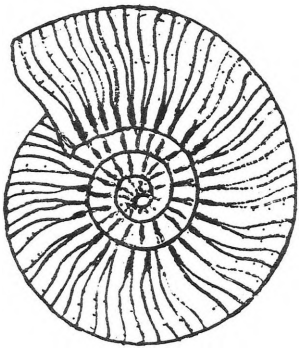
THE CUMBERLAND GEOLOGICAL SOCIETY



PROCEEDINGS

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THE CUMBERLAND GEOLOGICAL SOCIETY

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General Secretary

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

[redacted]

Publications Secretary

S.H. Gate, Esq., M.Sc.,

[redacted]

Editor

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

[redacted]

CONTENTS

	Page
ORIGINAL ARTICLES:	
A Study of Four Localities in the Martin Limestone (Lower Carboniferous, Dinantian) of Furness and Grange over Sands - D.Leviston.	3
A New Assessment of the Stratigraphy of the Skiddaw Group along the Northern Edge of the Main Skiddaw Inlier - D.E.Jackson.	21
Pre-Devensian Weathered Tills near Threlkeld Common, Keswick, Cumbria - J.Boardman	33
EXCURSION NOTES:	
The Redburn Fluorspar Mine in Weardale.	45
The Carboniferous Limestones of the area around Caldbeck and Uldale.	46
A Field Week in the Isle of Arran.	51
The Armboth Dyke	59
Weekend Excursion to the Settle-Skipton region.	62
The Ordovician and Silurian Rocks of Kentmere and Longsleddale.	67
Other Excursions and Short Evening Excursions.	69
LECTURE NOTES:	
The Study of Limestones by Stain and Peel Techniques.	70
The Evolution of the Structure of the Lake District.	71
The Outlook for World Energy.	75
The History of Haematite Mining in West Cumbria.	76
The Deep Structure of Northern England.	77
The History and Exploitation of Potash Deposits in North East England.	78
The Background to the Dinosaurs.	80
Radio-Carbon Dating and the Last Glaciation.	82
Exploration of the British Continental Shelf.	83
OBITUARIES: H.A.White and R.H.Hewitt	86
ANNUAL DINNERS: 14th April, 1978 and 28th April, 1979.	88
THE SEVENTEENTH AND EIGHTEENTH ANNUAL GENERAL MEETINGS	90
BOOK LIST AND NOTICES	100

A STUDY OF FOUR LOCALITIES IN THE MARTIN LIMESTONE (LOWER CARBONIFEROUS, DINANTIAN) OF FURNESS AND GRANGE-OVER-SANDS.

D. Leviston

SUMMARY

The Martin Limestone in the Furness and Grange-over-Sands areas has been investigated in detail. The effect of the adjacent 'Lake District' land mass on the lithology is discussed, together with the significance of the frequent dolomitized stromatolitic limestone and highly dolomitized limestone beds.

A new interpretation involving deposition and pene-contemporaneous erosion is suggested for the Chadian-Arundian boundary in the Furness area.

1. INTRODUCTION

This paper provides an account of the lithology, palaeontology and petrology of the Martin Limestone at four localities in the Furness and Grange-over-Sands areas and relates these to their environments of deposition.

The 46 metres to 138 metres of light to mid-grey limestones immediately succeed the Basement Beds of the Lower Carboniferous and were first discussed by Garwood (1913) who referred them to the Athyris glabistria Zone. Currently they are classified in accordance with Vaughan (1905) as being C_1 pars - C_2S_1 pars age. Dunham and Rose (1941) named these beds 'Martin Limestone' during their detailed mapping of the Lower Carboniferous in South Cumbria and Furness. Ramsbottom (1973) extended the earlier observations of Dixon and Vaughan (1912) on cyclic sedimentation and proposed a model of six transgressive-regressive cycles based on lithology and available palaeontological information. Within this model the limestones occupy the regressive phase of cycle 1 and the whole of cycle 2. George et al. (1976) propose six new regional stages for the Lower Carboniferous which closely relate to the cycles of Ramsbottom (1973). A comparison of the classifications

Table 1. Comparison of Classifications of Dinantian Rocks
(Based on George et al. 1976)

Vaughan 1905 – 1906 (Avon Gorge)	Garwood 1913 (Ravenstonedale)		Ramsbottom 1973 Major Cycles	George *et al.* 1976 Proposed new stages	Furness & Grange Limestones
Horizon ϵ	Dibunophyllum Zone	Dibunophyllum muirheadi Subzone	D_Y	6	BRIGANTIAN	*Gleaston Formation*
Dibunophyllum Zone (D): Lonsdaleia Subzone (D_2)		Lonsdaleia floriformis Subzone Girvanella Band	D_2			
Dibunophyllum Zone (D): θ ϕ Subzone (D_1)		Cyathophyllum murchisoni Subzone	D_1	5	ASBIAN	*Urswick Limestone*
Seminula Zone (S): Main Seminula Zone (S_2)pars	Productus corrugatus hemisphericus Zone	Bryozoa Band Nematophyllum minus Subzone Cyrtina carbonaria Subzone	S_2	4	HOLKERIAN	*Park Limestone*
Seminula Zone (S): S_2 pars; S_1 - Upper Carinia Zone		Gastropod Beds	S_1	3	ARUNDIAN	*Dalton Beds*
Syringothyris (Lower Carinia) Zone (C): Horizon δ (C_2) pars	M. grandis Zone	C. carinata Subzone C. isorhyncha Subzone	C_2			*Red Hill Oolite*
Syringothyris (Lower Carinia) Zone (C): C_2 pars	Athyris glabistria Zone	Seminula gregaria Subzone	C_2	2	CHADIAN	*Martin Limestone*
Syringothyris (Lower Carinia) Zone (C): C_1 pars		Algal Band	C_1			
		Solenopora Subzone				
Zaphrentis Zone (Z)		Shap Conglomerate	Z_2?	1	COURCEYAN	*Base-ment Beds*
		Pinskey Gill Beds	Z_1?			
Cleistopora Zone (K)	S.W. PROVINCE EQUIVALENT					
Modiola Zone (M)						

Note: Vertical rulings are non-sequences not present in original classifications, but are the result of current interpretation.

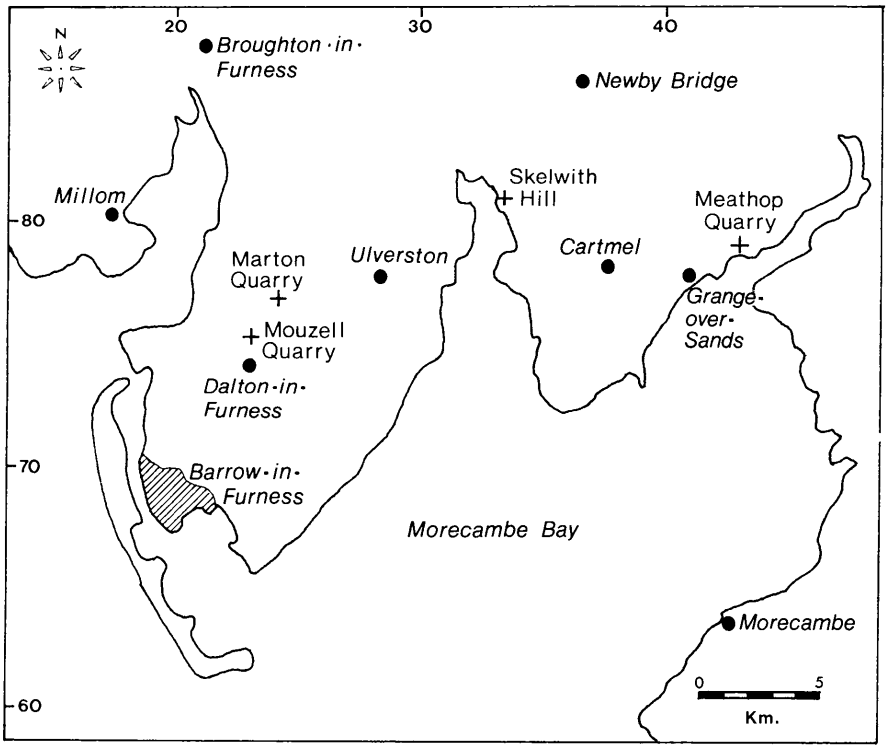


Fig.1 MAP OF LOCALITIES

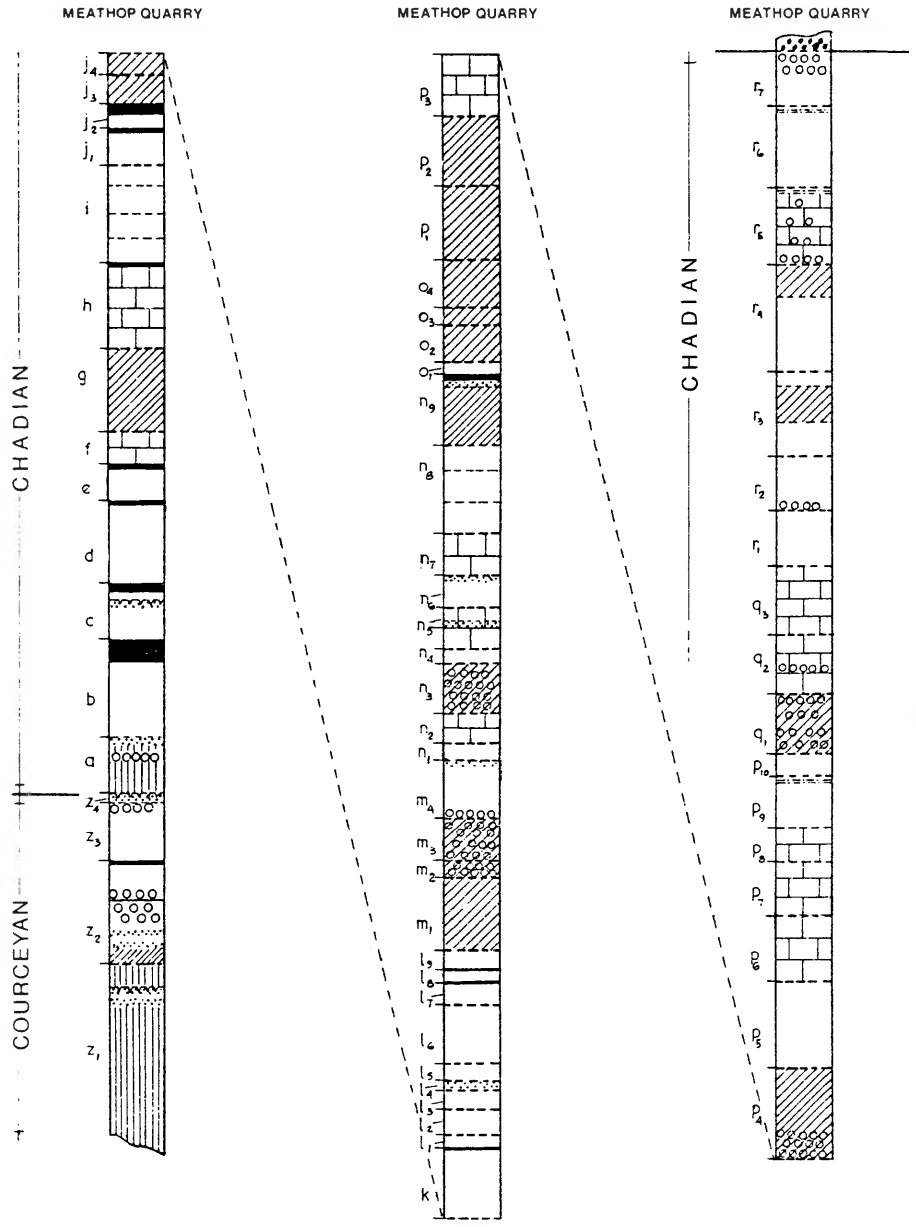
and the modifications necessary to the earlier ones is shown in Table 1.

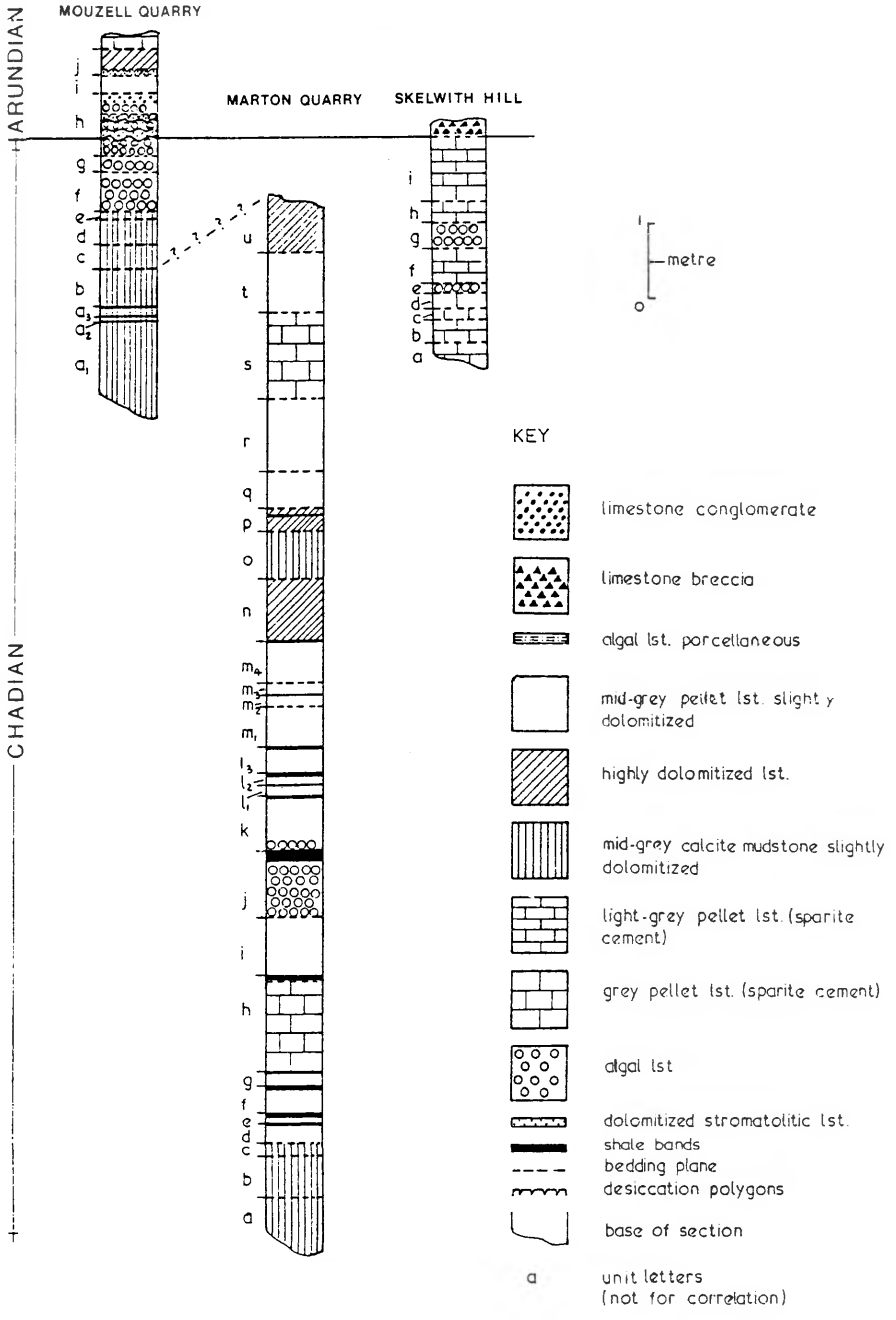
The four localities examined (Fig.1), were Meathop Quarry, (Grid Ref. 432.792); Mouzell Quarry (231.754); Marton Quarry (243.769)* and Skelwith Hill (332.810). The beds at each locality were logged and samples taken for thin section examination.

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* Note: An explanation of the two names 'Marton' and 'Martin' is pertinent. Reference to the 'Early Iron Industry of Furness and District' by Alfred Fell (Frank Cass & Co. Ltd. 1968) gives the original name of the village as 'Merton'. Over the past 500 years this has changed to Marton or Martin and both these names can be seen on sign posts around the vicinity of the village. Dunham and Rose chose to call the limestone after the more modern name, hence Martin Limestone, whilst the Ordnance Survey maps use Marton. Therefore it seemed prudent to use both names in this paper, 'Marton' for the locality, and 'Martin' for the limestone.

Fig.2 Vertical Sections, Meathop Quarry and Other Sites with suggested correlations




HARUNDIAN
CHADIAN
MOUZELL QUARRY
MARTON QUARRY
SKELWITH HILL
metre
KEY
limestone conglomerate
limestone breccia
algal lst. porcellaneous
mid-grey pellet lst. slightly dolomitized
highly dolomitized lst.
mid-grey calcite mudstone slightly dolomitized
light-grey pellet lst. (sparite cement)
grey pellet lst. (sparite cement)
algal lst
dolomitized stromatolitic lst.
shale bands
bedding plane
desiccation polygons
base of section
a
unit letters
(not for correlation)

Generally, only one thin section was made of each bed, but where obvious changes in lithology occurred within a bed, additional sections were made.

2. SUCCESSIONS

The lithology of the limestone can be divided into the categories noted in Fig. 2.

Meathop Quarry

The limestones exposed in this section can be considered to represent three groups of beds:-

(i) Regressive phase of the Courceyan Stage.
(ii) Transgressive and regressive phases of the Chadian Stage.
(iii) Transgressive phase of the Arundian Stage. (The limestone of this phase is called Red Hill Oolite and is not discussed in this paper).

(i) The regressive phase of the Courceyan Stage is represented by thin-bedded, mid-grey, fine grained dolomitized bioclastic limestone with interbedded lead-grey micaceous shale bands and frequent

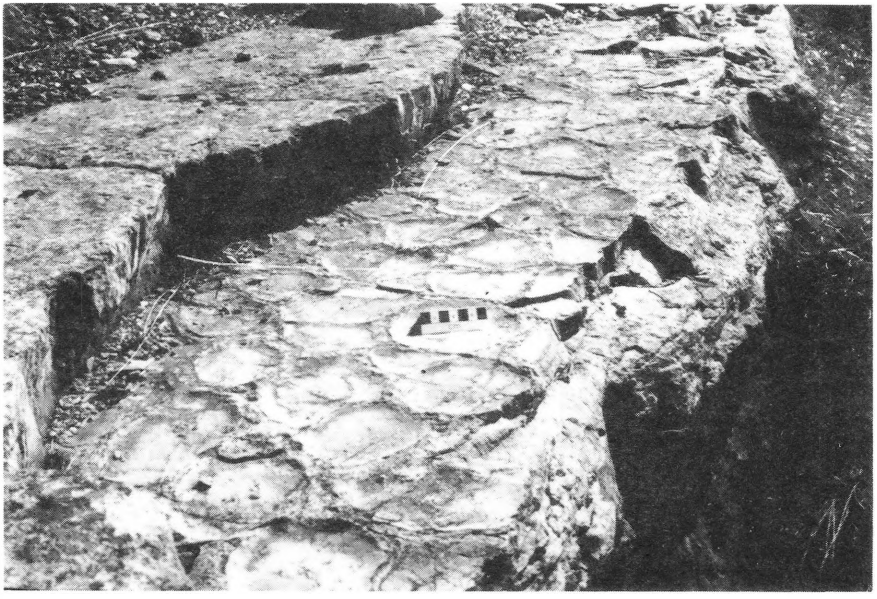


Plate 1. DESICCATED STROMATOLITIC LIMESTONE. Unit 'z_4' Martin Limestone, Meathop Quarry.

algal bands of stromatolitic and oncolitic types, the former being highly dolomitized. The limestone weathers to a mustard colour with the minute fossil fragments giving it a sandy texture.

Desiccation polygons in the dolomitized stromatolitic limestone can be seen at 2 metres and 4 metres above the base of the section, being very well developed at the higher levels. (Plate 1). This horizon marks the limit of the regressive phase and hence the boundary with the overlying Chadian Stage. It has been taken as the datum for all measurements quoted for this locality.

(ii) The 41 metres of Chadian limestone (Plate 2) can be divided broadly into two parts:-

(a) The bottom 21.7 metres contain thin-bedded grey and slightly dolomitized mid-grey pelletic bioclastic limestone with frequent bands of black micaceous shale. Horizons of dolomitized stromatolitic limestone are common and since they are considered to be intra-tidal in origin, are interpreted as representing minor transgressions; the band of desiccated dolomitized stromatolitic limestone 2.5 metres above the datum providing good evidence to support this. Highly dolomitized beds are common in the upper horizons, some containing evenly distributed algal nodules which weather into light grey areas 1 to 1.5 mm in diameter. The top is marked by a band of black calcareous shale. Generally the shale bands are black and micaceous, but 1.75 metres above the datum is a 0.34 metre thick band of green-grey micaceous mudstone containing iron-pyrite crystals.

(b) The remaining 19.5 metres of bioclastic limestone is similar in lithology to the beds below, except that shale bands are absent and a greater proportion of the beds are highly dolomitized. Stromatolitic limestones are absent but a thin bed of porcellaneous* algal limestone is present 31.5 metres above the datum and is interpreted as marking the commencement of the regressive phase. Other porcellaneous algal bands are present in the top two beds of the section.

Some of the highly dolomitized beds have algal nodules up to 15 mm in diameter evenly distributed throughout their thickness.

The top bed is rust coloured on the fresh broken surface and has prolific large algal nodules distributed throughout, becoming intermingled with the overlying basal Red Hill Oolite conglomerate which marks the limit of the

---

* Porcellaneous in this sense is used to describe a fine-grained rock which tends to stick to the tongue when wet.

regressive phase and hence the base of the overlying Arundian Stage. (Plate 3).

Mouzell Quarry

The limestones at this locality can be divided into two distinct lithologies:-

(i) 4.5 metres of thin bedded, mid-grey, dolomitized bioclastic calcite mudstone and algal limestone weathering to a mustard colour, with lead-grey micaceous shales common in the bottom 2.9 metres.
(ii) Approximately 15 metres of massive, current bedded grey pellet limestone.

Details of the most significant units are given below:-

		Thickness (metres)
Arundian		
Unit j.	Highly dolomitized limestone with possible desiccated stromatolitic limestone. Trace fossils in bottom 0.08 metres.	0.60
Unit i.	Slightly dolomitized mid-grey pellet limestone with current bedding.	0.25
Unit h.	Stromatolitic limestone.	0.04
	Oncolitic limestone with eroded surface 0.03 metres from top.	0.21
	Desiccated stromatolitic limestone.	0.03
	Oncolitic limestone with eroded surface.	0.11
	Erosional debris in a matrix of apparent stromatolitic limestone with eroded surface.	0.10
Chadian		
	Oncolitic limestone with eroded surface.	0.22
Unit g.	Oncolitic limestone.	0.25
Unit f.	Oncolitic limestone.	0.50

Skelwith Hill

This foreshore exposure consists of 3 metres of light-grey porcellaneous limestone containing no macrofossils, but it has

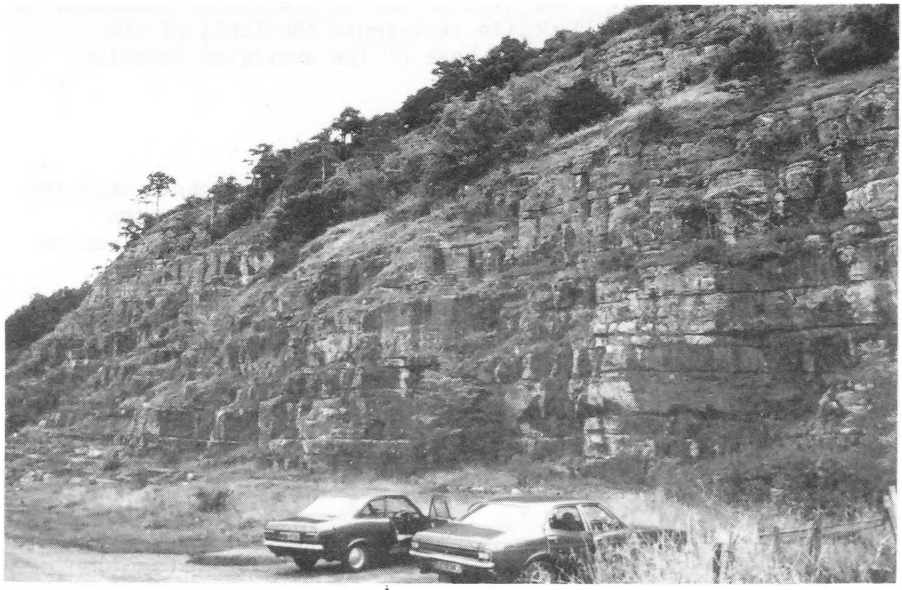


Plate 2. TYPICAL THIN BEDDED MARTIN LIMESTONE - Meathop Quarry.

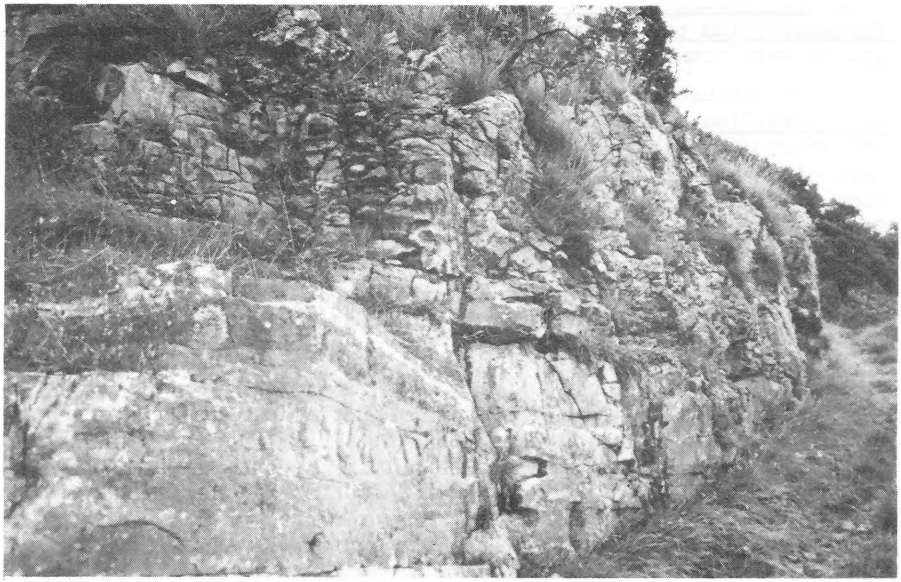


Plate 3. CONGLOMERATE MARKING THE BASE OF THE RED HILL OOLITE - Meathop Quarry.

three oncolite bands. The 1.35 metres of brecciated limestone at the base of the Red Hill Oolite represents the limit of the regressive phase and forms the base of the overlying Arundian Stage.

Marton Quarry

Detailed mapping by Dunham and Rose (1941) suggests that the top bed of the quarry lies approximately 3 metres below the boundary with the overlying Red Hill Oolite, therefore it can be approximately correlated with Unit 'b' at Mouzell Quarry.

In appearance the 14 metres of bioclastic calcite mudstone are identical to those at Mouzell Quarry, with lead-grey micaceous shales being common. A well developed oncolitic limestone is present 5 metres above the base. Shrinkage cavities due to dolomitization are common especially in the higher beds.

3. PALAEONTOLOGY

The classification by Garwood (1913) was based on the faunal evidence and this excellent paper is well supported by illustrations of the important fauna. Mitchell (1972) gave the coral fauna in the Furness and Grange areas to include Carcinophyllum simplex Garwood, Koninckophyllum sp. praecursor Howell group, small Palaeosmilia murchisoni Milne Edwards and Haime and Thysanophyllum pseudovermiculare (McCoy). In addition Syringopora sp. is very common.

The brachiopod fauna include smooth spiriferoid and Spiriferellina sp., Punctospirifera sp., Composita aff. ficoidea and other Composita sp. Of particular interest is the recording here of what is probably an early form of Delepinea sp. in the Mouzell and Marton quarries. A solitary loose specimen of Stenoscisma isorhyncha (McCoy) has been found by the author at Marton quarry.

A list of the corals and brachiopods collected by the author is given below. Many of the specimens show signs of abrasion through transportation.

Unidentified gastropods of various sizes were found particularly at Marton and Meathop. Oncolitic limestones are common at all four localities with a 1.5 metre band being particularly well developed at Mouzell and to a slightly lesser degree at Marton. Stromatolitic limestones are only found at Meathop and Mouzell, where they are represented by 2.5 cm. thick highly dolomitized bands. Plant fragments were found 16.1 metres above the base of the section at Meathop.

Examination of thin sections suggests that the species of

foraminifera are very restricted. The following have been identified: Globoendothyra sp., Endothyra similis group, Eoparastaffella sp., Palaeotextularid (senso lato), Palaeospiroplectammina sp., Tournayella sp., Calcisphaera sp. and algae of Koninckopora sp. The microfauna content varies between the beds, being absent in some, prolific in others particularly at Skelwith Hill. Globoendothyra sp. and Eoparastaffella sp. are the most common species in the thin sections examined.

4. PETROLOGY

Grains.

In addition to the foraminifera previously mentioned, the grains are predominantly pellets and ooliths, with fragments of brachiopods, ostracods and crinoid ossicles being secondary.

The pellets are characterised by being brown in colour, devoid of any internal structure and may be round or ovoid in shape. The ovoid pellets have a major axis of approximately 0.1 mm, whilst the spherical pellets can attain 1.5 mm in diameter, although this is rare. The ooliths are approximately 0.5 mm in diameter and consist of a nucleus, which is invariably a pellet surrounded by calcite. In some instances this calcite coating is further encased by a brown outer shell of possibly algal origin. In many cases lack of compaction indicates early diagenesis. Staining in accordance with Dickson (1966) proved the brown coating of both the pellets and the ooliths to be cryptocrystalline calcite.

Terrigenous clasts are very rare, and have only been found in the lower and top beds at Meathop, where they are represented by rounded and sub-rounded quartz clasts approximately 0.5 mm in diameter constituting less than 1% of the rock.

Matrix and Cement

The mid-grey limestone and calcite mudstones have a matrix of micro-crystalline calcite termed micrite, (Plate 4), whilst the grey and light grey limestones have a sparry calcite or sparite cement, (Plate 5).

Ramsbottom (1973, p.570) suggests that the calcite mudstones and associated beds provide evidence that they are deposits of early stages of the evaporitic sequence formed in the extremely shallow waters of wide flat shelf areas. Precipitation of calcium carbonate from the sea water begins when the salinity has been increased by evaporation from the normal 35 parts per million to 72 parts per million, this precipitate being the source of much of the material of the calcite mudstones. Greensmith (1970, p.225) states that the mode of origin of the micrite is not so certain and that it may be of physico-chemical, biochemical, or even biogenic

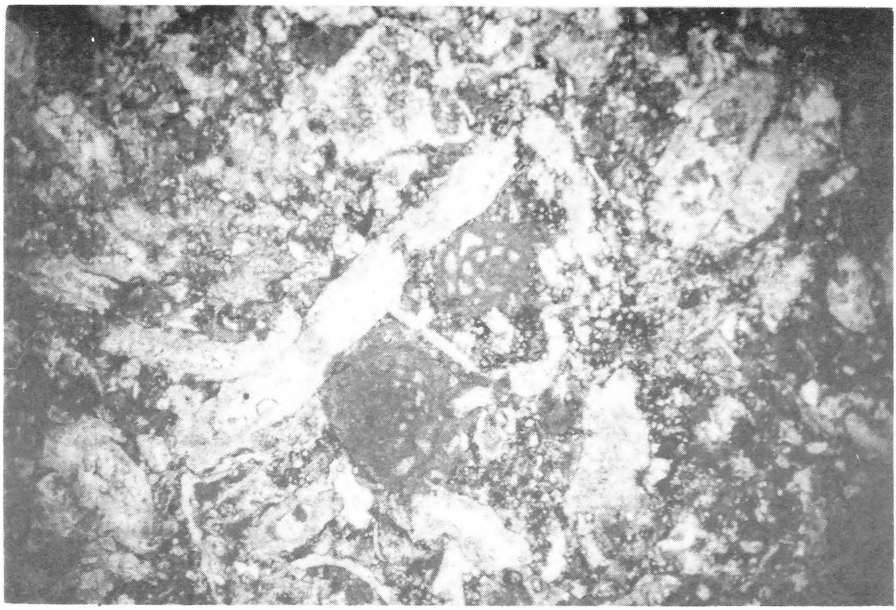


Plate 4. MARTIN LIMESTONE, MARTON QUARRY UNIT 'a'. Dusty sub-opaque micrite matrix charged with crinoid stems and ossicles filled with recrystallised calcite, foraminifera, spines and brachiopod fragments. Small euhedral crystals of dolomite are evident in the black irregular areas of iron oxide. Magnification x 33.4

origin. However, the conditions which favour all these origins are warm surface waters of tropical or sub-tropical regions, saturated in calcium carbonate and with restricted circulation. They imply a rapid rate of accumulation and lack of powerful winnowing currents.

Sparite is a secondary mineralisation in the pores left after the micrite has been winnowed away and therefore implies a period of fairly strong currents.

Dolomitization

Ramsbottom (1973, p.571) outlines the following mechanism for dolomitization:

> "With the increase of salinity carbon dioxide is driven off and the pH increases. Water evaporated to high salinity in the surface layers becomes dense and sinks to the sea bottom where it may either escape downslope and return to the open sea, or, if this is not possible, and if the underlying

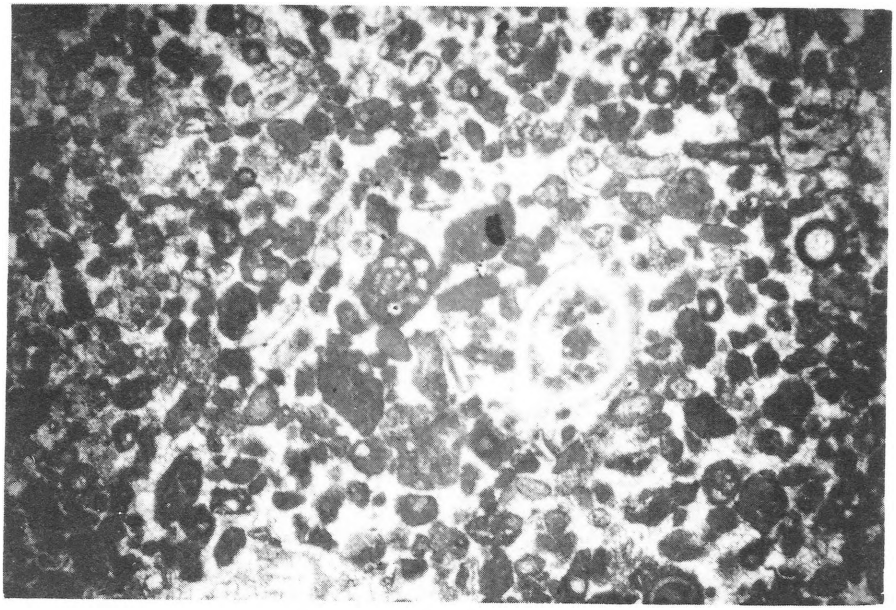


Plate 5. MARTIN LIMESTONE, SKELWITH HILL UNIT 'i'. Dusty sub-opaque micropellets, concentric coated grains, foraminifera, crinoid ossicles, spines and an ostracod in a sparry calcite cement. Magnification x 33.4

rocks are sufficiently permeable, seep into the sea floor where it will replace less dense connate waters. Having had much of the calcium carbonate removed (as precipitated calcium carbonate) the salts in this dense saline water have a much higher magnesium to calcium ratio than that of normal sea water. It is the downward seepage of this dense alkaline, warm magnesium-rich water which causes the dolomitization so typical of the regressive phases and of the dolomitization just below them in the Dinantian. The precipitated calcium carbonate may also be dolomitized, as is happening today in the Bahamas (Shinn et al. 1965). Such dolomitized calcite mudstones are the characteristic rock type found in the lagoon phases. The fact that dolomitization is so widespread in the British Dinantian suggests that the escape seawards of the dense saline waters was seldom possible."

The limestones under discussion are dolomitized to various degrees, particularly at Meathop. Study of the stained thin sections and cellulose acetate peels shows that the majority of the limestone contains between 0% and 10% by volume of dolomite crystals, whilst the highly dolomitized beds contain between 40%

and 100% by volume of dolomite crystals (Plate 6). The variation of dolomitization across a 17.8 metre section of Meathop Quarry is given in Table 2. Although only one sample was taken from each bed the results indicate that there is a definite cyclic nature in the degree of dolomitization. Studies on the thermodynamics of dolomitization have shown that, with the conditions of temperature and concentration prevailing in the sea, dolomitization will proceed spontaneously (Mason, 1966, p.157). Therefore, the highly dolomitized beds must have formed at the sediment-water interface during the dolomitization period. In all instances the limestone not dolomitized has a sparite cement and forms the base of the next sequence of dolomitized beds. This can be interpreted as being the result of an influx of new sea water into the basin, terminating the dolomitization process and producing the strong currents responsible for winnowing away the micrite.

Analysis of some of the limestone is shown in Table 3, and it is interesting to note that only 10% by weight of magnesium is required to produce 100% dolomitization. The presence of euhedral dolomite crystals formed within calcite filled cavities shows that in some beds dolomitization took place after diagenesis.

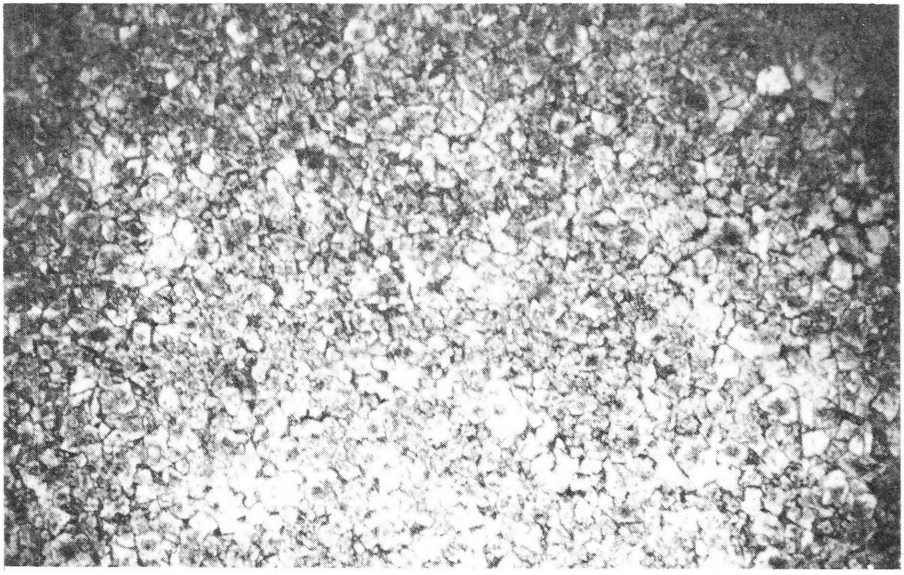


Plate 6. 100% EUHEDRAL CRYSTALS OF DOLOMITE. Note that all evidence of original limestone has been obliterated. Unit 04 Martin Limestone, Meathop Quarry.
Magnification x 33.4

Table 2. POSSIBLE CYCLES OF DEPOSITION AS SUGGESTED BY DEGREE OF DOLOMITIZATION IN A 17.8 METRE SECTION OF MEATHOP QUARRY.

Unit	% of dolomitization by volume
q 3	15
q 2	0
q 1	40
p 10	20
p 9	40
p 8	20
p 7	0
p 6	10
p 5	10
p 4	96
p 3	0
p 2	100
p 1	70
o 4	100
o 3	80
o 2	80
o 1	30
n 9	50
n 8	10
n 7	0
n 6	0
n 5	7
n 4	20
n 3	50 ?
n 2	0
n 1	50

Veining

Calcite veins can be seen following the boundaries of the dolomite crystals, and in some instances actually cutting across and fragmenting them.

Staining the limestone in accordance with Dickson (1966) shows that there were at least two distinct periods of veining. The first veins were filled with calcite, whilst the second phase produced veins filled with ferroan calcite $(CaFe)CO_3$.

5. CONCLUSION

The Martin Limestone in the Furness and Grange-over-Sands areas is composed of mid-grey, pelletic, bioclastic limestone with interbedded calcite mudstone, grey pelletic limestone and shale bands. The lithology is typical of regressive phase facies deposited in warm shallow lagoonal waters. This is supported by the low symmetrical wave ripple index of 8.5 (Reineck and Singh, 1976, Tables 5b and 6). The presence of oolitic grains suggests a depth of not more than 3 metres (Ramsbottom, 1973, p. 569).

The oldest limestones in West Cumbria are of Holkerian age and a land

Table 3.
COMPARISON BETWEEN % BY WEIGHT OF MAGNESIUM AND % BY VOLUME OF DOLOMITIZATION

Unit	Locality	% Mg by weight	% dolomitization by volume
j	Mouzell	10.4	100
a	Mouzell	0.55	1
3_4	Meathop	3.8	45
o_4	Meathop	10.2	100
q_1	Meathop	2.8	40
f	Marton	0.52	1

mass existed to the North West of the present area during early Carboniferous times. Formation thicknesses quoted in Rose and Dunham (1978 pp.28-29) suggest that at the start of the Chadian Stage the maximum height of this land mass was in the order of 490 metres above sea level, the transgressive sea reducing this to some 370 metres by the end of the Stage. The close proximity of this land mass undoubtedly played a major role in controlling the depositional environment and its effect was to mask the transgressive phase of the Chadian Stage, with regressive type facies. It is possible that this land mass was also the source of the terrigenous material which forms the shales. The absence of terrigenous clasts in the majority of the limestone is possibly due to the low relief of this land mass with the presence of frequent and sometimes desiccated horizons of stromatolitic limestone, of probable supratidal or intratidal origin, forming carbonate flats which isolated the land mass from the area of deposition.

Throughout the whole period of deposition the basin would be subjected to frequent fluctuations in sea level; any fall in sea-level increasing the effectiveness of the low barrier which must have existed at the mouth of the basin, restricting not only the influx of fresh sea water but also the reflux of denser bottom waters. Intermittent breaching of this barrier would introduce fresh sea water into the basin, thus raising the sea level and terminating the dolomitization process.

By the end of the Chadian Stage the depositional environments in the Furness and in the Grange-over-Sands areas were markedly different. The basal Red Hill Oolite conglomerate at Meathop Quarry and the breccia at Skelwith Hill are both indicative of high energy environments, the former being typical of beach deposits, whilst the latter was probably formed by waves breaking over limestones exposed above the sea. Two possibilities can be considered for correlating these rocks with the succession at Mouzell Quarry. First, during the period when the conglomerate and the breccia were being formed the depositional environment in the Furness area was one of relatively low energy allowing the deposition and, at times, penecontemporaneous erosion of the carbonate sediments which are evident in Unit 'h'; the limit of this regressive phase being marked by the desiccated stromatolitic limestone 0.46 metres above the base of this unit. The upper 0.25 metres of Unit 'h' together with Units 'i' and 'j' are considered to represent the early stages of the transgressive phase of the Arundian Stage, and this correlation is shown in Fig.2. Secondly, the correlation can be based upon the marked change in lithology between Units 'j' and 'k'. This requires that the breccias and conglomerates of the Grange area be correlated to a non-sequence in the Furness area, as is shown in Table 1.

In the absence of an eroded surface between units 'j' and 'k'

at Mouzell Quarry the second correlation seems improbable and it is the author's opinion that the non-sequence shown in Table 1 is not applicable to the Furness area.

6. LIST OF FOSSILS

CORALS:

Rugose Corals:-

Koninckophyllum praecursor (Howell), group.

Marton Quarry, Bed 'n', very fossiliferous bed yielding excellent samples.

Mouzell Quarry, Beds 'g' and Unit 'h'.

Palaeosmilia cf. *murchisoni* (Milne Edwards & Haime)

Marton Quarry, Beds 'h' and 'l'.

Mouzell Quarry, Bed 'c'

Thysanophyllum pseudovermiculare (McCoy)

Marton Quarry, Beds 'l', 'm' and 'o'. Only single corallites found with excellent samples obtained from Bed 'm'.

Tabulate Corals:-

Syringopora sp.

Abundant at all localities except Skelwith Hill.

BRACHIOPODS:

Spiriferellina sp.

Mouzell Quarry, Unit 'a', third shale band - excellent samples.

Delepinea sp.

Mouzell Quarry, Bed 'f'.

Marton Quarry, Beds 'o' and 'p'.

Composita aff. *ficoidea* (Vaughan)

Marton Quarry, prolific especially in Unit 'n'.

Meathop Quarry, excellent samples can be easily obtained from Bed 'j_4' and are prolific in Beds 'n_3' and 'r_1'.

Stenoscisma isorhyncha (McCoy)

Marton Quarry, loose specimen.

7. ACKNOWLEDGEMENTS

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A NEW ASSESSMENT OF THE STRATIGRAPHY OF THE SKIDDAW GROUP ALONG THE NORTHERN EDGE OF THE MAIN SKIDDAW INLIER

D. E. Jackson

SUMMARY

The grits of Watch Hill and Great Cockup are shown to belong to the widely accepted Loweswater Flags and are confidently dated as of deflexus age (early Arenig). Only three formations are recognised, namely: Kirk Stile Slates (conformable with the overlying volcanics), Loweswater Flags and Hope Beck Slates (base not seen). The Sunderland Slates are synonymous with Kirk Stile Slates and therefore the term is suppressed.

A new fauna characterised by multiramous dichograptids and Didymograptus protobalticus is documented from the Uldale Fells. This fauna is thought to be slightly older than the deflexus Zone developed in the Lorton area and therefore the oldest known occurrence of graptolites in the Skiddaw Group.

1. INTRODUCTION

> "In truth, no one can collect in this region without doing some good; for the Skiddaw Slates is the metropolis of the Graptolites"
>
> Salter 1863, p.140

The number of mappable units within the Skiddaw Group and their stratigraphical position have been contentious for more than a hundred years. Anyone familiar with the literature will note that the only common ground between published accounts is that the lower arenaceous Loweswater Flags are overlain by

mudstones of the Kirk Stile Slates. Across the central region of the main inlier these two units are quite well endowed with graptolites showing that they are of Didymograptus extensus and hirundo ages. The apparent rarity of graptolites from similar looking rocks along the northern margin of the inlier has long been a puzzle and has contributed in large measure to the problem of where to assign the grits of Watch Hill and Great Cockup. The age of these beds has ranged from Precambrian (Rastall 1910) to late Ordovician (Green 1917). Further confusion has been added by Simpson (1967) who placed the 'Watch Hill Grits' above the Mosser Slates and proposed a new unit called the Sunderland Slates for the still younger mudstones. However, if the 'Watch Hill Grits' are truly devoid of graptolites it would not be unrealistic to assign them to a very low position in the stratigraphic pile - say comparable to the Manx Group.

Clearly, however, such negative evidence requires scrutiny. The apparent lack of graptolites in mudstones can be accounted for in at least three different ways. In today's oceans for example, plankton can have a patchy distribution due to helical vortices being formed by wind action on surface layers. Such 'wind rows' (as these patches are called) may develop on scales that vary between tens of metres and tens of kilometres. However, the span of time involved in the 'Watch Hill Grits' may be more than a million years so this mechanism seems inappropriate. Another explanation is that cleavage has made it difficult to view large areas of bedding surfaces. A more likely explanation is the lack of large natural or man-made screes such as exist at Barf and Randel Crag. Indeed, where large screes do occur, as on Burn Tod Fell, graptolites can be found. A very interesting and prolific collection was made about 50 years ago by T.C.Nicholas from this place but its existence came to light only recently, and it is this new information which stimulated the writing of this paper. Salter may have overindulged in the belief that Cumbria was a Clapham Junction for graptolite migration, but his views about the need for collecting still apply today.

In the rest of this paper the stratigraphy of the Skiddaw Group is re-examined in three areas, namely, east of Cockermouth, the Bewaldeth area, and the Uldale Fells.

2. THE AREA BETWEEN COCKERMOUTH AND SETMURTHY

Within sight of the geology room in Cockermouth Grammar School are some low lying hills which stretch from Slate Fell eastwards to Seathwaite How and Higham. If in the past these hills have had claim to fame it is for their igneous rocks rather than for any stratigraphical interest, for the strata tend to be highly cleaved and locally affected by contact metamorphism. Unaltered strata comprise striped mudstone and siltstone of

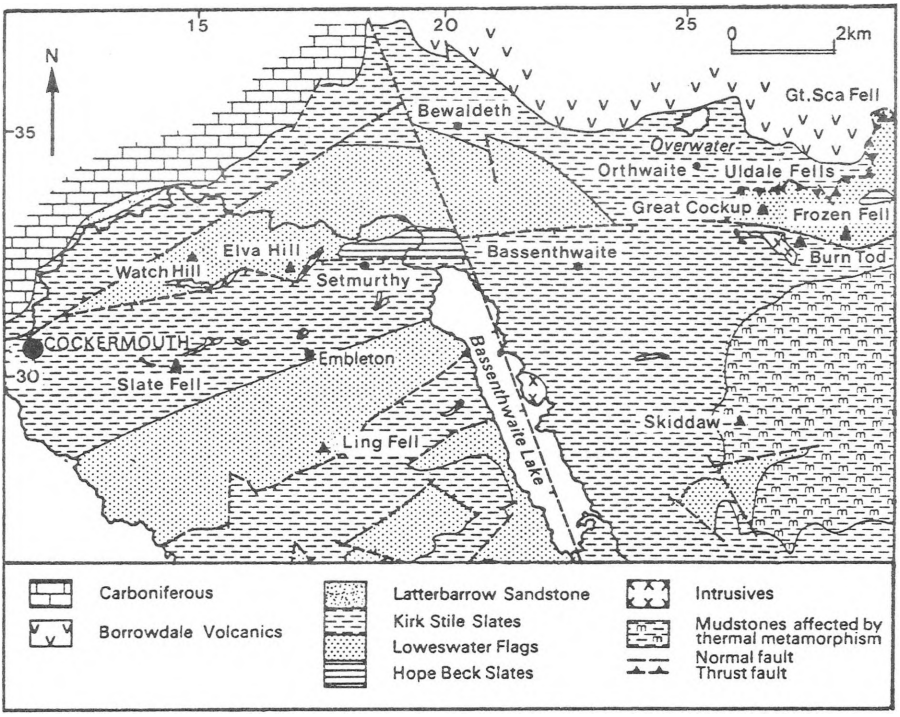


Fig.1 GEOLOGICAL INTERPRETATION AND LOCALITY MAP (Modified from Figs. 33 & 34 of 'The Geology of the Lake District', Occasional Publication No.3 of the Yorkshire Geological Society and reproduced with their permission)

varying hues of black, blue, grey and green which tend to weather to a rusty colour along cleavage and joint planes. Considered in their regional context, these northward dipping strata could be viewed as dipping beneath the grits of Watch Hill; indeed the literature shows that several workers have in the past embraced this view. That such an interpretation is incorrect is shown by the discovery that black mudstones in Embleton Quarry yield Didymograptus cf. D.protobifidus, Glyptograptus cf. G.dentatus and one doubtful Isograptus. A hirundo age seems probable and assignation to the Kirk Stile Slates is unquestionable.

North of the Golf Course lies another east-west ridge that extends from Watch Hill to Elva Hill. This ground owes its elevation to dioritic sills and dykes, as, for example, on Watch Hill (1495.3190) and Elva Hill (1711.3199), and to resistant flags

(= Ward's grits of Watch Hill). An igneous body of considerable interest is the columnar-jointed pink felsite (Eastwood et al. 1968,Pl.IIA) west of the summit of Watch Hill (1490.3170). The discovery of a pocket of monomictic conglomerate in a depression on top of the felsite is taken as proof of its extrusive nature. The lava has a maximum thickness of 9.1 metres and crops out for 365 metres.

Greywackes and interbedded mudstones can be traced northwards from Watch Hill to Hewthwaite Hall and eastwards to Elva Hill where they are nicely exposed in an old quarry (1730.3205). The relationship between these beds and the northward dipping dark mudstones (with rare posts of sandstone) such as crop out on Dodd Crag (1565.3157) and in the forest on Setmurthy Common (1650.1355) is obscure but possibly faulted. Eastwood et al. (1968 p.31) alluded to the possibility that they could be Hope Beck Slates, in which case they would be separated from the Kirk Stile Slates south of Bitter Beck by a major, but as yet undetected, east-west fault.

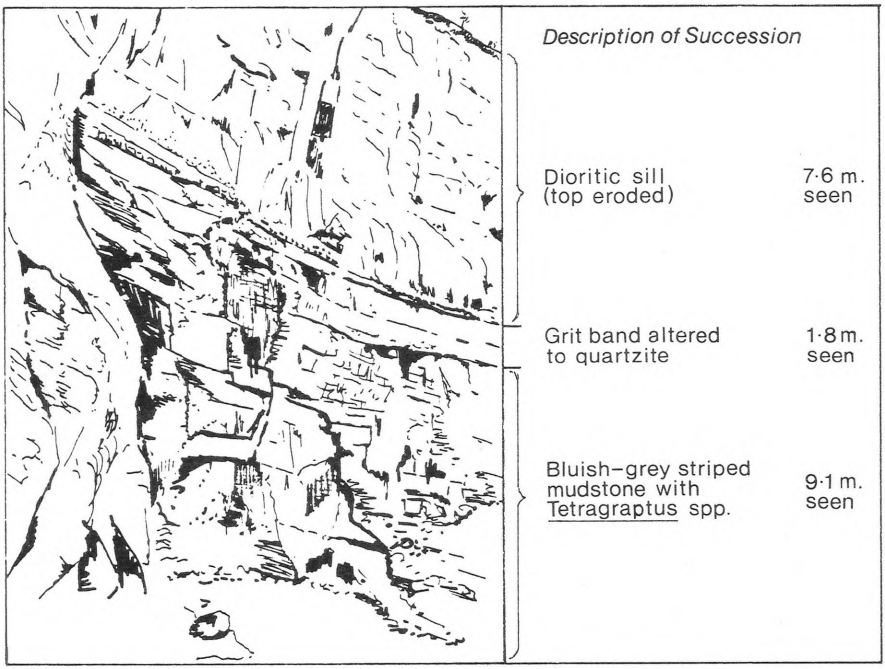


Fig.2 PROFILE OF QUARRY WEST OF SETMURTHY CHURCH AS SEEN IN 1955 (The main face is bounded to the east by a near-vertical fault)

Northeast from Elva Hill the greywacke facies is displaced to the north by a NE - SW down to the NW fault into which a large dyke has been intruded. Basal beds of the formation were well exposed in the late 1950s in a small worked quarry 300 metres WNW of Setmurthy Church (1820.3237).

Graptolites were collected in situ at two levels close to the base of the quarry face. The higher of the two comprised a bedding plane profusely covered with Tetragraptus aff. T. quadribrachiatus (J.Hall) and the lower occurrence is one specimen of Tetragraptus aff. T. amii Elles and Wood (Fig.4 g & h).

My inclination is to look upon this assemblage as of early Arenig age thus implying that the mudstones are the Hope Beck Slates. It was this line of reasoning that led Jackson (1956) to view the 'Watch Hill Grits' as synonymous with the Loweswater Flags (see also Rose, 1955). But although the notion seemed a good working hypothesis indisputable palaeontological support was not available. The irony is that collections made by S.Hester and T.C.Nicholas a few miles from here actually solved the problem for us nearly 50 years ago.

3. THE BEWALDETH AREA

North of the River Derwent rock exposures are mainly restricted to small streams and the picture that one can build up from this information together with the inferences from topography amounts to a continuation of the Watch Hill-Elva Hill stratigraphy. Light grey sandstones and alternating siltstones and greyish-green mudstones crop out in Howgill Wood where in Jonah's Gill (1905.3407) a 3 metre thick succession dips northwards at 30°-40°. It was from this exposure that S.W.Hester collected graptolites (Institute of Geological Sciences reference numbers Ht.1250-1260) over 40 years ago and these came to light again quite fortuitously when Mr.W.C.C.Rose gave me a list of fossil localities together with identifications made by G.Elles. The significance of the fauna is the presence of three well preserved Didymograptus deflexus Elles and Wood (Fig.4) as well as D. ?balticus Monsen and D. ?nicholsoni Lapworth which dates these beds as of deflexus age thus proving beyond doubt that the 'Watch Hill Grits' are correlative with the Loweswater Flags.

Eastwards along strike, one finds northward younging, near-vertical Loweswater Flags in Coal Beck both up and down-stream from Burthwaite Bridge (2153.3311). Up-stream from the bridge, Loweswater Flags crop out as far as the confluence with Burthwaite Beck (2170.3330) where the lithology changes to Kirk Stile Slates. Further up-stream, northward younging sandstones (?Loweswater Flags) reappear in Atkinson's Gill where the strike direction is

NW-SE. Hester also collected graptolites in the Gill but they are not sufficiently well preserved to be of stratigraphical value.

To the northwest lies Blumer Beck and its various tributaries. Between Blumer Bridge (1760.3490) and Beckgrains Bridge (1900.3550) the stream section exposes a mixture of bluish mudstones and greywackes which bear evidence of intense deformation. This is hardly the place to expect graptolites, nevertheless, in 1929 Hester collected Didymograptus hirundo (Salter), Phyllograptus angustifolius Hall and the trilobite Cyclopyge from the beck at Scalegill (probably 197.355) and Jackson (1956) recorded Glyptograptus dentatus (Brongniart) from the bank of the stream 50 metres west of Beckgrains Bridge. Clearly, the mudstones represent the Kirk Stile beds and their age is upper Arenig but the exposures are completely inadequate to work out the structural relationships.

4. THE ULDALE FELLS

Eastward from Messengermire Wood, the Skiddaw Group crops out between Bassenfell and Orthwaite in many old quarries, roadside cuttings and stream sections. These exposures collectively suggest that the area is underlain by contorted and highly cleaved striped mudstones which have been intruded locally by dioritic rocks. Perhaps like the rocks forming the fells north of the Vale of Embleton these are the Kirk Stile Slates, but this is pure speculation for they have not yielded dateable graptolites. If this speculation turns out to be correct the NW-SE trending Loweswater Flags seen in Coal Beck must be terminated by a major NE-SW trending fault approximately through Castle Hill.

The final area I wish to discuss extends from Orthwaite to Great Sca Fell where again the high ground is due to resistant greywackes (= the gritty beds of Great Cockup, Ward, 1876). The headwaters of the River Ellen cut down into bluish striped silty mudstones and brownish weathering siltstones which dip southwestwards. Apart from worm trails, no fossils have been reported from these beds although uppermost Skiddaw strata at the Overwater spillway are alleged to contain late Arenig microfossils (Wadge 1978, p.70). Thus it seems reasonable to consider these beds as Kirk Stile Mudstones. Everywhere to the north the Kirk Stile - Volcanics junction is obscured by superficial deposits.

Much better known are the controversial grits to the south that crop out on Castle How, Little Cockup, Great Cockup, Burn Tod, Meal Fell, Frozen Fell and Great Sca Fell. Their anomolous position relative to the underlying volcanics on Brae Fell led Green (1917) to propose an unconformable relationship, but by 1929, Survey geologists were explaining the relationship in terms of thrust faulting. This interpretation was followed by Jackson

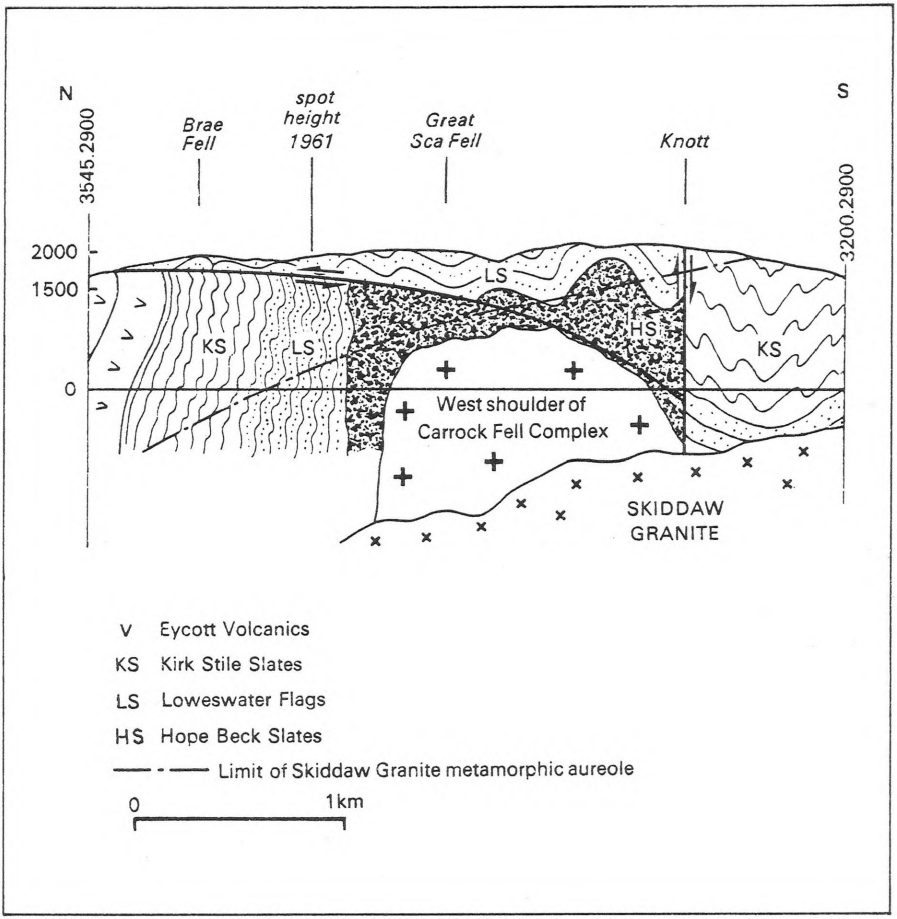


Fig. 3 SCHEMATIC STRUCTURAL CROSS-SECTION FROM BRAE FELL TO KNOTT

(1956) and Eastwood et al. (1968, pp.38,89 and 140) purely on the grounds of lithological similarity between these grits and the Loweswater Flags. Recently Jackson (1978, p.96) briefly argued the case for this correlation on palaeontological grounds and this evidence is given in full below.

All the graptolites that are known to the writer have been collected from various localities in Frozenfell Gill and the complete list of identifications is as follows:

FAUNAL LIST (All numbered specimens are housed in the Sedgwick Museum, Cambridge):

Clonograptus cf. C. herrmanni Monsen A55012

Collected by T.C.Nicholas in 'north bank of Frozenfell Gill, 400 yards S 35° W of point 2131 on Great Sca Fell'. (2891.3362)

?Clonograptus galgebergi Monsen A55011

Collected by T.C.Nicholas '20 yards NW 14° N of point 1403 on north bank of Frozenfell Gill' Comparable to Monsen's Clonograptus galgebergi. (2795.3360)

Clonograptus sp.

Collected by D.Jackson in 1978 from scree in north bank of Frozenfell Gill 230 metres ENE of point 1431. (2827.3344)

Dichograptus sp. indet. A17898

This is a five-branched form and was collected by W.G.Fearnsides from Burn Tod Gill (exact location unknown). It is associated with fragmented Tetragraptus.

Didymograptus protobalticus Monsen A17632 (Fig.4a)

Collected by W.G.Fearnsides from Burn Tod Gill (exact location unknown). Figured as D. patulus (Hall) by Elles 1933, p.100 fig.9. Ten specimens on one bedding plane (including Fig.4b)

Didymograptus protobalticus Monsen A55086 (Fig.4c)

Collected by T.C.Nicholas from 'scree 20 yards NW 14° N of point 1403 on north bank of Frozenfell Gill. (2795.3360)

Didymograptus aff. D.nicholsoni Lapworth A55054 and A55055 (Fig.4e)
Collected by T.C.Nicholas '45 yards W 12° N of point 1403, on N. bank of Frozenfell Gill'. More than 40 specimens in all: other specimens possibly referable to this species are A55056 and A55057. This declined didymograptid is comparable to only one of Elles & Woods' lectotypes, namely, Pl.11 Fig 4a. It also compared very well with D.sinensis Lee & Chen (1962) with respect to length of sicula, thecal spacing, inclination of thecae, and thecal overlap. This specimen occurs in the D.filiformis Zone of China which follows the T.approximatus Zone.

Didymograptus aff. D.nicholsoni A55084 and A55085

Collected by T.C.Nicholas in screes '45 yards W 12° N of point 1403 on north bank of Frozenfell Gill'. (2794.3360)

Didymograptus aff. D.nitidus (Hall) A55069

Collected by T.C.Nicholas '20 yards NW 14° N of point 1403 on north bank of Frozenfell Gill. (2795.3360)

Didymograptus sp. indet.

Collected by D.Jackson in 1973 from scree at 1750 feet elevation due west of Great Sca Fell (two specimens). (2878.3370)

Temnograptus sp.

Collected by D.Jackson in 1955 from scree at point 1431 in Frozenfell Gill. (2810.3340)

Tetragraptus ?amii A55120 a,b.

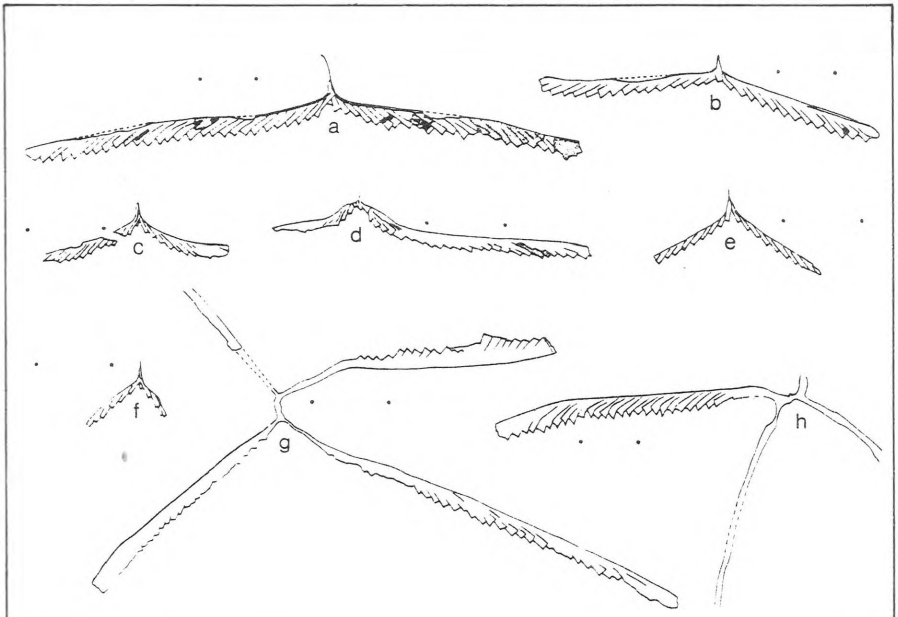
Collected by T.C.Nicholas from 'scree 43 yards W 12° N from point 1403 on north bank of Frozenfell Gill'. (2794.3360)

Tetragraptus ?quadribrachiatus (Hall) A55121

Collected by T.C.Nicholas from same locality as A55120.

The noteworthy feature of the Frozenfell fauna is the preponderance of declined Didymograptus and multibranched genera. Didymograptus aff. D.nicholsoni, Temnograptus, Clonograptus and Tetragraptus all constitute important elements of the deflexus Zone as known from Scaw Gill Quarry, Lorton. Furthermore, Didymograptus protobalticus Monsen is definitive of 3 bA beds in Norway where it forms a zone 0.4 metres thick in the lower Didymograptusschiefer where it occurs in association with Tatragraptus approximatus, T. cf. T.serra, T.quadribrachiatus and Clonograptus cf. C.rigidus. The absence of D.deflexus from the Frozenfell fauna is explained if we accept that these beds are somewhat older that the deflexus Zone at Scaw Gill. This deduction seems reasonable on lithological grounds too, because whereas Scaw Gill Quarry lies within the Loweswater Flags, Frozenfell Gill is cut in beds transitional between Loweswater and Hope Beck Formations.

In conclusion, the grits of Great Cockup and Great Sca Fell represent Loweswater Flags that have been thrust northwards over Kirk Stile Slates on to Eycott Volcanics in response to compression from the south against the Carrock Fell complex. (Figure 3).



(a) D.protobalticus Monsen A1732 Burn Tod Gill
(b) -do- same bedding plane
(c) -do- A55086 Frozenfell Gill
(d) D.deflexus Elles & Wood. Jonah's Gill. (1905.3407)
(e) D.aff.nicholsoni Lapworth A55055 Frozenfell Gill
(f) associated with (e)
(g) T.?quadribrachiatus (Hall),quarry W of Setmurthy Church
(h) T.aff.amii Elles & Wood, quarry west of Setmurthy Church

Note: Scale of 5mm is indicated by two dots for each specimen.

Fig. 4 EARLY ARENIG GRAPTOLITES

5. ACKNOWLEDGEMENTS

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PRE-DEVENSIAN WEATHERED TILLS NEAR THRELKELD COMMON, KESWICK, CUMBRIA.

J. Boardman

SUMMARY

Four sites are described in the vicinity of Threlkeld Common near Keswick in Cumbria, which record a sequence of weathered till and glaci-fluvial beds overlain by sands, gravels and till which are unweathered. The stratigraphy, the pedogenesis, the climatic implications and the nature of the weathering suggest that it is Last Interglacial in age and that the tills themselves are most likely to be Wolstonian.

1. INTRODUCTION

The sites are located in the south eastern part of the Glenderamackin drainage basin east of Keswick (Fig. 1). Two south bank tributaries, Mosedale Beck and Thornsgill Beck, have cut through up to 30m of Quaternary sediments into Skiddaw Slate bedrock. The surface of the bedrock is extremely irregular and in Mosedale at least, the superficial deposits are probably infilling a buried valley. The topography of much of the area is that of a gently sloping till plain. To the north east of Highgateclose (358.255) poorly defined drumlins occur, while the area around Troutbeck Head (383.250) is characterised by ice-stagnation features and meltwater channels. Stone-banked solifluction lobes are found on Threlkeld Common. At the head of Mosedale is one of the Lake District's lowest corries fronted by a fine arcuate moraine. Pennington (1978) has shown that this site was occupied by ice in Younger Dryas time (circa 11,000-10,400 BP). Morphological and sedimentological evidence in Mosedale shows that the valley is substantially the result of erosion by high flow discharges almost certainly related to meltwater from the corrie glacier.

The Quaternary deposits exposed in these valleys are of great interest since Pre-Devensian glacigenic deposits are not known to exist in Cumbria or adjacent areas. The 'Early Scottish' till of the Solway lowlands is of unknown age. Till beneath organic beds in Low Furness has been described in the nineteenth century and may pre-date the last ice advance (Huddart et al.,1977).

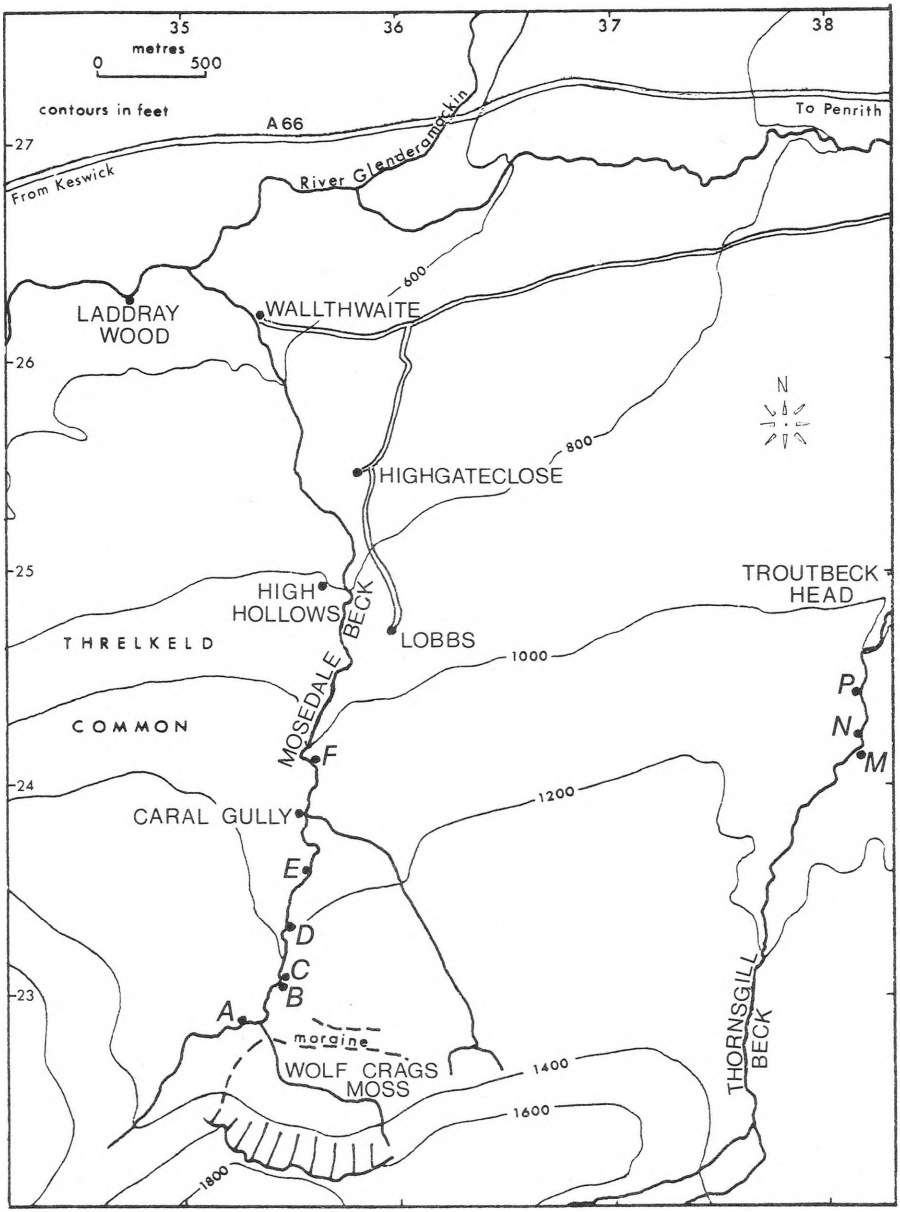


Fig.1 LOCATION OF SITES IN MOSEDALE AND THORNSGILL

The deposits have been recorded in the field, and then subjected to lithological, particle-size, macrofabric and micromorphological analysis including the study of thin sections. Scanning electron microscopy (S.E.M.) has been used to examine the surface textures of quartz grains. The sediments have been considered in the morphostratigraphical context of geomorphological mapping of the area between Keswick and Penrith.

2. STRATIGRAPHY

The stratigraphy is represented by four sites in the Mosedale-Thornsgill area and it should be noted that at these sites, with the exception of Caral Gully, the upper till appears to be thin or absent. This is due to the fact that the exposures do not reach the general level of the ground surface in the area and therefore the full sequence is not visible.

(i) Site D

At Site D (3550.2332) in Mosedale a stream cliff exposure shows a thin, basal unweathered till overlain by weathered beds (Fig. 2). These are sub-divided on a textural basis into brown

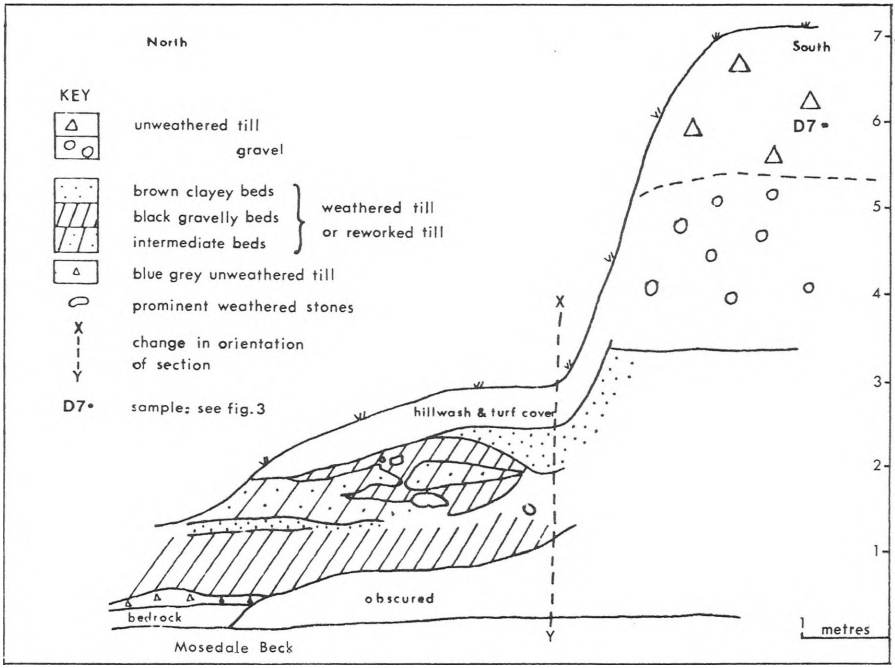


Fig. 2 MOSEDALE, SITE D: STRATIGRAPHY

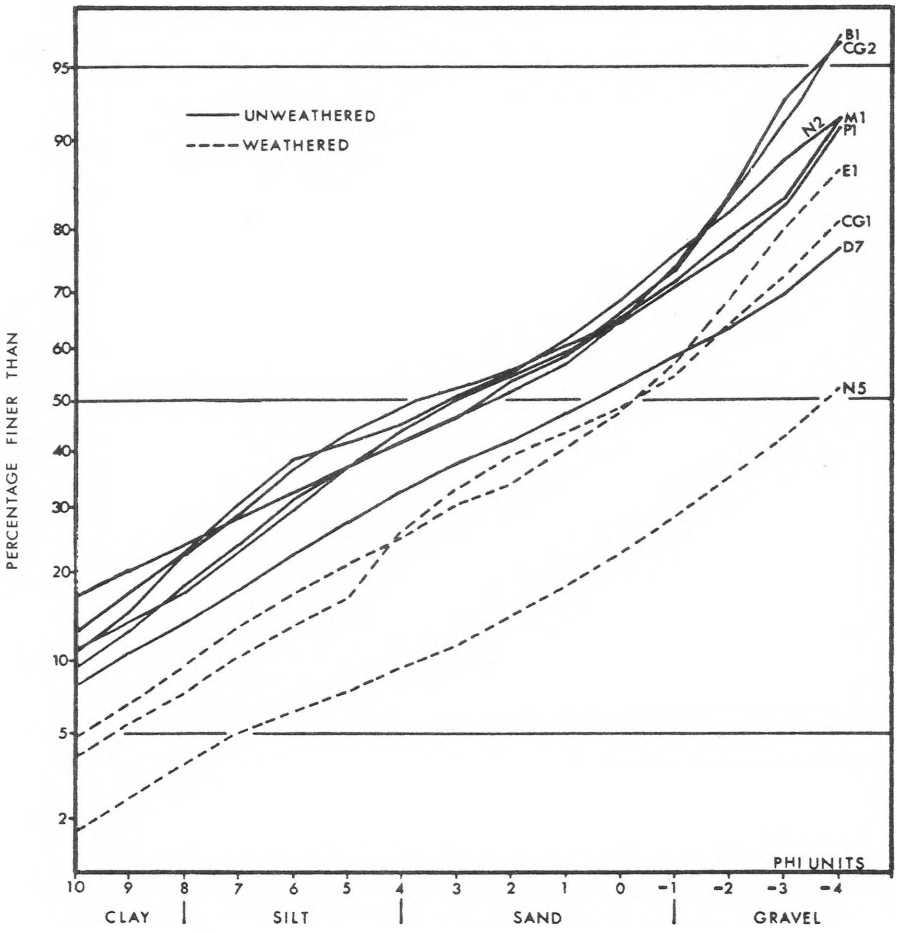


Fig. 3 PARTICLE SIZE DISTRIBUTION: TILL SAMPLES

clayey beds, black gravelly beds and those that are intermediate in character. The upper part of the section consists of unweathered gravel overlain by unweathered till.

The basal till rests on Skiddaw Slate but it is rich in pebbles from the Borrowdale Volcanics. The gravel above it has a black manganese-stained colour. The stones in this gravel break easily in the hand and their interiors are yellow throughout, e.g. 10 YR 6/6*. An apparent gradation in the texture and the severity

* Refers to Munsell Soil Colour Number. See Hodgson, 1974.

Table 1. PARTICLE SIZE DISTRIBUTION DATA: TILL SAMPLES

Sample No.	Site	gravel %	sand %	silt %	clay %	50% value phi units
UNWEATHERED TILL						
B1	B, Mosedale	26.38	23.45	27.51	22.66	+ 3.8
CG2	Caral Gully	25.75	32.72	24.26	17.27	+ 2.3
N2	N, Thornsgill	23.95	30.80	23.01	22.24	+ 3.0
M1	M, Thornsgill	27.93	30.09	17.61	24.37	+ 2.4
P1	P, Thornsgill	28.48	26.94	26.85	17.73	+ 2.5
D7	D, Mosedale	41.93	25.57	19.10	13.40	+ 0.4
Mean		29.07	28.26	23.06	19.61	+ 2.4
WEATHERED TILL						
E1	E, Mosedale	43.72	30.66	15.85	9.77	- 0.3
CG1	Caral Gully	44.75	29.05	18.48	7.72	- 0.3
N5	N, Thornsgill	71.73	18.80	5.72	3.75	- 3.8
Mean		53.40	26.17	13.35	7.08	- 1.5

of the weathering, from the basal till to the overlying gravel, suggests that the gravelly texture may result from loss of fines during weathering and that the weathered beds may therefore be part of a till sequence. However, the beds as a whole display a crude stratification which may not be solely the product of differential weathering but of redeposition as a series of discrete flows after originating as a till. Examination of the surface texture on quartz grains from the black gravel using the Scanning Electron Microscope (S.E.M.) reveals:-

(1) there are no obvious glacial breakage patterns and,

(2) most of the surfaces appear to be weathered, i.e. rough and flaking, similar to features described by other workers on grains subject to intense chemical weathering (Wilson, P., personal communication).

The weathering of this deposit is clearly post-depositional since material in this condition could not have been transported to this site.

These beds are truncated by a sharp erosional break which is associated with the deposition of fresh, structureless gravel. In

view of its position and character this is interpreted as pro-glacial outwash from the advancing ice-front which laid down the overlying till. The upper till thickness at this site may be of the order of 10m, though only 1.8m is exposed. At small exposures nearby the till is seen to reach the ground surface. In terms of particle size, samples from this bed are typical of the unweathered till in the area (D7 on Fig. 3 and in Table 1). These tills are characterized by a high silt and clay content and low quantities of gravel in comparison with the weathered till samples.

(ii) Site E

At Site E (3557.2356) weathered sands and gravels occupy a channel cut into underlying severely weathered till (Fig. 4). Coarse, unweathered gravel is seen at the top of the exposure. The weathered till is structureless and characterized by stones that have totally lost their original colour. Similar weathering effects are seen in the overlying sands and gravels in the channel. The stones are soft, their interiors are yellow and their exteriors stained black with manganese. The results of particle-size analysis of a sample from the till at site E are shown in Fig. 3 and Table 1.

(iii) Caral Gully

On the western side of the Mosedale valley and close to the junction with the Caral Beck tributary, a thick sequence of Quaternary deposits form precipitous slopes undercut by Mosedale Beck. Access is possible up a small gully referred to in Fig. 1 as Caral Gully (3556.2388). At the base of the section is 4m of yellowish-brown till containing clasts that have in almost all cases lost their natural colour and are relatively soft throughout (Fig. 5). Texturally, the till is gravel-rich and clay-deficient (CG1, Fig. 3), and is similar in its severely weathered condition to that at site E and at site N (see below). The junction between the weathered till and the overlying grey unweathered till is gradational. Lenses and patches of yellow till discolour the grey till as far as the top of the gully indicating that the most recent ice-advance across the area entrained and incorporated the underlying previously weathered glacial deposits in its basal load. The upper part of the section is dominated by glaci-fluvial deposits, though fresh grey till occurs near the top of the highest east-facing scarp of the valley side (sample CG2, Fig. 3). All these sediments are unweathered but contain some weathered particles that have clearly originated in the lower beds.

(iv) Site N

In Thornsgill at site N (3814.2427) 4.5m of sediments are exposed but at least 6m must overlie them (Fig. 6). It is reasonable to suppose that this includes an upper unweathered till

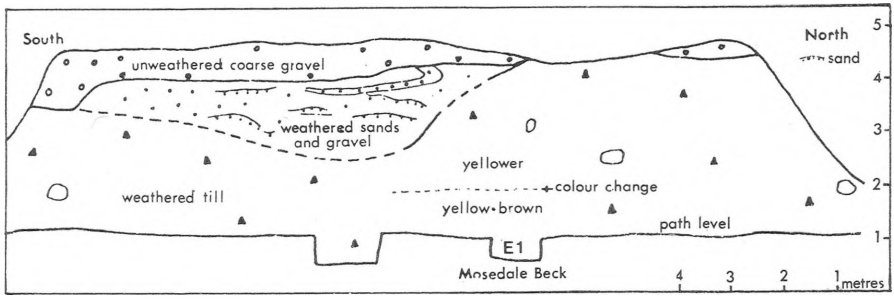


Fig. 4 MOSEDALE, SITE E: STRATIGRAPHY

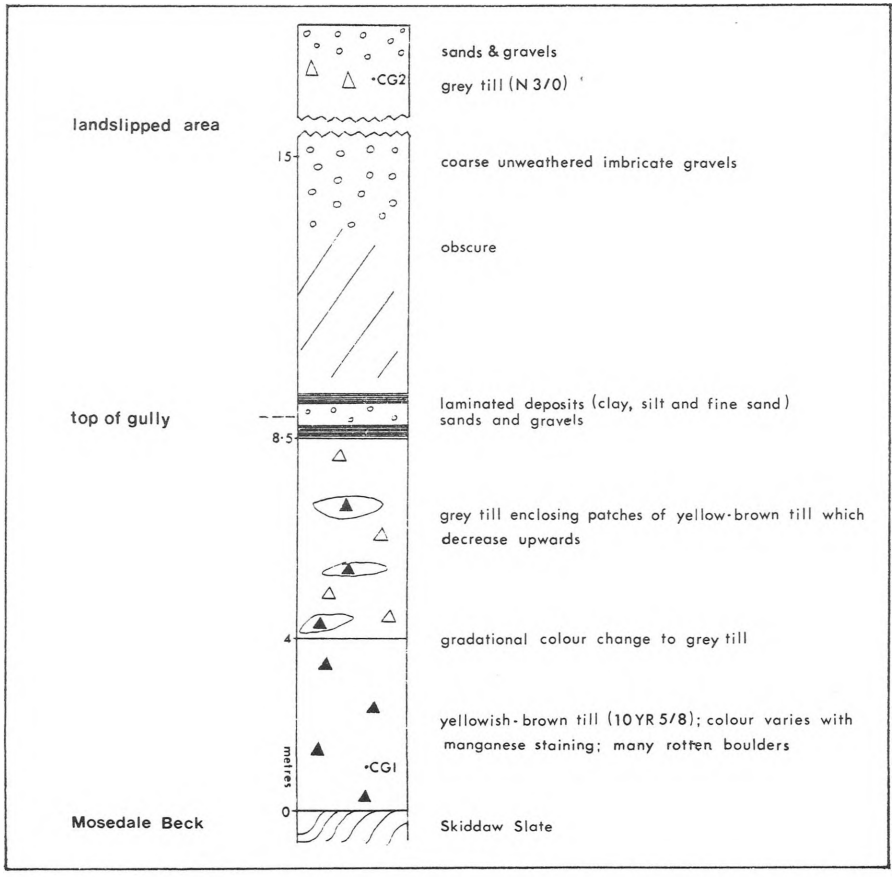


Fig. 5 CARAL GULLY: GENERALISED STRATIGRAPHY

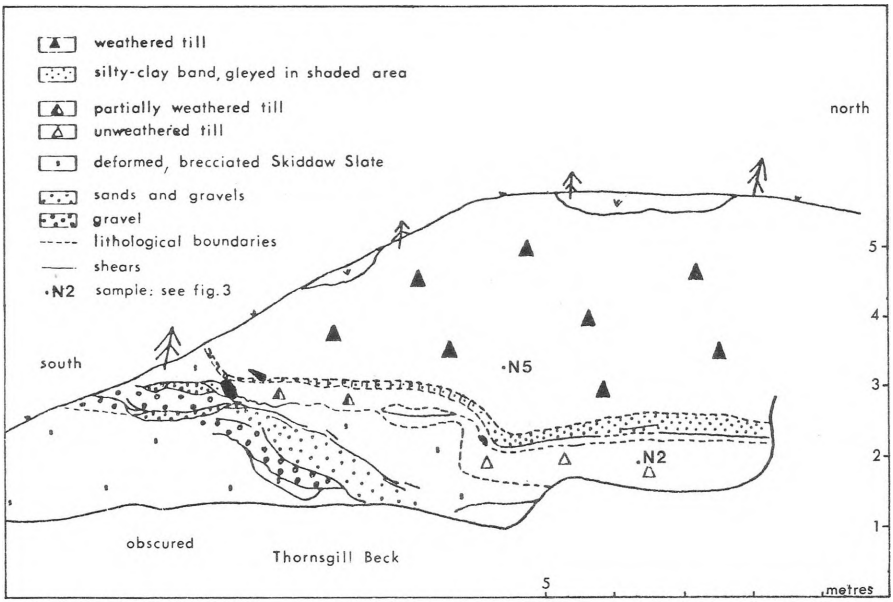


Fig. 6 THORNSGILL, SITE N: STRATIGRAPHY

since it is seen at adjacent sites P (3813.2442) and M (3816.2413). The section at site N consists of deformed Skiddaw Slates overlain by, and intermixed with, glaci-fluvial sands and gravels. Above these sediments is a weathered profile in till. The lower part of the section is complicated by glaci-tectonic structures involving deformed blocks of Skiddaw Slate bedrock and in some places this material is mixed with far-travelled till and takes on the character of deformation till (Dreimanis, 1976). Shearing of the beds is a prominent feature at this site; many boundaries between units being coincident with shear planes which are also clearly seen in thin-section. Deformation occurred as the till and the associated sands and gravels were being deposited.

In the till at site N a weathering profile is evident in the change from unweathered grey till upwards through a partially weathered zone into a severely weathered yellow-brown till similar to that at sites already described. The base of the severely weathered zone is characterized by a clay and silt-rich band possessing features typical of a gleyed, or cambic horizon (U.S.D.A., 1975). The dominant colour of the band is orange (7.5YR 6/8) but it contains many irregular mottles of low chroma e.g. 5Y 7/1. In thin section these can be seen to be iron-depleted areas (albans). Channels and hambers can also be seen and are often lined with manganese. They are assumed to be of

biological origin (Brewer, 1976) and in some cases are lined with clay or silty-clay oriented parallel to the void walls; clearly the result of deposition of translocated material. Gleying, translocation of clay and biological activity are characteristic of the B horizon of certain soils and this is therefore regarded as a palaeosol. Cambic horizons have only rarely been reported in palaeosols (Yaalon, 1971). The depth of this horizon below the original ground surface is not known nor have any traces of pedogenic features been observed in the overlying till.

3. SYNTHESIS

Table 2 presents a generalised sequence for the sites described and formation names have been added. Two deposits of contrasting character exist at Caral Gully and at site D. The lower deposit is part of a weathered sequence which includes till, sands and gravels. The till is deficient in silt and clay, it is yellow-brown in colour and it contains rotten stones. Lithologically it shows great variation between sites and macro-fabric studies show dispersed patterns statistically non-significant at

Table 2. GENERALISED QUATERNARY STRATIGRAPHY IN MOSEDALE AND THORNSGILL

Sediments and Palaeosol	Lithostratigraphy		Age
	Formation	Member	
gravels of Mosedale terraces - outwash	Wolf Crags	*Wolf Crags Till Wolf Crags Gravel	Late glacial Younger Dryas
till, sands and gravels, laminated deposits gravels - outwash	Threlkeld	Threlkeld Till Lobbs Glacifluvial Sands and Gravels Mosedale Gravels	Late Devensian
Palaeosol	Laddray Wood Palaeosol		Ipswichian (?)
till, sands and gravels, reworked till	Thornsgill	Thornsgill glacifluvial Sands and Gravels Thornsgill Till	Pre-Devensian: Wolstonian (?)
Skiddaw Slate			

* Not described in this paper

the > 95% level. S.E.M. analysis and thin-section studies confirm the severe weathering.

Profile development and pedogenic features within the weathered beds are seen at site N. At Laddray Wood (3475.2628) (Fig. 1) pedogenesis has affected a partially weathered lower till. The till is rubified and contains a weakly developed argillic horizon. Rubification is regarded as being indicative of humid, warm temperate conditions such as are not found in Britain today (Birkeland, 1974, Rose and Allen, 1977). Colouration of a redder hue than 5YR, such as occurs at this site on ferri-argillic channel linings, chambers and fissures, is due to haematite in the soil. This mineral is absent from soils formed recently under a humid temperate climate and is usually associated with warmer climatic regimes (Schwertmann and Taylor, 1977). Climatic inferences from the pedogenic features in the Laddray Wood palaeosol are in accord with the observed depth and severity of the weathering at the other sites in the area and with the conclusions from the S.E.M. analysis. It is clear that the weathering of these beds occurred in situ as soil profiles and friable stones could not be transported without disruption.

At site D and at Caral Gully the sequence is completed by unweathered glacigenic sediments which have not been described in detail in this account, but serve as a contrast to the underlying beds and as a valuable stratigraphic marker.

4. THE AGE OF THE DEPOSITS

The terrace gravels at site E represent the extremely coarse outwash from the Younger Dryas corrie glacier at Wolf Crags. Unweathered till and associated sands, gravels and laminated sediments are part of a widespread glacigenic sequence related to the Late Devensian glaciation of the area (Evans and Arthurton, 1973). The weathering of the underlying beds relates to a prolonged period, or periods, of warm, humid temperate conditions. It is suggested that the evidence available from these sites, particularly that relating to the development of soil profiles, indicates that the weathering could only have occurred during climatic conditions of an interglacial character. On stratigraphic grounds this is considered most likely to have been the Ipswichian interglacial. This implies, in terms of the currently accepted British stratigraphical sequence, that the basal weathered till is most likely to be Wolstonian (Mitchell et al., 1973). The deposits seem to have been preserved as a result of irregularities in the underlying bedrock. Deposits of comparable age or character have not previously been described from North West England though till of this age has been reported in Lincolnshire (Madgett & Catt, 1978) and palaeosols of comparable stratigraphic significance have been recorded only in East Anglia (Rose and Allen).

5. ACKNOWLEDGEMENTS

The author would like to acknowledge the advice and assistance received from a number of individuals. Dr.P.Bullock of the Soil Survey, Rothamsted, provided invaluable advice on micromorphological interpretation and Mr.C.Murphy prepared some excellent thin sections. These were funded by a grant from the Central Research Fund of London University. S.E.M. photomicrographs were kindly provided by Mr.P.Wilson of Salford University who also commented on the surface textures. The author would like to thank Mr.J.Rose of Birkbeck College for much help and encouragement. Mr.Rose suggested improvements to the draft of this article and supervised the research of which it formed a part. He also first pointed out the existence of weathered deposits in upper Mosedale.

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AUTHORS OF MAIN ARTICLES IN THIS ISSUE:

D.Leviston, B.A., C.Eng., M.I.Mech.E.,
[redacted]

D.E.Jackson, B.Sc., Ph.D., F.G.S.,
[redacted]

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

EXCURSION NOTES

VISIT TO THE REDBURN FLUORSPAR MINE IN WEARDALE

Leader: Mr.E.L.Day, A.R.S.M., C.Eng., M.I.M.M.

5th April, 1977

On 5th April, 1977, a party of twelve members of the Society visited the I.C.I. Redburn Fluorspar mine near Alston. This mine is situated some 10 miles east of Nenthead, close to the source of the River Wear, and lies in the Pennine Carboniferous Limestone.

The party was in the charge of Mr. Ted Day who introduced the members to Mr. Dennis Thomas, the mine manager. Mr. Thomas first gave an outline of the layout of the mine and described the separation processes. The fluorspar is produced mainly for the steel making industry where it is used as a flux to ensure ease of slag removal. It is also used for the manufacture of hydrofluoric acid and fluorocarbons which are used in spray dispersants.

The mine has several levels; access to the lowest is by a shaft, but the uppermost level is a horizontal drift with motorised trucks running approximately one mile into the hillside. The fluorspar deposits occur within a vertical fault in the limestone, the sides of which moved in opposite directions to produce 'necks' and 'pockets', and it is within the latter that the mineral is most abundant. Evidence of movement on the fault was indicated by a 10 foot square vertical face of calcite showing marked slickensiding. Both iron pyrites (FeS_2) and bornite (Cu_5FeS_4) are found in small amounts and traces of blue copper carbonate were observed on the calcite in the area. There is also a considerable deposit of limonite interspersed with shale at the entrance to the mine. Galena is scattered in small amounts throughout the fluorspar but no well-formed crystals of any size were discovered. Limestone fossils are not generally encountered but a small band was pointed out where corals could be seen. The fluorspar is mostly white in colour although a few green and yellow crystals were seen in the separation plant. No blue or purple fluorspar is found here although it was stated that these varieties had been found within half a mile in an older disused mine. Large sized crystals of fluorspar were not to be seen because the shot firing techniques used to win the ore tended to shatter the brittle crystals and, additionally, the associated quartz made the fluorspar friable.

The fluorspar deposits are discontinuous because of displacements of the vein from secondary faulting. Skill and perseverence on the part of the surveyors and miners has been necessary to pick

up the vein and this has resulted in ramifications and tortuosity of the access tunnels.

After excavation the ore is subjected to preliminary washing and grading. It is then broken up by a jaw crusher and passed through a ball mill. Separation of the various constituents is achieved by the flotation method involving the use of frothing agents and blowing compressed air through the slurry. In addition mechanical sorting methods are used involving vibrating inclined tables and elutriation with water. As a result of these processes separation of quartz, limestone, galena, pyrite and fluorspar is achieved. The final product is filtered, dried and supplied as a fine white powder. Effluents are treated by the flock method using alkaline ferrous sulphate in co-precipitation.

At the conclusion of a most interesting tour thanks were expressed to Mr. Thomas and his staff for acting as guides and providing so much information. Mr. Day was thanked for organising the event and I.C.I. for granting permission to visit the mine.

F.J.

THE CARBONIFEROUS LIMESTONES OF THE AREA AROUND CALDBECK AND ULDALE

Leader: Mr.E.H.Shackleton, F.G.S.

14th May, 1977

This excursion was held to study the limestones in the general area of Uldale and Caldbeck. About 20 members were guided round the exposures by the President, Mr.Edgar Shackleton, who has compiled the following notes which may serve to assist members visiting this area on their own:

Introduction

'Over the years the limestones of this area have been found to be more closely related to those of the Alston Block rather than to the West Cumberland limestones with which we are perhaps more familiar. The reason for this is that as we move towards the north and east the Series becomes more estuarine in nature. The tendency is for the limestone bands to become thinner while the intervening shales and sandstones assume more significance. Whilst the fauna is at least comparable, the fossil marker bands we are accustomed to are not so easily located. The following notes indicate the stratigraphic succession and the chief exposures. The principal fossils are also mentioned, but finding these is not so easy as it is in West Cumbria because most of the quarries have long been abandoned.

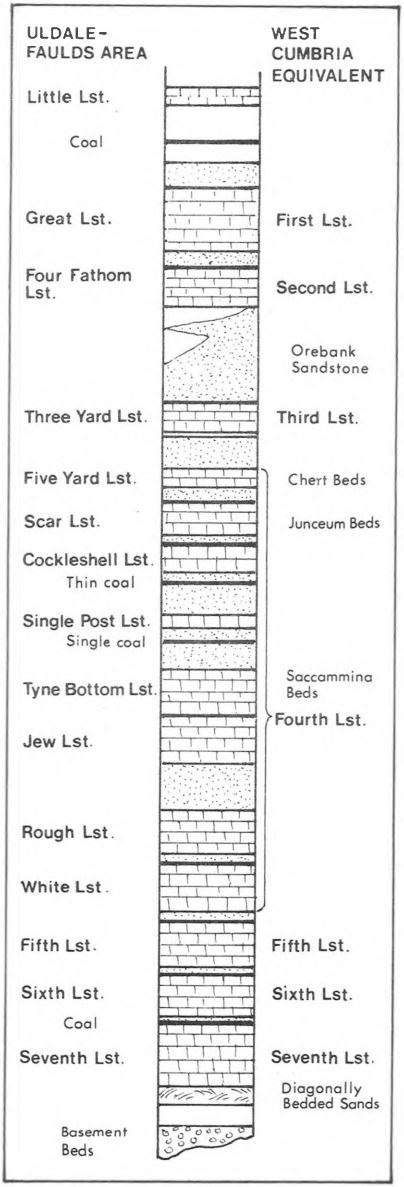


Fig.1 LIMESTONE SUCCESSION IN THE ULDALE AND FAULDS AREA WITH WEST CUMBRIA EQUIVALENTS.

In keeping with the transitional nature of the Uldale limestones the nomenclature used is partly that of West Cumbria and partly that of the Pennine area. Starting at the bottom we can work our way upwards through the succession.

The Seventh Limestone

The West Cumbrian name is retained and in the Uldale context this formation is on the average about 150 feet thick, although this varies considerably. Some three or four hundred yards ESE of the cross-roads in Uldale (2524.3689) there are small crag exposures and two old quarries. Here some 20 feet of dark blue-grey limestone overlie 10 feet of false-bedded sandstone corresponding to the 'diagonally bedded sands' of West Cumberland. The limestone includes highly crinoidal beds with abundant polyzoa, the 'Bryozoa Band' of Professor Garwood. The fauna also includes Syringopora, Fenestella and Hemitrypa, Actinoconchus, Camarotoechia, Productus garwoodi and Linoproductus. Mr. Charles Edmonds reported Lithostrotion martini, Linoproductus corrugato-hemisphericus and Punctospirifer. Although no longer exposed, the strata above the Seventh includes sandstones and shales and a 14 inch coal, once worked around Uldale.

Five hundred yards SW of Parkend (2976.3853) there is an exposure in the left bank of the stream. Here a fine-grained dark limestone and calcite mudstone are succeeded by the diagonally-bedded sands and shales and interbedded limestones of the Bryozoa Band.

Besides the fauna recorded from our first exposure we have Fenestella nodulosa, Linoproductus globosus with Punctospirifer redesdalensis.

The Fifth and Sixth Limestones

These two limestones have a combined thickness of about 270 feet in this area.

The Sixth Limestone is exposed in an old quarry 750 yards approximately east of the cross-roads at 2560.3700. Here some 27 feet of dark grey limestone is seen with bands and nodules of black chert marking the base. In a conveniently situated roadside quarry 350 yards NE of the site of Uldale church (2540.3720) similar beds can be seen again with the chert bands noticeable. The fossils are Syringopora sp., Lithostrotion junceum, L. pauciradiale and Megachonetes siblyi, Gigantoproductus maximus and Pugilis.

The Fifth Limestone is exposed in a quarry 250 yards N of Snowhill (2796.3879). Here corals are said to be abundant in the lower 20 feet of dark grey limestone including Chaetetes septosa, Lithostrotion junceum, Lithostrotion minus, L.portlocki, Lonsdaleia duplicata and Palaeosmilia murchisoni. The upper 10 to 12 feet of massive limestone has brachiopods including Davidsonina septosa and Delepinea comoides, and this looks suspiciously like the White Beds! A similar fauna is recorded from an old quarry 650 yards NNW of Baggra Yeat Farm at 2645.3720.

The White Limestone

This horizon is not too often exposed but can be seen in the stream some 350 yards NNW of Thistlebottom. Perhaps the best exposure in the area is 400 yards SSE of Paddigill (3029.3987). Here the succession is 10 feet of dark limestone with few fossils overlain by 8 feet of intermixed limestones and shales. In the shales Megachonetes siblyi is said to be abundant. The interbedded limestones have a most peculiar form. The upper 12 feet is pale grey to creamy and the contained fossils are: Lithostrotion maccoyanum, L.minus and Lonsdaleia floriformis floriformis. (This Lonsdaleia is not usually found as low down as the White Beds).

The Rough Beds

No exposure is known in the immediate area of Uldale.

The Jew Limestone and the Tynebottom Limestone

These two formations are usually taken together as they are only separated by a few feet of shale and even this is not always present. There are good exposures close at hand:

1. A roadside quarry on Green How (2576.3734) some 800 yards E by 25°N of the Church site at Uldale. The succession is:

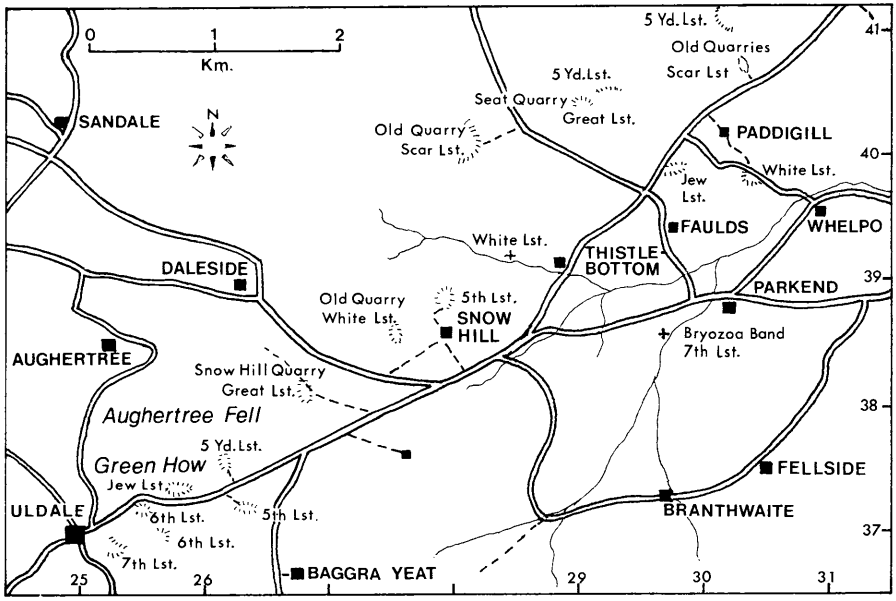


Fig.2 MAP OF LOCALITIES

(4) Dark grey limestone 3 feet
(3) Lithostrotion band 6 inches
(2) Well bedded and rather splintery limestone 18 feet
(1) Grey-white limestone with reddish spots 6 feet

The fossils in these beds are as follows:

(4) Caninia juddi
(3) Lithostrotion phillipsi and Saccammina
(2) Saccammina is fairly common with corals Aulophyllum, Dibunophyllum and Nemistium
(1) Lonsdaleia floriformis and Gigantella crassus with G. latissimus

2. A quarry 500 yards N of Faulds (2978.3992). Here in addition to the fauna already noted we have Lithostrotion junceum, L.portlocki, Palaeosmilia murchisoni, Gigantoproductus edelburgensis and Pugilis pugilis.

The Single Post Limestone

There are few exposures but the Single Post can be seen in small crags 400 yards NE of Paddigill. Here the limestone is pale or creamy in colour and is pseudo-brecciated. There is little mention in the literature of the fauna, but a thin coal seam associated with the limestone has been worked in several places. Some of the small hollows, often thought to be swallow holes, are in fact old excavations for coal.

The Great Scar Limestone

This is the limestone which is the chief object of our excursion and it is thought to be roughly the equivalent of our Junceum Beds. Exposed in a line of quarries 500 to 900 yards NNE of Paddigill (304.409), some of which also expose the overlying Five Yard Limestone, the succession is as follows:

(4)	Dark grey, thin bedded limestone with thin shale partings	12 feet
(3)	Massive grey limestones with seven foot posts	14 feet
(2)	A calcareous shale	9 inches
(1)	A dark grey bed of limestone	2 feet

The fossils are reported to be numerous with Bed 2 containing many Aulophyllums. Bed 3 has scattered Saccammina and Lithostrotion junceum whilst the top beds have numerous Zaphrentids including Z.delanoui and Z.delanoui disjunctis.

The Five Yard Limestone

Apart from the quarries mentioned above there is one on Aughertree Fell (2617.3761) exposing the Five Yard Limestone where the succession is:

(3)	Limestone	1 foot
(2)	Highly fossiliferous dark shale	10 feet
(1)	A bed of limestone underlain by a hard grey-white siliceous sandstone. Although the thickness of this bed varies it averages about 3 feet and helps to identify the other beds.	

The fossils recorded here are: Fenestellas, Fasciculophyllum, Heterophyllia, Lithostrotion junceum, Productus scoticus, P.redesdalensis, Rhipidomella michelini, Spirifers and Pectens and the trilobite Weberides.

Above the Five Yard Limestone there are shales succeeded by the Three Yard Limestone which is the equivalent of the Third Limestone of West Cumbria. This is overlain by a variable series of sandstones and shales the equivalent of the Orebank Sandstone. The Four Fathom is the equivalent of the Second Limestone and the Great Limestone the equivalent of the First. This limestone is exposed in quarries in the vicinity of Parkhead where such type fossils as Lonsdaleia floriformis laticlavia and Aulophyllum fungites pachyendothecum are recorded.'

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A FIELD WEEK IN THE ISLE OF ARRAN

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

4th - 12th June, 1977

INTRODUCTION

Five members of the Society under the leadership of Mr. Tom Shipp and accompanied by a tutor and five students from St. Annes College of Further Education, spent a week on Arran based at Corrie on the north east coast.

Daily excursions were organised to examine aspects of geological interest on the island, notably its stratigraphy and the variety of its igneous forms. The evening sessions, illustrated by slides, specimens and petrological microscopy provided a background for the following day's work.

GENERAL DESCRIPTION (See Fig.1)

The sedimentary succession on the island extends from the Upper Cambrian to the Quaternary, but Silurian deposits are not in evidence. The Highland Boundary Fault terminates in the form of an arc to leave Dalradian Schists followed by Old Red Sandstone around the margin of the northern granite region. Permian New Red Sandstone is exposed extensively further south and the downward sequence from this, through Carboniferous Limestone to the Old Red Sandstone can be followed along the north west shoreline. The rock sequence of the northern area is disturbed, however, because of the uplift of the granite and the occurrence of igneous metamorphism.

Extensive volcanic activity occurred during the Tertiary period resulting in three main events:

(i) A domed upthrust of granite in the north which has been intruded into the older rocks. These have in turn been largely removed by subsequent erosion, including glaciation, to leave a mountainous region of exposed granite surrounded by semicircular rings of schists and Old Red Sandstone.

(ii) A central ring complex caused by the collapse of a volcanic caldera, which left various types of igneous material and also retained remnants of Rhaetic, Jurassic and Cretaceous rocks.

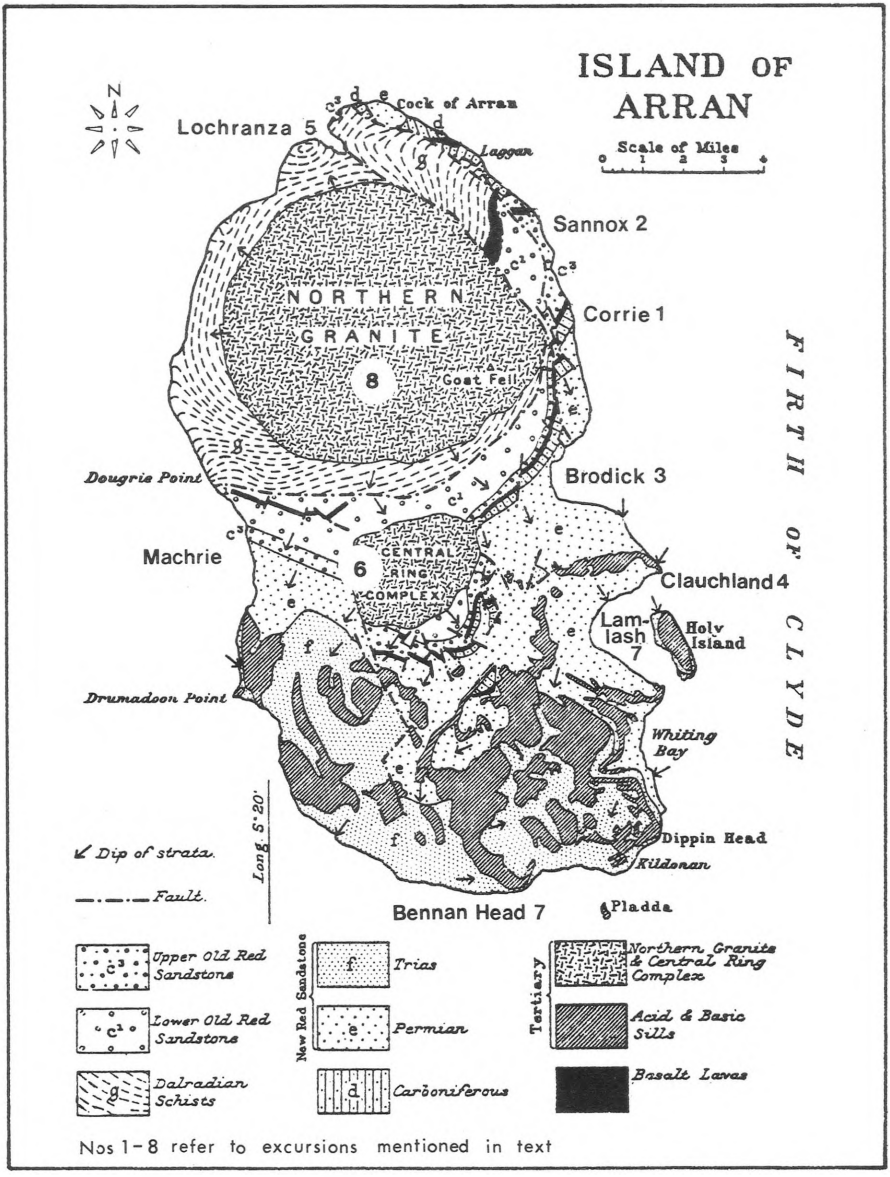


Fig.1 MAP OF LOCALITIES
(Based on Crown Copyright Institute of Geological Sciences diagram reproduced by permission of the Controller of HMSO)

(iii) An area centred on Lamlash Bay to the south-east where a submerged eruption occurred and produced the encircling sills of igneous rock including Holy Island.

Dyke intrusions and sills are to be found in profusion, particularly along the southern shores of the island.

Finally the residual effects of glaciation are to be seen in the 'U' shaped valleys of Glen Rosa and Glen Sannox. Also to be seen are the raised beaches which surround Arran resulting from depression under the weight of the ice cap and the subsequent recovery of the land mass when the ice melted. Extensive glacial deposits to the south west and numerous erratics provide additional evidence of this period.

THE EXCURSIONS

1. Corrie Shore

A Permo-Carboniferous sequence from south to north. The dune-bedded Permian red sandstones and breccias, cut by basaltic dykes, extend northwards from Brodick to an area south of the Corrie Hotel. Here the last division of the cross-bedded sandstone, as exemplified at a local quarry, gives way to the pebbly base of the Permian, and the junction with the white-yellow sandstone of the Carboniferous period is a region of unconformity. Despite the absence of actual coal seams the next succession of strata is placed in the productive Coal Measures as it consists of alternating bands of fireclays and shales which lie above undoubted Carboniferous Limestone horizons. Pink sandstone and shale of the Lower Carboniferous follow until a thick band of true limestone is reached. This was examined at a nearby quarry and found to contain Productus giganteus. The Calciferous Sandstone follows with intersections of olivine dolerite dykes and then a succession of basaltic lava flows showing spheroidal weathering are seen to be resting on volcanic agglomerates. These agglomerates contain large, rough quartz fragments as distinct from the rounded pebbles of the conglomerates seen further north.

The base of the Carboniferous series terminates at the 'Corn-stones, this being a layer of argillaceous sandy limestone. Calciferous Sandstone follows and eventually layers of conglomerate. Northwards the conglomerate merges with the Upper Old Red Sandstone which is flood plain material with a dip of 30° to the south east. A large erratic granite boulder, 'Clach a'Chait', lying on the Old Red Sandstone provides evidence of the glaciers which covered the land, as also does the continuous 25 foot raised beach.

2. Sannox and its environment

This excursion commenced at the old burial ground in Sannox. The sequence was a continuation of that already described. The

Upper Old Red Sandstone meets a purple transition stage of the Lower Old Red Sandstone and is interleaved with bands of calcareous red mudstone. Barytes deposits occur on both sides of the stream and well-formed crystals were obtained at the mine.

An excellent example of massive conglomerate was seen in Glen Sannox in the bed of the stream, with 6" pink quartzite pebbles closely compacted in very little matrix. The conglomerates continue upstream and up the hillside until they meet the schistose grits in the vicinity of the Highland Boundary Fault. North eastwards a clearly defined boundary between the granite and the thermally metamorphosed gritty schist was located in North Glen Sannox, while lower down Dalradian Schists in the bed of the stream meet Ordovician (Arenig) lavas with well-developed pillow formation, which were evidently extruded below water.

The majority of the gritty schists in this area have been baked and indurated by the close proximity of the granite, but where they are unaffected graded bedding was seen, which indicates that the more recent deposits are to the east.

3. Brodick and its environment

South of Brodick on the shore are large beds of breccias containing both angular and rounded fragments of quartzite and schist, set in dune-bedded New Red Sandstone of Permian age and inclined at about 15° to the south. These are thought to have accumulated during torrential rain storms in a desert climate.

A small area several metres across was investigated in which large blocks of Permian rocks showed evidence of violent disruption. This may have been caused by explosive out-gassing during a Tertiary volcanic episode. In the School House yard a dark green, glassy, pitchstone sill was examined which had been intruded parallel to the bedding plane of the Permian sandstone. At the footbridge in Glen Rosa, a composite sill of basalt and felsite was studied and the junction of the Carboniferous and Permian rocks at the road bridge nearby made this an interesting location. Large alluvial deposits cover much of the bedrock in this area, but Old Red Sandstone is exposed in a quarry at the entrance to the Glen.

Glen Rosa is a 'U' shaped valley with a level floor of alluvial deposits. The stream passes through coarse Old Red Sandstone past an intrusion of altered dolerite and eventually reaches a region where gritty schists are in contact with the sandstone. Eventually below the junction of the Garbh Allt and Rosa Water the schist meets the granite and has been altered to hornfels due to the heating effect during the granite upthrust. The effect of the chilling of the granite can be seen in the change from medium sized crystals at the boundary to coarse ones beyond. The ascent of

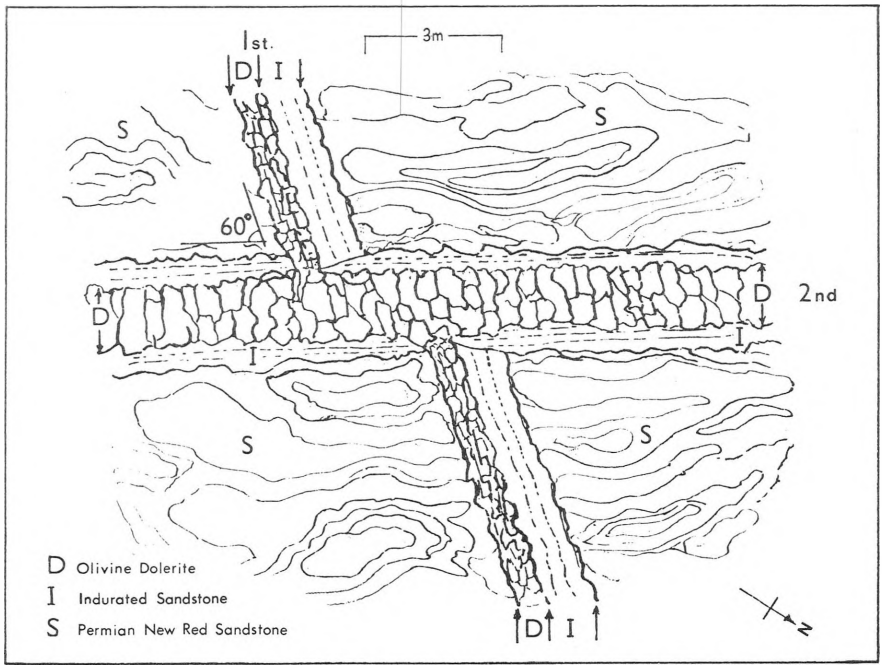


Fig. 2 INTERSECTING DYKES NEAR CORRYGILLS BURN.

Garbh Allt was made alongside the large granite slabs, smoothed by the numerous waterfalls. At the summit gritty schists and Lower Old Red Sandstone occur in succession to terminate as conglomerates which drop into Glen Shurig where there is a large felsite dyke. This excursion was particularly interesting because of the severe heating effects on adjacent rocks.

4. South Corrygills and the Clauchland Dykes

The 25 foot raised beach continues along this shore and dune-bedded 'millet-seed' sandstone of Permian age extends southwards from Brodick, with occasional interruption by dykes.

The majority of the dykes are parallel to each other in a north to north easterly direction. However, two of the dykes intersect at a point 45m south-east of the mouth of Corrygills Burn and these were studied in detail (see fig.2 above).

Both dykes are composed on olivine-dolerite. Dyke material in both cases has been eroded away to leave hard-baked pale yellow sandstone ridges 1m high along their outer margins. The narrow dyke 0.3m wide had been intruded first and the later dyke 1m wide,

crossing it at an angle of 60°, had displaced it over a distance of 3m. This was most evident when looking at the parallel sides of the former dyke. Dykes in this neighbourhood have eroded away to leave the indurated marginal sandstone up to 2m in height, and, being more resistant to the marine conditions they are a feature of this coastal region. Probably the best example of a dyke is the 'Mile Dyke' up to 10m wide and 1500m long made of olivine dolerite running in a straight line from south east to north west.

The high cliffs consist of bedded sandstone through which a 6m thick intrusion of felsite, consisting of a pale yellow quartz porphyry, extends to the beach. Half way up the cliff the dark green pitchstone sill was examined and its 6m thick intrusion into the sandstone noted. Further up the cliff the Clauchlands Sill was examined. This rock was intruded from a magma which filled in gaps following the collapse of the volcanic region around Lamlash, and is composed of Crinanite (a coarse analcite-olivine-diorite). The descent to South Corrygills from Dun Dubh passed through intrusions of quartz porphyry and at the car park the micro-structure of the spherulitic felsite was examined.

5. Loch Ranza and Newton Shore

The Dalradian schists predominate along the South Newton shore and show a dip to the south, but on progressing eastwards they reach the cross axis of the synform and dip to the north when they reach Loch Ranza. A further change in direction was seen to the south east once the Catacol synform was crossed and the foldings of the strata are typical text book illustrations.

The main object of this excursion was to examine the well known 'Hutton's Unconformity' north east of Newton Point. Here the Dalradian schists dip to the south east at an angle of 45° and are covered unconformably by upper Old Red Calciferous Sandstone, a type of Cornstone, which dips to the north west at an angle of 30°.

6. Ard Bheinn and the Central Ring Complex

Ard Bheinn is one of the centres which retain the remnants of a volcanic caldera, containing blocks of rocks which range from sedimentary to basic lavas and pyroclastic rocks, all of which appear to have subsided some 1000m. Erosion removed the overlying volcanic pile but has not yet reached the top of the magma chamber. The various types of rocks are scattered over a wide area and a large scale map is required to locate each and every type. Many were located, however, during a circular route to the south from String Road junction to Machrie returning via the summit of Ard Bheinn and Binnein na h-Uaimh.

Commencing with the granite at Allt nan Dris the ascent alongside a stream led to red Keuper marls and Rhaetic black shale bands where some doubtful evidence was found of fossil plant remains. The route lay upwards through vent agglomerate outcrops of mixed Old Red Sandstone and schist onto a long layer of basalt. Further east the basalt gave way to Craignurite (an intermediate acid rock) and felsite. A Liassic pale brown shale containing minute fossils was located by a diversion to Ballymichael Glen. A wide variety of lavas were examined on the way to the summit and added considerably to the knowledge of the party. These were as follows:

> Granite porphyry, andesite, mixed breccias, gabbro, blocky lava, amygdaloid lava, dacite, volcanic agglomerates and, most interesting of all, an exposure of a typical ropy lava which had been overturned during flow.

The view from the summit of Ard Bheinn extended from the Mull of Kintyre and Northern Ireland to the volcanic plug of Ailsa Craig south of Arran. The east side of the summit is mainly andesitic but towards Binnein na h-Uaimh basaltic breccias are found followed by agglomerates containing felsite. Massive formations of basalt were noted on the way up, whilst on the summit plagioclase-porphyry, felsite and sedimentary agglomerates were found, all of which serves to illustrate the complex volcanic lithology of the area.

During the descent a visit was made to the 'Pigeon Cave' where the original Cretaceous chalk has been metamorphosed into porcellaneous chalk or crystalline limestone below a layer of basalt. Finally at Creag Mhor the agglomerate-granite boundary was encountered once more.

7. Southern Tour of the Island

Magmatic Rolls. A quarry near to Brodick on the String Road was visited where an 8m band of felsite is intruded into sandstone. Close inspection of the felsite revealed margins of a spherulitic hornstone followed by pitchstone and the former contained small cylindrical spirals of a different nature which had been produced by the rolling of the magma during the felsite intrusion.

Lamlash Cone Sheet Complex Visits were paid to Lamlash and Kingscross Point to view the surrounding region of the submerged volcanic eruption that had been centred on Lamlash Bay. The circular range of sills were obvious and Holy Island with its trachyte southern sill completed the evidence.

Southern Dyke Swarm. A fine view of the dyke swarm was obtained at low tide east of Bennan Head and although their general trend is towards the south a number of transverse dykes intersect in different directions. (Plate 1.)



Plate 1. DYKE SWARM EAST OF BENNAN HEAD.
(Photograph by Mrs.P.R.Wallace)

8. The Northern Granite

A full day was spent on the coarse granite of the north Arran mountains. The granite consists of quartz, orthoclase feldspar, biotite and black mica which together gives a sparkling grey-yellow appearance. Evidence of the severe weathering and splitting of the granite blocks was seen throughout the climb. The route from Glen Sannox led over the Cioch na h-Oighe ridge alongside a steep drop eastwards to the Punch Bowl (a glaciated corrie) and continued across pinnacles and slabs via North Goatfell to the peak of Goatfell itself at 2866 feet. The view included the Witches Step where a narrow gap has been eroded at a dyke. Good views were obtained of the saddle between Glen Rosa and Glen Sannox indicating the separation of the two icefields at the end of the ice age. The view of the Kyles of Bute and the Ayrshire coast tended to support the theory of a tectonic rift between the island and the mainland.

CONCLUSION

For the members who took part, this venture of the Cumberland Geological Society has added to their knowledge of volcanic activity and its effects beyond that gained from local studies of the Borrowdale Volcanic Series. They gained additional insights into the various types of igneous rocks, their structural relationships and associated metamorphism.

Thanks and appreciation are expressed to Mr.T.Shipp for a well planned programme of excursions and lectures and to Miss D.Slater, the Excursion Secretary, for the organisation of the excellent accommodation at Corrie.

F. Jones

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EXCURSION TO THE ARMBOTH DYKE, ARMBOTH FELL, THIRLMERE

Leader: Mr.M.F.Burton

Saturday 17th September, 1977

Members of the Society met at the car park at the foot of Fisher Gill, Thirlmere (306.171), where the leader gave a brief description of the dyke and its exposed sections in the fells above the road. He also referred to J.Clifton Ward's six inch geological map of the area which was published in 1876. Mr.Burton explained that the dyke rock is a quartz-porphyry of characteristic

and attractive appearance. For details of the petrology and the distribution of erratics from the dyke the reader is referred to the previous excursion notes in Vol. 2, Part 4 of these Proceedings.

The party proceeded to take the Watendlath track via Middlesteads Gill to a point where the path crosses a prominent exposure of the dyke at about 1000 ft. O.D. (302.171). This exposure lies in a NW-SE direction on the steep hillside in line with the general trend of the intrusion, and mainly consists on the surface of a mass of loose rocks, many of which show heavy weathering. This characteristic weathering of the dyke rock is well seen in the material used for building cairns at this place; the quartz phenocrysts have disappeared leaving the rock full of holes. The loose material mentioned above and the lack of apparent contact with Borrowdale Volcanic country rock, give the dyke at this locality an exaggerated apparent width of around 50 - 60 feet. A measurement taken later on the higher ground towards Fisher Crag gave a result of about 30 feet which is probably more reliable and matches the information given in Ward's Memoir.

On the Society's previous excursion to the Armboth Dyke in June, 1969, the leader took the party to the south of Fisher Gill to investigate the exposures in the direction of Fisher Crag. However, on the present occasion it was decided to attempt to trace the dyke along its entire course except for sections inside the forestry fence which would have presented difficulties of access. The total distance over which the dyke is exposed is rather more than one mile, but the party walked a great deal further than this owing to the results of faulting and the nature of the terrain.

From Fisher Gill the dyke was followed over hummocky ground towards Middlesteads Gill where a small displacement occasioned by faulting was noted. The incidence of wrench faulting along the dyke gave rise to a discussion concerning the movement of the country rock. The General Secretary commented that they were 'dextral' wrench faults and the leader was inclined to agree with him. In the vicinity of Middlesteads Gill the dyke was displaced laterally about 800 ft. by faulting and was rediscovered immediately above the forestry fence north of the Gill. From there its exposed sections were followed over higher ground to its apparent termination on a hill top towards the head of Shoulthwaite Gill (294.174). A degree of contact metamorphism giving a reddish hue to flow-banded lavas contiguous to the dyke in this area was observed.

After lunch the party retraced their steps back to Fisher Gill along the line of the intrusion. At the Gill they discovered that the dyke was displaced 1200 ft. to the west where it reappeared on

the south side of the stream as exposed rocks on a small knoll (297.164). Fisher Gill apparently occupies this fault plane. From here flattish boggy ground had to be crossed to a pronounced scarp leading to higher ground where the dyke again reappeared. At the foot of the scarp large angular boulders presented good specimens of the rock showing a pinkish felsitic matrix. In some places the matrix appeared to be grey, but X-ray powder diffraction tests made on various specimens collected on the previous excursion suggested uniformity of composition throughout the intrusion. Although phenocrysts of quartz were fairly evenly concentrated in the rock, in contrast, a few specimens showed a greater profusion of red orthoclase phenocrysts. South of the aforementioned scarp the country rocks lie horizontally for a considerable distance and the task of locating the dyke within them was made much easier.

The Armboth Dyke has been described as being garnetiferous in places but the only garnet discovered on this brief visit was found by the Excursion Secretary in this locality. It was of the usual iron-rich variety associated with the rocks of this part of the world and under the lens was found to be euhedral.

A further area of boggy ground was circumvented before the dyke was finally discovered as a small cliff with loose debris immediately above the forestry fence below Fisher Crag at 1250 - 1300 ft. O.D. (305.160). Here some of the party collected further specimens including one exhibiting very pale green crystals in the sunlight - probably orthoclase, before returning to the road via a track through the Fisher Crag Plantation.

J.Clifton Ward's map of the Armboth Dyke shows nine localised faults trending NE - SW causing minor displacements. The exceptions are a single fault at each extremity of the exposure which trend NNW - SSE. The northernmost of these is not apparently within range of the observable dyke and the southernmost finally faults the dyke out in the Fisher Crag Plantation.

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WEEKEND EXCURSION TO THE SETTLE - SKIPTON AREA

Leaders: Mr.R.S.Arthurton and Dr.E.W.Johnson

A weekend meeting of the Society was held in the Settle - Skipton area of North Yorkshire on 20th - 21st May, 1978. The excursion was led by Mr.R.S.Arthurton, assisted by Dr.E.W.Johnson, both of the Institute of Geological Sciences and members of a group of four geologists working in the area.

Saturday 20th May, 1978.

The party assembled at 9 a.m. in the car park at Settle and after depositing some of the transport at Scaleber (836.630) reassembled at Malham (900.628). There Mr. Arthurton set the scene for the first day's excursion, differentiating between the shelf sediments of Dinantian and Namurian age to the north of Malham, and the corresponding basin sediments, accumulated in relatively deep water, to the south. Reef limestone forms a transitional facies between shelf and basin. The reef belt lies just to the south of the Middle Craven Fault, an important fracture with a long tectonic history including episodes of movement during Dinantian and early Namurian times. These events are recorded along the reef belt by unconformities.

From the car park the party proceeded to Malham Cove, pausing to note the line of the Middle Craven Fault where it intersected the footpath at Grid Ref. 896.636. At the base of Malham Cove the lowest limestones of the exposed Dinantian sequence were seen in small exposures west of the stream (897.640). These limestones were dark grey, conspicuously darker than the Asbian limestones forming the main part of the section above, and they are mappable as a separate formation. The overlying limestone, which forms the principal cliff feature of the Cove is pale grey and massive, and notable for its virtual absence of bedding planes. The highest limestones above the main cliff were similarly pale grey in colour, but included well-marked bedding planes and gave rise to the characteristic shelf and scar topography which extends northwards from the Cove. The pale limestones and their contrasting morphological expressions were examined from the steep track up the west side of the Cove.

At the top the party welcomed a pause to view the scenery. Looking to the south back across the Middle Craven Fault, the reef limestone at the top of Cawden was pointed out by the leader who

also drew attention to the northward facies change from reef to bedded shelf limestones seen dipping to the north at about 20°. The next stop was made at Grid. Ref. 880.639 WNW of Pikedaw to examine NNW-trending ribs of a spongy looking rock. The pale grey limestone had been largely replaced by silica and dolomite and it was suggested that this process may have been related to the mineralization seen nearby at the abandoned Calamine Mine (875.640). At the mine itself, the party searched the dressing floor and spoil heaps and recovered small specimens of azurite, malachite, galena, sphalerite, barytes and calamine (Zinc Carbonate).

From the mine the party moved south west to examine a series of potholes (873.638) which lie just north of the Middle Craven Fault along the northern edge of Kirkby Fell. In these pots, a major unconformity is well displayed, with Bowland Shales of E_{1b} age (Namurian) directly overlying tilted Yoredale limestones (Brigantian). The limestones included oncolites and probably form part of the Girvanella Band near the base of the Yoredale sequence.

Lunch was taken (869.639) at the head of Stockdale, from where a superb view was obtained of the ground to be covered during the afternoon. Rye Loaf Hill formed a conspicuous feature to the south west - an outlier of the Grassington Grit just south of the Middle Craven Fault. After lunch the party left the track to contour round the hillside into a dry valley dissecting Great Scar (865.643). Here the mainly dark grey limestones of the Yoredale sequence form terraces on the hillside. The Girvanella Band was crossed at Grid Ref. 868.639. Hereabouts the Band is about 10m thick - much more than the regional average. It is a particularly useful marker horizon, persisting into the Alston Block and north westwards into West Cumbria.

A small quarry in the Hardraw Limestone was seen at Grid Ref. 863.643. Here members of the party examined silicified brachiopods and bryozoa. From the top of the quarry Dr. Johnson pointed out features of special interest in the fine view to the north. These included Black Hill (865.662), which lies immediately south of the North Craven Fault and is believed to be capped by Grassington Grit. The outliers of Grassington Grit equivalent on Fountains Fell and Pen-y-Ghent, north of the North Craven Fault were also seen. The Hardraw Limestone was seen again in a cliff section (659.645) to the west, where excellent silicified specimens of Lithostrotion martini, L. junceum and other colonial corals were examined in the dark cherty limestones. Capping these cherty limestones was a local 6m bank of coarse crinoid debris.

After careful examination of this interesting locality, the group descended Great Scar to examine rocks on the south side of Stockdale Beck, the upper reaches of which closely follow the line

of the Middle Craven Fault. In the beck (862.637), the fault is marked by a prominent vein of quartz, with Bowland Shales resting unconformably on Yoredale limestones thrown down to the south against pale limestones of Asbian age.

Most of the party opted for a final climb up High South Bank, on which Yoredale limestones dip north at about 25°. The underlying pale Asbian limestones crop out on the upper part of the hill. In a sinkhole (859.630) just over the top of the bank the Bowland Shales were seen again, abutting in sedimentary contact against a south-facing scarp of pale limestones, here showing reef facies. This unconformity was comparable to that seen earlier in the day north of Kirkby Fell. From this locality Mr. Arthurton demonstrated the continued effects of the tectonic instability of the reef belt in late Dinantian-early Namurian times. If the Grassington Grit (Pendleian) of nearby Rye Loaf Hill was projected westwards across High South Bank, barely thirty metres of strata, including the Bowland Shales and the Pendle Grit Group (Brigantian-Pendleian), would separate it from the pale Asbian limestones at the summit of the Bank - only a fraction of these sequences to north or south.

The walk back to Scaleber was made via Stockdale Farm. On the way the reef of High Hill was noted, another component of the dissected zone of reef facies extending westwards as well as eastwards from Malham. A tired but cheerful party returned to the cars at Scaleber, having enjoyed stimulating and varied geology on a warm hazy day.

Sunday 21st May, 1978.

The party reassembled at 9.30 and took the cars to a suitable parking place near Flasby Hall (941.559). A pleasant walk beside Flasby Beck brought the party to the Hall itself (946.564) which lies approximately at the base of the Bowland Shales. During the late Dinantian and early Namurian this area was one of relatively deep water, basin sedimentation, and there is no evidence of a non-sequence between the Bowland Shale Group (Brigantian-Pendleian) and the underlying Worston Shale Group (Arundian-Asbian). A fine view to the south from the Hall showed the geomorphological expression of the Bowland Shales, the Pendle Grit Group and the Grassington Grit, the first two divisions totalling several hundred metres of strata in marked contrast to the thin sequence seen the previous day at High South Bank.

The party then continued upstream to Flasby and in a farm track cutting (949.565) examined fissile and partly calcareous mudstones near the base of the Bowland Shales. The mudstones yielded a goniatite-bivalve fauna, including Posidonia becheri suggesting a P_{1b} age. Further south east Mr. Arthurton demonstrated the sequence in the upper part of the Bowland Shales

in Rom Side Beck (956.562 - 958.562). In contrast to the lower shales, these are non-calcareous and unfossiliferous, and iron-stone nodules feature at intervals. A lenticular sandstone bed was noted, probably of turbidite origin, and upwards through the sequence micaceous and sandy laminae become increasingly common. The onset of thin beds of sandstone (958.562) mark the base of the Pendle Grit Group. Debris from a small quarry just upstream from this locality comprised fine sandstones, commonly micaceous, with ripple marks, groove-casts, and load-casts. These also include mudstone flakes and plant fragments.

From Rom Side Beck the party headed uphill towards Sharp Haw crossing rib-features formed by sandstones within the Pendle Grit Group dipping ENE at 15°-20°. A reddened coarse-grained pebbly sandstone, probably the Grassington Grit forms the cap of Sharp Haw and this was seen to lie on the Pendle sediments with marked angular unconformity on the north west side of the summit. The reddening which has affected the summit sandstone was probably imparted through deep weathering during the Permo-Triassic period.

Lunch was taken on the south side of Sharp Haw sheltered from the strong wind. This vantage point gave a panoramic view over the village of Gargrave.

After lunch the party headed northwards to visit further outliers of low-dipping reddened coarse-grained pebbly sandstone (?Grassington Grit), including Rough Haw (963.559), and two unnamed hills to the north where (e.g. 961.564) the angular unconformable relationship was once again clearly displayed. At Grid Ref. 963.567, a lower leaf of the outlying sandstone thins abruptly from about 25m to less than 5m over an underlying steeply inclined rib of Pendle sandstone.

The existence of the angular unconformity within the Pendleian sediments of Flasby Fell marks an important tectonic event in this part of the Craven Basin during the E_{1c} sub-zone and it seems probable that such an event corresponds to the period of uplift and erosion which affected much of the Askrigg Block to the north prior to the deposition of the Grassington Grit.

To end the day Mr. Arthurton described some features of the view towards Rylstone and Cracoe from a viewpoint (961.569) on the north side of Flasby Fell. These include Swinden Knoll, one of the Asbian reef knolls of Cracoe now being actively quarried, and the fine scarp feature of the Grassington Grit forming Rylstone Fell. The party returned to the cars having enjoyed another full day. Mr. T. Shipp expressed the gratitude of the party to the leaders for their clear explanations and expert knowledge of the area. He also mentioned that on neither day, at the leader's request did members carry hammers, yet it must surely be significant that this did nothing to spoil the enjoyment of the weekend's geology.

Table 1. MAJOR STRATIGRAPHICAL DIVISIONS OF THE CARBONIFEROUS. (Adapted from RAYNER & HEMINGWAY, 1974 and GEORGE et al., 1976).

Chronostratigraphic divisions			Lithostratigraphic divisions
Subsystem	Series	Stage	
Silesian (Upper Carboniferous)	Stephanian		
	Westphalian	Westphalian D, C, B, A	Coal Measures
	Namurian	Yeadonian Marsdenian Kinderscoutian Alportian Chokierian Arnbergian Pendleian	Millstone Grit
Dinantian (Lower Carboniferous)	Visean	Brigantian 6 Asbian 5 Holkerian 4 Arundian 3 Chadian 2	Carboniferous Limestone
	Tournaisian	Courceyan 1	

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THE ORDOVICIAN AND SILURIAN ROCKS OF KENTMERE AND LONGSLEDDALE

Leader: Mr.D.Leviston

25th June, 1978

Members and friends assembled at Kentmere Church (456.041) where the leader explained that the geological structure of the area is dominated by the results of two phases of deformation; one pre-Caradocian and the second Caledonian. Mitchell (1929) interpreted the structure as involving Caledonian isoclines superimposed upon pre-Caradocian NNE trending folds. Soper and Numan (1974) demonstrated that this interpretation is incorrect and they suggest that the Nan Bield Anticline was formed in pre-Caradocian times as a large open fold trending E - W. The present geometry and that of the Wren Gill Monocline result from super-imposition of the end-Silurian cleavage obliquely and inhomogeneously across the pre-existing fold. The object of the excursion was to examine the volcanic rocks of Raven Crag (457.051) and Iving Scar (453.048) and then follow the Ordovician - Silurian boundary over into Longsleddale examining rocks of Caradocian and Llandovery age en route. Itinerary IV of Mitchell, 1970, was used for this purpose.

At Calfhowe Crag (458.052) a quartz-porphyry dyke intruded into the augite-andesite was examined along with some large boulders which had the appearance of being derived from flow-breccia.

At Iving Scar a fine section of bedded tuff in the Upper Rhyolite was examined. This locality provided a magnificent view down the Kentmere valley which at one time contained a glacial lake. The evidence for this can be found in the diatomaceous earth which is excavated for fire-bricks and other uses. The party then returned to the cars, collected their haversacks and set out to follow the outcrop of Coniston Limestone across into Longsleddale.

In Nunnery Beck, but above the bridge (462.043), a grey mudstone forming the transition of the Browgill Beds and Brathay Flags was examined. Descending to Force Jumb waterfall (467.044) in the River Kent, Browgill Beds can be seen faulted against the Coniston Limestone Group.

The party then made their way to Stile End (467.048) where a view up the valley provided a good reason for pausing to regain breath. Following the path towards Longsleddale, Upper Rhyolites were seen on the left hand side while fossiliferous Stile End Beds containing trilobites, are exposed on the right. However, the party did not stop to search for these elusive creatures but pressed on to the Old Quarries (478.051), also in the Stile End Beds, where a well-earned lunch was taken. Those who were not too fatigued after the morning's exertions searched for fossils such as the trilobite Chasmops as well as dalmanellid and strophomenid brachiopods.

After lunch the party examined a severely weathered diorite dyke containing small bore-holes presumably produced by some research geologist obtaining orientated samples for geomagnetic studies. From here the group proceeded on their journey and examined a small stream section in the Skelgill Beds which yielded excellent graptolites. According to Hutt (1974) the convolutus Zone and the sedgwickii Zone are exposed at this locality, and details of the sequence here are given in his paper and the graptolite assemblages for these two zones are given by Elles (1928).

After obtaining a good selection of specimens the party made its way down to Sadgill in Longsleddale (482.057) and then followed the Stile End Beds, showing good sedimentary structures, back up to the Old Quarries where good samples of corals and trilobite casts were obtained. In the lower beds of the Stockdale Rhyolites nearby, good examples of nodular rhyolites were examined, some the size of footballs, which provided a suitable ending to a strenuous but rewarding day.

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OTHER EXCURSIONS

23rd April, 1977	Borrowdale Volcanics on Stonethwaite Fell. Leaders: Miss D.Slater and Mr.T.Shipp.
1st October, 1977	The Skiddaw-Borrowdales Junction. Grange-in-Borrowdale. Leader Dr.F.Moseley, (see note on page 74).
11th March, 1978	Opencast Coal Mining, Low Close near Broughton Moor. Leader: Mr.E.Lawrence.
5th April, 1978	Force Crag Mine, Braithwaite.
30th July, 1978	Devensian Deposits on Threlkeld Common. Leader: Mr.J.Boardman.
23rd September, 1978	The Skiddaw Group at the Northern Edge of the Lake District Anticlinorium. Leader: Dr.D.Jackson.

SHORT EVENING EXCURSIONS

27th April, 1977	The Coal Measures on Harrington Shore. Leader: Miss D.Slater. (Expedition modified as a result of very bad weather conditions).
11th May, 1977	Coal Measure Fossils at Whitehaven Brickworks. Leader: Mr.T.Shipp.
25th May, 1977	Carboniferous Rocks of Whitehaven Shore. Leader: Mr.S.H.Gate.
22nd June, 1977	Marron Bridge - Civil Engineering Geology on the A66 Trunk Road. Leader: Dr.F.J.Cockersole.
29th June, 1977	Skiddaw Series - Loweswater Flags, Fangs Brow. Leader: Miss D.Slater.
6th July, 1977	Drilling for Haematite, Egremont area. Leader: Mr.E.H.Shackleton.
26th April, 1978	Upper Carboniferous Sedimentation, Middle Gill, near Distington. Leader: Mr.G.Rudd.
10th May, 1978	Lower Carboniferous Faulted Outlier at Mousegill, Wilton, near Egremont. Leader: Mr.E.H.Shackleton.
24th May, 1978	Old Iron-ore workings at Frizington. Leaders: Mr.M.B.Dodd and Mr.L.Davies.
14th June, 1978	Opencast Coal Mining, Outgang near Branthwaite. Leader: Mr.E.Lawrence.
28th June, 1978	Junction between Granophyre and Borrowdale Volcanics in Wasdale. Leader: Miss D.Slater.

LECTURE REPORTS

THE STUDY OF LIMESTONES BY STAIN AND PEEL TECHNIQUES

Dr.J.A.D.Dickson

The first indoor meeting of the 1977/78 season was held at the Whitehaven College on 7th September, 1977. Dr. Tony Dickson of Nottingham University gave a lecture-demonstration on the use of staining methods and acetate peel techniques in the study of limestone rocks. The President introduced the speaker mentioning that he was a member of the Society and one of 'our local lads'.

Dr.Dickson began by pointing out that many minerals including carbonates, sulphides and silicates could be chemically stained to facilitate their study. Many of the staining agents used were expensive and somewhat dangerous, but two in particular, alazarin red S (A.R.S.) and potassium ferricyanide (P.F.), could be used in conjunction quite simply and effectively in the study of carbonate rocks. In brief the procedure involved etching the polished surface of the specimen with dilute hydrochloric acid, applying the staining solutions and, after washing, fixing the stained surface with a sealant. In the case of A.R.S. the degree of staining is related to the rate of reaction between the carbonate and the HCl and to the axis of the particular crystals stained, so that the detailed structures and texture of the specimen are delineated. The stains in conjunction enable distinction to be made between crystals of most carbonates including calcite, aragonite, dolomite, witherite, cerussite, siderite, rhodocrosite and ferroan compounds.

Such staining methods are ideally used on thin sections but can be applied to surfaces of rock and even to specimens in the field. The method can also be used in conjunction with acetate peels because the stain is actually a surface precipitate which comes off with the acetate sheet. The result is similar to a stained thin section.

Dr. Dickson, to the delight of the audience, then proceeded to demonstrate the A.R.S. - P.F. method on some thin sections in a Petri dish under the overhead projector so that members were able to watch the development of the image on the screen. Some excellent prepared slides of the results that can be achieved were also shown.

In the final part of his talk Dr. Dickson turned to the use of staining techniques as a research tool by describing some of his

own work on cementation processes during diagensis. He showed remarkable film sequences of recrystallisation taking place in pore fluids and showing how the study of crystal growth and zoning by staining methods could reveal the history of mineralisation. There were also very important applications in the grading and assessment of reservoir rocks in the context of water and oil resources. The speaker concluded by referring to future developments of still more sophisticated techniques including cathodoluminescence.

A sincere vote of thanks was accorded to the speaker who also answered a number of questions from the audience. Simple staining methods and the use of acetate peels are well within the capacity of amateur geologists and are particularly applicable to an area like our own where the Carboniferous Limestones are so readily accessible. It is hoped to include in a future issue of the Proceedings an article giving full details of the methods than can be employed.

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THE EVOLUTION OF THE STRUCTURE OF THE LAKE DISTRICT

Dr.F.Moseley

A meeting of the Society was held on the 30th September, 1977, at the Workington branch of the West Cumbria College at which Dr. Frank Moseley from Birmingham University addressed a gathering of nearly 60 members and their friends on the subject of the Evolution of the Structure of the Lake District.

Dr. Moseley started by saying that in the time available he would concentrate for the most part on the modern interpretations of the geological history of the area in Ordovician and Silurian times which laid the foundation for subsequent changes. Before proceeding, however, he paid tribute to the many famous geologists of the past whose accurate and painstaking mapping, culminating in the work of Professor J.E.Marr, had established the fundamental stratigraphy of the area upon which all subsequent work has been based. The members present were intrigued by a slide that Dr. Moseley put on the screen showing the name 'J.Marr' and the date '1887' chiselled on a rock surface near Coniston. Since it is known that the great man was working in that area at that date it could well be his signature.

Proceeding with his lecture Dr. Moseley showed a slide of the supposed positions of various present day territories in the early

Ordovician era. A continent comprising Scotland, Norway and Greenland was separated from a block containing parts of U.S.A., England and other European countries by the 2000 kilometre wide proto-Atlantic Ocean. Recently this has been more appropriately renamed 'Iapetus' to emphasise the fact that the present day Atlantic is an entirely separate entity which did not open up until the Mesozoic.

The Iapetus was perhaps more comparable with the Pacific in that it had a mid-Oceanic spreading axis with subduction zones beneath both continents so that the Lake District at that time was placed on the southern margin and could be compared with a section of the present day Andean mountain range.

The Skiddaw Slates were deep basin mudstones and turbidite deposits moving down the continental slope into the adjacent oceanic trench. The vulcanism associated with subduction gave rise firstly to the Eycott Group and continued somewhat later with the main Borrowdale Volcanic Series. There is geochemical support for this interpretation in that the Eycott lavas are basaltic with tholeiitic affinities and differ from the calc-alkaline andesites of the Borrowdales. A progressive increase in alkalinity away from the destructive margin is noted if the Welsh volcanics are included. Again present day parallels can be noted in the Andes and the North American Cascades.

The closure of the Iapetus occurred during late Ordovician and Silurian times. As the gulf narrowed varying marine environments were brought about. For example, the B.V.S. shows evidence of both sub-aerial and sub-aqueous deposition such as might have occurred in an island arc situation. The Coniston limestone indicates an episode of shelf seas deposition while the main body of Silurian rocks in the southern Lake District accumulated in what must have been a temporary return to deep sea conditions.

These events provide a logical explanation of many previously ill-understood observations. For example the fossil record shows evidence of faunal provinces initially quite separate but later becoming mixed and then fusing into a single entity as the Iapetus no longer constituted a barrier.

In late Silurian times the two continents finally collided and fused giving rise to the Caledonian orogeny of Himalayan proportions which had such a marked effect on the structures and textures of our local rocks.

Dr. Moseley went on to describe how the tectonic history could be unravelled from close study of Lake District rocks to reveal polyphase folding; the effect of which varied greatly with the degree of competence of the different rock types and strata. The speaker spent some time in describing with the help of splendid slides the great variety that we are familiar with in the

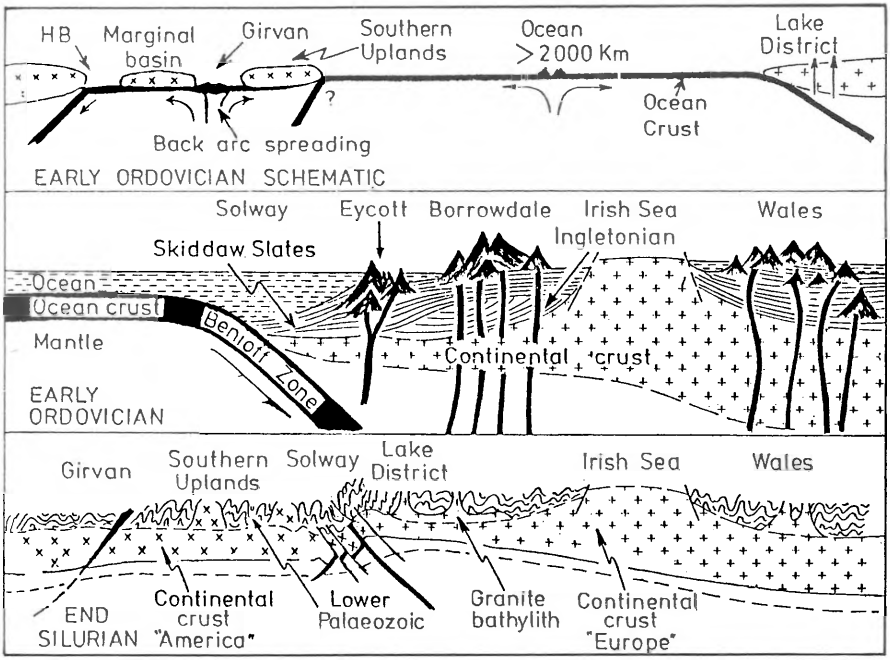


Fig. 1 IAPETUS CLOSURE AND SUBSEQUENT OROGENY
(from Bull. Geol. Soc. America, 1977)

Borrowdale volcanic rocks. Dr. Moseley is a world authority on this particular topic and he sketched the circumstances that gave rise to successive phases of vulcanicity with magmas of varying composition. He described the lava flows and their characteristic flow banding and flow brecciation, and the pyroclastic phases which were the origin of the tuffs and ignimbrites.

The end of the orogenic period saw the emplacement of the granite batholiths beneath the area that is now northern England and the high points are now represented in our area by the Skiddaw and Shap granites. The morphology of the batholiths greatly influenced deposition in the Carboniferous and thereafter.

The limitations of a single lecture prevented Dr. Moseley pursuing the story into upper Palaeozoic and Mesozoic times but the events he had described were the most significant in determining the pattern of the later geological history of the area. He mentioned, for example, the frequently quoted concept of the radial drainage pattern which postulates that present geomorphology was determined by the pattern of erosion in the softer Mesozoic sediments cutting down into the Palaeozoic core. There is increasing evidence nowadays that the pattern is in fact related

more to structural elements in the basement dating from the earlier period.

After the lecture the speaker dealt confidently with a number of penetrating questions from the audience and the proceedings were drawn to a close by the members according an enthusiastic vote of thanks to Dr. Moseley.

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Note:

On Saturday 1st October, 1977, the day following his lecture, Dr. Moseley led a Society Excursion starting at Grange-in-Borrowdale and followed the Skiddaw Slate - B.V.S. junction over High Spy and down into Newlands Vale. Dr. Moseley did his best to illustrate many of the points he made in his lecture, but the weather was so atrocious with high winds, hail-storms and heavy rain virtually throughout the day that conversation was difficult and none of the stalwarts present were able to make any record of the event!

Interested readers are referred to Dr. Moseley's article on 'Structural Relations between the Skiddaw Slates and the Borrowdale Volcanics' in Volume 3, Part 3, of the Proceedings which deals with some of the localities visited.

THE OUTLOOK FOR WORLD ENERGY

Sir Kingsley Dunham

A meeting of the Society was held on October 5th, 1977, at the Derwent Centre, Cockermouth. The speaker was Sir Kingsley Dunham, lately Director of the Institute of Geological Sciences and a world authority on mineral resources. Sir Kingsley chose a very topical subject for his address; 'The Outlook for World Energy' and the meeting attracted a large gathering of some 60 members and visitors.

Sir Kingsley gave a scholarly resumé of the various energy sources available to mankind; the various fossil fuels and nuclear energy as well as solar, tidal and geothermal sources. He indicated the pattern of energy use up to the present time and showed how the processes of world wide economic growth could be expected to require ever increasing supplies of energy from one source or another.

Oil reserves may not last until the end of the century and although there are very large amounts of coal which might supply the needs of civilisation for hundreds of years there are unsolved problems of extraction. Even now there is difficulty in finding the thick level seams necessary for efficient mechanical mining. The speaker spent some time talking about the rôle of nuclear fuel. In the distant future nuclear fusion holds the promise of abundant power but for the foreseeable future we may be very dependent on uranium reserves for nuclear fission reactors. The Institute of Geological Sciences has been active in seeking workable uranium deposits but it is not widely appreciated that material to fuel the present generation of reactors will be exhausted before the end of the century. The breeder reactor programme would make better use of the available uranium for a much longer period but the associated risks of plutonium pollution and waste disposal would have to be accepted.

Sir Kingsley concluded by emphasising that fossil fuels which take millions of years to form are being utilised in a prodigal fashion at an ever increasing rate and cannot be re-cycled like some other mineral resources.

The meeting ended with a lively battery of questions and comment from the audience and finally a vote of thanks to the speaker was proposed by the Society's Editor, Dr.F.J.Cockersole.

THE HISTORY OF HAEMATITE MINING IN WEST CUMBRIA

Mr.C.F.D.Johnston

A meeting of the Society was held on 2nd November, 1977, at the Whitehaven branch of the College at which Mr. Frank Johnston, the Agent of the Beckermet Mine, spoke about past and present aspects of haematite mining in the area.

The speaker began by referring to the beginnings of iron ore mining on the lands of the Abbey of St. Bees. His comments as a mining engineer on the early techniques involving, for the most part, the use of wooden tools, helped us as amateurs to appreciate more fully the difficulties and limitations of the mediaeval pioneers. By the nineteenth century however, large numbers of men were employed underground and extensive 'sops' were worked. The lecturer illustrated the conditions of work at that time by means of slides made from old black and white photographs taken in the workings of the Cleator Moor and Frizington mines.

The main theme of the talk, however, was present-day mining activities at Beckermet. Graphic descriptions of the difficulties encountered in re-opening the Florence workings and of exploration towards Calderbridge were especially interesting to the members. Colour slides taken underground were of high quality and held the attention of the audience, especially those of 'vugs' in the roof of galleries in the Florence mine currently being 'robbed'.

Samples brought by Mr. Johnston and his colleague Mr.Clements, the Mine Surveyor, were inspected with interest by members as they included several varieties of barytes and specularite, besides the more usual calcites, dolomites and quartz which demonstrated the considerable differences in the mineral assemblages of the ore bodies worked near the Beckermet and Florence shafts.

In reply to questions Mr. Johnston explained how National Park regulations were preventing the development of fairly extensive recently proven deposits and he discussed how the British Steels Corporation hope to gain access to the considerable ore bodies known to exist between Egremont and the St. Bees valley.

A sincere vote of thanks was accorded to both Mr. Johnston and Mr. Clements for a fascinating insight into the mining of the haematite deposits which are almost the geological trade mark of West Cumbria.

THE DEEP STRUCTURE OF NORTHERN ENGLAND

Professor M.H.P.Bott, Ph.D.,F.R.S.

At a meeting of the Society held at the Derwent Centre, Cockermouth on the 22nd March, 1978, and attended by over 40 members and visitors, Professor M.H.P.Bott of Durham University, gave a lecture on 'The Deep Structure of Northern England'.

Professor Bott enlarged upon the theme that he had introduced as the Society's Guest of Honour on the occasion of the Annual Dinner in 1974. He showed how sensitive gravity measurements over the northern regions of England had revealed a zone of low Bouger anomalies running through the central and northern areas of the Lake District. This was apparently at variance with the belt of relatively dense volcanic rocks extending through the territory, and even more intriguing was the finding that the gravity 'lows' extended in an E.N.E. direction into the Northern Pennines. Further anomalies have been discovered in Wensleydale and in the Market Weighton area between York and Hull.

Considering the densities of the various categories of the Lake District rocks in conjunction with the gravity anomaly distribution Professor Bott was led to formulate computerized models showing possible profiles for the various Lake District igneous intrusions. These ranged from the flat-topped, steep-sided form of the Skiddaw Granite to much more complex forms based on the varying densities in the Eskdale Granite and the Ennerdale Granophyre.

The lecturer spoke of the prediction that had been made on the basis of gravity anomalies of the existence of buried granite under the Pennines. This had later been proved by drilling through the Carboniferous cover at Rookhope in Weardale. This granite has been shown from examination of the cores to have a weathered surface below the limestone and is therefore pre-Carboniferous in age. More recently it has been shown by radiometric dating that it is contemporary with the Lake District granites. It is reasonable to infer from the data that all the granitic intrusions beneath Northern England are related and are of Caledonian age.

Professor Bott pointed out that, as a consequence of its relatively low density, a large mass of granite exerted an upward pressure, a buoyancy, on overlying rocks. This has led to the formation and maintenance over very long periods of time in Northern England of stable upland blocks, as in the Lake District, the Alston Block and the Askrigg Block. The implications of this on the geology, the mineralogy and the topography of the region are profound and well known.

The lecture was concluded with a reference to an interesting development; the discovery of another marked gravity anomaly suggesting a buried granite mass in the Market Weighton area of Yorkshire. The thinning out of Jurassic sediments in this locality has been well known for a long time. Could it be that a buried granite mass has been exerting its upward influence in this region, causing a 'swell' in the topography and consequent thinning out of later sediments?

The lecture provoked many questions, all comprehensively answered by Professor Bott and following this a vote of thanks to the speaker was proposed by Mr. Eric Lawrence.

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THE HISTORY AND EXPLOITATION OF POTASH DEPOSITS IN NORTH EAST ENGLAND

Mr.P.J.E.Woods, M.A.

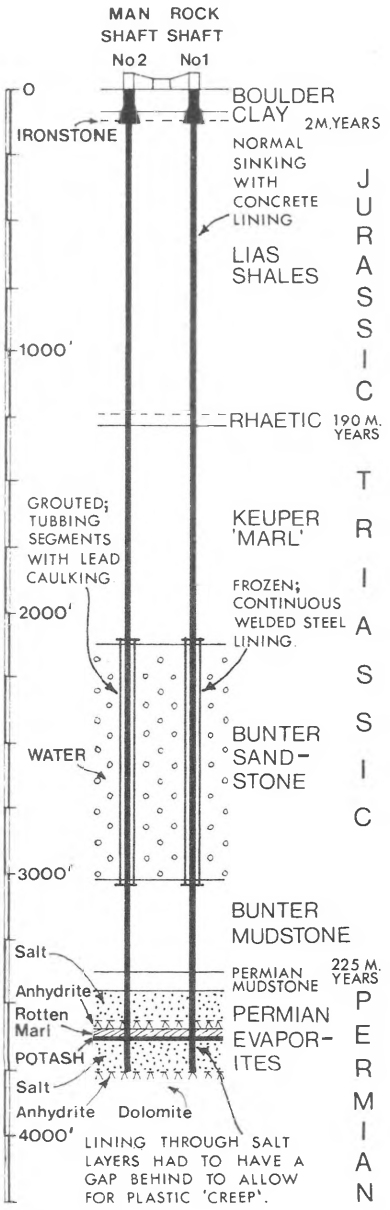
The first meeting of the 1978-1979 season was held at the Whitehaven branch of the West Cumbria College on 4th October, 1978. 22 members and 4 visitors attended to hear a talk on Potash Mining in North East England given by Mr. Peter Woods, the Chief Geologist with Cleveland Potash.

The speaker began by explaining that the organisation he represented was a consortium of mining companies formed to exploit potash (potassium chloride) in Permian evaporite deposits beneath the North Yorkshire Moors. The potash, which is virtually the last salt to be precipitated in an evaporite sequence, occurs in this locality in a 5 - 6 mile wide strip at a depth of 4,000 feet. West of Whitby the evaporite sequence thins out as a result of solution from exposure.

Mr. Woods went on to describe the details of the Boulby mine. A concrete-lined shaft was taken down through 2,000 feet of Lias shale, Rhaetic deposits and Keuper marl. Below this a further passage through pervious Bunter sandstone had given rise to serious technical problems due to the contained water under great pressure. Modern shaft sinking methods involving pre-grouting and freezing techniques had been used.

Evaporite deposits are plastic and as a result of deformation are difficult to mine. The geologist has to anticipate and locate

CLEVELAND POTASH LTD.
BOULBY MINE SECTION



the potash horizons and complications occur, for example, from overfolding. Horizontal drilling up to 1000 metres ahead of the workings is carried out using directional techniques.

The extraction rate of 48% is limited by the need to leave thick rock pillars to avoid subsidence and consequent alteration of the water table.

The mine is worked by caterpillar tracked and wheeled vehicles operating in wide roadways. The workings are dry, otherwise solution would dissolve the pillars. Wide roadways are possible because of the homogeneous nature of the rock material, but roof bolts are used.

The speaker concluded by commenting on the problem of mining in a National Park. Impact on the environment in this instance is minimized in that the above-ground installations are compact and are grouped around a pair of shafts.

Waste material is disposed of in a novel fashion. The anhydrite and rock salt waste is conveyed through an undersea tunnel to a point about a mile off-shore where it is brought into contact with sea water admitted through a vertical shaft. The rock waste goes into solution and is carried further out to sea.

The lecture was splendidly illustrated by colour slides and diagrams of both the subterranean and above-ground aspects of the project.

The speaker was plied with questions after his talk and was accorded a warm vote of thanks.

THE BACKGROUND TO THE DINOSAURS

Dr. Dorothy Rayner

On 8th November, 1978, Dr. Dorothy Rayner of Leeds University addressed the Society on the subject of 'The Background to the Dinosaurs'. The meeting was held in the Derwent Centre, Cockermouth and 35 members and 5 guests were present.

Dr. Rayner began by explaining the theme of her lecture which was splendidly illustrated by maps and slides. It was often thought that the evolutionary development of the Dinosaurs showed a straightforward pattern from their origins in the Triassic, through the Jurassic until their rapid demise in the Cretaceous. In all probability, however, the picture is much more complicated. Many other animal groups about which much more is known have complex evolutionary histories and this may well be the case with the Dinosaurs.

The fossil record of the Dinosaurs is fragmentary. Knowledge of their mode of life and behaviour is based purely on skeletal remains and there is much scope for different interpretations. Remains are scanty until the upper Jurassic but by the Cretaceous Dinosaurs had a world wide distribution. The bulk of the evidence in the fossil record is derived from five localities and the speaker went on to describe the findings at each site.

At Tendaguru in Tanzania in upper Jurassic deposits Dinosaur remains are found in beds separated by marine sequences. Reliable dating is possible from associated ammonites. The creatures seem to have had heavy, possibly water-supported bodies and pillar-like hind legs. Problems of interpretation exist because of the possibility at this site of the transport of the fossil remains. The 'German' view is that the marine interbeds indicate a marshy coastal environment, whereas the 'English' view is that these are probably transported assemblages of basically land animals.

In northwest U.S.A. the Morrison formation in the Upper Jurassic contains fresh water molluscs, reptiles and primitive mammals as well as Dinosaur remains. This was a classical collecting area in the 1870's. The species are very similar to the large sauropods of Tendaguru. The strata of silts, sandstones and shales suggest an environment comparable with the lower

reaches of the present day Amazon. The bones are found semi-assembled suggesting that at any rate the palaeocurrents were not energetic enough to move large bones.

In Wyoming, the Lance formation in the upper Cretaceous resembles coal measure facies. The Dinosaur remains disappear at the top of the Maestrichian and yet there is no evidence of a sudden environmental change that might have been responsible.

In Mongolia in the 1920's American investigators exposed Dinosaur bones and eggs in patches of rock outcrops in the Gobi Desert. Eggs about 3" x 1" were found in nests with embryo bones inside. There was evidence of repetitive egg-laying in the same area over a period of time and the eggs must have been preserved in terrestrial sediments.

Finally in Bernissart, in Belgium, there are lower Cretaceous beds comparable to the Wealden. Below these are coal measures of the Namur syncline. Fossil Dinosaur remains were found during coal mining operations. A collection of 29 Iguanodon skeletons were found in an infilled depression in the coal measures containing other Cretaceous material. The bones were in four distinct levels separated by barren sequences. Again a variety of interpretations is possible. These vary from the entrapment of animals in a ravine as a result of sudden storms to the collapse of limestone caverns.

Dr. Rayner went on to describe the discovery in the Jurassic of Bavaria of the famous fossil Archaeopteryx. This was found in the well-bedded 'lithographic limestone' so called because of its use in the printing industry. Archaeopteryx had a mixture of reptilian and avian characters, and had it not been for the undoubted impressions of feathers the specimen would have been taken for a reptile or possibly a lightly-built Dinosaur. The gap between the lightly-built small Dinosaurs of the Triassic and the birds of the late Cretaceous could well be filled by Archaeopteryx.

The speaker completed her talk by referring to evidence provided by Dinosaur tracks in the Arizona desert and to the occurrence of Dinosaurs in marine lower Jurassic and lower Lias deposits in Britain at Charmouth. The fragmentary evidence is susceptible of various interpretations and the whole story is likely to be complicated.

During questions from the audience after the lecture the current controversy about whether or not Dinosaurs were warm-blooded inevitably arose. Dr. Rayner commented that the very vigour of the controversy was an indication of how much there was still to learn about dinosaurs.

The evening was rounded off by a vote of thanks to the lecturer proposed by Dr.Cockersole for what had been a fascinating and absorbing talk.

RADIO-CARBON DATING AND THE LAST GLACIATION

Dr.L.F.Penny

A meeting of the Society was held at the Derwent Centre, Cockermouth on 7th March, 1979. 21 members and 5 guests attended to hear Dr.L.F.Penny of Hull University give a talk on Radio-carbon Dating and the Last Glaciation.

The speaker first outlined the principles of radio-carbon dating. A minute proportion of atmospheric carbon is in the form of the unstable isotope C^{14}. Following the death of living tissue which has taken up atmospheric carbon this radioactive component decays in an exponential manner with a half-life of about 5,500 years. By measuring the proportion of residual C^{14} in fragments of preserved organic material such as wood, bone or shell it is possible to derive a figure for the age of the specimen. The method can be applied to material up to 60,000 years old, but is considered to be more reliable up to about half that length of time. Tree-ring dating has provided a good check on the method back to about 5,000 years ago.

Dr. Penny went on to explain that the results had to be interpreted with caution because there were many pitfalls. The experimental error can be calculated and expressed in some such figure as 10,000 $\pm$ 1,000 years, but unknown errors arise from possible contamination of specimens with 'modern' carbon derived, for example, from ground water and there is also the assumption that the C^{14} content of the atmosphere has remained constant. This may not necessarily have been the case because we know that the Industrial Revolution altered the atmospheric C^{14} content and it is at least possible that episodes of vulcanicity in times past could have had an effect too. There is in fact some discrepancy between ages derived from carbon dating and from tree-ring evidence, which may indicate greater errors at the upper levels of the age range.

Dr. Penny then turned to the use of the radio-carbon method in establishing the date of the last glaciation (Devensian). Using the East Yorkshire area as an example he described the identification of the Devensian till and showed that it was composed of two elements; the Withernsea Till above and the Skipsea Till below. The difference between the two indicating different origins of the ice burden. Silts at the base of the Skipsea Till have yielded material which has shown a confirmed radio-carbon date of about 18,000 years B.P. The silt contains mosses and ostracods typical of an arctic climate and mark the onset of the glacial phase in this area. On the upper surface of the Withernsea Till hollows

were found containing peat which had accumulated subsequent to the melting of the ice. Radio-carbon dates in this horizon gave ages just above 12,000 years B.P.

The speaker went on to explain the use of Space-Time diagrams to narrow down the time range and also mentioned other work from the fields of archaeology and palynology which has provided some corroborative evidence. From all this the lecturer concluded that one could say with some assurance that in East Yorkshire the last advance of the ice was about 17,000 years B.P. and that it had gone again by 13,000.

Dr.Penny then widened his topic by referring to similar evidence in the Severn basin relating to the Irish Sea ice and to evidence from New Zealand that the last glaciation there was dated at about 18,000 to 20,000 years B.P. Some theories hold that glaciations alternated in the two hemispheres but it now seems virtually certain that glaciations were associated with world-wide climatic changes.

The speaker concluded on a cautionary note by referring to some anomalous findings from post-glacial material in a kettle-hole in the Isle of Man which gave dates around 18,000 years B.P. It seems that the dating must be erroneous or alternatively it is a different till. The problem is still unsolved and serves to sound a warning that the last word in the matter has not yet been said.

There was a lively question and answer session and to conclude the proceedings a warm vote of thanks to the speaker was proposed by Mr.S.H.Gate.

EXPLORATION OF THE BRITISH CONTINENTAL SHELF

Sir Peter Kent, F.R.S.

A meeting of the Society was held on 28th April, 1979, at the West Cumbria College, Whitehaven, which was addressed by Sir Peter Kent on the subject of the Exploration of the British Continental Shelf. 34 members and 5 visitors were present.

Introducing the speaker the President, Mr.Edgar Shackleton, mentioned that Sir Peter was Chief Geologist for the British Petroleum Company and was a world wide authority on hydrocarbon

exploration. He had gained experience all over the globe and had worked on the original Oil Survey of Great Britain.

The speaker began by describing the exploration of the North Sea. The similarities between the geological strata on both sides of the Channel, together with the occurrence of natural gas in small quantities in Britain, but in much greater amounts at Groningen in Holland had led to the suspicion that significant hydrocarbon reservoir rocks might be present beneath the North Sea basin.

In the 1950's agreement was reached by the nations bordering the North Sea on defining the areas of sovereignty and this cleared the way for systematic exploration. Sir Peter went on to review the methods used. Firstly generalised submarine gravity surveys revealed 'lows' which were shown to coincide with salt basins in the Permian.

In view of the extensive salt deposits in North Germany it was not unexpected to find two such large basins in the southern North Sea.

Next aerial magnetic surveys served to show areas where the crystalline basement was at relatively shallow depth and in this way a broad picture of the structures beneath the North Sea was built up. This picture was then refined mainly by ship-borne seismic reflection profiles. The seismograms were enhanced by computer processing and by these means the details of fault structures and salt pillars and flows were discovered. The way was now clear for the exploratory drilling of possible hydrocarbon-containing structural traps.

In the southern North Sea porous and pervious Permian desert sands, especially the Rotliegendes formation, were reservoirs for natural gas accumulations derived from the coal measures in the underlying Carboniferous. The reservoir rocks were sealed by the overlying impervious Zechstein salt.

To the north the sea depths were greater, 400 - 600 feet as compared with less than 100 feet in the southern North Sea. This made exploratory drilling much more of a technical problem involving the use of floating rigs. In these more northerly areas the pattern of salt pillars and flows together with fault structures provided traps in which oil rather than gas predominated. A great thickness of Tertiary rocks was present and on a world wide basis these are the chief oil-bearing strata. Alternations of pervious and impervious sediments provided the environment in which hydrocarbons could be contained. Initially the results were not promising but Sir Peter retailed how persistent drilling of exploratory boreholes led to the discovery of the Ekofisk, Forties and Frigg fields, followed by many others whose names have passed into common parlance. The deepest

boreholes passed into dark shales in the Cretaceous and below this more oil was found in porous Jurassic sands. It was also found that extensive rifting had occurred in the Mesozoic which had controlled the thickness of subsequent sedimentation.

The speaker then gave an account of how all the geological information obtained had added detail to the picture of palaeo-geography built up from years of painstaking land-based studies. In a series of excellent maps projected on the screen he showed how the shore lines in the whole area had changed from Carboniferous times to the present day. He showed, for example, how the Jurassic strata in the southern North Sea gave way to the north to pervious deltaic sands and also evidence had been found pointing to a large central vent volcano midway between Scotland and Norway in Jurassic times.

Sir Peter went on to comment on the remarkable achievements of geological mapping in depths down to 10,000 feet. He also demonstrated with the help of more excellent slides the incredible technological advances and endeavours that had been stimulated by the commercial aspects of the search for fossil fuels.

In conclusion the speaker referred to other areas round Britain, Cardigan Bay, the Atlantic approaches and the Hebridean area where exploration was at present taking place. He commented that in many places round the globe where hydrocarbons had been found in relation to continental margins the picture had emerged of block faulting in the Mesozoic coming to an end in the Jurassic and Cretaceous and this phenomenon was at present poorly understood.

It was no surprise that such a stimulating and comprehensive lecture provoked a spate of questions. One of these raised the possibility of hydrocarbons, especially natural gas, arising from inorganic reactions in the upper mantle rather than from diagenetic changes in organic deposits. Sir Peter replied that there seemed little question that all commercially exploited hydrocarbon deposits were related to the decomposition of organic matter, but agreed that deeper sources might be related to vulcanism. Other questions concerned the variable quality of hydrocarbon deposits, the techniques of directed drilling and the means used to improve extraction rates from oil and gas fields.

The Secretary, Mr. Tom Shipp, proposed a vote of thanks on behalf of the Society.

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OBITUARIES

HERBERT ARTHUR WHITE, B.A.

As recorded elsewhere the Society's Treasurer, Herbert White, died rather suddenly on 19th December, 1977, at the age of 76. He was loved and respected by a great many people and all the members of the Society who knew him felt a great sense of loss.

The President writes:-

'In my long association with geology in Cumbria no sadder task has ever been my lot than to write a few lines in memory of Herbert White, a very dear friend and a tireless worker for our Society.

My long association with him began some thirty years ago when I was persuaded by Herbert first to join, and later to take charge of, a W.E.A. geology class. He was a highly qualified teacher as was his delightful wife Margaret and both were keen supporters of the W.E.A.

Out of these classes, with the help and encouragement of the late Charles Edmonds, sprang the West Cumberland Geology Group. Herbert and his wife were enthusiastic members but tragically Margaret White died as a result of complications following an operation. Herbert continued to live at 'Stoneycroft' with his mother-in-law, becoming even more closely involved with the Geology Group and with the Cumberland Geological Society that developed from it. A Founder Member, he served on the Council and for a time was Vice-President. From 1965 onwards right up to his death he was Honorary Treasurer and as part of his duties he meticulously maintained the membership records.

Herbert White had many other interests. Apart from his work as Head of the Geography Department at Workington Grammar School up to his retirement in 1965, he was a loyal supporter of the Geographical Society, travelling abroad on their excursions and bringing back interesting and beautiful photographic records, now unfortunately lost.

He was a founder member of the Workington Playgoers Club, producing several plays and serving as an active behind-the-scenes worker up to shortly before he died.

I can do no better than to echo the words of Tony Murray, a senior member of the Playgoers Club, who said - 'He was a very likeable man in every way, quiet, unassuming, and always very helpful. He was a real gentleman.'

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ROBERT HENRY HEWITT

The longer-standing members of the Society were saddened to learn of the death of 'Bob' Hewitt which occurred on 28th December, 1978 when he was 63. Born in Liverpool, he worked initially for I.C.I. and later for the Atomic Energy Authority at Preston. He was transferred to Windscale where he worked as a Nuclear Engineer and later as a training officer for British Nuclear Fuels.

Geology was a hobby, but as a gifted amateur he developed a profound knowledge of the subject particularly in the fields of petrology and mineralogy. He conveyed his enthusiasm to others through the medium of evening classes and as a result of his work for the Society. His remarkably fine collection of rock and mineral specimens has been donated to Wyndham School.

R.H.Hewitt's name appears amongst the contributors to the first issue of these Proceedings in 1961. He was a member of the West Cumberland Geological Group that preceded the Cumberland Geological Society of which he was therefore a founder member. Bob became the Society's first Excursion Secretary in 1962, a post which he held for eight years. Among the events that he arranged were memorable week-end excursions to the Ambleside, Coniston and Mungrisdale areas, and visits to Tullie House and to the Freshwater Biological Research Station at Windermere. In conjunction with John Moon, whose untimely death was recorded in our last issue, he organised many expeditions to both modern and disused mines of different sorts.

The Society has lost one of the original band of stalwarts who carried it along in its early formative years. Bob will be greatly missed by all those who knew him.

ANNUAL DINNERS

1978

The 1978 Annual Dinner of the Society was held on Friday April 14th, at the Hundith Hill Hotel, near Cockermouth. The evening was fine and clear and the setting superb with Hobcarton Crags, seen through the dining room window, forming a dramatic back-drop. There was a gathering of 45 members and friends who welcomed as Guest of Honour Dr. Winifred Tutin (Pennington) of Leicester University.

In her after-dinner talk Dr. Tutin, who is internationally famous for her work on pollen analysis and on climatic and vegetational changes in the Quaternary, gave her audience a fascinating insight into conditions in the Lake District at that time. After referring to her family connections and childhood recollections in the County she went on to explain, with the help of slides, some of the basic concepts of pollen analysis. Dr. Tutin then described some aspects of the field-work that her studies involved, including a dramatic account of sampling the muds of Esthwaite Water in inclement weather conditions.

In the final section of her talk Dr. Tutin described her deductions about the nature of the plant cover and the living conditions experienced by pre-historic man in the classic Cumbrian sites in post-glacial times. The conditions under which men worked in the Stone Axe Factories above Langdale and on Scafell were contrasted with upland settlements like those on Birker Moor and with life in the Lakeside Villages at Ehenside Tarn.

A vote of thanks to the speaker was proposed by Mr. Russell Arthurton who also paid tribute to various other people who had contributed to an enjoyable and successful evening. These included Mr. and Mrs. Hayton and their staff, the Bennett brothers who had provided table decorations and Mervyn Dodd who had organised everything.

1979

The 1979 Annual Dinner was held on Saturday, 28th April, at the Hundith Hill Hotel, Cockermouth. On this occasion the Guest of Honour was Dr. Frank Moseley of Birmingham University who also received the Society's Charles Edmonds Memorial Prize.

In making the presentation the President, Mr.E.H.Shackleton, explained that the Prize was awarded by the Society in alternate years to a geologist, either professional or amateur, who had made a significant contribution to the understanding of the geology of the Northern English Counties. Mr. Shackleton referred to some of the land-marks in Dr. Moseley's career. After serving as a pilot during the war he studied geology at Sheffield and obtained a Ph.D. for work on the Carboniferous stratigraphy of the Bowland Fells. After periods of work at the Universities of Keele and Cambridge Dr. Moseley moved to Birmingham where he is now Reader in Geology. The results of his field work and research in many parts of the globe are embodied in over fifty scientific publications. His main geological interests, however, are in Northern England and his work in our area has culminated in the recent publication under his editorship of 'The Geology of the Lake District' referred to elsewhere in these Proceedings.

The President concluded his remarks by making particular mention of the fact that Dr. Moseley had always been a good friend of the Society as a lecturer and as an excursion leader and as an important contributor of original papers to the Proceedings.

After receiving the Prize Dr. Moseley expressed his thanks to the Society for the honour accorded to him and proceeded to give an entertaining after-dinner address. He used splendid colour slides to illustrate some of the more interesting and amusing episodes he had encountered while working as a field geologist in different parts of the world. Field work and mapping, he said, were the basis of all geological studies which were, however, becoming more complex and scientific. He described, for example, hydrogeological survey work in Southern Arabia involving the use of a helicopter and cross-country transport under the armed protection of the body-guard of the local Sheik. Similar work had been undertaken in the Western Deserts of North Africa, the historical battle-grounds of the last war. The Army had originally employed water-diviners with little success before seeking expert geological help. The need today was to provide water supplies for oil drilling installations and it was being sought by drilling down to the water table at considerable depth. In Roman times, however, the land had been quite extensively cultivated although the climate was probably not very different from the present day. The Romans had learnt how to obtain water by excavating large cisterns beneath the 'caliche' or surface limestone. Many thousands of examples were still to be seen. These excavations collected water during the winter rains and the cover prevented evaporation during the summer heat.

Dr. Moseley went on to fascinate his audience with accounts of further experiences in places as far apart as Spain, Greenland, Kenya and the Canary Islands.

A vote of thanks to the speaker was proposed by Mr.Eric Lawrence who also conveyed the thanks of all present to everyone responsible for the organisation of what had been a most successful and enjoyable evening.

17th ANNUAL GENERAL MEETING

The seventeenth Annual General Meeting of the Society was held at the West Cumbria College of Science and Technology, Whitehaven on the 15th February, 1978, with the President, Mr.E.H.Shackleton, in the chair.

GENERAL SECRETARY'S REPORT

Membership.

Membership numbers remained relatively steady during 1977. There were 241 paid-up members at the end of the year compared with 230 at the beginning. 26 new members were admitted during the year, whilst 15 either resigned or allowed their membership to lapse. A survey of the various categories of members is given at the end of this report, and it is interesting to follow the pattern of membership from year to year. 1976 saw a relative surge in numbers of associate and husband-and-wife members, whilst in 1977 there was a further build-up in associates; an encouraging feature suggesting that geology seems to be catching on again in our local schools.

I record, with sadness, that our Honorary Treasurer, Herbert White, died suddenly on December 19th, 1977. He was a founder member of the Society and served it faithfully firstly as a Council member and then as Treasurer. The work of the Hon. Treasurer has been eased by the large number of members (74) paying subscriptions by Banker's Order. The financial strains on the Society brought about by increased postal charges and inflation generally have been lessened by 71 members electing to take out Deeds of Covenant which enabled the recovery of £55 in Income Tax refunds. The prompt manner in which most members responded, in January and February to subscription requests and tax declarations has been appreciated by both Treasurer and General Secretary. Once again, we are indebted to those members who volunteered to act as postmen for local delivery of Society mail.

Meetings.

There have been eight indoor meetings during the year.

1. The Annual General Meeting held on February 9th, 1977 at the West Cumbria College, Whitehaven. A film 'Living Sediments' was shown, followed by colour slides illustrating 'palaeo-environments'. 34 members and 2 visitors attended.

2. A programme of films, 'The city that waits to die' and 'An approach to the prediction of earthquakes' was shown at the West Cumbria College, Workington on March 16th. 36 members and 5 visitors attended.

3. A lecture/demonstration on 'How to study limestones by stain and peel techniques' was given by Dr. Tony Dickson (Nottingham University) at the West Cumbria College, Whitehaven on September 7th. 28 members and 2 visitors attended.

4. A lecture on 'The evolution of the structure of the Lake District' was given by Dr. Frank Moseley (Birmingham University) at the West Cumbria College, Workington on September 30th. 31 members and 13 visitors attended.

5. On October 5th, Sir Kingsley Dunham lectured on 'The outlook for World Energy' at the Derwent Centre, Cockermouth. 31 members and 24 visitors attended.

6. A lecture on 'The history of haematite mining in West Cumbria' was given by Mr. Frank Johnston (Beckermet Mines Agent) at the West Cumbria College, Whitehaven, on November 2nd. 26 members and 20 visitors attended.

7. On December 7th Mr.Nat Dawson (Chairman of the Cumbria Naturalists' Trust) gave an illustrated talk on the work of the Trust, at the Derwent Centre, Cockermouth. 18 members attended.

8. A programme of films 'As old as the hills' (Burlington Slate) and 'Iron Ore' (Australian) was shown at the West Cumbria College, Workington. 31 members and 2 visitors attended.

Attendances at meetings have once again risen, from an average of 35 per indoor meeting in 1976 to 38 in 1977, although this is quite a small fraction of the Society's local membership.

The Annual Dinner was held at the Red House Hotel, Keswick, on Friday, March 25th, 1977. Some 50 members and guests were present. The Society's Official Guests were Mr. and Mrs. Colin Rose and Mr. and Mrs. Gerald Winn. Mr. Rose spoke informally of his associations with Cumbria and his present work concerned with the International Law of the Sea. Once again the Society is indebted to Ken Bond and his staff, to the Bennett family and to Mervyn Dodd for organising the event.

Council has met on six occasions, and there have been two meetings of the Editorial Sub-Committee. We are indebted to the Cockersole, Dodd, Shipp and Slater households for hospitality for these meetings.

Proceedings Vol.3, Part 4 was issued to members during the year and appears to have been favourably received. Thanks are due to the Editor, Dr. Cockersole, and to Denys Hinde who nobly undertook the typing and artwork involved in the preparation of the photographic master sheets.

Publicity for Society functions has been freely accorded by Radio Carlisle, The Times and Star, 'Cumbria' magazine, The Lake District

National Park Authority, 'Copeland Diary' and the Journal of the Association of Teachers of Geology. The Society reciprocates publicity and attendance (on request) with The Geological Society, The Geologists' Association, The Yorkshire Geological Society, The Liverpool Geological Society, The Westmorland Geological Society and the Eden Field Club.

Conclusions.

Once again an ambitious programme of events during the year has contributed to stability, and indeed a slight increase, in membership. Despite some large increases in items of expenditure, including the production of Proceedings Vol.3, Part 4, the cash reserves of the Society still remain healthy. That the subscriptions have been held stable for so long in this period of expansion of our activities and national economic inflation is a credit to the wise planning and thrifty work done on the Society's behalf by the Officers and Council. My thanks to all who have contributed towards the successful running of the Society in 1977.

SURVEY OF THE MEMBERSHIP OF THE CUMBERLAND GEOLOGICAL SOCIETY AT 31.12.77

Year of admission	Ordinary			Associate		Institutional	Total
	Male	Female	H & W	Male	Female		
1959	5	1					6
1960	1	2	1				5
1961	3						3
1962	16					1	17
1963	4						4
1964	3					2	5
1965	6	3				1	10
1966	11		2			1	16
1967	5	2		1			8
1968	5	1	3				12
1969	2		2	1		1	8
1970	6					1	7
1971	6		1	1			9
1972	6	1					7
1973	10	3	1				15
1974	9	8	3		1	1	25
1975	12	1	1		1	1	17
1976	14	2	7	10		1	41
1977	11	3	1	9	1		26
	135	27	22x2	22	3	10	241

In the absence of a 'Treasurer's Report' owing to the recent sad death of Mr.Herbert White the accounts were presented by the General Secretary, Mr.Tom Shipp. The balance sheet was circulated and the duly audited accounts were adopted.

The following Officers and Members of Council were elected to serve for the year 1978:

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

STATEMENT OF ASSETS AND LIABILITIES AT 31st DECEMBER, 1977

LIABILITIES	£	ASSETS	£
Subscriptions paid in advance	4.00	Moneys in hand and at Bank	598.96
		Duplicator	8.00
		Typewriter	4.00
		Estimated value of publications in stock at 50% of selling price	1170.00
Balance, being excess of assets over liabilities	1776.96		
	£ 1780.96		£ 1780.96

THE CHARLES EDMONDS MEMORIAL FUND

Balance at Bank on 1.1.77	12.43
Year's interest on 3½% War Stock (Nominal purchase value £146.25)	5.10
Bank Interest on Deposit account	.68
	£ 18.21

CUMBERLAND GEOLOGICAL SOCIETY

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDING 31st DECEMBER, 1977

EXPENDITURE

(1976) £		£
(42)	Stationery, materials, membership cards etc.	59.01
(5)	Telephone calls	9.21
(64)	Postages	79.66
(2)	Subscriptions to other Societies	4.00
(112)	Printing: Proceedings	285.00
	Offprints	75.00
(16)	Lecturers' expenses	41.00
(-)	Hire of films	19.96
(5)	Advertisements	-
(5)	Room Hire, affiliation fee	26.70
(1)	Wreath	4.30
(1)	Photographs	-
(4)	Refunds: Overpaid subs.	-
	Overpayment on Proceedings	1.60
	Annual dinner a/c	5.80
(-)	Loss on Annual Dinner	7.60
(-)	Purchase of library book	5.36
(-)	Purchase of books on behalf of members	18.56
(2)	Bank commission	3.10
(698)	Balance 1.1.78	
	Current account	81.61
	P.O.not yet presented	1.30
	Deposit account	541.10
	Cash in hand	1.95
		£ 1244.82

INCOME

(1976) £		£
(283)	Balance at Bank 1.1.77	
	Current Account	100.63
	Deposit Account	609.43
	Cash in hand	8.14
(263)	Subscriptions:	
	Arrears: 5 @ 1.25	
	1 @ .75	
	1977: 1 @ 1.00	
	1 @ 1.26	
	146 @ 1.25	
	19 @ .75	
	20 @ 2.00	
	1978 3 @ 1.25	
	1 @ .25	263.51
(-)	Receipt on annual dinner	5.80
(10)	Surplus from annual dinner	-
(24)	Donations and contributions towards film hire	9.05
(47)	Refund of Income Tax on covenanted subscriptions	55.08
(339)	Sales of Society's publications	135.07
(-)	Sales of books to members	24.75
(27)	Bank interest on deposit account	33.36
		£ 1244.82

18th ANNUAL GENERAL MEETING

The eighteenth Annual General Meeting was held on 14th February, 1979, at the West Cumbria College or Science and Technology, Workington, under the chairmanship of the President, Mr.E.H.Shackleton.

GENERAL SECRETARY'S REPORT

Membership.

During 1978 membership numbers maintained their slight upward drift. By the end of the year the Society had the following numbers and categories of members. (Those joining in 1978 shown in brackets).

Ordinary	162	(7)
Husband and Wife joint	24x2	(2x2)
Associate	30	(9)
Institutional	12	(1)

The total number of members, in all categories, has risen from 241 to 252, a net increase of 11 over the year. Eight members have resigned or allowed their membership to lapse, and two have died. It is with sadness that I report the deaths during the year of Bob Hewitt and Frederick Rothwell. Bob did sterling work as Excursions Secretary in the Society's early years, whilst Wing Commander Rothwell, after retiring to Portinscale was a staunch attender at meetings until illness overtook him.

There has been little change in the number of members paying by banker's order (82) and making payments under deed of covenant (74), but the Society is still able to recover over £50 from the Inland Revenue, making a useful contribution to its general funds. Once again the Society is indebted to those members and others who have helped to minimise its postal bill by delivering circulars to neighbouring members and enclosing stamped addressed envelopes with letters requiring a reply.

Meetings

There have been six indoor meetings during the year.

1. The Annual General Meeting held on February 15th, 1978 at the West Cumbria College, Whitehaven. This was followed by a Members' Evening, with exhibits, photographs and colour slides. 19 members and 2 visitors attended.
2. A lecture 'The Deep Structure of Northern England' was given by Professor M.H.P.Bott at the Derwent Centre,

Cockermouth on March 22nd., 1978. 31 members and 9 visitors attended.

3. A lecture 'The History and Exploitation of Potash in Northern England' was given by Mr.P.J.Woods of Cleveland Potash, at the West Cumbria College, Whitehaven on October 4th, 1978. 22 members and 4 visitors attended.

4. A lecture on 'The Background of Dinosaurs and other Fossil Vertebrates' was given by Dr.D.H.Rayner at the Derwent Centre, Cockermouth on November 8th, 1978. 35 members and 5 visitors attended.

5. A lecture 'Some observations on Modern Glaciers' by Dr. H.Lister at West Cumbria College, Workington on December 6th, 1978. 20 members and 6 visitors attended.

6. Films: 'The Earth Beneath the Sea', 'History Layer by Layer' and 'Beneath the North Sea' at the West Cumbria College, Workington on January 17th, 1979. 32 members and 6 visitors attended.

Attendances at these meetings have averaged 32 per meeting during 1978 as compared with 38 in 1977.

The Annual Dinner was held at Hundith Hill Hotel, Lorton Vale, Cockermouth on April 14th, 1978. The Guest of Honour was Dr. Winifred Tutin (Pennington) who spoke of her work in palynology. We are also indebted for the success of this function to Mr. and Mrs. Hayton and their staff, to the President and the Bennett brothers for table decorations, and to Mr.Dodd for organising the event.

Council has met on five occasions, and enjoyed the hospitality of Messrs. Dodd, Cockersole and Shipp. The Editorial Sub-Committee has met once.

Publicity for Society functions has been freely given by Radio Carlisle, The Times and Star, Cumbria Tourist Board and 'Copeland Diary'. The Society reciprocates publicity with The Geological Society, The Geologists' Association, The Yorkshire Geological Society, The Liverpool Geological Society, The Westmorland Geological Society and the Eden Field Club. In addition, our Members who wish to attend functions of any of these Societies are able to do so freely by prior arrangement with the respective secretaries.

Conclusions.

Once again, this has been a satisfactory year, with a programme of events that appears to have been well received by Members. May I extend by thanks to fellow Officers, Council Members and others who have contributed to the progress of the Society in 1978.

T. SHIPP

HONORARY TREASURER'S REPORT

The end of 1978 sees the Society with a satisfactory total of £936 in the bank, including cash in hand. Financially, it has been a quiet year, however, despite a net increase in funds of £338.18.

Subscription income for the year has only marginally increased over 1977 at £268 compared with £264 (membership reached a peak in 1976 and has held at that level for the last two years). Sales of Society Publications during 1978 only reached £115.33, although strictly the income from the sale to Birmingham University of the reprints of Dr. Moseley's article should be included making £171.58 in total. Inland Revenue refunds in respect of deeds of covenant remain at the 1977 level of £55 whilst Bank interest of £46.04 on the deposit account has been received. Donations to the Society stand at £16.62 for 1978 and include a sum of £13.37 being the total receipts from the sales of specimens generously donated to the Society by Mr.G.S.Gowing.

Expenses for 1978 have, in general, been kept below the 1977 peak. Stationery, postages and telephone calls cost us a total of £131.83 compared with £147.88 in 1977, whilst films, room hire and lecturers' expenses cost us £65.44 compared with £87.66. The item of £21.86 shown against cost of printing is paper costs for a reprint of the 'Limestone Series' and further costs for this item will be met during 1979. The Society has not been involved in the publication of any 'Proceedings' during 1978 and the money accrued during this year should be sufficient to fund the next volume.

The Yorkshire Geological Society publication on the Lake District received popular support from our membership and advance orders for thirty copies were received and the books distributed at cost (£5), although the banking of the monies will have contributed to our Bank interest for the year.

Finally, I would like to express my sincere thanks to our Honorary Auditor, Mr.T.J.Dawson, for his help in analysing our accounts and for the patience and care with which he verified their correctness.

S.R.ALEXANDER

The following Officers and Members of Council were elected to serve for the year 1979:

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

STATEMENT OF ASSETS AND LIABILITIES AT 31st DECEMBER, 1978

LIABILITIES	£	ASSETS	£
Subscriptions paid in advance	5.75	Cash in hand and balance at the bank on 1.1.79	935.84
		Duplicator	8.00
Banker's order overpaid	1.25	Typewriter	4.00
		Estimated value of publications in stock at 50% of selling price	1142.00
Balance, being excess of assets over liabilities	2082.84		
	£ 2089.84		£ 2089.84

THE CHARLES EDMONDS MEMORIAL FUND

Balance at Bank on 1.1.78	18.21
Year's interest on 3½% War Stock (Nominal purchase value £146.25)	5.10
Bank Interest on Deposit Account	1.19
	£ 24.50

CUMBERLAND GEOLOGICAL SOCIETY

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDING 31st DECEMBER, 1978

EXPENDITURE

(1977) £		£
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(7)	Refunds	-
(8)	Loss on Annual Dinner	-
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(3)	Bank commission	3.52
(-)	Bank interest (charged in error - to be refunded)	.36
(597)	Balance at Bank 1.1.79	
	Current Account	59.98
	Deposit Account	870.14
(2)	Cash in hand at 1.1.79	5.72
		£ 1314.85

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(1977) £		£
(710)	Balance at Bank 1.1.78	
	Current Account	81.61
	Deposit Account	514.10
(8)	Cash in hand 1.1.78	1.95
	P.O.not banked	1.30
	Cheque not presented	5.28
(264)	Subscriptions:	
	Arrears: 1 @ 1.25	
	1 @ .76	
	1 @ .25	2.26
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ERRATUM

On pages 244 and 245 of Volume 3 (part 4), the captions of Plates 1 and 2 should be reversed.

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