney ore, specularite, quartz, calcite and dolomite, often with two or three minerals on the same piece, were collected from the fine vugs exposed in the roof. Mining methods used to win this rich ore yielding 50 - 55% of metallic iron were explained. It is worked in small tonnages of high quality and the variable demand for the ore is mainly for foundries, pigments, annealing and occasionally for heavy aggregate.

British Nuclear Fuels Ltd. use the water from the mine and pay half the pumping costs.

Saturday afternoon

A party of nearly 50 met at the 'Ratty' car park at Boot, Eskdale (176 012) to visit the Nab Gill Hematite Mine site, under the direction of Mr. Brian Young. Mr. Young has kindly contributed a paper on this mine which appears on page 269 of these Proceedings, to which the reader is referred.

Saturday evening

The Societies were honoured by an address by Sir Kingsley Dunham on the local hematisation. About 50 members and friends assembled at Hensingham in the Nurse Training School Lecture Theatre by kind permission of West Cumberland Hospital Authorities. Sir Kingsley has written a paper on this subject which appears on page 259 of these Proceedings, for which the Cumberland Geological Society is most grateful.

Sunday 17th July

A party of about 50 was split into two groups with Messrs. Shipp, Loftus, Lawton, Martin and Dodd, of the C.G.S., acting as guides. The more leisurely began by visiting the old buildings and open shaft of the Margaret Mine (046 171). The more energetic started from the old Eskett (051 167) and Eskett Park Mine tips. Both traced the positions of the Yeathouse fault and an older pre-Triassic fault, before visiting the *Chonetes* marker band in Yeathouse Quarry (043 168). By kind permission of Mr. Wilson of Winder Farm, shelter from a thunder shower was found in one of his barns!

After lunch the groups rejoined and visited Winder Gill Mine, with its tolerably good hand specimens of hematite, specularite, dolomite, quartz and calcite. As time was pressing the party drove past the old collapsed workings on the Keltonfell Top veins (085 185). Most of the party followed the abandoned Rowrah and Keltonfell branch line track to the Knockmurton Shaft area (095 078). The keener, more energetic spirits climbed the steep hillside to the tips by the open adits. Manganiferous samples were found and a few members followed a vein down an open adit.

During the afternoon Dr. Coverdale of the Yorkshire Geological Society expressed the appreciation of the visiting Society for the weekend programme.

A section of the 'handout' relating to the Sunday excursion is reproduced as Appendix 'A'.

A short article by Mr.J.J.Martin on the economic development of the orefield follows as Appendix 'B'.

APPENDIX 'A'

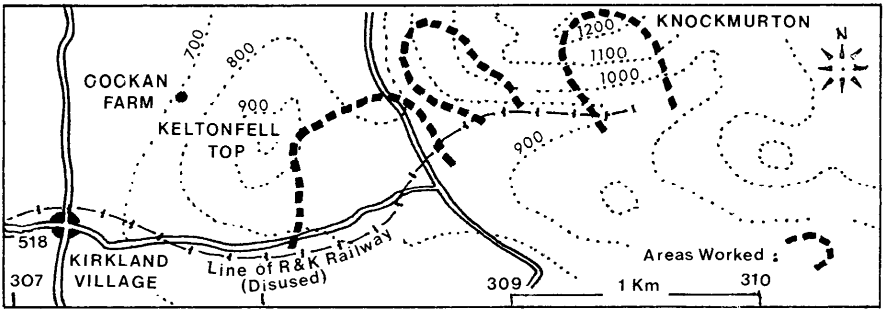
KNOCKMURTON AND KELTONFELL MINES

These are the only major hematite mines in the Skiddaw Slate Series. The deposits were very irregular and the ore of poor grade (50%) and often more greyish than in the limestones, being silica-rich. It occurred in veins, dipping E. or N.E., 45 to 80° below horizontal. Usually the vein walls were heavily slickensided and well-defined. The ore was normally in lenticular form, swelling out into bunches in places. Loughs contained quartz, some kidney ore, shale-slate mixtures and gangue. The veins are often N.W. to S.E. and were worked down to 100m on Murton Fell where they were thinning out irregularly. Approximately 20 veins were discovered, the main concentration being on Keltonfell Top (on the east side sloping down to Leaps Beck), workings there going down to 200m.

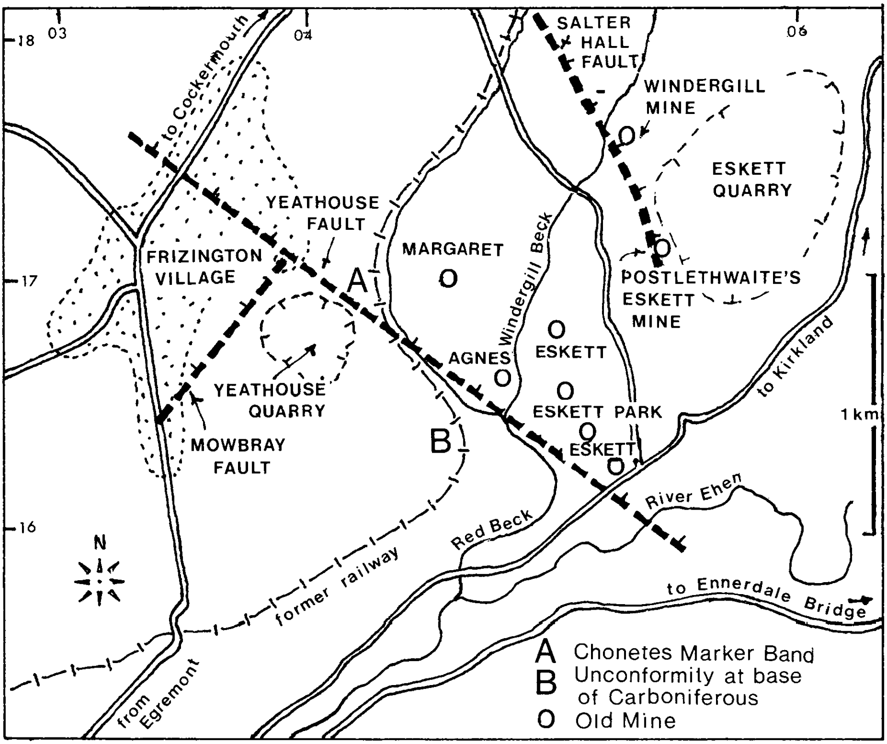
Knockmurton mines were operated spasmodically from 1853 to 1914, Keltonfell mines a little later.

The branch line known as the Rowrah and Keltonfell was built from the Whitehaven, Cleator and Egremont railway. Maximum output was about 62,000 tonnes in 1883 dropping to 10,000 to 20,000 tonnes per annum just before closure about 1920, when reserves were very small. Keltonfell Top was the more productive of the two, being worked from three shafts, with adits. The ore was proved west to Kirkland village and north to Cockan Farm. The Knockmurton mines were worked from two or three shallow shafts and several 'day-levels' following the strike of the veins, with a level draining into Cogra Moss valley de-watering the workings.

The Hematite Memoir gives the position of the productive parts of the Knockmurton veins as between the Loweswater Flags and the Mosser Slates (? Dixon's 1925 divisions), (? Jackson between D. nitidus and I. gibberulus zones). The best (small) mineral specimens are found on Knockmurton, mainly of quartz, hematite, specularite and dolomite.



THE OLD IRON ORE MINES NEAR FRIZINGTON



Structures

The two sets of faults are more important than the general regional dip which is 15 - 20° to the west. Those of set 1 run N.E. to S.W. with N.W. downthrow, are pre-Trias, with limestone butting against the Skiddaw Slates and with Coal Measures sometimes on the N.W. sides, and are thus known as the 'Coal Faults'. Set 2 faults are post-Trias, run N.W. to S.E. with very big downthrows, are usually hematised on the downthrow sides, and displace the earlier fault planes.

Stratigraphy

Two main outcrops are of interest:

(A) In the cutting leading into the abandoned Yeathouse Quarry is the Chonetes marker shale band separating the 7th and 6th Limestones (Holkerian to Asbian boundary), very rich in the small Chonetids and spines from Productids. As one goes further into the quarry, down the westward dip, the overlying 5th and 4th Limestones can be found.

(B) In the railway cutting to the south of Yeathouse Station the Carboniferous - Skiddaw Slate unconformity is exposed. It is described in the Whitehaven Memoir: 'The basal Carboniferous is a pyritous siltstone with a few small quartzes tightly welded to the Skiddaw Slates, which are bleached white and soft along the contact, but are deeply reddened some distance below'.

ESKETT AND ESKETT PARK MINES

These have most left in the way of 'industrial archaeology' - the old sidings, shafts, engine houses, chimneys, parts of winding gear. At first sight their tips are rather unrewarding, but on an evening excursion in 1982 'blue' barytes, aragonite and calcite needles, besides hematite, quartz and dolomite were found.

Most of the details given in these notes are interpretations of what little is extant of the mine records, mostly lost soon after mining ceased. The working period of the mines was quite short - from 1873 to 1902, with 110,000 tonnes being produced, if the records can be relied on, in the best year. Eskett (N) was the most productive area. No. 9 shaft at 50m closed in 1902.

The vein follows the Yeathouse fault dipping N. hading E., up to 800m long. It is near the surface in No. 5 shaft (Eskett (S)), at 40m in Eskett Park and is widest in Eskett (N).

THE MARGARET MINE AREA

Margaret is one of the best known and largest of the mines, described by Kendall and with a cross-section in the Hematite Memoir. The Yeathouse Fault guides the ore on its downthrow as a vein, with 'flats' in the 1st and 4th Limestones (Brigantian). Agnes Pit, worked before 1854, was the first important pit to work the shallower part of the fault vein. Smaller, older pits (Edward, John and Moorfield) worked ore bodies in the 5th, 6th and 7th Limestones on the upthrow side of the fault.

The Margaret Pit, recognisable by its chimney, shaft and engine house remains, its long low walls and tip banks, worked the veins and flats. Here the fault had a downthrow of 400m and a dip of 45°, with a vein thickness of 20 - 26m. Unfortunately, few good samples remain on the tips today.

WINDER GILL MINE

Another small mine with a short working history, extracting ores along the Salter Hall Fault with its very big throw - over 230m. Its main interest is its small but very rich tip in the field by the present day farm house.

APPENDIX 'B'

THE ECONOMIC DEVELOPMENT OF THE WEST CUMBRIAN IRON ORE FIELDS

Mr.J.J.Martin, B.A.

Monastic Houses (St. Bees and Holme Cultram amongst others) are recorded as working iron ore early in the 12th century, possibly around Crowgarth. Such working carried on through mediaeval and Tudor times to feed the many small bloomeries that existed in the area, for example at Smithy Beck in Ennerdale.

Systematic exploitation of the deposits began in the 18th century to meet the demands of the new type furnaces being built in places like Little Clifton (1723) and Maryport (1750). There was also an export trade developing from Whitehaven to South Wales and Scotland. This early activity centred on Cleator Moor and Frizington.

Output grew slowly and by 1855 only some 200,000 tonnes of ore were produced per year, making a contribution of 2.1% of the total U.K. ore output. All of this ore was from the Cleator Moor - Frizington area. In 1841 the Whitehaven Haematite Iron Co. built a new generation blast furnace iron works at Cleator Moor with four blast furnaces.

The high iron content of the ore (54% - 60%+) and its freedom from phosphorus (characteristics shared by the ores of Hodbarrow as well), made it suitable for use in the Bessemer Steel making process, developed in 1856. From that time ore production developed rapidly to meet the needs of the new blast furnace iron and steel works, particularly in Workington. Export of ore was also an important outlet. Mining activity proliferated and encouraged the rapid development of small townships like Cleator Moor and Frizington.

Some 20 mining companies, employing 6,000 men prospected and mined for ore within a complicated pattern of leases and royalty rights. Some were more successful than others and many small ventures failed altogether.

The local, high grade limestone was quarried as a fluxing agent in the blast furnaces. A complicated railway system was developed serving the mines and quarries.

Ore output varied with the state of the economy, technical advances like the Gilchrist - Thomas steel process (accommodating any quality of ore) in the 1870's, competition from foreign ore imports and the pressures of Continental and American steel outputs becoming important.

By 1870 Cumbrian ore production (including that from Hodbarrow, Millom) reached 1 x 10^6 tonnes per annum, and continued to rise to a peak of 1.75 x 10^6 tonnes in the mid-1880's. After that output began to decline, steadying at 1.25 x 10^6 tonnes per annum from 1895 - 1920. The highest level of production represented about 12% of the total U.K. output.

Between 1861 and 1900 some 48.5 x 10^6 tonnes of ore were produced at an average price of 14/3d (£0.71) per tonne, a total value of £34.47 x 10^6. Of this output 35.7 x 10^6 tonnes came from West Cumbrian ore mines. The balance came from Hodbarrow.

The fortunes of the ore mines declined after the end of World War I. Production became erratic and continued so from 1920 to 1935. Many mines closed down, Margaret Mine in 1923. The United Steel Company concentrated its ore mining mainly on new deposits (and new mines) in the Egremont and Beckermet areas.

Typical analyses of West Cumbrian Iron Ores:

	Fe_2O_3	MnO_2	Al_2O_3	MgO	CaO	SiO_2	CO_2	P_2O_5	S_2	H_2O	Metallic iron
%	82.3	0.42	3.06	0.18	0.00	10.53	0.60	0.04	0.14	2.20	57.6
%	85.5	0.06	3.02	0.00	0.90	7.40	0.00	0.02	0.07	3.10	60.0

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SHORT WEDNESDAY EVENING EXCURSIONS

The following evening excursions were arranged and proved very popular:

		Leader:
12.5.82	Granite features in Great Hall Gill	Mr.F.Lawton
9.6.82	St.Bees peat beds and pollen analysis	Mr.C.Haworth
7.7.82	The old iron ore mines around Frizington	Mr.M.B.Dodd
22.6.83	Geological sites around Bigrigg	Mr.S.H.Gate
29.6.83	Carboniferous rocks and fossils in Snebro and Bedlam Gills	(Mr.L.Colquitt (Mr.A.McCourt
13.7.83	Lower Carboniferous rocks around Dean	Mr.S.Yearsley

LECTURE REPORTS

A MODERN LOOK AT THE GEOLOGY OF THE LAKE DISTRICT

Dr. P. M. Allen

The first indoor meeting of the winter session was well attended on the 15th September, 1982, at the Derwent Centre, Cockermouth. The speaker was Dr.P.M.Allen of the Institute of Geological Sciences. Introducing Dr. Allen the President, Mr. Mervyn Dodd, referred to the valued contributions made by the Institute to Societies such as ours, particularly with the provision of speakers and leaders of field meetings.

Dr. Allen explained that, together with a group of colleagues from the Institute, he was involved in a selective study and re-mapping project in the Lake District aimed at attempting to re-interpret the geology in terms of modern knowledge and theories. The project involved a five-year programme, and differed in many respects from traditional geological surveys. Full use was to be made of a multidisciplinary approach: field mapping would have close geophysical, geochemical and palaeontological support. After taking a regional overview with the help of aerial gravimetric surveys, certain critical areas would be identified and re-examined in detail. The project was to be concerned primarily with the Lower Palaeozoic strata and it was intended to publish a special series of 1 : 20,000 maps together with interim and final reports.

Areas already identified for special study included territory to the west of Bassenthwaite Lake and Derwentwater for studying the diverse lithology of the Skiddaw Group, parts of Borrowdale extending south to Wastwater and on to Black Combe including the Eskdale and Ennerdale intrusives, and areas of Kentmere extending south into the Silurian deposits.

The geology would be interpreted in the light of modern ideas about orogeny such as those embodied in plate tectonics. The speaker digressed at this point to remind his audience about the basic concepts of plate tectonics. He then reviewed the history of the application of these ideas to the British Isles. Tuzo Wilson had postulated that the Caledonides/Appalachian belt was the result of continental collision at the time of closure of the proto-Atlantic or Iapetus Sea. Dewey had taken the argument further, describing three zones: Zone A was the foreland of the northern continent and formed the Archean basement down to the Highland Boundary Fault, Zone C he regarded as the foreland of the southern continent, while Zone B included the Ballantrae complex, the Irish Sea horst, the Lake District and the Southern Uplands. Closing subduction occurred during the late Pre-Cambrian with deposition continuing into the Silurian prior to closure.

These ideas still left unexplained anomalies, and there was good evidence for short-term subduction along the southern shore of Iapetus. For example, volcanic activity in the southern continent showed progressive geochemical changes to the south, indicative of the increasing depth of the subduction zone. The Ballantrae Ophiolite complex of pillow lavas and sheeted dykes was ocean-floor material, and, being calc-alkaline, could hardly be subduction related. The complex was probably pre-Caradoc in age and the subduction followed some time later with closure along the Solway Line. Additional evidence for this interpretation came from the lithospheric seismic traverse of Britain in 1976 and the collision was thought to be oblique with a dextral movement of about 1000 km.

Dr. Allen described this as the last of the 'megathink' concepts, and since 1976 the evidence has accumulated in smaller increments. There has been the recognition of trench deposits with subduction deformation of the accretionary prism. This could provide an explanation for otherwise puzzling anomalous 'younging' of the rock in certain localities. Perhaps complex folded and re-folded structures in the Skiddaw Group and north of the Border could contain both accretionary folds and collision folds. Perhaps the Solway line was the southern limit of the accretionary prism and not the collision line which had been displaced between the superficial deposits and the basement. The existence of distinct faunal provinces as well as the palaeomagnetic evidence however, pointed to oceanic separation along the Solway line.

In conclusion the lecturer referred to quite recent work about the development of marginal basins as a result of tensional spreading above a subduction zone, and elaborated on how such ideas might be shown to have important significance as the current project developed.

The lecture provoked a number of questions from an appreciative audience and at the conclusion the President thanked Dr. Allen for his excellent talk and commented that the members would follow the programme of the I.G.S. project during the next few years with great interest.

THE SCIENCE OF GEMSTONES

Dr. R. Braithwaite

At a meeting at West Cumbria College, Workington on 6th October, 1982, the speaker was from the University of Manchester Institute of Science and Technology (U.M.I.S.T.).

Dr. Braithwaite began by identifying the qualities by which gemstones are distinguished from other minerals. These include colour, brilliance, general attractiveness, contemporary fashion and rarity value. At present some 3000 mineral substances fulfil the criteria.

The lecturer went on to explain in some detail the scientific basis of some of the characteristic properties present in gemstones. Cleavage, for example, is dependent on planes of relative weakness in the three-dimensional molecular structure of the mineral, and is often a disadvantage. Solubility is clearly undesirable in terms of permanence and is related to the type of molecular bonding in the crystal lattice. Covalent electron pair bonding is the general rule in gemstone materials. Hardness is an important characteristic of the majority of gem materials and is again related to the type of chemical bonding ranging from covalent through ionic to Van der Waal's forces only. The audience was reminded of the details of Mohs' scale of hardness, depending on the relative scratch resistance of a range of minerals extending from diamond down to talc.

Attractive colouration is a common feature associated with gemstones and arises from a variety of causes. The transition elements tend to have coloured ions and, occurring as impurities, may impart colouration to the parent material. Thus rubies consist of carborundum with chromium as an impurity, while the sapphire is the same mineral containing traces of titanium and iron. Colouration can also be due to defects in the crystal lattice as in the case of Blue John spar. Such defects can be caused by natural or artificial irradiation. Again the crystal lattice can act as a diffraction grating giving rise to the colours of the spectrum. Pleochroism is a property of some gemstone minerals whereby the apparent colour varies with the direction in which they are viewed, examples being tourmaline and cordierite.

Some gemstones exhibit fluorescence which represents the re-emission of an invisible ultraviolet input as a low energy output of light in the visible spectrum.

Brilliance is a characteristic related to the refractive index of the particular crystal, while the term dispersion refers to the difference in the refractive index for light rays of differing wavelength.

Dr. Braithwaite punctuated his talk at various points to show many very beautiful slides of different types of gemstones which illustrated the points he was making.

In conclusion, after answering many and varied questions, the lecturer, obviously having extensive knowledge of and great enthusiasm for the subject, was warmly thanked for a most interesting talk.

A HISTORY OF COAL MINING IN WEST CUMBRIA

Mr. P. Findley

A well-attended meeting of the Society was held on 3rd November, 1982, at the Derwent Centre, Cockermouth, for a lecture on the history of coal mining in West Cumbria. The speaker, Mr. P. Findley of the Association of Mining, Electrical and Mechanical Engineers, was introduced by the President.

Mr. Findley illustrated his talk with slides showing old documents, maps and prints as well as older and more recent photographs.

The speaker began by describing some of the features of the West Cumberland coalfield. A section of No. 5 shaft at the Haig Pit showed the multiplicity of coal seams; many, however, are thin and not commercially exploitable by deep mining. Those that have been chiefly worked are the Upper Metal Band, the Bannock Band and the Main Band. The coal measures generally have a gentle dip to the west and are exposed at various localities inland such as Preston Isle, Howgate, Moresby, Keekle, Bridgefoot, and Broughton, Dovenby, Gilcrux and Aspatria. The westward dip carries the seams out under the sea where they are currently being worked from the Haig Pit.

Initially the seams were exploited at outcrop by means of shallow adits, and this phase of the story dates back to the sixteenth century or earlier. At this stage superficial seams were also exploited by bell-pits, and there may have been a thousand such excavations in the Greysouthen area alone.

More extensive working of the dipping seams was limited by the problems of draining the accumulated water. This required both capital investment and organisation.

Mr. Findley referred to some of the more important events and personalities in the development of the industry in the area over the centuries. The documentary records date back to the grant by Edward VI to mine coals in the St. Bees area. These rights passed to the Lowther family in the seventeenth century and were extended so that mining enterprises were undertaken at Howgill and Greenbank in 1650 and Whitehaven itself in 1700. Further north in the next century the Senhouse family of Maryport was involved.

Drainage problems as the mines extended were countered in the first instance by connecting soughs enabling more workings to be opened, and later mechanical pumping by horse ginns. The Ginns at Whitehaven derives its name from the number of these contrivances at work in that area. Later still the atmospheric engine - worked by the condensation of steam in a large cylinder - was brought into use.

Many improvements were introduced by Carlisle Spedding, the son of a steward of the Lowther Estates. He introduced, for example, a wheel machine producing showers of sparks to illuminate the workings. This was less likely to ignite an explosive gas mixture than a naked flame, and was used extensively until supplanted by the safety lamp. Spedding also introduced primitive ventilation systems leading to the first installation of a fan system at Duke Pit in 1840. Further generations of the family, James Spedding and his son, introduced mechanical winding gear. An early steam engine from this area is preserved in the Science Museum in Kensington.

Undersea workings were driven from Wellington Pit, the remains of which can be seen near Whitehaven harbour.

The speaker spent some time describing the many accidents that have occurred over the years from the double hazards of inundation from the sea and methane gas explosions.

Finally, turning to modern times, the speaker showed how deep coal mining in West Cumbria had declined during this century. The peak year was 1901 when 2,100,000 tons were produced from 42 pits and 8,600 men were employed. At the time of nationalisation 8 pits employed 8,500, but now only the Haig Pit remains with a work force of 780. The workings extend out under the sea for three or four miles. The latest machinery is used: long wall face cutters are moved forward by multiple hydraulic jacks while the roof is allowed to collapse behind. Mechanical shovels are used and there are special machines for cutting roadways.

Mr. Findley brought along for inspection by members maps of old and modern workings and mentioned that one of the important functions of the National Coal Board was the recording and charting of old shafts and workings. These are more numerous than is sometimes appreciated: there are, for example, 145 known shafts in the Broughton Moor area alone, 92 around Dearham and 97 in the Seaton - Flimby section. Readers may be interested in this connection to refer to an article by the late John Moon, in Part 3 of Volume 3 of the Society's Proceedings, on old shafts in the Harrington - Workington area.

The lecture proved to be one which aroused much local interest as evidenced by the questions raised by the audience after the lecture. The President concluded the proceedings with a warm vote of thanks to the speaker.

TRACE FOSSILS

Mr. J. S. Crossley

At a meeting of the Society at the Derwent Centre, Cockermouth on 12th January, 1983, the speaker was Mr.J.D.Crossley from the Liverpool College of Higher Education. Introducing the speaker, the President mentioned that Mr. Crossley was an active member of the Liverpool Geological Society and much involved with the Association of Teachers of Geology.

Trace fossils can be defined as any sedimentary structure that results from the activity of a live animal. Some trace fossils may have the same appearance throughout Phanerozoic times but be produced by animals which have changed considerably, and this must be borne in mind in any direct comparison between marks left by present day animals and those of the past.

Most types are confined to particular environments and thus can be used very effectively in rocks of any age to determine palaeo-environments. They have an advantage over body-fossils in that they are unlikely to have been transported before preservation, and thus are found 'in situ', not in an environment foreign to the organism. Body fossils are most abundant in limestones, but are relatively few in clastic rocks, whereas trace fossils may occur in rocks barren of body fossils. Trace fossils are most easily found and best preserved in alternations of sandstone and shale rocks: they often complement body fossils in palaeontological studies. The traces, which record an organism's activity, may vary according to what it is doing, and may be dependent on the life stage of the animal. These traces may be the only preserved record of soft-bodied animals.

What originated as a vertical burrow may be finally a cone-shaped depression due to sand having avalanched, distorting the surrounding bedding: referred to as 'monocraterism', it may be of use in sedimentation rate studies. Some 'U'-shaped burrows made by lugworms are referred to as 'arenicolites'. Burrows may be for food or shelter, avoidance of desiccation or of sediment choking.

Trace fossils correlate with the energy of their environment. On a high-energy shallow wave-cut platform the only indication of life in the fossil record may be borings. Herring-bone tidal cross-bedding in sandstones indicates a high-energy environment. Crawling trails, e.g. of trilobites, would be, in finer-grained sediments, associated with low-energy water. Feeding (?) burrows, nearly horizontal, by an organism working the plane of sedimentation, also indicate low-energy conditions. Some moving, and also resting, traces may show some orientation, suggesting palaeocurrent direction, as also do inclined burrows. Some trails are systematic patterns suggesting the animal's well-organised search for food: some general evolutionary progress might be inferred on comparing earlier random meanderings.

The Arenig rocks of the Lleyn and other areas in Wales were quoted as examples of the depth controlled zonation of the facies, and how radiating trace fossils can shed light on the rate of sedimentation from the angle of inclination of the feeding horizon.

The lecture was well illustrated by excellent slides and Mr. Crossley had also taken the trouble to bring with him a considerable collection of specimens which, after his talk and the warm vote of thanks which followed, members examined with great interest.

LANDSLIDES, SUBSIDENCE

AND OTHER FORMS OF GROUND MOVEMENT.

Dr. I. L. Whyte

The last lecture of the 1982-83 winter programme was held at West Cumbria College, Whitehaven, on March 2nd, when about 30 members and guests attended, and the speaker was introduced by the President.

Dr. Whyte drew attention to the relationship between geology and engineering and, in particular, to civil engineering. In the construction of a road, for example, more than three-quarters of the operation is the shifting of natural material. The plan for a civil engineering project must suit the ground conditions: these have to be carefully assessed. Every previous record should be examined: a dotted line, without further explanation on an old map of one area, turned out to be a culvert which by then was near to collapse. Drilling boreholes provides samples of the substrate, but often more important is the influence on the material of ground-water. It is not surprising that it was William Smith, a canal engineer, who produced the first geological map.

The application of geology as a pure science, however, used to lead to disasters on some occasions. There have now developed the applied sciences of engineering geology and soil mechanics. The engineer is less likely than the geologist to be preoccupied with solid rock as opposed to drift: to him of greater importance is a knowledge of the properties of superficial deposits.

The largest factor governing the stability of an accumulation of uncemented small rock particles will be friction, which is dependent on weight. When all the particles are surrounded by water, however, Archimedes' Principle applies, their weight decreases and therefore the strength of the material decreases - an extreme case of this is quicksand. This saturation will be brought about by positive fluid pressures. Negative fluid pressures can be encountered through capillary action, e.g. as clay dries, water retreats into capillaries in its structure.

The same grade size for clastics used in geology is used by engineers, but it was stressed that this is a logarithmic size scale and that the water flow rate also changes logarithmically between the successive grades. Properties of deposits of the small particles are most noticeably controlled by moisture. Damp sand has enough strength for sand-castles, but this is easily lost. Clay has some sponge-like properties, except that water is not easily squeezed from it, and flow through it is slow.

Obtaining sub-surface samples is essential and is often carried out using the same simple tripod drilling-rig principle as has been used for perhaps 2000 years (dating from early Chinese technology). Today samples are sometimes obtained from lake-beds, and are often of geological interest, e.g. varved clays. The limits of the information obtainable from small samples must be realised. They will not, for example, usually indicate fissures. Soft samples may have been distorted by extraction, and particle-size analysis sieve-tests destroy minor laminations or grading. Bore-hole data can be misinterpreted: identical rock samples at the same level from two bore-holes may mean a horizontal bed; but the samples could be from a symmetrically folded bed. An Irish example quoted involved identical rock samples from three bore-holes: it transpired at a much later stage that three separate boulders had been sampled.

The term subsidence has been widely applied to account for collapsing walls, leaning lamp standards or breached dams. The mechanism responsible is likely to be the same as that causing landslip - influence of water resulting in loss of strength. This Archimedean effect has been most obviously demonstrated by cases where massive piles have risen, to be left protruding above the ground. These effects, together with the other main points of the talk were illustrated by slides, and a short film showed experimental work on wet sediment strength, using centrifugal force to increase effective weight.

Question-time showed that much thought had been stimulated, and in his replies Dr. Whyte further extended his audience's acquaintance with these topics. Once a landslip has occurred there is increased possibility of a recurrence along the same plane which is likely to have been friction-polished to some extent.

Prediction of natural disasters he considered to be complicated by the vast difference in scale compared with experimental laboratory work, but he considered that failure of a construction project was now predictable, provided all the data was available, and mentioned that progress of a construction could be monitored for signs of impending trouble, contingency plans for various modifications having been prepared beforehand. The most frequent source of trouble lay in getting the geology wrong.

The President expressed the thanks and appreciation of all present to the speaker for a most interesting evening.

ANTARCTICA AND THE GONDWANA JIGSAW.

Dr. J. Gunner

The first lecture of the 1983 winter series was held at the Derwent Centre, Cockermouth, when the President introduced Dr. Gunner of the Brathay Centre.

The speaker commenced by showing the 'jigsaw fit' of the southern continental masses of Africa, South America, Australia, Madagascar and Antarctica into the postulated former supercontinent of Gondwanaland. He stressed that, according to hypothesis, Antarctica should be considered to be the hub of Gondwanaland, but is at present in a position completely isolated from the other southern landmasses which are now more or less linked by land bridges to the northern continents. Dr. Gunner proposed to follow three lines of evidence for the former existence, and subsequent fragmentation of Gondwanaland, namely lithological and structural 'fits' between one continent and another, existence of fossil plants, and discoveries in the late 1960's of fossil reptiles.

In order to set the scene Dr. Gunner showed slides that he had taken in and around the American base of McMurdo Sound, followed by spectacular air and ground views of ice formations on the Ross Ice Shelf and the Beardmore Glacier, and pictures of the Trans-Antarctic Mountains and Mt. Erebus. He then outlined the geology of the continent. Eastern Antarctica consists of a Precambrian Shield with gneisses dated at over 2000 ma old overlain by younger Precambrian clastic sediments and intruded by granite plutons. These are overlain towards the west by an unconformable cover of largely horizontal sedimentary rocks ranging from Devonian to Triassic in age, capped by Jurassic basalts extensive enough to suggest the commencement of the break-up of Gondwanaland. Field evidence from the southern parts of South America, South Africa, India, Australia and Antarctica suggests extensive glacial erosion and deposition during the Permo-Carboniferous. Whilst it is clear that ice sheets covered large areas of southern continents, the pattern of glacial deposits, and inferred directions of ice movements are not in themselves sufficient evidence for the existence of Gondwanaland.

Permian glaciation in the southern hemisphere was followed by coal measures of Permian age, derived from Glossopteris, a genus of treefern found fossilised throughout the southern continents.

Dr. Gunner showed pictures of leaves and even considerably-sized trunks of these plants that he had found fossilised in Antarctica. However, since it is well known that plants can be dispersed across considerable stretches of ocean, the Glossopteris flora does not, in itself, provide evidence for the former fitting together of the southern continents into Gondwanaland.

The evidence for this former continental fit was discovered in Antarctica in 1968 when fossil bones were found of an ungainly-looking, sheep-sized, land-living reptile called Lystrosaurus. This creature's remains were well documented from the Permo-Triassic rocks of India and South Africa, and its discovery in Antarctica provided the vital clue in substantiating the former joining of that continent with at least some of the southern land masses.

Dr. Gunner's answers to questions provided further interesting information on Antarctica. It has the biggest coal deposits in the world, much of it converted to anthracite, probably by heat from Jurassic igneous activity. Minerals include chromite, and the presence of oil was confirmed by the work of the 'Glomar Challenger'. While late Tertiary to recent vulcanism is found in the west (e.g. Mt. Erebus), the east is part of an ancient continental shield.

Antarctica is not strictly all land: much is below sea-level, but the weight of a mile or so of ice has depressed the surface, and if the ice were removed isostasy would presumably allow it to rise.

Asked about the possibility of towing ice-bergs to arid countries to act as water supplies, he was of the opinion that it was just about feasible.

Eventually the President, Mr.M.B.Dodd, in bringing the meeting to a close, thanked the speaker for a most interesting and stimulating talk.

FIRST IMPRESSIONS OF THE GEOLOGY OF ICELAND

Mr. T. Shipp

This lecture was given at a meeting of the Society held on 5th October, 1983, when 40 members and friends were present. The President remarked that on this occasion introduction of the speaker was unnecessary, Mr. Shipp having been the Society's General Secretary for many years, and that it was a great pleasure on this evening to benefit from his expertise and travel.

The expedition had been arranged for a party of 24 by the Adult Education Department of Leicester University. It entailed a journey of 2000 km using a four-wheel drive bus (with an Icelandic driver) often over rough tracks, usually camping at nights. Though July, there were often snow white-outs on the hills. The route was, in outline, Keflavik (airport), around Faxflōi Bay to near

Fig. 1 SKETCH MAP OF ICELAND SHOWING PLACES MENTIONED IN THE TEXT.

Snaefellsjökull, Akureyri, Myvatn Lake, swinging south to Askja crater, re-tracing back to Goðafoss, south to Sprengisandur (desert), Gullfoss, Thingvellir, Reykjavik.

The scenery was illustrated by plentiful slides, though overcast skies prevailed. Reykjavik, population 80,000, is of pleasant aspect, built in sprawling American style. An historic early farmhouse was shown, of turf and timber: later, corrugated sheet was used; now most of the building is in reinforced concrete. One window in Akureyri church was rescued from Coventry. By the shore in the open (surprisingly in the wet climate) drying racks for fish (cut in strips) were numerous. The coastline is commonly fiords and peninsulas, the latter often plateaux, demonstrating Miocene uplift. One slide depicted some of the apparently numerous Icelandic ponies.

Steam jets were seen on the Reykjanes Peninsula. The coastline had splendid marine arches in basalt, the flow-banding clearly evident. One of the waterfalls east of Akureyri was illustrated, with volcanic hills in the background. Myvatn Lake is broad and shallow; its diatomaceous sediments are dredged and processed commercially.

The party travelled mostly over gravel desert or lava flows between hills usually of three types - table mountain, collapsed caldera, and shield volcano. The worst terrain was in the Herðubreið area, desert and jagged lava alternating. In contrast was the green, pleasant Bardardalur Valley, used as the access route to the high gravel desert with faceted stones. After viewing an ice-cap edge, the most spectacular waterfall, Gullfoss, was seen. The largest valleys drain meltwater torrents from the ice caps. Thingvellir lies in a rift zone, and a series of landscape cracks was evident. The famous Geysir has now lost some of its more youthful vigour.

The Icelandic rocks are very young, dating back sixteen million years to the Miocene, and are predominantly basalt, often with a pronounced hexagonal jointing. Iceland has grown from the Mid-Atlantic Ridge as the plates moved apart and fresh basaltic material came in. There is a Central Icelandic Depression from the south-west towards the north of the island, the rocks along one side of it showing remanent magnetic patterns in strips which are mirror-images of strips on the other side. It seems, therefore, that there has been, from a huge fissure, a succession of basalt extrusions, each parted by crustal extension (and later basalt) into two parallel strips. On each basalt crystallising, the prevailing direction of the earth's magnetic field would be recorded by the magnetic minerals present. A simpler impression of this parting movement is given by the easterly tilt of blocks on the east compared with the westerly tilt of the blocks on the west side of the Depression. These phenomena, together with the vast quantity of basalt involved and the fact that there have been between 150 and 200 active volcanoes in the last 15,000 years, suggest the probability of a hot spot in the earth's mantle under Iceland. The audience was reminded of the current hypothesis on formation of basalt from mantle peridotite, the essential basalt minerals having lower melting points than olivine.

The relative ages of recent lava flows were easily judged, the new ones showed black surfaces, rather older ones had weathered grey, and still older ones supported lichen growth. These had mostly been erupted from restricted fissures, or aligned vents, now seen as shallow rifts on the ground, or as craters, some still warm. Such was the site at Krafla (north of Myvatn) when visited in 1983. Aerial photographs were shown illustrating its eruptions (showing fire-fountaining) in 1977 and 1980. In places gas-vents were seen, showing the glazing typical of the escape of high pressure (hence high speed) high temperature gases.

Textural features were examined at Krafla. Most flow surfaces showed a 10 - 20 cm depth of ropy texture with flow-banding below, sometimes with parallel bands of vesicles (as in some of our Lake District lavas). Slickensides were common where the last movement of partly consolidated lava produced shearing. Splats of lava from the rotatory motion of an advancing lava front could produce peculiar 'cow-pats' or 'horse droppings' features. Pipe-vesicles, such as those seen at Gullfoss, formed by steam generation when lava flowed over wet ground, could be useful in indicating the base of a flow.

Escape of lava through cracks in a hardened front could leave behind empty tunnels, sometimes resulting in collapse of the surface. On one area south-east of Myvatn this has resulted in remnants of castle-like appearance, hence the Icelandic 'dark castles' name for the area. These features, and large lava blisters were sited on the flanks of shield volcanoes, of which there are several.

Some spatter cones were seen near Myvatn, each with a tail of ash showing the wind direction during eruption. In the same area were 'pseudocraters', their formation thought to be due to steam explosions when ponds were quickly engulfed by advancing lava. Tephra features seen included two eroded craters showing bedded pyroclasts. At Snaefellsnes (the peninsula on which is Snaefellsjökull) were bedded tuffs including fine lapilli considered to have been formed by raindrops falling through a cloud of ash.

There has been recent volcanic activity off the south coast. The island of Surtsey was formed during 1963 - 7, whilst the start of a violent eruption of Heimaey (Vestmanneyjar) in 1967 led to evacuation of the area.

Solfataric activity is of two types, (i) alkaline hot springs and geysers of relatively low temperature, and (ii) the acidic and sulphurous type. The latter is of more use commercially, as at Krafla geothermal power station.

Some eruptions have occurred under ice-cover, the rapid chilling resulting in the formation of a brownish hydrated glass, palagonite, fragmented into sand which settles in the meltwater produced. The palagonite sand is referred to as a surge deposit, forming rock of hyaloclastite type. Further eruption (into water now) can produce pillow lavas, whilst if the build-up is eventually sufficient, normal sub-aerial lavas complete the sequence. Fissure eruptions have produced palagonite ridges. Central eruptions, if the sequence was completed, have left table-mountain forms since the normal basalt caps are more reistant to weathering than the underlying phases. Of such a type is Herðubreið. Perhaps the greatest hazard from eruption under ice-cover is the probability of flash-floods: it is estimated that peak discharges have equalled the rate of flow of the River Congo.

Ice-margin features are displayed at the edges of the ice-caps, and the party had examined some on the borders of Langjokull, (our Lakeland scenery in the making, it was remarked). One meltwater lake was dammed between the ice-front and a hyaloclastite ridge which was cut by a series of meltwater notches. The ice contained a large amount of volcanic dust as well as other fragments. On the ice surface were some conical gravel mounds where meltwater springs surfaced: some of their channels had drain-pipe appearance, being lined with recrystallised ice. Outwash deposits, vast moraines and roches moutonnées were all in evidence.

The last slide depicting the Gullfoss reminded the audience of this 'Niagara of Iceland'.

Answers to a variety of questions and some further discussion included the largely glacial origin of the desert gravel which became faceted, and the possibility of distinguishing between marine and fresh-water pillow lavas.

In conclusion Mr. Shipp was warmly thanked by the Vice-President, Dr.J.F.Cockersole, for this splendid combination of travelogue and scientific observation.

THE CALCULATION AND ESTIMATION OF OIL AND GAS RESERVES

Mr. G. Brunstrom

The President introduced the speaker, a now-retired petroleum geologist, to a meeting of 26 members and friends on the 2nd November, 1983, at the Derwent Centre, Cockermouth.

Mr. Brunstrom set the scene, most aptly, as it transpired, by remarking that considerations in any proposed exploitation would start from precise petrophysics data and inevitably end in little more than crystal ball-gazing.

Every rock has pore spaces and these are capable of holding oil or gas which has moved in the direction of lowest pressure. These two substances are common in sedimentary rocks: it is their accumulation (the term 'deposit' is deprecated) which is unusual. The whole amount of pore-space, or porosity, of a sedimentary rock is not available for occupation by petroleum, since there is always water in a sediment, as a film around each grain. Of great importance also is the extent to which the pores are connected, i.e. the permeability. Though clays and shales have high porosity (perhaps 40%), their permeability is almost nil.

The speaker explained some of the terms used for oil-bearing areas. The unit of accumulation is the 'pool' (corresponding to an ore-body). A 'field' is an area of ground within which one can drill and find oil (and thus is more discrete than the term 'ore-field'): the field may have one or several pools. 'Basin' or 'province' indicates where oil or gas have been found, and there is some prospect of more.

A pleasing insight into calculations was given. Supposing an oil well had been drilled in limestone or sandstone and the rock characteristics on measuring showed a porosity of 10% (about average): hence each $100m^3$ of rock would have $10m^3$ of pore space. If the water saturation is 30%, there will be $7m^3$ of oil at the temperature and pressure of the reservoir. However, the only way of getting it all out would be by mining and then by heating or by solvent extraction. With customary techniques one third recovery is good, one half very fortunate, the density and viscosity of the particular accumulation dictating the proportion recoverable. (It is interesting to note that this means that half or more has been left in past exploitation). Therefore of the $7m^3$ only $3\frac{1}{2}m^3$ at most can be got out. The oil would be at a pressure equalling a well-depth column of water. At the surface, dissolved gas will come out of solution to the extent of perhaps 10%.

In a gas-producing well estimation is similar, but in this case 90% extraction could be expected, and there will be a large expansion as it surfaces (nearly 10x per 100m depth).

Some secondary recovery of oil may be attempted by methods such as drilling around the periphery of the field and pumping down water or waste gas, to push more oil out. Tertiary recovery - only talked about - would involve the use of solvents or burning underground. All further recovery steps cost money!

A large number of drillings are needed to obtain adequate information about the rocks. An electric log penetrates only 0.3m each side of the bore, so that one drilling gives information on perhaps one millionth of the accumulation, whilst sandstone is unlikely to have constant character over one kilometre. Initial theory on the rock structure is often modified in detail as exploratory drilling goes on, and features such as faults are discovered.

The economics to be considered have to include services, e.g. transport, dwellings and roads. In remote areas, or at sea, there needs to be a higher minimum quantity of oil to justify development. The Forties, a B.P. venture, has been the most successful of the North Sea Fields, although this lies 160 km from Aberdeen, in a sea-depth of 100 m, and the reservoir rocks are not seen on land. Only a giant field could justify this development in 1963. Now a field one-tenth of the size would be acceptable.

It is necessary to consider whether a particular development cost is likely to be justified by the price of oil when that development comes into production. It is here, said our speaker, that we lose touch with any scientific base! The 'lead-time' is the time taken to do what you decide today - probably five years. The size of the field and the extraction rate must be guessed, and selling envisaged over probably twenty years, following the five years 'lead-time'. By applying the compound interest principle (if the rate does not change), the present worth is only one tenth of the worth in twenty-five years time (another way of saying that £1 today would be worth £10 in that time).

More complications: if the chance of success is one in ten, a possible value of £500 million would have to be regarded as only worth £50 million, and to obtain a 2x return on investment, costs of £25 million only would be justified. The degree of profitability, moreover, depends on whether government promises materialise or whether tax rules change once oil has been found. The latter, it was implied, was more common.

The extent of world oil reserves has long engaged attention.

Present known reserves are estimated at 677 billion (10^9) American barrels. Current production is 20 billion barrels per year. (1 barrel = 42 U.S.Gallons = 35 Imperial Gallons = $0.159m^3$). The question of when oil will run out has been receiving pessimistic answers for at least 60 years. The question of what oil remains undiscovered can, of course, have only one answer: nobody knows. Future areas for investigation might include the continental shelf from Argentina to the Falklands, or the rocks below the Greenland ice-cap.

At question time, further information included the facts that to effectively drain each well necessitates a spacing of approximately a quarter mile on land and half a mile at sea, and that stratigraphically the lowest oil-bearing strata is the Pre-Cambrian.

Mr.Brunstrom was congratulated and thanked by the President for providing this fascinating look at the petroleum business.

SILURIAN GEOLOGY AND FAUNAS IN SCOTLAND

Dr. E. N. K. Clarkson

There were 21 present at a meeting on 7th December, 1983, held at West Cumbria College, Whitehaven, when the President welcomed the speaker, from Edinburgh University, met previously by those members who attended the memorable Dobbs' Linn excursion.

On this occasion, however, Dr. Clarkson directed attention to the Midland Valley of Scotland, where there is a chain of Silurian inliers (surrounded by Carboniferous rocks) from Girvan to near Edinburgh. These inliers are some distance north of the Southern Upland Fault and whereas all are of shallow water facies, they are sedimentologically and faunally quite different from each other. The speaker set out the differences between the largest inlier west of Lesmahagow and the Pentland Hills inlier, and illustrated his talk with excellent slides.

The Lesmahagow inlier begins with a turbidite facies and passes up through unusual laminated mudstones and sandstone with fish and eurypterids into a siltstone dominated by ostracods, gastropods and bivalves, and finally into red beds laid down in desert - fluviatile conditions in which temporary lakes allowed the development of fish-beds. The rocks are poorly exposed and the fossils are not numerous. It was the large eurypterids (water scorpions) found by James Darrell beside Logan Water and shown by the local doctor, Robert Slimon, to Murchison which attracted attention to the laminated beds and led to a eurypterid's name, Slimonia: other genera present are Pterygotus and Caratiocaris. The fish fossils are flattened impressions of the world's oldest jawless, but scaled, fish, related to modern lampreys. There are no marine fossils, and all the evidence points to brackish lake or lagoon conditions, their quietness shown by the presence of both valves of bivalve fossils. The overlying siltstone represents the final stages in the drying up of the lagoon, and also the end of the Lower Silurian; the red beds are Middle Silurian.

The Pentland Hills are of less desolate appearance; the rocks are rather better exposed. The Silurian strata, lying vertically, comprise a great thickness of material; lying unconformably over it is gently dipping Old Red Sandstone. Near the base of the sequence there are Eurypterids, but different (some with legs, e.g. Parastylonarus) from those at Lesmahagow. Thereafter the beds pass up, in contrast with Lesmahagow, through a normal marine shallow-water sequence. In it trilobites (16 species including Phacops and Acernaspis which was able to roll up so tightly its tail fitted into grooves round the head) and brachiopods (30 species) are abundant and exquisitely preserved (e.g. at Wether Law Linn) as moulds. The brachiopods decrease in size and quantity in upward sequence, suggesting decreasing salinity, i.e. onset of lagoon conditions liked by bivalves, which consequently increase in numbers. Further upwards the beds become siltstone just below the red beds, resembling Lesmahagow, but the ostracods, bivalves and gastropods are different species. The only brachiopod present is Pentlandella, which tolerated low salinity. Presumably here too there was a lagoon, though short-lived. This overall regressive sequence can be traced as far east as Estonia.

The Midland Valley inliers illustrated by these two contrasting areas still have much in common. They are now interpreted as parts of an upper slope basin, north of a northerly dipping subduction zone, into which sediment was fed from the eroding land mass rising to the south. When the northern and southern continents collided, squeezing the Southern Uplands between, the eastern end of the Midland Valley may have been more directly affected, for in the Pentland Hills the beds are vertical whilst the Lesmahagow structure forms a more gently sloping dome.

In answering a very large number of questions, Dr. Clarkson, inter alia, confirmed that the unusual fauna of Lesmahagow is not found elsewhere, neither are one or two of the Pentland Hills trilobites. The red beds are Wenlockian in age, and just below there are a few trilobites similar to those of the Welsh Borders. He agreed that the marine conditions could resemble those of the Black Sea today, upper layers oxygenated and the lower stagnant: there are no trace fossils, as animals would not burrow in stagnant mud.

The speaker enlarged upon the tectonics of the continental collision, pointing out that the site of the subduction zone is below the present Solway: Girvan basalts are believed to have been shifted 120km north then faulted down. The Ballantrae pillow lavas (the product of an ocean floor) are difficult to account for: plate tectonics have often been too theoretical!

In thanking the lecturer, Mr. T. Shipp conveyed the audience's fascination with the application of palaeontology to reconstructing geography, and their pleasure in Dr. Clarkson's enthusiastic interest.

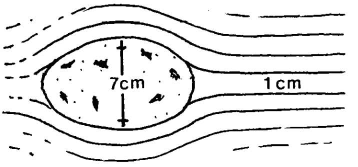
COAL AND COAL-BEARING ROCKS: HOW LONG TO FORM THEM?

Dr. F. Broadhurst

At the Derwent Centre, Cockermouth, 34 members and six guests met on the violently windy evening of 11th January, 1984, which had entailed, the President remarked, a wild as well as long journey for our speaker from the Department of Geology, University of Manchester.

Dr. Broadhurst prefaced his talk on this unusual aspect of coal geology by an illustrated reminder of the origin of coal and the stratal sequence of the Coal Measures. Coals are formed in the same way in systems other than the Carboniferous, e.g. the Cretaceous of Utah, where plant fossils are of Sequoia, and trace fossils include dinosaur footprints. An example of a modern coal-forming environment is the Mississippi delta on which cypress forest is periodically flooded.

The extent of the compaction when peat changes to coal can be inferred from coal-balls in a coal-seam. These are hard, but show peat structure within, and were formed by $CaCO_3$ precipitating in peat. The bands in the adjacent coal indicate compaction around the already hard nodule, and that 7 cm of peat form 1 cm of coal. Radiocarbon dating on currently accumulating peat in Florida shows that the topmost 1 cm accumulated over 6 years, and at 2 metre depth a (more compressed) 1 cm peat layer represents about 32 years' deposit. The rate matching the probable depth at which coal-ball precipitation occurs would be approximately 1 cm per 10 years, i.e. 1 mm of peat per year. Applying the compaction ratio, this means 1 mm of coal per 7 years, or 1 metre of coal per 7000 years.



How fast the sandy and muddy sediments accumulated can be estimated. A slide depicted an upright fossil tree at Blackrod, near Chorley, Lancashire, its base in the roof of a coal-seam, the rest passing through overlying sediments. The tree's height was 13 metres. The sediment would accumulate around the tree whilst it was still living, and before it rotted completely. Probably a river bank gave way and successive floods banked up sediment. Whilst none of these particular trees grow today, a reasonable estimate of the time involved would be about 100 years. The rate of sedimentation is then 1 metre per $\frac{100}{13}$ years, i.e. 1 metre per 7 years.

Another way of estimating sediment deposition rate has been possible in a sequence of remarkably parallel fine/coarse sediments between coal-seams: it must have been deposited in a standing lagoon. In places escape trails of fresh-water mussels have been identified. As fresh sediment shot in, the mussels, to survive, would have to climb to the new bed-surface. At one horizon, taken as a base line, old and young shells occur together. The successive ascents of this population were noted, together with shell mortality, until only the survivors' shells marked the upper limit of the episode. There had been no fresh arrivals. The life-span of a mussel, and therefore the episode time, would be roughly 20 years. It was concluded that each couplet of fine and coarse sediment was due to an annual monsoon. Measurements of the couplets and the depth of the 'episode' indicated a deposition rate of 1 metre in 6 years, which agrees with the tree estimate.

'Contemporary tectonism' was outlined: it provides an explanation of many cases where a thick seam, beyond a certain lateral line, is split into two or more thin seams. The lower thin seams are concave upwards near the split. It appears that an original widespread surface on which peat was accumulating became bent into monocline shape by small fault movements below it (which would fracture only deeper indurated sediments). Peat formation would continue uninterrupted on the 'upper limb', but there would be a silting phase on the 'lower limb' before plant growth was re-established. The lines of a number of coal-seam splits investigated in part of the Lancashire Coalfield showed the same NE - SW trend and were 'stacked' vertically above one another. This suggests fault control from below, since faults usually repeat movements along the same lines.

No sign of fault control is found in the inter-seam sediments. Variations in thickness here are patchy, which may be explained by considering a large delta, e.g. the Mississippi, where in some parts at a particular time there may be no sedimentation and/or peat growth.

Coal-seams show evidence of contemporary faulting because they took a long time to form and so were exposed for long periods to the 'risk' of movement on underlying faults. Though coal-thicknesses represent only 7% of a coal measure column, they represent over 96% of the time of deposition.

Answers to many questions included the following: 7000 years per metre of coal is the peat formation time only, 1000 metres of overburden may be needed to convert peat into coal. Coals in the Permo-Trias occur in Gondwana. Coal-balls are found only where marine incursions brought in $CaCO_3$. The thickest coal-seams resulted from peat-forming sites lying over stable blocks.

The President, Mr. M. B. Dodd, thanked the lecturer who had spoken with great enthusiasm, aroused much interest, and given us some very useful, clearly expressed ideas.

TOURIST REPORTS FROM C.G.S. MEMBERS

<u>THE AUVERGNE</u> - sites of geological interest - tertiary and quaternary volcanics. M.B.D.

Le Puy de Dôme, just west of Clermont-Ferrand and N 9, is a 'must'. The toll road to the top makes it easy for the less energetic. Samples of a hornblende-rich rock are easily available, but difficult to identify. As an old 'plug' of a dome of internal growth it makes a good viewpoint for the numerous small cones and domes to the north. A small but good museum is open.

Lac d'Aydat, the famous lava-dammed lake is a disappointment, as the 'dam' is inaccessible in heavily wooded private land. More rewarding are short walks between N 89 and D 5 to small cones like the Puy de Combegrasse over lava flows and scoria/pumice spreads.

Puy de Sancy, the summit of the Mont Dore strato-volcano, is accessible by téléfrifique and is very worth while. Most of the summit is pyroclast, mainly coarse tuffs, but the trachyte dykes catch the eye. They form long comb-like ribs which are always steep. These are also well exposed on the Col de Diane on D 996 near the ski lift to Puy de la Tache. On D 983 above the Col de Guéry the Roches Sanadoire and Tuilière show columnar jointing on a large scale. Sanadoire, the old plug, shows a radiating pattern, while Tuilière, part of an old flow, has vertical jointing.

Lac Chambon, also near D 996, is lava dammed. Here the flow, ash and cindery material, are easily accessible down valley from the Marina. Murol, further down the valley from the same road, has an impressive fortress on a crag formed by a particularly dark coloured basalt dyke with well marked horizontal jointing.

Carboniferous granites are spectacularly seen in the gorges of the Couze and Allier, between Murol and St. Nectaire and near Issoire respectively. They are very variable, in places red and pink, elsewhere almost black and white, often porphyritic.

<u>Useful books</u>

P.G.A. Vol. 63 part 3, 1954, p 278. Summer field meeting in the Massif Centrale.

Principles of Physical Geography - Monkhouse. The chapter on Vulcanicity has a short but clear description of the Puy de Dôme area with a helpful sketch map.

History, people and places in Auvergne - Brangham. Spur Books, 1977. A guide book which gives ideas rather than authoritative descriptions.

Michelin map 1:200,000 Carte 73 essential.
Carte Topographique 1:25,000 for areas of particular interest.

Pliocene (?)	Upper Coralline Limestone	0 - 175 m
	Greensand	0 - 10 m
Miocene	Clays	0 - 75 m
	Globerigina Limestone	25 - 225 m
Oligocene	Lower Coralline Limestone	350 m

The Greensand acts as an upper aquifer, the water being held by the clays below it, and numerous 'aeromotors' are seen on higher points of the island pumping up the water. The Lower Corallime Limestone is at sea-level, and is the lower aquifer: rainwater percolates downwards to form a lens of fresh water floating on salt water. This does not make good tea!

The pleasing light buff, easily cut freestone of local buildings is from the Globerigina Limestone; the lower part is best. The clays, which often contain selenite, are used in pottery. The Greensand is suitable only for rough walling. The Upper Coralline Limestone mostly outcrops as a strip on the east of the island: it contains abundant algae at the base.

(The above information was obtained at the Museum of Natural History at Valetta).

Members are invited to submit short notes on their geological tours, either in this country or abroad, for inclusion in future issues of the Proceedings.

ANNUAL DINNERS

1982

The Annual Dinner was held on Friday 23rd April, 1982, at the Hundith Hill Hotel, Cockermouth, the Guest of Honour being Dr. Lewis F.Penny of Hull University. The occasion was attended by 45 members and their guests.

Dr. Penny, a Quaternary Geologist, chose as the topic for his after-dinner talk 'A Geologist in New Zealand', a country he had recently visited. His talk centred on a series of beautiful colour slides which captivated his audience and vividly illustrated the points he discussed.

By way of introduction Dr. Penny explained that South Island was roughly equivalent in size to England and Wales, and the North Island to Scotland. The geology is essentially that of a gigantic Alpine Fault. The Southern Alps form a spine along South Island. There is vulcanicity all along this zone which is a great transcurrent fault with 300 miles of lateral movement since the Mesozoic, and which is still alive. This is an active plate boundary where the Indo-Australian Plate is moving against the Pacific Plate, with a Benioff Zone dipping west. Part of the boundary is above sea level.

The speaker went on to describe the nature of contemporary glacial activity in South Island. Glaciers arise at the summit of the Alpine Range and flow east and west. There is a remarkable variation in climate: Mount Cook rises to 12,350 feet, but is only 18 miles from the sea, and its glaciers descend rapidly to temperate rain forest. One of Dr. Penny's slides showed giant tree ferns in the same shot as a glacier snout. Rainfall is high: 21 feet of rain a year have been recorded. These factors give rise to some unexpected results, one of which is that glacial till and forest deposits exist together! Morainic boulder clays are seen at the foot of glaciers, but further down the enormous development of meltwaters gives rise to extensive braided outwash fans, where material is re-sorted and which provide the fluvio-glacial gravels which form important deposits in New Zealand.

The speaker now turned to the contemporary vulcanicity in the west of North Island. Here several vents have produced ash deposits - pyroclastic tephra - in geologically recent times. Isopachyte maps of the ash deposits are used to identify the locality of extinct centres, and the chronology of volcanic activity in the region can be worked out by identifying the characteristics of particular eruption products deposited on a particular chrono-stratigraphic horizon. This is done on a basis of texture, colour and chemical and microscopic examination. One ash-layer, for example, is instantly recognisable by the occurrence of white spots which represent fossil rain drops, formed when rain falling through an ash cloud gave rise to mud droplets.

Fossil soils can be identified in the stratified tephra and fossil wood in the more recent horizons is within the range of radio-carbon dating. Evidence of Quaternary climatic changes can be gleaned from palaeosols, an example being that analysis of the fossil soil of the last intergalcial period shows it to have been warmer than the preceding one.

Dr. Penny's talk stimulated a number of interesting questions. It transpired, for example, that the glaciers in New Zealand are retreating like those in the Northern Hemisphere. Indeed, the evidence at present points to glacial and interglacial events occurring at the same time in the two hemispheres, rather than alternately as was once thought.

A warm vote of thanks to the speaker was proposed by the Treasurer, Mr.S.R.Alexander, who also gave credit to all those involved in the organisation of a most successful evening.

1983

On the 22nd April, 1983, 35 members and guests gathered at the Globe Hotel, Cockermouth for the Annual Dinner of the Society. As is our custom, the Guest of Honour, Dr. Denys B. Smith, Regional Director of the British Geological Survey, was invited to address the Society after the meal. As one of his major interests lies in the Permian, he took members on a scenic tour of a Permian coastline, now far removed from present seas, which he had investigated in the Guadalupe Mountains of New Mexico, U.S.A. The section he chose, some tens of miles long, and involving up to 4,000 ft. of ascent and descent, he graphically interpreted as a traverse from a shore line, with abundant algae and other shallow water remains, towards a former reef, extending down into what had been deep water, but which was now a semi-arid valley. With the aid of colour slides, Dr. Smith was able to show some intriguing geological structures and formations, whilst for the less geologically-minded members of his audience there were pictures of the flora, including magnificent cacti, and fauna, including exotic insects, spiders and snakes.

A vote of thanks was proposed by Mr.T.Shipp, who complimented Dr. Smith on a fascinating and lucid portrayal of an area which few present would ever have the good fortune to visit.

22nd ANNUAL GENERAL MEETING

The twenty-second Annual General Meeting of the Society was held at the Royal British Legion Club. Workington, on the 9th February, 1983, with the President, Mr.M.B.Dodd, in the Chair.

GENERAL SECRETARY'S REPORT

Membership

During the year 22 new members were elected, whilst 17 resigned or were removed from the list. The numbers and categories for 1982 (1981 numbers in brackets) were:-

Ordinary members	163	(158)
Associate members	19	(20)
Joint husband and wife members	30	(30)
Institutional members	17	(16)

K.R.(Bob) Baker, Publications Secretary 1967-8, died during the year.

Meetings

The Society held 7 indoor meetings during 1982/3, as follows:

1. The A.G.M. held on Wednesday 10th February, 1982, at the Royal British Legion Club, Workington. This was followed by a Members' evening, with displays of Members' geological work. 23 members attended.

2. A Promotion Evening for the Society's new Fieldwork Guide to the Geology of the Lake District. Messrs. Bond, Shipp and Dodd spoke about their contributions to the Guide. The meeting fell a little flat due to the non-availability of the book from the publishers, Allen & Unwin. The meeting was held at the West Cumbria College, Whitehaven, and was attended by 17 members and 2 visitors.

3. A lecture entitled 'A modern look at the geology of the Lake District' was given by Dr.Peter M.Allen on the 15th September, 1982, at the Derwent Centre, Cockermouth, when 23 members and 5 visitors attended.

4. A lecture entitled 'The Science of Gemstones' was given by Dr.Richard S.W.Braithwaite at the West Cumbria College, Workington on the 6th October, 1982. 16 members and 3 visitors attended.

5. A lecture by Mr.Paul Findley on 'The History of Coal Mining in West Cumbria' was given at Derwent Centre, Cockermouth on 3rd November, 1982. 20 members and 13 visitors formed the audience.

6. A programme of geological films was held at the West Cumbria College, Whitehaven, on 1st December, 1982 at which 17 members and 8 visitors attended. The films were 'Operation FAMOUS', 'Dunes, Rivers and Ice in the Sahara' and 'Limestones'.

7. A lecture on 'Trace Fossils' was given by Mr.Joseph D. Crossley at the Derwent Centre, Cockermouth, on 12th January, 1983, when 23 members and 8 visitors attended.

There were two meetings fewer than last year, with a further drop in average attendance from 29 to 26. Council has met on four occasions, and the Editorial Sub-Committee met once.

The Annual Dinner

This was held at the Hundith Hill Hotel on Friday 23rd April, 1982. About 55 members and their guests attended. Guests of Honour were Dr. and Mrs.Lewis Penny of the Yorkshire Geological Society. Once again the Society is indebted to Mr. Dodd for organising the event, and to the Bennett brothers for providing floral displays and geological specimens.

Publications

Proceedings Volume 4 Part 2 was issued during the year, and its quality is a tribute to the work of Dr. Cockersole as Editor and Mr.Hinde who assisted him. Dr. Cockersole has been Editor for the last nine years and has, by his painstaking and meticulous reporting, brought our Proceedings to a level where they are accepted and read by geologists the world over. Mr. Hinde, by his careful typing, pagination and artwork, has been instrumental in making the Proceedings attractive to read and has very substantially reduced printing costs by presenting our printers, Messrs. Bethwaite, with pages ready for offset litho reproduction. The Society is indebted to them both.

'The Lake District', a geological field guide, eventually appeared from the publishers, Allen & Unwin, at the end of April. Unfortunately, it missed the Easter trade, but royalties representing sales of an estimated 1200 copies to the end of June were received. Approximately 200 copies have been sold through the Society, many of them at the reduced rate to Members.

Conclusions

I find the Society in good heart. Membership is the highest for some years, and we are providing a varied programme of geological events and services for Members. Your Officers would, however, very much like to hear your opinions of what is being laid on, and receive requests, offers and suggestions for lecturers and excursion leaders at future meetings.

I have received a very large number of communications by post and telephone. The Cumberland Geological Society appears to be on the mailing list of practically every European and North American geological publisher. Requests for information and advice have been numerous, and I have spent a good deal of time on these, although the more importunate ones, usually from students virtually demanding unlimited free handouts of our literature (and without even the courtesy of a stamped addressed envelope), I tend to ignore.

The Society has received some intriguing requests for assistance with North American parties coming over in 1983. Arising from these, an informal network of UK contacts is being set up to liaise with visiting groups from overseas. I have been nominated into that network.

I have received and fulfilled a number of requests for lectures, including one to the Institute of Sedimentary and Petroleum Geology in Calgary, which I gave when on holiday in Canada. Additionally I have provided the Forestry Commission with notes on a Geology Trail in Thornthwaite Forest which should be available to visitors in 1983.

May I express my thanks to all, especially fellow Officers, who have assisted with the considerable administrative burdens of the Society. 1983/4 will represent my tenth year as General Secretary, and I would like it to be my last, for the reasons I gave in my previous annual report.

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

6th February, 1983.

HONORARY TREASURER'S REPORT

The year 1982 has been a very active year for the Society as reported by other Officers of the Council. This activity is reflected in the Statement of Accounts which shows a record income of £1,897 against a record expenditure of £1,745.

Funds have been increased by £155 to a record £1,816.61½. Furthermore, our stock of publications has increased in value by £476 to a figure of £2,343.36 which is derived from 50% of retail value.

I have not attempted in these accounts to show any breakdown of costs and income between the latest Proceedings and our 'Lake District' publication. However, it can be seen that we have received income against sale of publications of £707 plus royalties from Allen & Unwin at June, 1982, of £408. We can anticipate further royalty payments in relation to the last half of 1982 and future sales income in excess of the stock valuation.

The total cost of publications for 1982 of £1,377 include production costs of the Proceedings, the 'Lake District' publication and various offprints, together with the purchase from Allen & Unwin of 280 copies of the 'Lake District', now sold or included in stock.

Subscription income for 1982 is marginally increased from 1981 at £535, although it should be mentioned that it has been a particularly difficult year obtaining subscriptions from some of our Members. Late payments are obviously better than non-payment but cost the Society in lost bank interest and postal charges for reminders.

Inland Revenue refund relating to covenanted subscriptions was £91.82, again a marginal increase on 1981. Bank interest paid on the deposit account was down at £144.11 due to cash flow relating to production costs of publications being met before receipt of sales income. Expenditure relating to costs of lectures and excursions was significantly reduced at £67.80 compared with £248 for 1981. General administrative expenses were generally much reduced at £242.26 compared with £303 for 1981 although an increase of 50% can be seen in the cost of postages, primarily due to distribution of publications.

The Charles Edmonds Memorial Fund has increased to a balance of £34.26 with income from a year's interest on 3½% War Stock and Bank interest at £2.51.

I would like to conclude my report by offering thanks on behalf of the Society to our Honorary Auditor, Mr.T.J.Dawson.

S.R.Alexander
Honorary Treasurer.

The following Officers and Members of Council were elected to serve for the year 1983:-

President	M.B.Dodd, M.A.
Senior Vice-President	E.H.Shackleton, F.G.S.
Vice-President	F.J.Cockersole, F.R.C.O.G.
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	S.H.Gate, M.Sc.
Librarian	M.F.Burton
Members of Council	J.D.Hinde
	F.T.B.Lawton
	T.P.Loftus
	J.D.Quine
Honorary Auditor	T.J.Dawson

Year ended 31st December 1982

INCOME AND EXPENDITURE ACCOUNT

INCOME:	£	1981 £	EXPENDITURE:	£	1981 £
Subscriptions			Publications	1377.12	86
Arrears for 1981	27.75	15	Lectures & Excursions		
1982	473.25	482	Lecturers' expenses	48.00	174
Advances for 1983	34.00	10	Hire of films	10.00	-
Sale of publications	707.25	91	Hire of rooms	9.80	74
Royalties 'Lake District'	407.92	-	Subs. to other Societies	15.00	5
Inland Revenue refund	91.82	88	Administration		
Other income			Stationery & Materials	64.64	100
Donations	11.00	8	Telephone	20.40	27
Income from Geol.& Wine	-	72	Postages	156.68	108
Bank interest	144.11	164	Bank charges	0.54	5
			Council expenses	-	62
Total income for 1982	1897.10	930	Library Books	43.00	-
Surplus for the year	151.92	288	Total expenditure 1982	1745.18	642
Bal. forward from 1981	1664.69½	1376			
Bal. forward as revenue	1816.61½	1665			

CHARLES EDMONDS MEMORIAL FUND

INCOME:	£	1981 £	EXPENDITURE:	£	1981 £
Interest 3½% War Stock	5.10	5	none	-	-
Bank interest	2.51	2			
Increase in fund 1982	7.61	7			
Bal. forward from 1981	26.65	19			
Bal. forward to 1983	34.26	27			

BALANCE SHEET: 31st December, 1982

CAPITAL EMPLOYED:	£	1981 £		£	1981 £
Assets					
Equipment (nom.value)	8.00	8	Surplus for year 1982	151.92	288
Stock of publications	2343.36	1867	Accumulated funds	3974.13½	3241
Deposit a/c at bank	1319.57	1576			
Current a/c at bank	480.42	117			
Cash in hand	8.48½	-			
Cheques in hand	56.20	7			
	4208.11½	3575			
Less liabilities					
Creditors	48.06	35			
Subs. in advance	34.00	10			
	82.06	45			
TOTAL NET ASSETS	4126.05½	3529		4126.05½	3529

23rd ANNUAL GENERAL MEETING

The twenty-third Annual General Meeting of the Society was held at the Royal British Legion Club, Workington, on the 8th February, 1984, with the President, Mr.M.B.Dodd, in the Chair.

GENERAL SECRETARY'S REPORT - T. SHIPP, B.Sc., M.I.Geol., F.G.S.

Membership

During 1983 31 new members were elected, whilst 11 either resigned or were removed from the membership list for two years arrears of subscription. The numbers and categories of members for 1983 (1982 numbers in brackets) are:

Ordinary members	177	(163)
Associate members	21	(19)
Joint husband and wife members	34	(30)
Institutional members	17	(16)

Meetings

The Society held 7 indoor meetings during 1983/4 as follows:

1. The A.G.M. on 9th February, 1983 at the Royal British Legion Club, Workington. This was followed by a members' evening. 15 members attended.
2. On 2nd March, 1983 Dr.I.L.Whyte of U.M.I.S.T. spoke at the West Cumbria College, Whitehaven on 'Landslides, subsidence and other forms of ground movement'. Some 30 members and visitors attended.
3. On 14th September, 1983 Dr.J.Gunner of the Brathay Centre spoke at Derwent Centre, Cockermouth, on 'Antarctica and the Gondwana Jigsaw'. 13 members and 4 visitors attended.
4. On 5th October, 1983 Mr.T.Shipp spoke at the West Cumbria College, Workington on 'First impressions of the Geology of Iceland'. Some 40 members and guests attended.
5. On 2nd November, 1983 Mr.G.Brunstrom spoke at Derwent Centre, Cockermouth on 'The calculation and estimation of oil and gas reserves'. 23 members and 3 guests attended.
6. On 7th December, 1983 Dr.E.N.K.Clarkson of the University of Edinburgh spoke at the West Cumbria College, Whitehaven on 'Silurian geology and faunas in Scotland'. 21 members and visitors were present.
7. On 11th January, 1984 34 members and 6 guests heard

Dr.F.Broadhurst of the University of Manchester speak at the Derwent Centre, Cockermouth on 'Coal and coal-bearing rocks, how long to form them?'.

The recent trend in the decline in average numbers attending lectures has slowed down from 26 in 1982 to 25 in 1983. Council has met on four occasions, at the homes of Messrs. Cockersole, Dodd and Shipp. The Society is also indebted to its officers for providing hospitality in the form of refreshments and overnight accommodation for visiting lecturers. This is a necessary service in view of the fact that we are tending to attract speakers from distant parts of the country.

The Annual Dinner was held at the Globe hotel, Cockermouth on Friday 22nd April, 1983. About 45 members and their guests attended. Guest of honour was Dr. Denys Smith of the North of England Unit of the B.G.S. who gave an illustrated talk on the Permian of the Guadalupe Mountains of New Mexico. I am grateful to Tyson Loftus for making the necessary arrangements for this very successful social evening.

As I indicated two years ago I wish to stand down as general Secretary in order to give more time to some of my other interests and duties. The ten years I have spent in the post have been far from dull; there has been the satisfaction of communicating with and meeting a wide spectrum of professional geologist lecturers, and the interest of following up many enquiries on local geological matters for members and outsiders. I have received much cheerful and friendly advice and encouragement from fellow members, and if at some meetings I may have on occasion seemed a little stand-offish, it was probably due to the fact that I was trying to cope with several minor crises at once. To fellow Council members a special thank you. To Mervyn Dodd, our President, for listening patiently to my sometimes lengthy agenda and administrative ideas over the telephone. To both Mervyn and to Jim Cockersole for rising to the occasion as Chairmen at our various meetings. To Steve Alexander for coping with the various chitties and cheque requests. To Derek Allen for keeping me posted on membership matters, and providing sets of addressed envelopes on request. To Denys Hinde for unobtrusively being there with his projector whenever a lecturer had slides to show (and even when the lecturer had not - mea culpa!).

I really feel that the Council of this Society works as a team, and if I may make so bold as to offer advice to my successor, this is one aspect of the administration of the Society which might be developed even further. Perhaps the new General Secretary could promote his role as a co-ordinator, finding folks with the talent to do whatever needs to be done on the Society's behalf. It is pleasing to anticipate that I shall, as Vice-President (if you'll have me) be able to contribute to the activities of the Cumberland Geological Society.

HONORARY TREASURER'S REPORT - S. R. ALEXANDER.

Accumulated funds at the end of 1983 have been increased by £760.80 to £2577.42 and I am pleased to be able to report a healthy bank balance in preparation for the costs of the next volume of our Proceedings.

Income for the year totalled £1342.71½ and breaks down as:

- £495 subscription income down against £535 for 1982;
- £199 sales of publications significantly down against £707 for 1982;
- £174 royalties on 'Lake District' publication down from £408 received in 1982;
- £ 91 Inland Revenue refund unchanged from 1982;
- £ 15 donations compared with £11;
- £130 bank interest down from £144 due to the fall in interest rates;
- £239 receipts for Annual Dinners (not shown in 1982 accounts).

Total expenditure for 1983 was £581.91, comprising:

- £ 9 for cost of publications significantly down compared with the £1377 total in 1982, which included the cost of producing 'The Lake District' as well as Vol.4, part 2 of our Proceedings;
- £ 83 for costs of lectures and excursions (up from £68);
- £ 15 subscriptions to Societies, unchanged from 1982;
- £255 expenditure on the Annual Dinner (not shown in 1982 accounts), including small loss of £16 on the event;
- £220 on administrative and general expenditure down from £242 in 1982. Increases in stationery and material costs being offset by a reduction in expenditure on telephone calls and postages.

The Charles Edmonds memorial Fund has increased during 1983 by a total of £7.41 to a balance of £41.67 including bank interest of £2.31 and interest from Mr.Shackleton's War Stock of £5.10.

Our balance sheet includes nominal valuation of duplicating equipment of £8, and stock of publications at cost of £2259.35 (this is a slight reduction in the valuation at December 31st, 1982). Total bank balances stand at £2577.42 and I have quoted the Publications Secretary's cash in hand of £7.47. Four cheques totalling £57.62 relating to 1983 were not cleared at December 31st. 1983.

I shall 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. He is unfortunately moving to the North-east during 1984 and regrettably will not be in a position to continue this role on behalf of the Society.

INCOME AND EXPENDITURE ACCOUNT

INCOME:	£	1982 £	EXPENDITURE:	£	1982 £
Subscriptions			Publications	8.75	1377
Arrears for 1982	5.75	28	Lectures & Excursions		
1983	479.04	473	Lecturers' expenses	67.00	48
Advances for 1984	10.00	34	Hire of films	-	10
Sale of publications	198.93	707	Hire of rooms	16.35	10
Royalties 'Lake District'	173.53	408	Subs. to other Societies	15.00	15
Inland Revenue refund	91.28	92	Library Books	-	43
Other income			Annual dinner expenses	254.80	-
Donations	14.68½	11	Administration		
Bank interest	130.30	144	Stationery & Materials	123.43	65
Annual dinner	239.20	-	Telephone	14.12	20
			Postages	82.46	157
Total income for 1983	1342.71½	1897	Bank charges	-	1
Surplus for the year	760.80½	152	Total expenditure 1983	581.91	1745
Bal. forward from 1982	1816.61½	1665			
Bal. forward as revenue	2577.42	1817			

CHARLES EDMONDS MEMORIAL FUND

INCOME:	£	1982 £	EXPENDITURE:	£	1982 £
Interest 3½% War Stock	5.10	5	none	-	-
Bank interest	2.31	3			
Increase in fund 1983	7.41	8			
Bal. forward from 1982	34.26	27			
Bal. forward to 1983	41.67	34			

BALANCE SHEET: 31st December, 1983

CAPITAL EMPLOYED:	£	1982 £		£	1982 £
Assets					
Equipment (nom.value)	8.00	8	Surplus for year 1983	760.80½	152
Stock of publications	2259.35	2343	Accumulated funds	4071.43½	3974
Deposit a/c at bank	2086.91	1320			
Current a/c at bank	298.11	480			
Annual Dinner a/c	248.98	-			
Cash in hand	1.04	8			
Publ.Sec.cash in hand	7.47	-			
Cheques in hand	-	56			
	4899.86	4208			
LESS liabilities					
Creditors	57.62	48			
Subs. in advance	10.00	34			
	67.62	82			
TOTAL NET ASSETS	4832.24	4126		4832.24	4126

The following Officers and Members of Council were elected to serve for the year 1984:-

President	F.J.Cockersole, M.B.,Ch.B.,F.R.C.O.G.
Senior Vice-President	M.B.Dodd, M.A.
Vice-President	T.Shipp, B.Sc., M.I.Geol., F.G.S.
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Treasurer	F.T.B.Lawton
Membership Secretary	B.D.Allen
Excursion Secretary	M.B.Dodd, M.A.
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Editor	S.H.Gate, M.Sc.
Librarian	M.F.Burton
Members of Council	I.Gray, B.Sc.
	J.D.Hinde
	T.P.Loftus

SOME ADDRESSES OF OFFICERS - MAY, 1984.

GENERAL SECRETARY	D.Leviston, B.A.,M.Sc.,C.Eng.,M.I.Mech.E., 74 Glenridding Drive, Barrow-in-Furness. Cumbria. LA14 4PB Telephone Barrow-in-Furness 36316
MEMBERSHIP SECRETARY	B.D.Allen, 2 Etterby Close, Riverdale, Cockermouth. Cumbria. CA13 9ER Telephone Cockermouth 824087
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EDITOR	S.H.Gate, M.Sc. 8 West Spur, Moor Row. Cumbria. CA24 3LG Telephone Cleator Moor 811532
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