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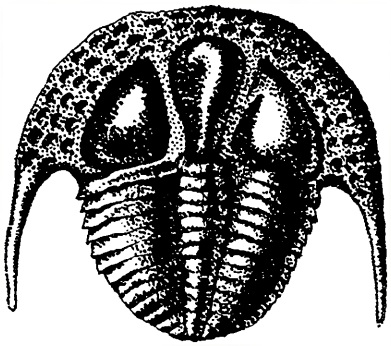

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CONTENTS

CORRECTION

Volume 3, Part 1, page 33.
Delete from the article, beginning at line 20,
"This title.....were studied".
end of line 25.

THE ORIGIN OF ESKER SEDIMENTS NEAR THURSBY, CUMBERLAND

by David Huddart

Abstract

This esker system is considered to be the result of sub-glacial fluvial deposition beneath the Scottish Readvance ice sheet. The two expansions, called the Torkin and How Hill, previously described as deltas into a proglacial lake are considered to have formed a sub-glacial esker delta and on an outwash plain respectively. The village of Thursby is located 10 km. S.W. of Carlisle at the junction of the A595 and A596 roads.

Introduction

There are three main hypotheses put forward for esker formation. The commonest theory is that eskers are the result of subglacial, meltwater deposition confined to a definite tunnel, (for example in Embleton and King 1968). A second mode of formation invokes deposition by subglacial or englacial meltwater as it emerges from the ice sheet into ponded water, (for example Synge 1950). In this case eskers would form by the annual addition of small mounds of of sediment as the ice front retreated. The end product is a beaded esker, with the summer melt period adding each bead and the winter period represented by the intervening gap. The third type of esker is the supraglacial or englacial esker which has only been observed from modern environments, (for example Price 1966).

The Geological Survey officers working in Cumberland during the 1920's favoured the second hypothesis and a quotation from Gregory (1922) sums up their ideas on esker origin: ".....eskers are the deltaic deposits of glacial rivers and their ridged form is due to their continuous deposition at successive positions by the slow recession of the river mouth during the retreat of the ice sheet". This was understandable as the glacial model they adopted had little room for stagnant ice, and recession with a continuous and active ice border was a fundamental concept. However, this resulted in a misinterpretation of the evidence, especially in the Brampton 'kame' belt to the west of the Pennines where many subglacial eskers which formed in tunnels were interpreted as forming extraglacially parallel with the ice front – for example the Low Plains, Carrholme and Hallbankgate eskers (Huddart 1970). Within the Carlisle plain their ideas on esker formation could have more application as the ice does seem to have retreated with a continuous and active frontal margin, for example the evidence presented by succeeding lower lake deltas to the west and along some esker crests there are expansions which could have formed as deltas. Of particular importance is the esker system around Thursby, to the south-west of Carlisle. (see figure 1).

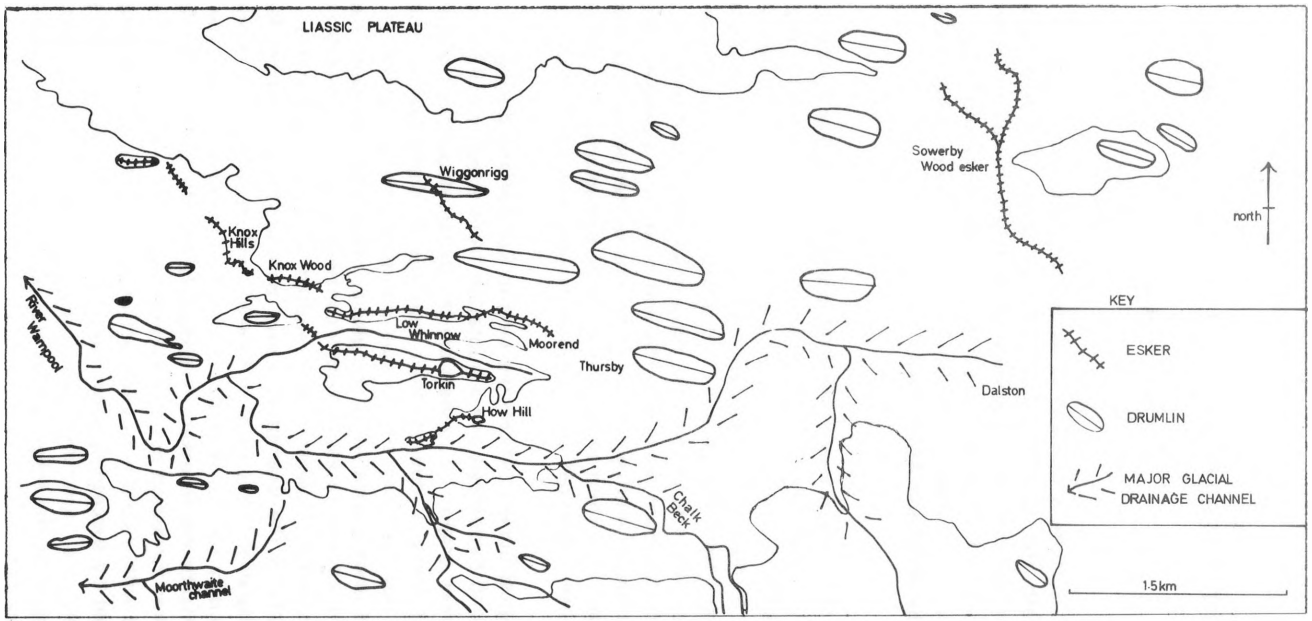


fig. 1 The esker system near Thursby, Cumberland

The Esker System

The great quantities of sand and gravel around Thursby were thought to be connected with the slowness of the retreat and with the topographic situation between the upstanding Lias plateau to the north and the rising ground south of the Wampool (Dixon et al 1926). The sand and gravel exhibits a typical esker morphology forming sinuous ridges, 5–7m above the general ground level, with undulating crestlines and occasional gaps in deposition. However, each esker, except the Sowerby Wood ridge, has somewhere along its crest an expansion, called an esker delta by Dixon et al (1926). The morphological elements that are useful in recognising esker deltas, according to these authors, are a lobate frontal margin and a steep and linear ice-contact slope. It is these expansions which make this esker system particularly interesting as they are comparatively rare. Furthermore, sectional evidence gives insight into the depositional processes and an attempt can be made to reconstruct the depositional environment.

A brief morphological description of the esker ridges will be given before the sediments are described:–

Sowerby Wood esker (NY367538 to 377514): this ridge starts as two distinct branches and runs from south of Newby West for 2.6 km to just south of Dalston Hall. It has a winding crestline, about 5m above the surrounding ground level which is between 45.7m and 53.3m in this area.

Low Whinnow esker (285516 to 323508): this feature runs discontinuously and sinuously, with an undulating crest, through the Knox Hills to Low Whinnow where it becomes more continuous, ending just north of Moorend.

Torkin esker: a ridge of sand and gravel extends westward from Thursby (325502) into an area of gravelly ridges of varying direction , north-east of Howend (316498). From this area the two hills, the Torkin (314503) and the How Hill (315498) rise fairly abruptly and are continued westward as ridges of much lower elevation. The Torkin esker extends as a long, narrow, steep-sided ridge parallel to the drumlin trend, from south-east of Shaw Rigg (293510) for 2.6 km to the Torkin, which rises 22m above the general level of the esker crest This hill is characterised by a steep slope to the west which trends NNE–SSW, with a tendency for lobe formation on the eastern slope. The hill top is flat over an area of approximately 58 sq.m.: a fact which suggested to Dixon et al (1926) that the hill accumulated as a delta into the 61.0m level of Lake Carlisle, with its surface at 58.2m O.D. However, this latter figure, along with other evidence was used by Anderson (1939a) to suggest that there was evidence for a 58.0m late-glacial sea level in the British Isles and, in a later paper (1939b), in the Northern Hemisphere.

How Hill esker: this esker consists of a continuous spread of sand and gravel from Howend (316498) to near Crofton Hall (306496). It has not a well marked esker morphology and Dixon et al (1926) suggested that this was because the ridge was modified by the 30.5m Lake Carlisle. The How Hill rises 16m above the general level of the deposit and its highest point reaches 48.5m O.D. A problem which worried the above authors was that '.....the mass has not the form of a flat topped delta and this is to be expected if, as seems

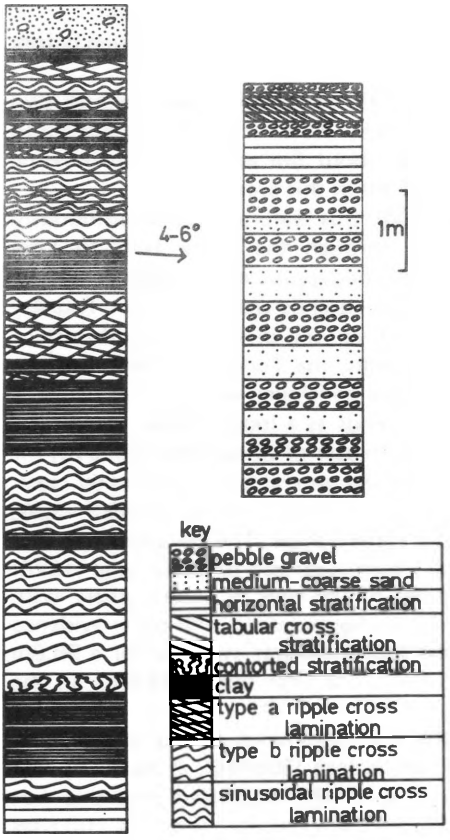
probable, its formation was contemporaneous with, and occurred in the same lake as the Torkin delta".

An attempt will be made to answer some of these problems and evidence will be presented which suggests that the two hills were formed in different glacigenic environments and that they need not have formed contemporaneously. This explains the height differential and the completely different sedimentary sequence.

Stratigraphic Succession in the Torkin

The 14.7m logged section can be divided into two distinct sedimentary facies.

Lower facies: this consists of 4.74m of pebble gravel, coarse and medium sand, with the sequence illustrated in figure 2.



The gravels are mainly imbricate, that is with pebbles overlapping like tiles on a roof, giving a palaeocurrent direction of 124° (towards the south-east) and generally fine upwards from pebble gravel at the base of each unit to coarse or medium sand at the top, although pebble gravel channels up to 17cm deep and 2m wide were noted. Each unit probably has temporal significance but whether this can be regarded as an annual cycle or a shorter time period remains uncertain. Succeeding these gravel units are horizontally stratified, coarse and medium sands, with thin pebble gravel units and a coset of small-scale, tabular, planar, cross stratified medium sands. Each set is 4-5cm thick and indicates deposition from the north-west.

This facies represents fluvial deposition largely in the upper flow regime with bedforms of longitudinal gravel bars or a plane bed with sediment movement. Although there is no evidence of ice control over deposition, it is thought that the sequence originated in a subglacial tunnel. Supporting evidence for this is that the palaeocurrent direction diverges from the average esker trend by only 19°.

fig. 2 The stratigraphic succession at the Torkin.

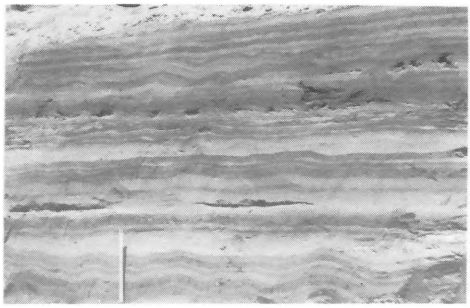
Upper facies: This consists of 8.86m of clays, silts and fine sands, dipping at between 4–6° to the east and is completely different from the lower facies. All the sedimentary structures, illustrated in plate 1, imply deposition in the lower part of the lower flow regime, with sedimentation from suspension being the dominant process. The thicknesses of the various sedimentary structures bear this out as parallel lamination and sinusoidal ripple lamination (the terminology of Jopling and Walker 1968) are the dominant structure types:–

Parallel lamination	*3.025m*
sinusoidal ripple lamination	*2.09m*
type 'b' ripple cross lamination	*1.0m*
type 'a' ripple cross lamination	*0.91m*
clay	*0.16m*

Type 'a' ripple cross lamination is confined to the upper part of the sequence, whilst the lowest units are dominated by parallel lamination and sinusoidal ripple cross lamination. This means that bed load transport was more important in the later stages of deposition, although suspension sedimentation was still important. The ripple geometry is summarised below and indicates that the origin of the stratification was a bedform of small-scale ripples:

sinusoidal ripple lamination		**type 'b' ripple cross lamination**
mean vertical form index, B/H (ratio of length to amplitude)	8.8	4.4
standard deviation	4.2	1.7
standard error of the mean	2.1	0.9
n=4		4

Small flame structures are common both in parallel laminated silt and on the upper surfaces of sinusoidal ripples where a coarser grain size overlies silt. This implies that the silt was in a plastic state and easily deformed by coarser material falling out of suspension. The sand had a lower porosity, was denser and tended to sink into the silt which was displaced thixotropically. Occasionally this type of distortion affects whole units and the contorted stratification can be up to 20cm thick. Small compaction faults which have 3 to 5cm throws are common and occasional unconformities are present which can be recognised by



1a – parallel lamination and sinusoidal ripple lamination. Scale 20cm.

1b – sequence of ripple drift, parallel lamination and contorted stratification.

one group of strata having a slightly lower or higher dip. These are caused by slight changes in direction of sediment transport and have also been recognised in the Baronwood delta sections.

This facies has many of the characteristics of glaciolacustrine bottomset sediments which have been described in Huddart and Tooley (1972), from the Cumberland lowland. These include:—

a) the sediment grain size, with clay, silt and fine sand.

b) sedimentary structures indicating the predominance of suspension sedimentation, with parallel lamination, ripple drift, contorted stratification and clay bands.

c) occasional minor unconformities

d) the lateral persistance of any one individual unit.

e) the absence of erosional features.

f) the possible annual cyclicity of units which end in clay bands or parallel lamination.

However, dips in glaciolacustrine deltaic sediments usually vary from between 20—30° in the proximal foresets, through the distal foresets, to 2—3° in the bottomsets. The sequence at the Torkin, dipping at 4—6° could represent distal foreset deposition but there is an inexplicable absence of the steeper and coarser foresets and the discordant topsets.

An origin without ponded water must be considered as a possibility even though the morphology imposes certain restrictions. An outwash fan environment would produce a similar morphological expression, with a meltwater stream depositing its load onto land. Difficulties are soon obvious, however, when the sediments are considered because a meltwater stream could not produce such a vertically and laterally uniform sequence of silts and fine sands without erosional scouring of any kind in a terrestrial environment. Clearly lacustrine deposition of some description is necessary to explain these sediments. This lake could not be held up between an ice front and dry land because there are no topographic barriers but it could have been a local feature caused by ice stagnation in the immediate vicinity of the esker. In this area there is no evidence for a regional Lake Carlisle at 61m as suggested by Dixon et al (1926), although in the Irthing valley, 21 km to the east there is evidence for such a lake.

The problem of lack of typical foresets must be considered. Axelsson (1967) defined the foreset slopes and foreset beds as only those parts of the frontal slopes and beds of aggradational origin where the dips are greater than 10°. If this definition is accepted then the Torkin has no foreset beds. However, a prerequisite condition for a river to produce a delta with a well developed foreset dip is that bed load transport should take place right down to the river mouth. If the depositing stream carried only a suspended load then no real foresets would be formed, which is supported by McKee's (1957) idea that the presence of clay and silt reduces the angle of foreset dip and increases the

bottomset development. With increasing grain size of the transported material, and especially with an increased ratio of bed load to suspended load the extent of the foreset beds increases. Their height is also dependent on the depth conditions and may be high where the original inclination was steep. The rate of deposition close to the foreset slopes and the rate of reduction of water depth therefore decreases with decreasing grain size of the suspended load and the sediment can be widely dispersed. Thus the height and angle of dip of the foreset slopes can be low, the contact between the topset and bottomset slopes strongly tangential and the grain size contrast rather slight where deltas are built out into shallow lakes, especially where the inflow is an underflow of the turbidity current type. It is therefore possible that the Torkin could have been built up in a lake by a stream having a very low ratio of bed load to suspended load. This concept is given credence by the fact that the lower half of the upper facies is composed largely of parallel lamination and sinusoidal ripple lamination; whereas in the upper half, bed load transport, reflected in type 'a' ripple cross lamination becomes of greater importance. This is to be expected with suspension being the dominant factor in bottomset deposition and bed movement more dominant on foreset slopes. However, the lack of 'normal' foresets is thought largely to be explained by the fact that deposition probably took place subglacially directly into the lake. After an early initial period of direct deposition into the lake the subglacial stream would be forced to climb, under hydrostatic pressure, up a reverse slope which would lead to the deposition of the coarser bed load material as backset beds (Davis 1890, Jopling and Richardson 1966). Thus the delta would grow both by forward and backward deposition. It is unfortunate that the stratigraphic succession was obtained from the middle of the hill and no sections were observed in the 'ice-contact' slope to verify this hypothesis.

A reconstruction of the depositional environment at the Torkin

An attempted reconstruction of the depositional environment is shown in figure 3. The lower facies must be related to the development of the esker ridge and probably represents deposition within a subglacial tunnel, as illustrated in figure 3A. An unconformity marks the change in grain size of the sediment and the environment changes markedly with a lake being initiated for some reason. This is most likely to have been a subglacial lake formed in a chamber and pool in the subglacial tunnel but it is possible that the lake was proglacial in origin, formed in a hollow bottomed on drift within a stagnant ice mass within the Wampool valley. The delta would then be built up as described above, with ripple drift units deposited from density underflows, caused by the sediment concentration, on the gentle foreset slope. The units of parallel lamination and contorted stratification would be due to suspension sedimentation when there was no bed load movement, and the clay bands and some of the parallel lamination could represent deposition during the late autumn/winter period of little discharge and sediment input. The ice margin must have been stationary in this area for at least ten years as there are

nine cycles recorded in the sediments. The uppermost unit of coarse sand and occasional pebble gravel probably represents an increased discharge in the subglacial river because of increased melting upstream, just before a major period of retreat which left the Torkin as an upstanding hill. It is therefore likely that the Torkin need not have been related to the lake level at the time of deposition of the esker delta as sedimentation took place subglacially.

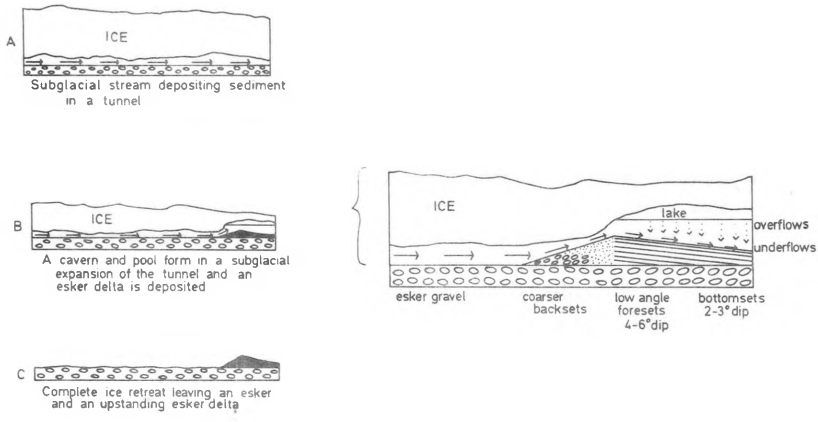


fig. 3 A reconstruction of the stages in the deposition of the Torkin.

Stratigraphic succession at How Hill

A small pit is situated at the eastern end of the How Hill esker and although only 7m of sediment is exposed it is sufficient to give some insight into the depositional environment. The hill is composed of a central gravel zone, 40m wide, which is flanked on either side by sands. On the southern side of the pit 4m of fine sands, silts and clays are exposed, dipping at 3–5° to the south-east and south. The sands consist of asymmetrical and sinuosoidal ripples, parallel lamination and thin clay bands, which sometimes show signs of injection into the overlying strata. The central gravel zone is poorly exposed, although a 4m section revealed at the base a metre thick unit of cross stratification, dipping at 28–30° and composed of pebble gravel in a granule gravel and coarse sand matrix. These foresets gave a resultant orientation of 51° (Steinmetz 1962) and change laterally upcurrent into sandy foresets. Above this unit are 3m of horizontal, imbricate, pebble gravel which gave a palaeo-current direction of 116°. There is some evidence of the close proximity of ice during the deposition of this unit as there is a 2m wide disturbed zone, thought to be the result of the melt out of a stranded ice block.

Origin of the sequence at How Hill

As the highest point on How Hill only reaches 48.5m, which is 9.75m lower than the Torkin, these sediments cannot have developed as deltas in the same proglacial lake as Dixon et al (1926) would have liked, and from the sediment succession it is suggested that deposition took place in a completely different environment. Both the lateral change in the facies from a central gravel core to fine grained sediments and the large-scale cross stratification are thought to represent fluvial deposition, the former a result of the change from a channel environment to over-bank deposition: the latter denoting the frontal edge of a longitudinal bar. The upper gravel unit truncates both the central gravel facies and the marginal sands, indicating a change in conditions. The sequence of environmental changes which is thought to have taken place is illustrated in figure 4 where initially it is thought sedimentation was in a subglacial tunnel, with the main flow confined to a major channel. Outside this

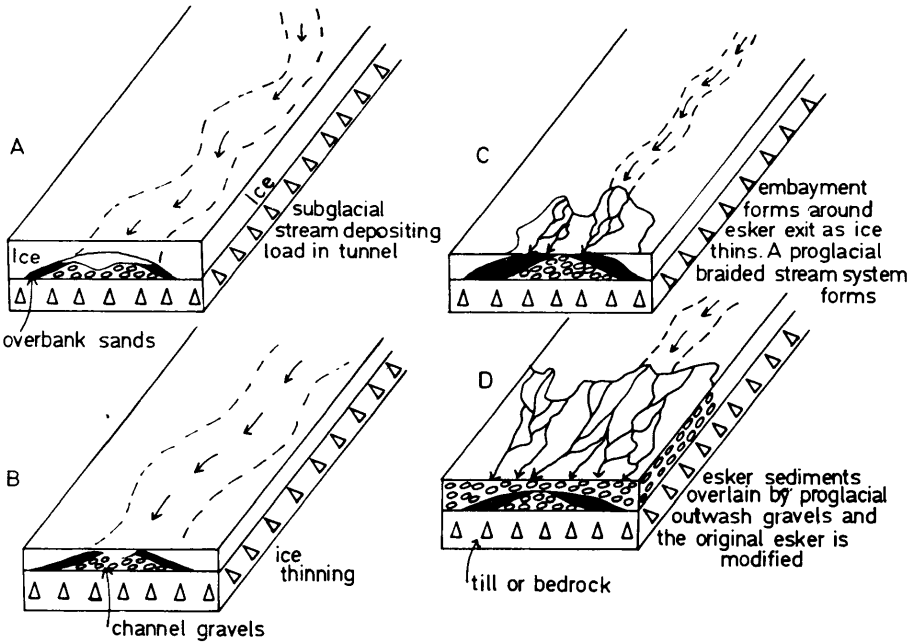


fig. 4 A reconstruction of the stages in the deposition of the How Hill

channel fine-grained sediment was deposited during periods of overbank flow. After a stage of ice downmelting and frontal retreat the surface esker deposits would be uncovered and proglacial gravels deposited. The ice front must have been retreating slowly at this time as a thick gravel unit was built up. This situation is reflected in the palaeocurrent directions where the unit of cross stratification only differs by 19° from the average esker trend, whereas the upper gravels depart by 46° from this trend because of the lack of ice control.

A stage of proglacial deposition also helps to explain the relative lack of freshness of this esker ridge.

Conclusions

The esker system west and north of Thursby is believed to be the result of subglacial, fluvial deposition beneath the thin, Scottish Readvance ice sheet which advanced approximately 5.6 km further east in the Carlisle plain. A lithology count of the pebble gravels at the Torkin and at Broomhills, 5.4 km to the north-east, revealed a high percentage of Criffel granite (12.3 and 14.5%), grits and greywackes (13.1 and 23.0%) Kirklinton sandstone (5.1 and 12.9%), coarse Bunter sandstone (1.5 and 1.3%) and Lower Calciferous Sandstone conglomerate (1.2 and 2.2%). This lithological assemblage has been found to be characteristic of Scottish Readvance sediments. The readvance ice margin is not thought to have been far to the east of this area and the two expansions known as the Torkin and How Hill, thought by Dixon et al (1926) to have accumulated in a proglacial lake, are considered to have formed as a subglacial esker delta and on an outwash plain respectively.

Acknowledgements

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[redacted]

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THE IGNEOUS COMPLEX OF CARROCK FELL

by Ian E. Skillen

Abstract

The rocks of the Carrock Fell complex comprise a series of gabbroic types, diabase and a series of acid rocks, chiefly granophyres.

Particular attention is paid to the contacts between the main rock types. The contacts prove to be of great importance in the discussion of the origin and the order of intrusion of the main rock types.

The origins of the rocks are discussed with particular reference to the hypotheses put forward by Clifton Ward, Alfred Harker and the Geological Survey. The latter hypothesis is favoured by the writer. This states that a stratified mush was injected, and that crystallisation of the inter-crystalline liquid was well advanced when one or more later waves of magma (with crystals) arrived, the whole complex still being hot.

The order of intrusion of the major rock types is discussed. The order of intrusion of gabbro first, then granophyre and finally diabase is favoured here. Evidence to support this does not prove to be entirely conclusive. However, evidence put forward by other workers is discussed and questioned.

Introduction

The Carrock Fell igneous complex occupies an area four miles long by one mile wide with its long axis trending W.10°N. The area has three 'natural' boundaries; the roads to the south and the east forming the south and east boundaries, and Carrock Beck forming the northern boundary. The western boundary is taken just to the west of Roughton Gill. The complex itself may be divided roughly into two parts, the eastern part with much exposure rising steeply to 2,174 feet (670 metres) at the summit, and the western part which is the larger one where the exposures are hidden and separated by wide areas of obscure ground.

The complex was first described by Clifton Ward (1876, page 16) who recognised three main rock types:–

(a) spherulitic felsite of Carrock Fell and Great Lingy Hill
(b) diorite of Miton Hill and Round Knott
(c) hypersthenite of Mosedale Crags.

In his opinion the rock types passed into one another and he concluded from this that their origin was one of metamorphism of the rocks of the Borrowdale Volcanic Series of the area. The evidence he put forward to support this was that the dip and strike and internal structures of the complex are similar to those of the surrounding volcanics. He also noted that xenoliths of Borrowdale Volcanic Series are included in the complex.

C.O. Trechmann in 1882 pointed out that the dominant pyroxene in Ward's hypersthenite is diallage and not hypersthene, and the rock is therefore more correctly called gabbro.

J.J.H. Teall in 1888 pointed out that the spherulitic felsite is a typical example of a granophyre in the sense of Rosenbusch.

T.T. Groom in 1889 pointed out the occurrence on Carrock Fell of tachylyte in thin veins, cutting the gabbro. He considered the tachylyte to be connected to the gabbro. He also confirmed the existence of all transitional stages between the acid granophyre and basic gabbro.

This idea of a passage of granophyre into gabbro seems to have been generally accepted at the time, until Alfred Harker produced his classic study of the complex in 1894. He described the rocks under the major headings of gabbro, granophyre and diabase. His explanation of the variations within the rocks was one of magmatic differentiation at two periods. The first was deep-seated and followed by the intrusion of gabbro, granophyre and diabase in that order. The second differentiation was in place, whereby the variations in the main gabbro came about. He advocated an application of Soret's Principle to account for the variation, suggesting that the earlier separating crystals, particularly ilmenite, were concentrated in the cooler parts of the magma adjacent to the margins of the body.

Radiometric dating of biotite hornfels from Mosedale Village by P.E. Brown and colleagues in 1964 confirms the conclusions obtained from the field relationships, namely that the complex is of Caledonian age and is geologically older than the Skiddaw Granite which lies close by to the south.

Field relations of the major rock types.

The rocks of the complex comprise a series of gabbroic, granophyric and diabasic types. The gabbros, virtually all containing quartz, range from ilmenite-rich melagabbro at the south and north flanks, through intermediate types to leucogabbro rich in feldspars. The mainly granophyric acid rocks vary greatly in composition. The diabase is formed of a suite of medium to fine grained basic rocks. It is the great diversity within and between the major rock types that makes the area such an interesting one. It is convenient to describe the general geology of the area under two headings, namely variation within each major rock type, and relations between the major rock types.

Internal variations within the major units.

Considerable variations are present within the major units, namely the gabbro, the diabase and the granophyre, and they will be described in that order.

THE GABBRO

The gabbro shows an approximately symmetrical variation about an axis running W.10^{o}N. This variation takes the form of differences in texture and

mineralogy. Indeed these differences allow division of the gabbro into distinct types which maintain their separate identities and contacts with each other for up to five kilometres.

Variations within the gabbro are best seen in the cliffs on the south of Furthergill Syke, Iron Crags and the hillside overlooking Swineside. They include the melagabbros, fluxion gabbros, banded gabbros, leucogabbros and Buck Kirk gabbros. Generally the melagabbros occur on the north and south flanks of the complex, separated by the fluxion, banded and intermediate gabbros from the central leucogabbros.

The **melagabbros** can be divided into two belts, both running east-west along the northern and southern edges respectively. The southern belt is in contact with the Skiddaw Slate Group to the south and the northern belt is in contact with the granophyre to the north. Description of this northern contact will be left until later.

The southern belt of melagabbro contains several modifications which are so intimately associated that they cannot be mapped separately. This belt includes ilmenite-rich gabbros (the ilmenite giving the rock a characteristically purple sheen), black gabbros (which are coarse and contain much hornblende giving the black colour), feldspathic gabbros and banded gabbros. These varieties are best seen in a belt 92 metres wide running along the contact.

To the west of Carrock Fell, where the exposure is often hidden, similar melagabbros are found.

The contact with the Skiddaw Slates is well exposed and runs roughly east-west. The contact can be traced quite easily starting from the hillside above the last house on the northern road out of Mosedale (grid reference NY356324). The gabbro in contact with the Skiddaw Slates is not particularly ilmenite-rich but is usually of the medium-grained type. Banded gabbro is seen in close proximity to the contact in several areas particularly to the north west of Mosedale. Another modification of the gabbro in contact with the Skiddaw Slates is seen in a gully to the east of Poddy Gill, where a very dark doleritic rock is seen in contact with the Skiddaw Slates.

An excellent traverse across the contact can be made starting from the last farm building in Mosedale on the Mosedale-Swineside road, showing the effect of the gabbro on the Skiddaw Slates. Ascending the fell the Skiddaw Slates are seen to be very dark and highly deformed. They are intensely folded, and graded bedding present in places allows the attitude of beds to be determined. The beds dip steeply, and due to recrystallisation become tougher (breaking with a conchoidal fracture) as they are traced uphill. The folding, being so intense, has resulted in the limbs becoming parallel (isoclinal), the cleavage being parallel to the axial plane of the folds. Higher up the fellside hornfels containing occasional garnets occurs and at the contact with the gabbro a great deal of biotite is present, although cordierite and andalusite are absent.

Another variation observed in the melagabbro is one seen above the gully already mentioned. Here the gabbro has inclusions of a vein-like nature, some

measuring up to 13 cm. wide by 3.7 m. long. Above and below is a coarser pegmatitic gabbro. Feldspar is dominant in places having an irregular and clotty distribution and almost vein-like in places. The long drawn out material is probably a xenolith of lava. The vein-like or clottish feldspar may have some connection with the xenolith which has obviously been drawn out by the gabbro, with its long axis parallel to the general trend of the gabbros. The feldspar and pegmatitic gabbro probably occur in association with the xenolith due to the partial assimilation of the xenolith. The feldspar becomes less abundant further away from the xenolith. This phenomenon is not seen elsewhere in the area even when xenoliths of lava do occur. Thus no firm conclusion can be drawn at this point.

No evidence of a fault (as suggested by Harker and Ward) is seen on this contact. The southern melagabbro is in contact with the leucogabbro on the north for most of its extent. Towards the west the leucogabbro gives way to the Buck Kirk Gabbro. The contacts are seen in a few places only and prove to be rapidly merging.

The northern belt of melagabbro is more readily divisible into three main types, namely the ilmenite-rich gabbro in contact with the granophyre to the north, the banded gabbro and the fluxion gabbro. The banded and fluxion gabbros, both ilmenite-bearing, form fairly distinct strips, both running roughly parallel east-west. These, however, have not been mapped as separate entities.

The **banded gabbro** consists of alternations of layers of light coloured feldspathic constituents and darker ferromagnesian constituents. As stated above, ilmenite is present. The bands vary in thickness from very fine (1 mm.) to about 2 cm thick. The strike of the banding is roughly parallel to the longitudinal axis of the complex, and dips with a high angle to the north, in contrast to the dip of the gabbros which appear to be inclined sheets lying parallel to the same axis dipping to the south. This is an easily distinguishable rock in the field, the banding being often well displayed on weathered surfaces.

The **fluxion gabbro,** to the south of the banded gabbro, is finer grained and carries a larger proportion of ilmenite than the banded gabbro. It has a distinct foliated texture and weathers very distinctively giving almost ripple-marked surfaces. Xenoliths do occur though not as commonly as in the southern melagabbro. They are best seen, in the northern belt, at Iron Crags. Here the xenoliths of lava are small, at most measuring only a few centimetres. The lavas are extremely baked, with contacts that are very sharp and distinct. The gabbro shows only minor modifications here, with fining of the crystals only in the immediate proximity of the contact.

Melagabbro also crops out elsewhere in the area. It is seen in contact with the Skiddaw Slates in the Grainsgill Beck area, and Arm o' Grain. There is quite an extensive outcrop of ilmenite rich melagabbro in the Roughton Gill area between the north and south veins, but it is highly altered in most exposures due to the extensive weathering and hydrothermal activity in this area. The best exposures of melagabbro in this area are seen in the stepped waterfall which forms a cliff about 200 feet (60 metres) in height.

The **Buck Kirk Gabbro** derives its name from a cliff on the west of the road running north from Mosedale. The rock is a medium grained, grey quartz gabbro previously called the Quartz Gabbro by Harker. In the well exposed eastern part of this area, the Buck Kirk strip is in contact with the leucogabbro to the north and south. In the western area the leucogabbro gives way to the melagabbro in the south and to the fluxion gabbro in the north. The contact with the leucogabbro to the south is transitional, taking place over about 5—10 metres. Again to the north the contact is transitional, the Buck Kirk merging into the leucogabbro in a distance of 20—30 metres.

The **leucogabbro** occurs in two belts separated from each other by the Buck Kirk Gabbro. The southern leucogabbro is a thin strip, some 50 metres wide running parallel to the trend of the complex for about 1.2 kilometres. It has a well defined sharp contact with the melagabbro to the south and a gradational merging with the Buck Kirk Gabbro to the north. This northern contact is characterised by a slight reduction in grain size towards the Buck Kirk Gabbro. This decrease in grain size of the leucogabbro is readily observed in the field, and consequently this northern contact though transitional is easily traceable. In contrast the southern contact although sharply defined is not readily traced. One of the characteristic features of this thin belt of leucogabbro is the absence of jointing, so characteristic in the Buck Kirk Gabbro.

The northern leucogabbro crops out, to the north of the Buck Kirk Gabbro, around White Crags. It is a coarse, black and white spotted rock, making it perhaps the most easily recognised type among the gabbros. The outcrop on White Crags is about 250-300 metres wide, decreasing eastwards until it disappears under the scree on the eastern cliffs. Westwards the leucogabbro loses its identity, being gradually replaced by fluxion gabbro and banded gabbro around Iron Crags. This northern belt and the southern belt are very similar in their mineralogy and texture, and like the southern belt the northern belt shows no internal variation or jointing. No modification exists in the northern leucogabbro in relation to either of its contacts.

THE DIABASE

The name diabase has caused much discussion among geologists. The representatives of the gabbroic rocks which fall within the limits of the medium grain size group should logically be termed microgabbros, by comparison with microgranite or microdiorite. Unfortunately the logic of this was not realised sufficiently early and two other names are in vogue at the present time. In Britain many petrologists use the name dolerite instead of microgabbro. In America 'diabase' replaces 'dolerite' but in this country, in spite of a veto by the committee on Petrographic Nomenclature, some petrologists use the term in the same sense as Rosenbusch did for pre-Tertiary dolerites. At present in this country a diabase is understood to be a rock of doleritic composition which is altered to such an extent that few of the original minerals have survived.

The name was first put forward by Harker (1894) and retained by the Geological Survey in their latest memoir on the area. Thus it is convenient to

retain this appellation of diabase for the suite of medium to fine grained rocks comprised of pyroxenes, hornblende (of secondary origin only) and highly altered plagioclase.

The diabase occupies a belt about 350–400 metres wide running along the north flank of Carrock Fell, dividing the Carrock Fell granophyres from the Rae Crags Granophyre following the general trend of the complex. The belt widens to encompass both Round Knott and Miton Hill, before dividing into two narrower belts which run to the north and south of the Great Lingy Hill Granophyre.

The diabase has a variety of colours and textures. In Brandy Gill the southern strip of diabase is variable throughout the outcrop from a coarse-grained dark coloured rock, to a finer grained, relatively light coloured rock. Here in the diabase jointing is prominent, the joints dipping at 56^{o} to the west. In this locality the diabase is in contact with the granophyre. This contact is characterised by a coarse, grey rock which may be a modification of either the diabase or the granophyre. No knife edge contacts are present. This grey variety of rock is not seen elsewhere. To the north of the granophyre the northern strip of diabase is exposed. Again the diabase is jointed and in contact with the granophyre. The jointing dips in exactly the same direction as that seen in the southern strip, but in this locality the diabase is banded, the banding running parallel to the contact dipping slightly to the north. The granophyre is veined with diabase close to the contact, the vein running parallel to the valley. The banding is perpendicular to this, and it takes the form of rapidly alternating dark ferromagnesian and light feldspathic bands. The dip and strike of the bands vary greatly throughout its outcrop, e.g.

Locality	Dip	Strike
Brandy Gill	approximately vertical	80^{o}
Round Knott	$50^{o} - 55^{o}$	85^{o}
Round Knott	65^{o}	184^{o}

The diversity of the diabase led Harker to state "In both rocks (diabase and gabbro) the texture is very variable. The rock on Miton Hill itself often assumes the coarsely crystalline characteristic of a gabbro, while many specimens from the crags in the gabbro area would, if taken apart, be designated 'diabase'." (Harker 1894 page 324). The southern strip is seen again in Arm O'Grain but is not seen to crop out to the west of this locality. The exact extent of the northern strip is open to conjecture, very few exposures being in evidence. One exposure is seen in the extreme north west of the area where diabase crops out at the head of Clints Gill. Here the diabase is grey in colour and highly weathered. Although no contact is evident here, it is one of the very few *in situ* outcrops in the area. Presumed glacial debris is evident at the heads of both Clints Gill and Blea Gill and this leads to confusion as to the exact extent of the diabase in this area.

This lack of good exposure and the resulting conjectural boundaries does not help the determination of age relations and order of intrusion. Like Harker (1894b) the writer has noticed the general absence of veining of the diabase by

granophyre in contrast to the veining of the gabbros by the granophyre. From this field evidence Harker supposes the granophyre to be younger than the gabbro. The Geological Survey apparently located veins of granophyre in the diabase at Round Knott, and this would seem to make the granophyre younger than the diabase also. More recently the writer has seen such veins cutting both diabase and granophyre in one specimen, thus casting doubts on veining as relevant field evidence for the relative ages of the rock types mentioned.

THE GRANOPHYRE

One of the best known British examples of granophyre is that which occurs at Carrock Fell. There are three major outcrops of granophyre, namely the Carrock Fell Granophyre, the Great Lingy Hill Granophyre and the Rae Crags Granophyre, separated from each other by the diabase. Their general lens-shaped outcrops and parallelism of strike with the general trend of the Carrock Fell Complex as a whole, and the similarity of these neighbouring masses, justifies the consideration that they are a connected group.

The one most easily studied is that which builds Carrock Fell itself and extends westward in a wedge-shaped outcrop nearly as far as Round Knott. The granophyre here is quite diverse, varying from a normal granophyre, best seen on the summit of the fell, to a basic granophyre at the southern flanks. The granophyre in this locality is well exposed and exhibits characteristic jointing. On the summit of the fell this jointing is well displayed giving a "book of leaves" appearance. The major joints dip 80° to the west, strike 170°. Although the different types of granophyre are distinctive they have not been mapped as separate entities.

A very good cross section of the various kinds of granophyre may be examined in a vertical crag at 1500 feet (460 metres) O.D. just north of Furthergill Syke. This crag is readily accessible by a ledge which runs along its foot. This section, already described by Harker (1895) and The Geological Survey, also contains the best exposure of the gabbro-granophyre contact. Description of this will be left to the section dealing with contacts. The southernmost part of the crag is a coarse melagabbro which persists for about eight metres. To the north it is in contact with the granophyre which is a dark, medium grained rock with an abundance of ferromagnesian minerals. This basic granophyre, given the prefix *mela-* by The Geological Survey due to an above average content of mafic minerals, forms a belt twelve metres wide, grading northerly within a further two metres into a somewhat less basic granophyre, but still termed a melagranophyre. This reddish brown rock with an abundance of mafic minerals persists for a few metres before passing into a normal granophyre which is much paler than the melagranophyre, being almost pink in colour. Northwards this passes into a green, mottled, reddish brown melagranophyre, the mottled appearance of which is due to green clots of ferromagnesian minerals. This belt persists for about twenty metres before it is in sharp contact with a grey, fine grained rock. This grey variety extends for some ten metres

before grading into the normal granophyre which makes up the rest of the crags. The knife edge junction of the melagranophyre with the grey variety could possibly indicate that the grey variety is a marginal variety of normal granophyre. However, this phenomenon is not present in the thinner belt of normal granophyre described above, where the contacts are gradational.

Towards the summit contacts can be seen between the normal granophyre and melagranophyre. One of the best contacts is seen about fifteen metres to the south of the summit of the fell. This outcrop shows the two distinct types of granophyre, normal and mela-, in contact with each other. Although the contact is not a knife edge junction, one type grades into the other within a distance of two or three centimetres. Thirty seven metres due south of this locality a much more basic granophyre is exposed, but its contact with the melagranophyre is not seen. Generally the granophyre becomes more basic towards the gabbro but it is possible that there are two distinct types of the basic or melagranophyre.

Granophyre is seen at certain points on the moorland of which Great Lingy Hill is the centre. This granophyre, separated from the Carrock Fell Granophyre by the diabase, has an easterly tapering outcrop. It is not well exposed except in the Roughton Gill area (Locality III on the sketch map). The granophyre is a light greyish coloured rock with dark clots of ferromagnesian minerals, some of which have weathered out to leave a rusty colour. Although not fresh, this rock has a resemblance to the grey variety of granophyre seen in the crags north of Furthergill Syke. In this area a cream-brown coloured granophyre crops out. No contact is visible between the two types, if indeed there are two types. The differences may be due to weathering and alteration by hydrothermal activity. The grey variety exhibits characteristic jointing which has a dip 30 – 40° to the west with a strike of 305°. In this locality the granophyre is in contact with a melagabbro rich in ilmenite. Downstream both types of rock become even more altered and identification becomes difficult.

The Rae Crags Granophyre lies to the north of the diabase outcrop. It is pale pink to red in colour, and is poorly exposed, the exact limits of its boundary being open to conjecture. Part of its boundary has been mapped along a change in vegetation. One of the few good outcrops of this granophyre, other than at Rae Crags, is in a gully of a southern tributary of Carrock Beck. Here, however, it is highly altered.

HARESTONES FELSITE

This occurs chiefly on the northern slopes of Hare Stones and around the Drygill Shales. It is a very pale grey to dirty white coloured semi-translucent rock with small phenocrysts of quartz and feldspar. The felsite borders the Drygill Shales and is seen in the gullies on the south of Dry Gill Beck. It is also seen to occur along the line of the Dry Gill Vein which marks the limit of its extent northwards in this area. The most westerly outcrop is seen in the north bank of Clints Gill where it has tapered to only a few yards giving the felsite a

wedge-shaped outcrop. The felsite in this locality may be mistaken for the mineral vein which marks the contact with the Borrowdale Volcanic Series. However, on closer inspection felsite is distinguished by the presence of small quantities of mafic minerals and the hardness of the feldspar, which is softer than the quartz of the mineral vein. It is also noticeable that the main mineral vein sends small offshoots into the felsite.

ARM O'GRAIN MICROGRANITE

The Arm O'Grain Microgranite occupies a small area some 250 metres upstream from the outfall of Arm O'Grain into Grainsgill Beck. It is found in contact with gabbro on its southern margin, and on first appearance its weathered nature leads one to believe it is a granophyre. However examination of the fresh rock proves it to be distinct from the granophyre seen elsewhere in the area. The contact is unusual in that acid enclosures are seen in the gabbro, whilst basic gabbroic enclosures are observed in the acid rock upstream of the contact. Thirty seven metres upstream of the contact an unusual rock, different from the immediate suite of rocks in the surrounding area, is found. It is a very dark, coarse grained rock cropping out in the north bank of the stream. In some parts it has a high proportion of quartz, comparable with leucogabbro, but in other parts quartz is almost absent, there being a predominance of mafic minerals. This may possibly be a hybridised rock but is quite a distance (37 metres) from the contact. Due to absence of outcrops outside the valley of the stream no definite conclusions may be drawn but it seems probable that the contact turns and runs roughly in the direction of the stream which would account for the distance from the first contact seen 37 metres downstream. The microgranite is seen to be in contact with the diabase just upstream from the junction of Arm O' Grain with a small tributary.

The very limited outcrop of the Arm O'Grain Microgranite is unfortunate, since its relations with surrounding rocks could throw some light on the relative ages of the rocks of the Carrock Fell Complex. Such contacts as are observable are interesting, the contact of the gabbro with the microgranite being unlike any seen elsewhere with acid rock, notably granophyre. Although the microgranite is seen to vein the gabbro in a similar fashion to that seen in the granophyre-gabbro contact on Carrock Fell itself, there appears to have been no chilling of the microgranite in proximity to the gabbro, nor does it show any marked basification towards the gabbro. The gabbro in Arm O' Grain does not possess the pegmatitic features displayed by that in contact with the granophyre on and around Carrock Fell. However, there is evidence of a hybrid rock further upstream, as mentioned in the previous paragraph.

The microgranite crops out for 200 metres upstream of its contact with the gabbro, where it is in contact with the diabase. Exposure is poor in this region and examination of the actual contact is not possible. Indeed there are few outcrops at all of diabase, but such as are seen show no intermingling of the acid and basic rock as was observed downstream. The diabase is a characteristi-

cally hard and tough rock, and examination of loose blocks (as was carried out at the gabbro-microgranite contact) revealed no further evidence as to its relation with the acid rock.

If, as is supposed, the microgranite belongs to the original granophyre magma then the evidence of the microgranite contacts will be important in a discussion of the relative ages of the major rock types.

Contacts between the major rock types.

The granophyre-gabbro contacts.

The best contacts between these two rock types are seen in the area around Furthergill Syke. This locality is interesting in that both rocks show modifications at the contact. This was first noted by Harker in his classic papers (1894 and 1895). His description of the contact was so comprehensive that little further work was done until the Geological Survey undertook a re-survey. One of the best exposures has already been described, namely the crags at 1500 feet (460 metres) O.D. a few yards north of Furthergill Syke. Here the typical marginal development of the northern belt of melagabbro is seen to be in sharp contact with the most basic granophyre. This typical marginal development of the melagabbro in contact with the granophyre is a rock which is dark in colour, very coarsely crystalline, pegmatitic in texture with abundant feldspar. As stated earlier, the granophyre is also modified at the contact. At this particular exposure there is within a few metres a noticeable increase in ferromagnesian minerals towards the gabbro.

Lower down, in the bed of Furthergill Syke another contact may be examined (Locality I). The stream flows over rocks which have well developed jointing. The outcrop is approximately ten yards across the stream by five yards upstream. To the south of the stream typical ilmenite gabbro is seen to crop out, gradually giving way to the hybridised, pegmatitic marginal modification of gabbro. In the stream bed this is in sharp contact with a medium grained acid rock which is seen to be most mafic near its contact with the gabbro. This acid rock is in sharp contact to the north with basified granophyre which is relatively coarser and more feldspathic. There is no chilling on either side of this contact. This basified granophyre is very distinct from the acid rock of the actual contact with the gabbro, and it grades into a more normal granophyre within a metre.

Granophyre-diabase contact.

This is best seen at Round Knott and to the north of the summit of Carrock Fell. At Round Knott the granophyre is separated from the diabase by a sheet of felsite, offshoots of which are seen to vein both these rocks. The contact is poorly exposed to the north of the summit of Carrock Fell in the Carrock Beck region. However, the contact may be traced from Round Knott, around the northern flank of the fell, and down to the crags on the east of the fell. The granophyre is markedly lighter in colour along this contact than seen elsewhere,

due probably to more advanced weathering. The diabase, however, is still fresh, due probably to its lower position on the hillside and consequent later uncovering. The diabase is variable along this contact becoming markedly coarse grained, almost gabbroic in places. One exposure shows the diabase to be pegmatitic in nature, and this may be a feature similar to the pegmatitic gabbro found to the south of the fell where granophyre is in contact with gabbro. The parallel is a tenuous one, for the phenomenon of pegmatitic texture of diabase in contact with granophyre is seen in the one small area only in marked contrast to the persistence of marginal pegmatitic gabbro along the whole of its contact with granophyre.

Discussion and conclusion

THE GABBRO

Clifton Ward (1876, pp. 11–27) was the first to put forward a hypothesis for the origin of the Complex. He postulated that it was produced by metamorphism of the Borrowdale lavas. This has been largely disproved both by Harker (1894) and The Geological Survey. The latter draws the conclusion that "Recrystallisation of the lava xenoliths was accompanied by local metasomatism, and that the process could go so far as to reproduce rock indistinguishable from the gabbro. The Buck Kirk and the banded types of gabbro clearly derived at least part of their substance from the Borrowdale lavas. On the other hand, in the leucogabbros there is no evidence of any such contribution by the lavas, though the compositions of the plagioclase and pyroxene in them do not differ from the counterparts in the other gabbros". (Memoir, 1968, p. 107).

The second major hypothesis put forward on the origin of the Complex was by Harker (1894, p.321) who extended Soret's principle. This called for a greater concentration of early-formed constituents in the cooler marginal parts of a magma chamber. In support of this he pointed out that the gabbro has more ilmenite and ferromagnesian minerals, and less quartz and feldspar, in belts near the northern and southern margins, than in the central belt. This distribution of the minerals throughout the gabbro is confirmed. However, Harker's extension of Soret's principle cannot be said to have received much recommendation from petrologists. There are many difficulties in detail:—

(i) The arrangement of the gabbro belts, which have a large degree of uniformity, together with some rapidly merging contacts, is extremely unfavourable to this hypothesis.

(ii) The distribution of the ilmenite in the northern and southern belts of melagabbro is not uniform as would be expected from this hypothesis. Many of the rocks owe their melanocratic characters to the abundance of late-stage hornblende.

(iii) If diffusion of titanium, ferrous and ferric ions toward the cooler

parts of the magma chamber did occur (as Harker states) it would be expected that concentrations of opaque minerals would be found around lava xenoliths which occur between the centre and margins of the gabbro. This is not the case. Therefore it cannot be considered that the whole body of the gabbro was at one time fluid in its present position.

The hypothesis of origin of the gabbro put forward by the Geological Survey states that it resulted from the completion of crystallisation of a mush of crystals and liquid in which some layering of minerals had already been produced before intrusion. It is stated that this hypothesis is not entirely satisfactory (as it stands it does not explain the relationship of the leucogabbros) and they suggest that a combination of their hypothesis and that of Clifton Ward is somewhere nearer the truth. This final statement is one with which the author agrees and which satisfies the information gathered, mainly that concerning contacts between the major types of gabbro. The transitional contacts between the gabbros, the lack of sharp contacts resulting from chilling (apart from the leugogabbro) and the absence of cross-cutting relationships between them suggest that successive injections separated by long periods of time did not occur. It would seem that a stratified mush was injected and that crystallisation of the inter-crystal liquid was well advanced when one or more later waves of magma arrived. This mechanism might account for the leucogabbro belts.

THE GRANOPHYRE

There is sufficient evidence to prove beyond doubt that the granophyre was intruded after the gabbro. This is shown by the widespread veining of the gabbro by the granophyre and the marginal modification of the granophyre in contact with the gabbro. The pegmatitic belt is regarded by Harker (1895) as a hybrid zone, a view which is confirmed by the Geological Survey and the writer.

The granophyres were thought to have originated, according to Clifton Ward, from a transformation of rhyolitic lavas. Although some xenoliths have been recorded in the granophyre, ample evidence with regard to chemistry and relict structures proves this not to be the case. It seems almost certain that the granophyres were intrusive at their present level. However, the succession on the crags to the north of Furthergill Syke needs some explanation. The available evidence, chiefly that based on the sharpness of the contacts, would suggest that these two belts of melagranophyre separated by normal granophyre existed as entities before emplacement into their present position.

THE DIABASE

The main contention about the diabase is whether it was injected before the granophyre (as the Geological Survey suggest) or after the granophyre as

Harker suggests. In the field relations of the rocks described above it has been pointed out that the evidence both authorities put forward is questionable. Both of these conclusions are discussed below along with other possible interpretations.

(i) Harker bases his evidence on the absence of veining of the diabase and the appearance which his map gave, namely that the granophyre was at one time all one outcrop, later divided up by the intrusion of the diabase. After his boundaries have been considerably modified by tracing them eastwards into the northern end of the crags flanking the fell on the east, and westwards as a narrow strip which splits and flanks the Great Lingy Hill Granophyre to the north and south, thus casting doubts on his interpretation.

(ii) The chief factor in suggesting the diabase to be earlier than the granophyre is the existence of granophyre veins in the diabase. Whether or not the veining is actually granophyric is doubtful, however. Separating the granophyre and the diabase at one point on Round Knott is a thin layer of felsite which is said to be later than both the granophyre and the diabase. It would seem plausible that these veins are related to this felsite and indeed a vein of felsite has been seen to cut both the granophyre and the diabase in one specimen.

(iii) Another interpretation of this felsite layer at Round Knott is that it is a chilled variety of granophyre, implying that the granophyre has been chilled against the diabase. This would prove the diabase to be the earlier of the two rock types. However, substantiating evidence of this interpretation is not available elsewhere, and indeed it is questionable whether or not the felsite is a chilled variety of the granophyre. The Geological Survey describe the felsite as "evidently emplaced later than either of the adjacent rocks, for it carries inclusions of minerals derived from the diabase, and it cuts sharply across the granophyre, sending branch veinlets into the latter carrying with them fragments of material from the diabase" (Memoir, 1968, p. 97).

(iv) The alteration of the plagioclase and the extensive development of hornblende from the pyroxene, justifying the term diabase, must be brought into consideration here. If the granophyres were injected after the diabase then this would be an acceptable source for the alteration. A similar development of hornblende is seen in the gabbros and is explained by the permeation of the gabbros by the hot late-stage solutions. Thus it would seem that the gabbro and the diabase have been affected by the same liquor. The sericitization of the plagioclase did not necessarily take place at the same time in the diabase. Though the gabbros show a certain amount of sericitization it is nowhere near the amount

shown by the diabase. The Geological Survey pointed out "It must be added that further hornblende, biotite, apatite and sericite were introduced into the gabbros in the Brandy Gill area in the course of the Skiddaw Granite metamorphism and hydrothermal mineralisation. Here it is difficult to distinguish alterations due to the late liquors of the gabbro from those due to the granite". (Memoir, 1968, p.109). Thus it may be possible that this later liquor affected the diabase as well as the gabbro, rather than the granophyre bringing about this effect. That the effects of the Skiddaw Granite did reach this area is shown by the presence of the felsitic layer at Round Knott. However, whether it could have enough effect to bring about the alteration resulting in the diabase is open to doubt due to the alterations seen in the Brandy Gill area not persisting outside that area.

The field relations described earlier, chiefly those seen in Brandy Gill and Arm O'Grain, indicate a younger age for the diabase. There is no evidence of any marginal modification of the granophyre in either of the areas mentioned similar to that where the gabbro is in contact with granophyre. This, however, is not conclusive due to lack of adequate exposure. It is the opinion of the author that the development of sericite and hornblende in the diabase would imply that it has been chemically altered by hydrothermal fluids emanating presumably from the Skiddaw Granite. This conflicts with the interpretations given by previous authors who state that alteration of the diabase has been brought about by late emplacement of the granophyre. To prove conclusively in which order the diabase and granophyre were intruded new evidence will have to be sought — not an easy task due to the critical parts of the area being hidden by peat and debris.

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[redacted]

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LANDFORMS AND LANDSCAPES IN THE CHEVIOT HILLS

by R. Clark

Introduction

The Palaezoic igneous rocks centred upon The Cheviot and the margins of their outcrop present complex landscapes. It could be easily assumed that the relief of the Cheviots is quite young, that though the igneous rocks are Devonian in age the relief is dominantly Cainozoic. Such a view would and could accommodate the influence of earlier structural events in defining preferred paths of erosion, and in determining lineations within the essentially younger relief. But the landscapes of the Cheviots are complex, episodic, and contain elements of extreme age. The purpose of this paper is to outline how that long and involved history has influenced the present scene.

Six themes are identified which can be represented in summary form by the following six questions.

What survivals and influences of the landscape of erosion which developed on the extinct Palaeozoic volcano can be traced?

What are the consequences of the subsequent period of Upper Palaeozoic sedimentation?

How did Variscan earth-movements influence later landscape processes?

What did Cainozoic tectonic activity contribute to present relief?

What have been the courses and results of Cainozoic morphological processes.

What additional touches have been applied in Pleistocene times?

Palaeozoic landforms on the igneous rocks.

The search for survivals of landforms which developed on the extinct volcano centres upon seeking evidence of its extent and bulk at the time of burial, and of recognising the shapes produced by erosion on the volcano.

Fig. 1. Map of northern Cheviots. Contour at 600 feet. Cheviot granite indicated by fine shading. Area of pre-volcanic rocks indicated by dots. Dotted lines indicate positions of Fell Sandstone (Lower Carboniferous) scarps. Margin of Cheviot igneous rocks shown by heavy line, dot–dash where faulted. Line of Section shown A – E.

Section across Cheviots denotes asymmetry of Cheviot granite. Broken line shows continuation near outcrop only of interface between igneous rocks and sedimentary mantle. ors – Old Red Sandstone, a – Andesites, rdc – Roddam Dene Conglomerate.

This evidence is located on the interface or unconformity between the igneous rocks and the younger sedimentary cover.

As the rocks lying on and against the volcano are Upper Devonian and Lower Carboniferous they date the unconformity and thus the processes which shaped its surface. Because many of the oldest cover rocks are terrestrial in character, and because of the nature of relief discussed below it is apparent that the extinct volcano was mainly fashioned by sub-aerial processes.

The main mass of igneous rock is about 20 miles (32 km) from north to south and about 22 (35 km) from east to west (Fig. 1). On all sides except the south-west this mass is bounded by younger sedimentary rocks. No limit to the previous extent of the volcano in those other directions can be inferred. Along parts of the periphery are slopes which truncate lava sequences hundreds of feet thick, and this suggests that the igneous rocks could have extended substantially further.

Only in the south-west are underlying rocks exposed and in this area there are spurs and outliers from the main igneous mass. Their eroded slopes show that the volcano extended at least a further six miles (ca. 10 km) west beyond its present main limits. Upper Old Red Sandstone strata overlap those spurs and outliers indicating their great age. Early erosion must have savagely fretted the western flanks of the volcano. These features are now partly exhumed from beneath the concealing sediments and appear to owe little to trimming by later processes. The alignment of some of these ridges and spurs across the direction of present drainage shows the influence of Palaeozoic relief on Cainozoic landscape development.

The exposed base of the lavas rises from about 500 feet (150 m) near Jedburgh to about 1700 feet (520 m) near Coquet Head. This slope may be a consequence of later earth-movement and cannot be used as clear evidence of a pre-volcanic slope. Irregularity on this overall slope is of more significance. In the upper valleys of Kale and Coquet the relief on the local sub-volcanic surface amounts to several hundred feet. It seems to consist of depressions and valleys in which lavas accumulated. It is possible that small areas where volcanic rocks have been eroded to reveal the older Palaeozoic sediments now display little – modified 'pre-volcanic' forms. It is also possible that the depression in the Silurian surface at Coquet Head has a Caledonoid (following the trend of the Caledonian structures) alignment which is also followed by valleys cut in the younger lavas. This structural guidance has clearly been extremely persistent.

The recognition of landforms of Palaeozoic erosion on the lavas in the Jed Water area can be matched elsewhere in the Cheviots. Three districts are selected from several such places along the fringe of the hills to extend this evidence. At Morebattle the embayment in the edge of the hills is floored by Upper Old Red Sandstones. The adjacent slope cut in the lavas represents a little-changed, and presumably recently-exhumed slope which passes under these Old Red rocks. The depth of the embayment, that is, the extent of the buried continuation of the unconformity is not known. What is clear is that the base of the volcano is here below the level of peripheral valley floors. This is

generally the case except in the west. At Morebattle the exhumed unconformity is truncated by a more horizontal surface at about 900 feet (275 m). This surface is interpreted as a late – Cainozoic erosion bench. Thus the unconformity below this altitude was exhumed after the cutting of this bench, the lowest parts being exposed quite recently. The present vertical extent of the whole exhumed facet exceeds about 600 feet (185 m).

Nearby at Cessford an outlier of Upper Old Red Sandstone sediments lies within a south-north depression which continues north and south as a valley in the lavas. The indication that the eroded andesite surface included such a depression leads to speculation that some present valleys, several of which also tend northwards, may also have been occupied by Upper Palaeozoic sediments now removed. That the base of the volcano is buried in the north allows the possibility that even the deepest valleys there were out in Palaeozoic time.

On the east of the hills near Milfield several facets afford consistent evidence. The hillside west of Milfield is a stripped sub-Carboniferous surface, its top truncated by Cainozoic erosion, its base still concealed by Cementstone Group sediments, small patches of which remain above the main outcrop. Residual exposed Palaeozoic relief is about 500 feet (150 m). Nearby, at Howtel, an outlier of Cementstones occupies part of a northeast-directed valley which matches the alignment of Variscan faults in and round the hills. It is possible that the southern side is fault-controlled but the northern slope appears to be a sub-Carboniferous eroded landform, its top cut across by later Cainozoic erosion but with its base exposed. The residual relief here is at least 300 feet (90 m) although there is the possibility that the attitude of this facet has been altered by Variscan tilting.

The basal Carboniferous Roddam Dene Conglomerate occupies an embayment and depression in the eastern flank of the lavas. The measurable sub-Carboniferous relief immediately adjacent to the conglomerate is about 600 feet (185 m). Heddon Hill, though somewhat modified by glaciation, is essentially a quite recently exhumed landform. The river Breamish crosses the southern edge of the sub-Carboniferous depression close to its base, and the present embayment in the hills south of Ingram is probably a wholly-exhumed continuation of the sub-Carboniferous surface. The East Hill ridge, so similar in shape to the projecting lava spurs and the hills in the upper Jed Water area, is also probably exhumed from beneath Cementstone strata. The Breamish has the same relationship to the local sub-Carboniferous embayment as has the Kale to the Morebattle embayment.

These examples of surviving Palaeozoic relief are taken from locations where cover rocks and lavas are in contact. Younger landforms within the hills, and the difficulties of extrapolating from beyond the contact necessitate other forms of evidence and this is provided by the Cheviot granite. That the present surface of the granite retains, except in its deeper valleys, a fair correspondence to its original form, is suggested by the nature of the uppermost granites and the survival of fragments of its roof. But the granite was exposed in Devonian-Carboniferous time and, as fragments in the surrounding sediments indicate, granite waste was carried away east to the Roddam Dene Conglomerate and west

e.g. to the Windy Rigg Conglomerate. At present the Roddam Dene Conglomerate is almost in contact with the granite outcrop and it is quite conceivable that it once overlapped onto the granite.

The rise of land from the upper edge of this conglomerate is steep, particularly so above about 1,300 feet (400 m). Below that break of slope features of the granite surface suggest that, at least locally, there has been little erosional inroad into the roof of the granite. It is thus possible that the rise from the conglomerate up to about 1,300 feet (400 m) approximates both to the sub-Carboniferous surface and to the roof of the granite. Consequently the steeper higher slope to Dunsmoor and Hedgehope cannot easily be explained, apart from the minor Pleistocene forms, as a later erosional form. In general outline it too may be a Palaeozoic feature, but it does not follow that all facets of the highest hills are so old.

Making minimal allowance for later eastward downtilting of the Cheviots but not allowing for the unknown depth to the base of the volcano in the north and east, the likely magnitude of relief of the extinct volcano when it started to be buried would be very similar to its present size.

The general conclusion is that, except for the faulted margins and changes in attitude determined by later earth-movements, the general bulk and extent of the present igneous massif was determined in Palaeozoic times. The selected evidence which has led to this viewpoint can be supplemented from several other places on the southern margin of the hills e.g. near Alwinton and Alnham.

The Upper Palaeozoic sediment cover

The sedimentary rocks in contact with the igneous outcrop are of Upper Devonian and of Lower Carboniferous age. Among the oldest of these are the conglomerates that tell of high-energy conditions and the initially-local derivation of contained pebbles. It has been noted that the granite was revealed at this time but that the general form of its roof remains. Subsidence to prevailing base-levels, or burial by younger rocks, or both would account for limited erosion and for preservation of the granite. Both appear to have occurred. Though earliest sediments were coarse and local most of the contact between igneous outcrop and its cover involves sediments which accumulated in near-horizontal sheets at or near sea-level and had a northern or northeastern origin Sediments from the Cheviots themselves became much subordinated to far-travelled detritus This is so even at the highest points where the overlapping sediments have survived.

It appears that Tournaisian sediments overstepped the Upper Devonian on the flanks of the hills. The general inference is that the subsidence of the old volcano allowed rapid burial. Palaeozoic relief soon ceased to act as a barrier to sediment movement and the whole mass was overwhelmed. The combination of rapid subsidence and rapid deposition allowed the relief developed on the igneous rocks to be preserved beneath its cover rather than reduced by sustained sub-aerial erosion. Before the lavas could be re-fashioned their cover had to be removed.

The significance of the Variscan (Carboniferous-Permian) earth-movements

The oldest igneous rocks of the Cheviots were laid on an irregular erosional unconformity cutting across Silurian rocks folded by Caledonian stresses. The regional variations in thickness of Lower Carboniferous rock tell of greater or lesser subsidence which was influenced by Caledonian structures. It is clear that in parts of northern England Carboniferous rocks had endured folding and faulting, uplift and erosion prior to the deposition of Permian rocks. The Bewcastle anticline and nearby Canonbie syncline with their Caledonoid trends exemplify this. In the Cheviot area the absence of rocks younger than the Carboniferous contributes to the difficulties in distinguishing between Variscan and later disturbances, probably in the Miocene.

The significance of Variscan orogeny to the present landscape is considerable. The compressive east-west stress affected the igneous rocks and their cover in a variety of ways which have subsequently acted to locate and influence morphological processes. Numerous lineations both in the igneous and in the cover rocks suggest the influence of older concealed Caledonoid structures though the folds in the Carboniferous rocks east of the Cheviots lie rather transverse to the earlier trend. There is also an important alignment with a more east-west trend.

Boundary faults define much of the southern and northern edges of the Cheviots and produce a quasi-horst massif. Exposed lava thicknesses along these faults are of the order of 1,000 feet (300 m) west of Wooler and also on the southern margin and this suggests that major masses of andesite lie, downfaulted and concealed, beyond the present outcrop.

The production of a quasi-horst by Variscan earth-movement was accompanied by alteration in the dips of the lavas. The lack of known lava succession and the poverty of exposures limit the inferences that can be made, but in the hills south of Branxton the lavas appear to dip east of south away from the northern fault-line scarp. Many streams follow faults and crushes produced by Variscan stresses, and intervening ridges reflect the lineations. Whether reactivation of movement in the Cainozoic was also effective is touched on below. It should be noted that faulting would disrupt the sub-Carboniferous unconformity which would henceforward include fault facets. This would also be the case with respect to those faults which were reactivated in the Miocene beneath the remaining cover, and it will be seen that there is some evidence that Miocene movement did occur.

Mesozoic developments.

Great erosion of Carboniferous sediments before Permian sedimentation is shown by the sub-Permian unconformities in northern England. There is no evidence from the Cheviot area to shed real light on landscape history from the Lower Carboniferous burial of the dead volcano to the Cainozoic. No sedimentary rocks and no erosional features ascribable to this stretch of time have been recognised. The absence of any rocks younger than Lower Carboniferous

(other than Pleistocene) in contact with the lavas suggests that whatever erosion and deposition took place in the Mesozoic may have failed to dispose of the Palaeozoic cover. Such evidence as there is rather points to the exhumation having occurred relatively lately.

Cainozoic landscape development.

The Cainozoic is a chapter in landscape history of which much can be speculated and postulated but little conclusively demonstrated. Reliance is placed in some measure upon extrapolation to the Cheviots of inferences from elsewhere.

An important specific feature is the Acklington Dyke which crosses the hills south of their highest parts. It is a member of the Mull dyke swarm and probably of Lower Miocene age. The highest points of its outcrop are over 1,600 feet (490 m) at Brownhart Law and over 1,750 feet (530 m) at Thirl Moor. These are close to the regional crestline. In the absence of any evidence of extrusion from this dyke it is clear that all land surfaces on which it outcrops are either younger than the dyke or were revealed by later Cainozoic exhumation or that facets of both type adjoin the dyke. The water-parting between the Coquet and Kale is crossed by the dyke and is partly cut in Carboniferous rocks. The present crest is thus younger than the dyke as a landform though its location was probably established earlier.

Robson (1964) described the displacement of the dyke along north-east directed faults, lateral movement being usual. It is likely that these faults originally affected the igneous rocks in the period of Variscan stress, the movement being transmitted from Caledonian faults in the Silurian basement. They are significant in demonstrating tectonic activity since the emplacement of the dyke. The horizontal component on the Thirl Moor Fault is over 3,000 yards (2,750 m). Robson suggested that the freshness of topographic features along the Shillhope Fault indicates a recent movement. This is an interesting point because Robson gave reasons for movement along this fault to have been earlier than the dyke emplacement. As noted, the local topography would not have been in existence then. Thus the structural influence probably made itself effective in one of two or in a combination of two ways. The fault-line located later erosion within the andesites, or it traversed and disturbed the subsequently revealed local andesite – Lower Carboniferous interface. This is not impossible for two parallel cognate faults bound a Lower Carboniferous outlier on the andesites less than two miles to the south. The behaviour of the Acklington Dyke as it crosses these two faults shows that the outlier dropped between them, that is, the sub-Carboniferous erosion surface was dislocated in the Cainozoic.

The manner in which the regression of the Chalk Sea initiated land surface and river systems in northern England has inspired speculation. In a recent appraisal Sissons (1960) stressed the simplicity of the major north-south watershed of northern Britain. For the present area he postulated a lateral regional crest which projected east from the main ridge and which divided Tweed –

directed streams from south-flowing streams. Sissons supposed this spur-crest to have been located where the present divide now fulfils the same function on the basis that the present stream pattern derives from that which followed the withdrawal of the Chalk Sea, and on the assumption that the primary divide would have been where the present divide is still located.

The regional crest from Peel Fell to the heart of the Cheviot Hills is on Lower Carboniferous and Silurian sediments, and on Cheviot andesites. This ridge, younger than the Acklington Dyke, does not appear to be much warped It may be a composite form, more than one base-level-controlled surface being represented, but if this is so there is little height difference between them. Faults which displace the Acklington Dyke do not disturb its surface and hence it is younger than the Miocene earth-movements.

It may be presumed that erosion during the early Cainozoic attacked Mesozoic and the Upper Palaeozoic rocks lying over the igneous mass. What progress in their removal had been made before the emplacement of the dyke and the subsequent occurrence of Miocene earth-movements is little known, though it can be inferred that exhumation had not proceeded below the level of the regional watershed. It is obvious that the dating of the Miocene movements depends on their relationship to the dyke and that away from the dyke this movement can only be presumed. It does however seem to be a reasonable presumption. It is possible that the boundary faults were reactivated but the present topographic features along these faults are more recent. If the interpretation of Miocene events in the Pennines is applicable to the Cheviots the effects would be to elevate the Cheviots in relation to the Tweed and Northumbrian lowlands thus accelerating exhumation.

There can be little of the present Cheviot landscape which could have been shaped in the early Cainozoic for the area higher than the highest outcrop of Acklington Dyke is small and part of that area may display sub-Carboniferous land forms. The locational relationship of present rivers to early Cainozoic streams depends partly on how the early streams responded to Miocene tectonic events, and partly on their response to structures, variation in rock type and to the form of the sub-Carboniferous unconformity met during erosion since the earth-movements. A basic control on later river development appears to have been the intermittent relative decline in sea levels and the extension of the landmass. The response has been the dominance of erosion, and its effects are several. They include the continued exhumation of the igneous mass, and the increased opportunity for Palaeozoic valleys diversifying the igneous-sedimentary interface to be reoccupied by streams. There would also be the opportunity for structures outcropping on the interface to influence landform development, and for the superimposition of streams from the cover onto the igneous rocks. Discontinuous falls of base-levels would lead to the formation of a flight of erosion surfaces. There has been an extension of streams outward so that the innermost valley and outermost path of the same stream are of different age. The horst-like form of the mass has been re-emphasised by the preferential erosion of the flanking sedimentary rocks.

Common (1954) identified a suite of erosional benches arranged quasi-concentrically and almost surrounding the Cheviot core. Among these Cainozoic benches and the steeper facets separating them are the residuals of the sub-Carboniferous surface. Discrimination between and description of individual bench surfaces require further refining but of their existence there can be little doubt. It is also unclear whether the area has been completely stable in the latter part of the Cainozoic, or whether the granite core and the flanking basins of thick Carboniferous sedimentation have moved differentially. As yet very little is known about variations in tilt and altitude between erosional benches within and beyond the hills which would provide evidence about warping.

To assume relative stability, however, permits some inferences about the ages of the erosional surfaces to be made. Important eroded benches and truncating surfaces at about 180 m O.D. (600 feet) in stable areas elsewhere have been related to major periods of stable base-level occurring at or about late Pliocene – early Pleistocene times (Evans, 1971, 285), although any bench at that height will have been subsequently modified and extended. In general it may be postulated that features below about 600 feet (180 m) have been shaped or exhumed during the Pleistocene. This lower ground includes certain erosional surfaces which appear to reflect periods of Pleistocene base-level stability. Those areas above about 600 feet may be regarded as shaped or exhumed by processes operating earlier and in relation to higher sea-levels, except that, of course, the higher area does not become immune from morphological processes and from modification of shapes broadly etched out earlier. Much Cainozoic and Pleistocene erosion would consist of the removal of the sedimentary cover.

The age distinction between the higher and lower parts of the area is important because of the consequences of climatic change during the late Cainozoic, the general trend from warm moist stable conditions to the sequence of cold – mild cycles which has characterised the Pleistocene. Higher land surfaces mainly developed in Miocene – Pliocene times have since been modified by the multiple sequences of processes associated with Pleistocene climatic fluctuation. The lowest part of the area has been shaped under three major influences, the progressively declining base-levels, the additionally lowered base levels of the cold episodes, and the corresponding glacial and periglacial processes.

It seems more likely that extensive deep sub-surface rock weathering occurred before the Pleistocene than in the limited durations of mild half-cycles in the Pleistocene. However the earlier development of deep-weathering would itself be influenced by the creation of new erosion surfaces perhaps particularly by the deepening of valleys and the local steepening of slopes in response to falling base-levels. The extent and intensity of deep-weathering would reflect the relative youth of outer lower areas and the modification of the higher areas.

In the Cheviots, thick residual masses of deeply-weathered igneous rocks occur on hills, plateaus, and in valleys. It can be shown that none of these masses is younger than the last glaciation. Whether they are all contemporary in initiation or overlap in course of development is not known. The present basal

surface is exceedingly irregular; it underlies some of the deeper inner valleys e.g. in Harthope, College, Bowmont catchments. It can be traced beneath steep hillsides in these areas. It underlies a variety of topographic situations in the Wooler Common area, and it is present on the summit of The Cheviot.

The minimal conclusion is that large masses of disaggregated altered rock have survived the last glaciation. It is also likely that much altered rock was removed during glaciation. Certainly local drifts contain a proportion of this material. The present distribution of residual masses argues for its once more continuous extent. Survivals on present valley sides in the higher parts of the hills confirm that these valleys pre-existed the last glaciation and suggest that they could be essentially pre-Pleistocene.

It is likely that landforms produced before the general climatic change and those sub-Carboniferous surfaces exposed in the same period were affected by deep weathering and hence it is unlikely that sound rock surfaces in the higher parts of the Cheviots are more than approximations to their earlier forms for depths of weathered rock have been removed from above them.

If the deeply-weathered rocks are associated with pre-Pleistocene climates and if the area below about 600 feet (180 m) was, except for exhumed facets, shaped during the Pleistocene then the main locations of deep weathering would be above 600 feet with allowance for the depth to which the weathering penetrated. Presently – known sites of deep weathering are so located.

Within the igneous outcrop there appear to be two types of anomalous river courses, the Kale with, in part, the upper Bowmont, and the lower Bowmont. The Kale is notable in that its path in the hills is markedly oblique to the linear watershed, and in that it runs in part parallel to the trend of Cainozoic erosion surfaces. The anomaly is compounded by the parallelism of the Kale to the Upper Devonian erosional depression at Cessford and by the Kale Valley floor being above the base of the Old Red Sandstone depression at Morebattle making it possible for the valley to have been cut in Devonian times. Among and near its headwaters there are exhumed hills and the upper Kale flows from this fretted edge of the hills into the main igneous mass.

It could be postulated that the Kale having been initiated at a higher level on sedimentary rocks was superimposed across the flank of the igneous mass and then drawn into an older valley during exhumation, and the way that the valley debouches into the Morebattle embayment supports this. The present obliquity could be explained in this way. But, if this postulate is discounted as requiring a long chain of events, the obliquity may be regarded as being a reflection of the original slope on which the stream originated, or as indicating the consequences of subsequent structural tilt, or both.

The Bowmont from Yetholm to Westnewton and the sinuous valley which runs from near Yetholm to Morebattle form the other major anomaly. It is peripheral to the core of the hills, and sub-parallel with the faulted northern margins of the andesites. It does not directly cross the erosional platforms along the northern edge of the hills but tends to parallel them. The Morebattle-Yetholm valley is in the form of valley meanders which may indicate that it carried very

large discharges. The valley appears to be cut into surfaces which now lie at about 900 – 1000 feet (275 – 300 m) and to have been in use until the last glaciation. In a more detailed examination (Clark, in press) it has been suggested that this route discharged Bowmont and Kale drainage, probably that of the Teviot, and possibly that of the Tweed prior to the opening-up of the Tweed lowland and the integration of the Tweed drainage system which was completed at the close of the last glaciation. The lower Bowmont valley is regarded as the result of superimposition from a sedimentary cover. The route persisted in the hard igneous rocks until the preferential erosion of sedimentary rocks, Cementstone Group particularly, laid bare the northern and eastern flanks of the Cheviots and led to the extension and abstraction of the Tweed system. However, it should be noted that the valley opens into the Morebattle embayment in the same way as does the Kale so that the idea of a Palaeozoic valley exhumed and reoccupied could be advanced for the lower Bowmont. In this case a complication is introduced by the coincident location of boundary faults and the Bowmont valley at Mindrum and at Westnewton. The north side of the Glen valley is probably a continuation of the Milfield sub-Carboniferous surface. It extends to Westnewton and shows that where the Bowmont leaves the hills Palaeozoic erosion had cut to a depth below the present valley floor, just as in the case of the Kale at Morebattle. Thus although superimposition provides a relatively simple explanation there are characteristics of the valley which could have been developed in a longer and more complex history starting with the erosion of the volcano prior to the upper Palaeozoic burial.

It is possible to recognise the products of the last glaciation (Devensian or Weichselian/Vistulian), only, for the effects of earlier cold periods have not yet been differentiated. Several detailed studies (Derbyshire, 1961; Clapperton 1969, 1970, 1971a, 1971b) have outlined the main consequences of this glacial event for landscape change. It does not seem necessary to reconsider glaciation in the present discussion. Other important characteristics of Pleistocene landscape development have already been indicated. It may be noted in conclusion that the surfaces on which some rivers now flow did not exist before the last glaciation. This is true of the Breamish after it has left the hills, the Glen, the Till, the Teviot below Eckford, and the lower Tweed. The degree of change cannot be clearly established, their courses during periods of glacially lowered sealevel are imperfectly known, but the recency of their present courses can be demonstrated convincingly. That the Till near Milfield runs on a surface of late glacial accumulation within a mile of a stripped Palaeozoic erosion facet possibly partly exhumed during the last glaciation seems to sum up the span and complexity of Cheviot landscapes.

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EXCURSION NOTES

EXCURSION TO THE BLINDCRAKE AREA, COCKERMOUTH

Director: T. Shipp, B.Sc.

Saturday, 19th June 1971

Discussion of the Geology of the Blindcrake area

The Lower Carboniferous commenced in the Cockermouth area with sub-aerial outpourings of basaltic lava over a land area of low relief thinly veneered with reddened conglomeratic material, possibly indicating hot arid terrestrial conditions. These "basement beds", which are certainly of Carboniferous age and quite distinct from the much thicker conglomerates of Mell Fell to the north east of the Lake District, underly much of the Lower Carboniferous south east facing escarpment which forms the northern side of the Derwent valley between Cockermouth and the village of Sunderland.

That the Cockermouth Lavas were quietly poured out on a land surface is shown by the fact that several flows each have vesicular tops and bottoms and fine-grained, almost doleritic centres in places, an absence of pyroclastic material, but some occurrence of scoriae, and local development of reddened earthy material or 'bole' showing contemporaneous sub-aerial weathering.

There followed a quiet submergence of the land surface below the transgressing Lower Carboniferous sea in S_2 times. There was probably a ridge of higher ground from the Lake District to the Isle of Man areas separating a westward extension of the Northumbrian Trough from more open sea to the south, and this is reflected by the Carboniferous Limestone of the Cockermouth area having more affinity with that of the Alston Block in the Northern Pennines than with those of the Egremont and Furness areas to the south. The quietness of the marine transgression in the area is shown by the absence at the base of high energy grainstones formed of granular material from which the finer fragments had been sifted away by violent wave and current action. In fact the series of beds exposed in Ghyll Beck, Blindcrake, are described by Edmonds and Shackleton as being deposited in a 'lagoon phase' and by Stabbins as representing deposition in a '(protected) shallow subtidal' environment. The first 20 metres or so of deposits are of calcareous silty or sandy shale, largely unfossiliferous, but containing in places fossilised ostracods (small crustaceans) and modiola (mussel-like lamellibranchs) indicating quite shallow water deposition adjacent to a land area of low relief. Eventually, after a brief re-emergence of the sea bed, deeper, clearer open-sea conditions resulted in the formation of relatively pure massive limestone (7th Limestone) containing fossils representative of an open marine regime. However, conditions were not entirely stable and a series of adjustments of surface level led to repeated shallowings and deepenings of the sea resulting in the alternations of sandstones and shales with limestones sometimes showing eroded, often potholed surfaces so familiar in the West Cumberland limestones, and to be seen developing at the present day on lime-mudflats in the Caribbean.

From the Cockermouth area eastwards towards the Pennines there was the added establishment of swampy forests similar in physical conditions, if not in plant species, to present-day mangrove swamps. Inundation of these Carboniferous swamp forests has led

to the formation of coal seams which increasingly appear intercalated with sandstones, shales and limestones in the Yoredale cyclothems eastwards from Cockermouth. The 'stepped' (scarp and dip slope) nature of this type of country reflects the differing resistance of the rock types in each cyclothem unit to erosion.

Excursion details.

About two dozen members and friends met at the Gill Yeat Inn, Blindcrake – surely one of the smallest pubs in the country – on a sunny Saturday afternoon. The director explained that the object of the excursion was to investigate the Lower Carboniferous rocks in the area and to judge, from their lithology, the conditions under which they had been laid down.

The first section to be visited was the upper part of Gill Beck (NY 149345) a few yards to the right of the road leading down from Blindcrake to Isel. Due to the overgrown and awkward access to the stream section, the party divided into two, one part led by Mr. Shackleton to the lower part of the Cockermouth Lavas, and the other led by Mr. Shipp to the upper part. Both parties worked up the stream bed, noting the variations in the Cockermouth Lavas, ranging from dark compact doleritic material, through vesicular spongy basalt to scoriaceous clinkery material, often in a highly decomposed state. The green infilling of some of the vesicles called for comment, some members being convinced that they had discovered a new source of copper. A mineralogical note on these from Mr. Morley Burton is appended at the end of this report.

Above the lavas there is an alternation of hard crystalline limestones and softer lime mudstones and shales which has led to the formation of a series of small waterfalls. Members found, while negotiating these obstacles, that there was a general increase of limestones and marine organic remains towards the top where the massive 7th Limestone occurs. The general dip was found to be about 10^{o} between west and north. At the top of the gill a short scramble out to the right brought the parties back to the road alongside the Gill Yeat Inn.

Opposite the inn a field gate gives access to a footpath leading to higher ground to the east. Members saw the fine outcrops of limestone towards the top of the hill giving a series of small tilted escarpments (shown on Pl. 5, page 156 in the Cockermouth Memoir). In about a mile, at the highest point, a very fine series of clints and grikes was investigated at a feature known locally as 'The Giant's Grave'. It was interesting to find these features very overgrown with moss and occurring partly within a small scrubby wood – a complete contrast to the much-publicised type area around Malham Tarn in the Yorkshire Pennines. To the west of the ruin of Thackray Cottage below the limestone scarp a small dry valley leads to a series of bumps and hollows in shaly ground which may have been coal diggings. Thin coal seams are recorded hereabout intercalated with limestones and shales and reminiscent of the Yoredale Series of the Northern Pennines. However, much probing by members failed to reveal any traces of coal. Whilst the more energetic members of the party were investigating the shale and limestone below the crest of the hill others took the opportunity of admiring the view of the north western part of the Lake District from what must be one of the finest viewpoints in England.

Whilst there were many details of the geology of even this small area which were not demonstrated during the excursion, even a superficial study was able to show that the onset of marine conditions in the Lower Carboniferous was far from the steady northward transgression assumed in some older textbooks. The area, lying on a ridge of raised ground in Lower Carboniferous times, was subjected to volcanic activity before being submerged, but even after submergence conditions fluctuated on both sides of the ridge leading to the very variable series of marine, deltaic or lagoonal and littoral deposits which constitute the Carboniferous Limestone Series in West Cumberland.

T.S.

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Note from M.F. Burton.

You might be interested in the result of a test I had done on a specimen of Cockermouth Lava from the bed of Ghyll Beck, Blindcrake. You will no doubt remember there was a "clinkery" boulder in the stream encrusted with a green mineral which I suggested later might be of chloritic material

X–ray diffraction tests on this green mineral suggest that it could be glauconite. the powder diffraction readings are as follows.

d	i
9.8	50
4.55	100
4.10	10
3.65	40
3.35	60
3.05	50
2.68	20
2.58	40
2.40	30
1.66	20
1.51	50

d = interplanar distance, Angstrom units
i = relative intensity

Non of the chlorites have indices similar to these.

There was another whitish powdery mineral along with the green one which turned out to be calcite.

WEEKEND FIELD MEETING IN UPPER TEESDALE

Directors: G.A.L. Johnson, Ph.D., F.G.S.
G. Larwood, Ph.D., F.G.S.

16th – 18th July 1971.

Some 28 members of the Society assembled on the Friday evening in the High Force Hotel near Middleton-in-Teesdale to begin what was to prove a most interesting and successful Summer Excursion. The joint directors were Dr. Johnson and Dr. Larwood both from the Geology Department of Durham University.

On the first evening, in an introductory talk, Dr. Johnson outlined the geology of the area and whetted the geological appetites of members with details of the excursions planned for the following two days. He explained how the Teesdale fault running up the valley is crossed near Langdon Beck by the Burtreeford disturbance running roughly north and south. This is regarded as a faulted monocline with a down-throw of 200 feet to the east. This results in a small exposure of Lower Palaeozoic rocks forming the Teesdale Inlier in the predominantly Carboniferous strata of the area.

The base of the Carboniferous in Teesdale is formed by the D_1 age Melmerby Scar Limestone while above this lies the Yoredale Series and higher still the Great Limestone is particularly well exposed. A very well known feature of the area is the intrusion of the Whin Sill which in these parts comes close to its maximum thickness of over 240 feet. The intrusive process giving rise to the sill persisted over an extended period of time and resulted in metamorphic change in the adjacent limestones. Important in this respect is the occurrence of saccharoidal marble or sugar limestone while garnets and wollastonite provide evidence of the temperature of the intrusion.

The speaker then turned to glacial times and referred to the unique arctic-alpine flora of Upper Teesdale round the new Cow Green Reservoir. Here the metamorphic sugar limestones mentioned above have given rise to a soil that has permitted the survival of the original floral suite that colonised Teesdale after the last glaciation.

Finally Dr. Johnson referred to the mineralization of the area with multiple vein systems and well defined zones of barytes and fluorite. Professor Dunham had shown that the mineralization began in Hercynian times but extended over a period of 180 million years. The speaker described how the famous Rookhope borehole was sunk in 1960 to test Professor Dunham's view that the mineralization arose from granite at depth, gravity anomalies suggesting this were already known. The bore penetrated the Whin Sill and the Carboniferous strata and reached the granite which was found to have a weathered surface overlain by a thin conglomerate. Therefore the granite pre-dated the Carboniferous Limestone and could not be the source of the mineralization which in fact was found to go through the granite and presumably to have a still deeper origin. The current view is that the granite formed a domed surface projecting up into the Carboniferous Limestone with peripheral impervious Palaeozoic slates serving to funnel up the mineralizing solutions into the limestone. The concept is of the mineralization process being very long drawn out and even continuing at the present time because a thin coating of fluorspar is sometimes seen forming on the faces which were worked by the 'old men' in the long disused mines.

On the Saturday morning the party led by Dr. Larwood first examined the outcrops of the Whin Sill below High Force. The Sill here intrudes into the Middle Limestone Group to outcrop at two different levels on each side of the river testifying to the presence of the fault running up the valley. At White Force and other points the features of the sill were examined:— the polygonal pattern of the columnar jointing in cross section; the baked and altered sediments above and below the sill; the alteration of grain size as an indication of the rate of cooling and the transgressive nature of the sill crossing at times from one horizon of the limestone to another. An interesting feature at one point was a 'raft' of baked siltstone within the thickness of the Whin.

The tip of an old mine in this locality yielded specimens of sphalerite, siderite and some light green crystals of dolomite.

Re-crossing the Tees our members examined a pavement of the Cockleshell Limestone' exposed by the river. This formation is so called because of the abundance of giant productids it contains. Crinoids and corals were also identified; in particular, Lithostrotion junceum and Syringopora. On the return upstream the successively older beds of limestone were examined as they were exposed by the general slight easterly dip of the strata. Reaching High Force itself the classical geological and scenic features were observed. The river plunges over the lip of the Whin Sill which here shows strong columnar jointing interrupted by two thin transverse layers of shale. Below the Sill at this point are shale and siltstone beds with the Tynebottom Limestone at the base. The intrusion of the Whin has been dated to early Permian times.

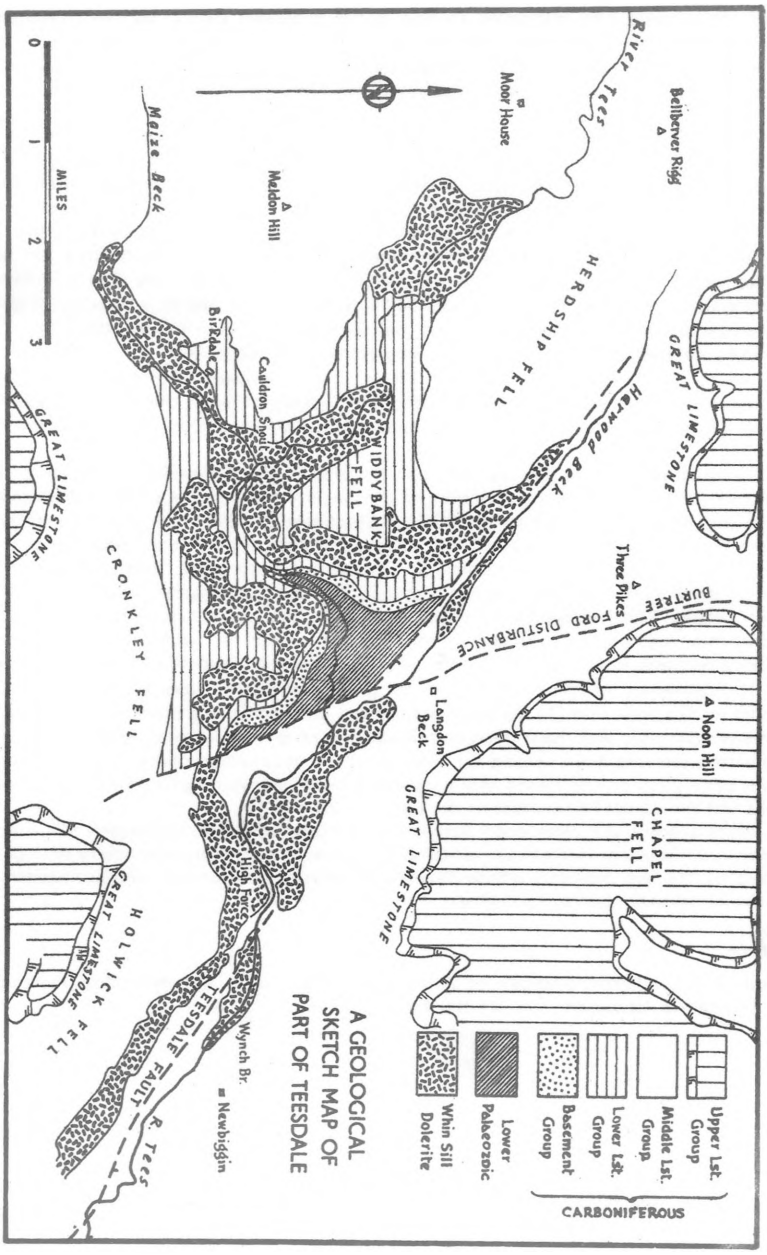
The morning was concluded by a visit to Hargreaves Quarry in the Whin close by. Here the considerable variation in crystal size was noted and laths of feldspar were found up to one inch in length. The unusual mineral pectolite – an hydrated aluminium silicate – was found on some joint surfaces. The typical radiating habit of the crystals was seen and good specimens obtained by the more athletic and venturesome members.

Following lunch the party proceeded in the cars to Langdon Beck and from thence toiled on foot in hot sunshine up to High Hurth Edge to examine a splendid outcrop of the Great Limestone which is regarded in this area as the base of the Upper Carboniferous. Below this the regular alternations of limestone, shale and sandstone forming the cyclothems of the Yoredale facies were well displayed. The fossils in this locality are mostly fully marine in nature and consist of corals and crinoids in the limestone and lamellibranchs in the shale, but there are occasional plant remains in the sandstone beds. Sitting down in the afternoon sunshine some of the members learnt from Dr. Larwood about the various theories put forward to explain these rhythmic deposits He spoke about the dynamics of deltaic sedimentation, about repetitive submergence and emergence in an area of crust sensitive to loading variation, and about variations in sea level due to glaciation in distant regions. Other members clambered about the outcrop of the Great Limestone where weathering and a previous dearth of geologists had resulted in corals standing fully half an inch proud of the rock surface.

The next visit was to some very old mine workings near Langdon Beck. These were in the fluorite zone of mineralization and some good specimens of fluorspar were obtained from the tips. Dr. Larwood referred again to the processes of mineralization arising from younger granite below the known Weardale mass. The members were also told of work done at Durham University on fluid inclusion studies in the fluorite which provided evidence that the mineral had been produced at temperatures between 100 and 200 degrees Centigrade.

The day concluded with a visit to the Gannister Quarry further up towards Weardale. The flat summits characterising the topography in this area are formed of this material indicating the start of Coal Measures conditions. The gannister forms a whitish sandstone in fact a recrystallised quartzite.

On the second day Dr. Johnson took charge of the party which made its way to the Cow Green Reservoir in Upper Teesdale. This is a new reservoir the outflow from which is automatically and remotely controlled to provide a regular minimum flow down the river to allow continuous extraction by the industrial installations at Teesmouth An outcrop of the Smiddy Limestone (base of D_2) was examined and the party moved on to examine evidence of mining adjacent to the water's edge. The reservoir, which had still not reached its final intended level, has inundated some old mining activities which penetrated the limestone and entered the slate beneath. The question of why the reservoir is watertight in these circumstances is apparently related to the fact that the surface of the water is always below the level of the water table in the surrounding rocks. The special geological conditions giving rise to the relict flora have already been mentioned, and the area of moorland involved was examined with interest especially by those members who combine an interest in botany with that of geology.



This map is printed by kind permission of the Geology Department of the University of Durham.

Members were also fascinated to hear about problems caused by the construction of the reservoir which was carried through in the face of strong opposition from conservationists. Criticism was partly stilled by the appointment of a Resident Naturalist, Mr. Tom Buffy, who met the party and conducted members over the dam and outflow control mechanism and also gave an impromptu talk about the research that was still going on into all aspects of the effect of the project on the local plant and animal life Some concern was felt about the erosion taking place on the lee shore of the reservoir as a result of wave action due to the long 'fetch' of the wind over the water. There was also evidence that the large area of water was resulting in a change in the micro-climate of the locality.

The dam itself was of some geological interest being of composite construction; part reinforced concrete and part earth embankment, the latter type of construction being employed where the dam is sited over a pre-glacial channel of the Tees now infilled with sand and gravel. The problem of water seeping from the reservoir and thus causing instability in this material was well appreciated, and the party were shown the positions of various piezometers inserted to detect and monitor any evidence of movement.

The party then moved to Cauldron Snout, a famous beauty spot and waterfall a few hundred yards downstream from the dam, and after a pleasant lunch there, moved down the left bank of the river and saw the famous and impressive Falcon Clints section of the Whin Sill.

The final part of the day was spent in the area of the Lower Palaeozoic inlier. This was of particular interest to the members of the Society because the shales and slates were for long thought to be related to the Silurian Stockdale Shales of our own area However Professor Dunham always maintained that they were Ordovician but the absence of fossils for long made precise dating impossible. Graptolites have since been found on four occasions, these including Didymograptus and Diplograptus and hence supporting Professor Dunham's views. The members were hoping to add to this number but although some time was spent hunting for fossils at the pencil Mill site, where for many years the slate was quarried to be made into slate pencils the only reward was a fragment of Caryocaris.

The presence of rock equivalent to the Borrowdale Volcanic Series has been suspected in this area, and Dr. Johnson invited the opinions of the members on one or two boulders which could well have been composed of fine-grained volcanic material but it was felt that thin sections were needed for final proof. A mica-lamprophyre dyke discerned in the river bank close to the Pencil Mill provided another convincing link between this suite of rocks and the Lower Palaeozoics of the Lake District.

At this point the week-end's activities were concluded. All concerned felt that this had been a particularly interesting, varied and rewarding excursion, and hearty thanks were extended to the two directors whose detailed knowledge preparation and enthusiasm had made the whole excursion so successful.

F.J.C.

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EXCURSION TO THE EYCOTT LAVAS

Director: S.H. Gate, M.Sc., A.R.I.C.

Sunday, 22nd August, 1971.

Introduction

The Eycott Lavas form part of the Borrowdale Volcanic Series of Ordovician age which overlie the Skiddaw Slates. The Borrowdale Volcanics have northern and southern outcrops (see fig. 1), and Marr, 1916, published a correlation. More recent work, however, has led the Institute of Geological Sciences in their Cockermouth Memoir 1968, to the view that there is no general correlation, the sources being different.

The approach of the northern and more extensive southern outcrops in the east of the area shown in figure 1 indicates the easterly plunge of the eroded Caledonian anticlinorium.

The type area for the volcanics of the northern limb is located to the south of High Ireby (NY232373) and the rocks are divided:

High Ireby Group	Approximate thickness
Fine-grained andesites) Upper Eycott Lavas)	3 500 feet
Middle Eycott Lavas	700 feet
Binsey Group	
Pyroxene andesites	1,600 feet
Andesites and tuffs	2,000 feet
Lower Eycott Lavas with interbedded slates and tuffs	300 feet

The source of these is deduced to be north west of Binsey and now overlain by the Carboniferous, since the Eycott Hill sequence is thinner and the matrix less glassy than the rocks in the type area.

Composition

Predominantly andesitic. The most typical Eycott Lavas have large porphyritic felspars (labradorite or bytownite). Pyroxene crystals are also seen. Vesicles contain chlorite, calcite or silica. The ground mass is usually almost glassy. Some mineral alterations are plagioclase to sericite, augite to calcite replacement, pyroxene to chlorite.

Some of the lavas, referred to as the "Berrier type", have no phenocrysts, therefore corresponding to the ground mass only of the Eycott type. The Berrier type lavas are usually dark grey, but some are tinted according to alteration: chlorite – green, oxidised glass – purple, calcite and chlorite – pale green, iron oxides – yellow or red.

The two types of lavas often occur interbedded and may be an example of magmatic differentiation.

Rock relations

There is a transition from the Skiddaw Slates to the Borrowdale Volcanic Series in the Eycott Hill area where the lavas are probably of the higher part of the Binsey Group. It is assumed that the Borrowdale Volcanic – Carboniferous limestone junction in the same area is an unconformity, though this is not exposed. The dip of the Lower Carboniferous rocks is about one third that of the Borrowdale Volcanic rocks hereabouts.

In the Greystoke Forest area the Borrowdale Volcanic rocks form a faulted inlier in the Carboniferous Limestone. The dip of the lavas has steepened and become more northerly about 70° N.N.E. They are probably of the Upper Eycott series and in places they show some cleavage.

Itinerary details

EYCOTT HILL AREA

From Eycott Farm, Berrier (NY399297) walk S.W. After the second gate, keep the dry stone wall on your left until, about 0.6 mile from the farm, is the point where the wall is lower and built on solid rock. About 200 yards S.E. is a small crag.

(i) At the base of the S.E. of this crag is an attractive lava with pink feldspar phenocrysts and green amygdales. Overlying are the more usual bytownite lavas dipping approximately 35° E.N.E.

(ii) From the crag about 500 yards N.W. is the lower end of a N.E.–-S.W. gorge of a tributary of Naddles Beck. About 50 yards downstream from the gorge end is seen a Skiddaw Slate exposure in the sides of the stream bed. No exposure of Ward's purple ash has been noticed.

(iii) The gorge end itself shows Ward's vesicular blue basalt and the band of altered Skiddaw Slates immediately above. These represent sedimentation between lava flows. By the stream a junction is seen near the base of a small hump. There follows upstream, and nearly in the dip direction, blue andesite, flinty andesite, then the typical Eycott lava. A thin tuff is exposed also.

(iv) Following the Eycott Hill section is time consuming. Faults introduce complications. The attractive lava seen at (i) is exposed here also near the bottom of the hill. Purple-stained lava occurs about a third of the way up. A attractive light-green lava with long narrow feldspars may be found near the the top. The dip section is followed by walking from the gorge north westwards around the base of the hill about 530 yards until the rocks seem to lie horizontal; more precisely, until true bearing 75° lines on the summit, then ascending.

FAIRY KNOTT (NY383305)

This has a stream section on its south edge showing a change from Skiddaw Slates sedimentation to volcanic activity. Access is most direct from the Berrier-Murrah road opposite (and 500 yards away) by a gate a few yards N.W. of the Council gravel dump (an infilled limestone quarry). Keep left of the bluffs (of volcanics) after a second gateway. The section is quoted in the 1968 Cockermouth Memoir as follows:

	Ft.	ins.
Bluish andesite with vesicular base and including fragments of coarse tuff	2	0
Greenish, fine-grained granular tuff	5	0
Fine tuffaceous shale	0	1
Bluish-grey tuffaceous sandstone	3	0
Grey shale	0	2
Hard bluish sandstone	2	0
Greenish-grey shale	0	4
Gap to greenish-grey slates	6 to 10	0

Though published in 1968, the information is older. It provides an exercise in deciding how much of it can be seen today (the slates are now hidden).

500 yards north weathered Skiddaw Slates shales show in a bank near a lane leading back to the road.

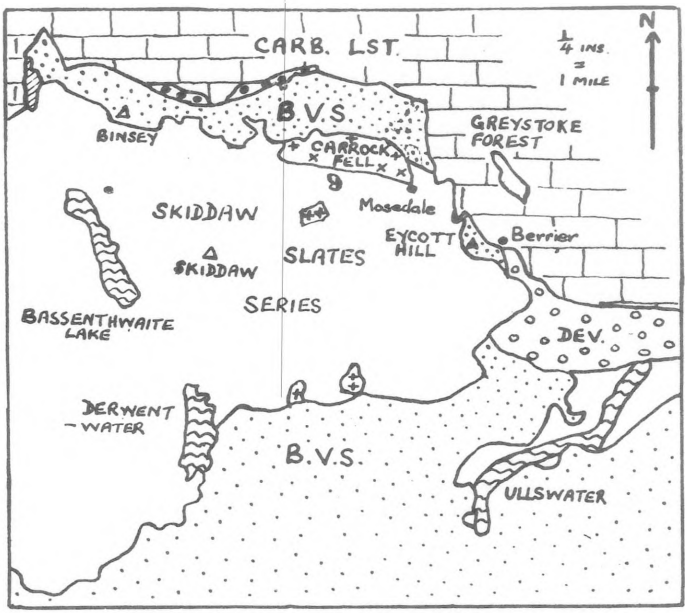

Figure 1. Geological sketch map of the north Lake District.

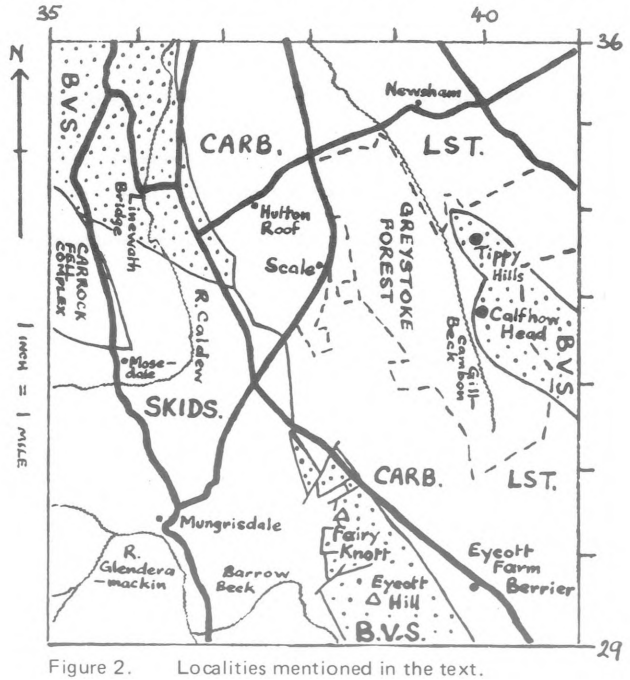

Figure 2. Localities mentioned in the text.

GREYSTOKE FOREST AREA

From a point NY408345 on the Newsham – Johnby road along the N.E. edge of the forest, the Forestry Commission have made a stone-surfaced main access road leading S.W. Keep to the main path from which some of the surrounding limestone is seen, after 0.8 mile where the main path bends left, twenty yards of grass track leads straight ahead to the Tippy Hills exposure.

The dolerite dyke swarm of Tippy Hills is intruded into lavas similar to those of Eycott Hill, though some here are strikingly highly vesicular, some are brecciated and others are cleaved. The positions of the dykes are not immediately obvious; sampling is necessary, the dolerites being coarser-grained than the lavas.

A further 0.6 miles along the main path leads to a large quarry in the thick pyroxene andesite sequence. From the end of the quarry furthest from the road, a way may be made between a few trees to an unplanted slope with a rock exposure known as the Calfhow Head Rhyolite. Most of the outcrop is of green rhyolite which is spherulitic especially in the lower part. On the summit the rock is lighter coloured.

LINEWATH BRIDGE (NY361343)

In the east bank a few yards below the bridge is a lava in situ showing the texture and colouring which is regarded as the most typical and recognisable Eycott lava Just downstream of it, also in the bank, is the upper part of the same flow, vesicular and rubbly. The sequence is therefore upward to the north, yet the dip here is south. These flows have been overturned. The succession to the north and north east is difficult to follow. Parts of these same flows outcrop in Carrock Beck to the north west, seen in an earlier excursion. They are of the Middle Eycott Series.

S.H.G.

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Way leaves must be obtained in order to visit any of the locations described above.

VISIT TO THE OPENCAST COALMINING SITE AT CLIFTON, WORKINGTON

Director: E. Lawrence, B.Sc., F.G.S.

Saturday, 10th June, 1972.

Some thirty members of the Society assembled at the site offices where the Director a National Coal Board geologist, explained the history of the site, the geological structure and the method of working. After a very interesting tour of the opencast the visit was concluded with questions about some of the aspects of the site, and votes of thanks to Messrs. George Wimpey and Company Ltd. for allowing us access and to Mr. Lawrence for conducting a very interesting and informative tour.

The following account is reprinted by kind permission of the National Coal Board Opencast Executive, No. 2 (Northumberland and Durham) Region, Cumberland area.

MABEL PLANTATION SITE (NAT. GRID. REF. 038282)

Introduction

The site, which covers a working area of 240 acres, is 3 miles east of Workington with sections on either side of the A595 Whitehaven – Cockermouth road. 1,600,000 tons of coal are to be recovered from 12 seams varying in thickness from approximately 1ft. to 6ft. The maximum depth of excavation will be approximately 180ft.

Prospecting was commenced by Opencast geologists in 1944, but the main drilling was carried out during the period 1955-1960. This proved as accurately as possible the geological structure, the presence of workable coal seams, and the extent of any former old workings, thus enabling an assessment of the quality and quantity of the coal to be made.

The contract was awarded to George Wimpey & Co. Ltd., and coaling commenced on 11th June, 1970, and to date over 430,000 tons of coal have been recovered currently at a rate of between 5,000 tons and 7,000 tons per week. The coal is delivered by lorry to the Executive's Disposal Point at Maryport where it is screened and distributed by rail and road. A large proportion is sent to the C.E.G.B. Power Stations at Barrow and Carlisle Coal is shipped once or twice a week from Whitehaven to the Associated Portland Cement Co., in Northern Ireland, and local industries account for a smaller tonnage, including coking coal to the Steelworks.

It is expected that coaling will take approximately 6 years and final agricultural restoration a further 4 years, although the first section worked has been filled and grassed last year.

Method of Working

Overburden is removed in a series of strips by the large Marion '7500' Walking Dragline with a 200 foot jib and 17 cu.yd., bucket, or by the smaller Lima '2400' Dragline with a 120 foot jib and 6 cu.yd., bucket, and also by a '150' RB 7 cu.yd., electric face shovel loading Terex 45 ton dump trucks which transport the overburden from the face shovel to spoil heaps. The top of the coal is first cleaned by Drott shovel, and then by hand spade before loading by '22' RB face shovels with 1¼ cu.yd., buckets into lorries for transportation by road to the disposal point.

The Marion '7500' Dragline is noteworthy for its size, weighing nearly 700 tons. The 200 foot jib is capable of lifting nearly 35 tons to a height of 84 feet from a depth of 94 feet. The walking shoes each have an area of 36 feet by 6 feet. The length of step is approximately 6 feet and the walking speed approximately 260 yards per hour. The machine is powered by a number of electric motors fed from a 11 KV main power supply. The whole machine was shipped in parts from America in 1971 and constructed entirely on the site in approximately 6 months.

Restoration is progressive and commences as soon as one part of the site is completed. After topsoiling the Ministry of Agriculture supervises the cultivation and drainage of the site so that what formerly may have been poorly drained marsh land is returned to land use in a much improved condition.

Opportunity is taken to carry out other improvements, and in this case the N.C.B. Land Use Consultants have planned a picnic area to be incorporated in the restoration.

Geology

The seams worked on the site lie within the Middle Coal Measures of the Carboniferous System. The general sequence proved on the site, is descending order is as follows:–

	DRIFT		
	Measures –		
	Unnamed 'G'	–	Not worked – impersistent
30'	Measures		
	Unnamed 'F'	–	Simple seam 1'1" (average thickness in-situ coal)
20'–35'	Measures		
	Unnamed 'E'	–	Split seam, 3'1"
18'	Measures		
	Brassy	–	Multiple seam 2'6"
25'	Measures		
	Unnamed 'C'	–	Variable split seam 2'4"
37'	Measures		
	Black Metal	–	Simple seam 1'8"
40'–70'	Measures		
	Top Fireclay	–	Simple seam 0'11"
2'–10'	Measures		
	Bottom Fireclay	–	Simple seam 1'2"
35'	Measures		
	White Metal	–	Multiple seam 4'0"
20'	Measures		
	Slaty	–	Not worked – impersistent
60'	Measures		
	Ten Quarters	–	Split seam, only upper section of top leaf worked 2'6"
20'	Measures		
	Rattler	–	Simple seam 1'5"
10'–35'	Measures		
	Bannock	–	Split seam only lower leaf worked 1'7"
110'	Measures		
	Main	–	Multiple seam 6'0"
60'	Measures		
	Yard	–	Not worked – too deep

The general dip is to the east and north-east, and varies from approximately 1 in 4 to 1 in 17. Three major faults occur and conform with a regional N.W. — S.E. trend. Numerous small splinter faults form off-shoots from the major faults.

The strata between the seams consist of mudstones, shales and sandstones, with occasional ironstone bands and nodules. Sandstones are best developed above the Brassy Top Fireclay, Ten Quarters and Main seams.

Major washouts occur in the Main and Ten Quarter seams, and smaller ones may be expected in some of the other seams.

The drift consists of mainly boulder clay up to more than 100 ft. thick, but normally varying between 5 ft. and 35 ft. over the site. Old workings were encountered in Brassy, Unnamed 'E' and Main seams.

During prospecting the quality of the coal was determined by analysis of samples taken from trial pits and cored boreholes, the seams proving to be bituminous coal of medium to high volatile matter — 31. to 39%. Sulphur varies between 1.2% and 4.3% and Ash between 4% and 14% average. Continuous sampling during working ensures the quality of the coal marketed.

April, 1972.

WEEKEND FIELD MEETING IN THE CHEVIOTS

Director: D.A. Robson, M.Sc., Ph.D., F.G.S.

23rd – 25th June, 1972.

Thirty members of the Society met at the Black Bull Hotel in Wooler on the first evening to hear an illuminating account of the geology of the Cheviots from Dr. D A. Robson, Senior Lecturer in Geology at the University of Newcastle upon Tyne. With the aid of a beautiful relief model of the geology of the area a useful and much used aid which had been hand painted on a plastics base, Dr. Robson outlined the history of the local rocks. He described the emplacement of the Devonian granite of The Cheviot with its surround of andesitic volcanics and the relation of these rocks to the Cementstones and the Fell Sandstones of the Lower Carboniferous. The tectonics of the area were also described, the effects of faulting, folding and tilting of strata, and the intrusion of dykes and sills of igneous rock, of which the Whin Sill is perhaps the best known.

On the Saturday morning the party travelled north east from Wooler to the valley of the Bowmont from which could be seen the Milfield Plain a depression in the Cementstones, as well as the strike of the Fell Sandstone away to the west. At the roadside monument to "Gefrin" the director pointed out that the Cheviot lavas dip gently towards the Milfield Plain, and that the lava rises very abruptly along a fault line which is thought to have been formed during the Tertiary Era. The blocks of stone built into the wall alongside the monument were used to illustrate lava lithology and it was pointed out that much of the Cheviot andesite has been 'weathered' in situ to the extent that the feldspars have been kaolinised and the pyroxene crystals have lost their structures. The unaltered andesite is predominantly dark in colour, showing crystals of plagioclase feldspar and pyroxene and is often characterised by thin bands of red haematite.

The party then drove into the College Valley where the effects of the harder and softer areas of lava on the topography of the valley sides were seen. The valley itself has been etched out by the burn along the line of a fault, and it is remarkably straight, although at one point, probably due to well-developed jointing in the rocks the burn does wander away from the fault line. From the road end members went on foot to the Hen Hole gorge cut in metamorphosed well-jointed lavas adjacent to the granite outcrop which was not seen. Thence along the Pennine way astride the English-Scottish border northwards to The Schil which has a number of very fine lava tors at its summit.

After lunch a visit was made to the Fell Sandstone outcrops to the east of Wooler. The director demonstrated the repetition of outcrop of the hard sandstone escarpment by a thrust fault running nearly parallel to the strike, as well as the offsetting of the escarpment by a dip fault. The effect of the Fell Sandstone ridge preventing free drainage of streams eastwards from the Cheviots was seen, with the Till and Breamish systems draining northwards to the Tweed. The Fell Sandstone was examined at Belford Moor from where the hollowed-out axis of the Holborn Anticline the western limb of which is almost vertical and faulted whilst the eastern limb dips gently eastwards, could be seen. The core of the anticline is of relatively soft Cementstones, thin-bedded alternations of shales, sandstones and the occasional limestone, whilst above the Fell Sandstone down dip to the east is the Scremerston Coal group of Lower Carboniferous rocks containing a few workable coal seams. The Fell Sandstone in this locality is even-grained, containing little or no mica. Evidence of cross bedding and slumping shows that it was deposited from a source towards the north east. In general, the Fell Sandstone tracts in Northumberland form infertile heather covered uplands. After admiring the extensive views of the Cheviot Hills and of the coastal tract, some members drove down to Bamburgh to admire the castle built upon the Whin Sill.

On a rather damp Sunday morning the party first visited the Roddam Dene Conglomerate, the type locality of which was reached after an awkward scramble through dense vegetation and along the stream bed. It forms the base of the Cementstone group locally and is formed of rounded pebbles, most of which are of Cheviot andesite mostly between 2 inches and six inches in diameter, set in a greenish-grey mudstone matrix. It appears to be a series of deltaic deposits of maximum thickness 300 feet, transported by rapid torrents. The similarity between this rock and the comglomerates at Pooley Bridge Ullswater, was remarked upon by a number of members, and this sparked off a discussion as to whether the two conglomerates could be classed as Upper Devonian or Lower Carboniferous.

The next stop was at Biddlestone. The director called a halt on the approach road and pointed out the form of the Harden Laccolith, formed of an attractive pink felsite which is extensively used locally as roadstone.

At the beginning of the afternoon the Coquet Gorge was visited, the section above Alwinton providing a magnificent section of the Cementstones showing shales, thin sandstones and limestones separated by two parallel faults from Cheviot Andesite to the north and Fell Sandstone to the south. Further up the Coquet Valley the Acklington Dyke was seen, one of a series of tholeiitic basalt dykes intruded in Tertiary times and radiating from the western highlands of Scotland across towards northern England. Dr. Robson commented that although basalt, whin and felsite dykes, (the felsite dykes are common enough in the Cheviots), are generally difficult to distinguish by eye from the surrounding andesites and are often covered by peat and drift, they could generally be accurately traced across country with the aid of a magnetometer.

Finally, at Carshope in Upper Coquetdale, the Blindburn Glassy Andesite was seen. This is a compact grey-black lava, relatively unaltered, but characterised by thin (less than 0.1 inch) veins of red haematite. The director pointed out some rather peculiar 'sandstone dykes' which were apparently formed soon after that particular bed of lava cooled by weathered material, green chloritic sand, being washed into cracks on the lava surface. The prominent siliceous vein on Raker Crag was pointed out, probably this crystallised from solutions finding their way upward from the Cheviot Granite during the last stages of cooling and crystallisation.

After a pause for tea-time refreshments, the President took the opportunity of thanking Dr. Robson for providing a most stimulating and interesting weekend.

Judith P. Straughton.

References

Carruthers, R.G. et al. *(1931). The Geology of Northumberland and Durham.* Proc. Geol. Assoc., Vol. LXII, 3.

Robson, D.A. *(1966). A guide to the Geology of Northumberland and the Borders.* Trans. Nat. Hist. Soc. Northumb. Vol. XVI, 1.

LECTURE REPORT

The Pleistocene of North Britain with special reference to the Pennines

Some thirty members met at the Workington Division of the West Cumberland College of Science and Technology on January 10th 1973 to hear a most interesting lecture given by Angus Lunn, Ph.D., of the Department of Adult Education of the University of Newcastle upon Tyne.

Dr. Lunn started by stating the current changes of usage of terminology. The Holocene and the Pleistocene are regarded as epochs, the latter extending back from 10,300 years before present (B.P.). However, the term Pleistocene is very unsatisfactory as a division of geological time as its commencement does not coincide with profound biological or environmental changes. The popularly-held view that the Pleistocene implies widespread glaciation is very far from the truth, the classic glacial sequence merely occurring at the end of a much longer period of time during which there is little evidence of glaciation in mid-latitudes. Nontheless there is a great deal of evidence, most of which in Britain comes from the Midlands and East Anglia, and little from the north, that the main characteristic of the Pleistocene was a series of rapid alternations of climate. The major work done on this theme has been carried out by West and his colleagues of the University of Cambridge who have adduced the following stages during the Pleistocene and Holocene:

W	Flandrian (= Holocene).	
C	Devensian (Latin; Deva, Chester) beginning about 70,000 years B.P.	equivalent to Weichselian or Wurm in Europe, or Wisconsin in U.S.A.
W	Ipswichian	
C	Wolstonian	
W	Hoxnian	
C	Anglian	
W	Cromerian	
C	Beestonian	
W	Pastonian	
C	Baventian	
W	Antian	W represents a predominantly warm climatic stage
C	Thurnian	C represents colder conditions
W	Ludhamian	
	Waltonian	

The lecturer stressed that the recognition and correlation of these stages was very difficult, and that the traditional Alpine terminology should not be applied elsewhere. The basis of division is to work back through stratified and laterally-correlated deposits, counting backwards from the present and trying to recognise features of deposits attributable to warmer or colder conditions. Conventional geological zoning by fossil species will not work in this type of situation as biological evolution is not rapid enough to delimit successive deposits each laid down within a few tens of thousands of years only, although, say, hippopotamus bones are likely to occur in a warm stage whilst woolly mammoth remains would be found in a cold stage. The main fossil evidence that has been used in Britain consists of pollen grains. Not only can pollen from individual families, genera and in some cases species of plants be recognised, with implied information on the climate in which they flourished, but sequences of vegetational changes within a stage can serve to characterise it. For example, the Hoxnian is characterised by sea-buckthorn pollen early and elm, hazel and silver fir late, whilst in the Ipswichian there is little conifer pollen, but abundant hornbeam.

The popularly-called "Ice Age" formed merely a small segment in the overall Pleistocene time scale, but it has been studied in far greater depth than the rest because of the obvious and very impressive effects that ice has had on the landscape. In fact, the first part of the Devensian was cold but not characterised by glaciation; the first evidence of ice cover in Northern Britain appears to date from about 30,000 years ago, and ice from the north spread as far as Wolverhampton about 18,000 years ago. There is also evidence of interstadials, periods of relatively mild climate, during both earlier and later parts of the Devensian. During much of the Devensian the environment was probably periglacial rather than glacial, and even the extent of ice cover varied very greatly, the readvance between 10,800 and 10,300 B.P., with ice occupying most of the mountain corries, being the best documented.

In the second half of his lecture Dr. Lunn explained the evidence adduced by recent researchers on highland glaciation to support their conclusions that ice had covered the crests of respectively the Northern Pennines, the Cheviots and the Cairngorms. Of relevance here was the theory, developed for Britain by Sissons, of the formation of meltwater channels. Sissons distinguished the upper layer of ice which was permeable from the lower layer where crevasses and tunnels were closed by pressure. As the ice sheets gradually melted down, the ice in places became permeable to its base. When this happened the meltwater was able to excavate channels in the underlying rock ridges, channels which followed the direction of ice surface slope rather than the shape of the buried land surface. Conditions for the formation of local ice caps had been suggested by Manley; if a hill mass rose more than 200 metres above the firn line and the diameter of the summit area exceeded 1000 metres, then ice would accumulate. The speaker, and Vincent, believe ice entirely, to have covered the Northern Pennines, with Cross Fell and Cold Fell nourishing their own ice caps, and the remainder of the uplands having been overridden by ice from the west. Evidence in support of this includes

(i) the alignment of meltwater channels,

(ii) the distribution of erratics of western origin (including Galloway) along the hills flanking the Tyne Corridor, red erratics becoming less common eastwards, and

(iii) the orientation of stones within till deposits.

Particular evidence that Cross Fell had nourished its own ice cap was given by the absence of erratics of western origin from its eastern slopes, and the S.W. – N.E. alignment of meltwater channels in the Alston district.

Dr. Lunn showed us several fine colour slides of meltwater channels in the Cheviots and the Alston area. He explained that long-held opinions that the existence of tors and of

deeply-rotted granite precluded the former passage of ice were no longer tenable. Clapperton had suggested that weakly-moving ice on the broad tops of the Cheviots would remove some of the loose debris but would leave the tors, and Dr. Lunn showed a series of slides of typical tors on the Cheviot hilltops, but modified into forms resembling roches moutonnees lower down the hill slopes where the ice would be expected to have been more active. Erratics have been found high in the Cheviots, pointing to a former ice cover. Similarly, recent work by Sugden suggests that the "unglaciated" surfaces above 3500 feet in the Cairngorms have been swept by ice moving from the Rannoch Moor area. Erratics of schist, and a glacially scoured pavement admirably photographed by Dr. Lunn high in the Cairngorms lent credence to this view. The dramatic overdeepening of N.E. – trending valleys, such as Glen Avon, and the tremendous glacial throughway of the Lairig Ghru were explained as a consequence of concentration of ice flow through respectively a preglacial and a newly-excavated valley leading N.E. and N. towards the Moray Firth.

In answer to the few questions that time allowed, Dr. Lunn said

(i) analogies between present day conditions at the Icelandic ice caps and Britain at the height of the Devensian readvance were very dubious.

(ii) no recent work had been published, to his knowledge, on high level ice flow in the Lake District, and

(iii) pollen analysis suggested that the St. Bees Cliffs peat deposits represented a late interstadial in the Devensian stage. Evidence from the Solway Firth has been tentatively interpreted as indicating a readvance of ice from Scotland whilst the Lake District icefield was waning.

In moving a vote of thanks, Mr. M.B. Dodd complimented the lecturer on his lucid explanations and on the excellence of his visual material. The Cumberland Geological Society feels very cut off from centres of higher academic learning, and is grateful that lecturers of the calibre of Dr. Lunn are able to make the long journey to visit us from time to time.

ANNUAL GENERAL MEETINGS

The eleventh Annual General Meeting of the Cumberland Geological Society was held on the 9th February 1972 at the Whitehaven division of the West Cumberland College of Science and Technology.

General Report

Once again a full programme of activities has been enjoyed. The winter programme of lectures and films was organised by the General Secretary, Mr. R.E.O. Pearson, and held at a number of venues. The summer excursion programme was arranged by the Excursion Secretary, Miss D. Slater, and she and the various excursion directors are to be thanked and congratulated on the high standards maintained. The traditional social events were again well attended. At the Annual Dinner, the guest of honour was Dr. Douglas A. Bassett of the National Museum of Wales, President of the Association of Teachers of Geology. The occasion was marked by the presentation of the Charles Edmonds Prize to Dr. R. Alan Smith of Padgate College in recognition of his work on deglaciation features and on the Bibliography of the geology and geomorphology of the Lake District. The soiree was held during September at Workington Grammar School, by kind permission of the Headmaster. As usual, members enjoyed the chance to look around and comment upon geological material on display, particularly a selection of books and specimens prepared by geology students of the host school.

The following **changes of rule** were approved on the 10th November 1971:

Rule 6 to read "Ordinary Members shall pay an annual subscription of seventy five pence" in place of "Ordinary Members shall pay an annual subscription of ten shillings".

Rule 8 to read "Associate Members shall be limited to persons under 18 years of age unless engaged in full time education, in which case Associate Membership will be continued until the age of 21 years".

Rule 12 to read "Associate Members shall pay an annual subscription of forty pence" in place of "Associate Members shall pay an annual subscription of five shillings".

Rule 14 to read "An Associate Member will cease to be such on attaining the age of 18, subject to Rule 8; he or she may then on the payment of the appropriate subscription become an Ordinary Member without further election".

Calendar of activities for 1971

	Lecturer or Director	Title	Venue
10.3.71	Mr. E.H. Shackleton	Presidential lecture: "The story of Lakeland geology"	Tullie House, Carlisle.
19.3.71		The Annual Dinner: Guest, Dr. D.A. Bassett	Eclair Restaurant, Whitehaven
24.4.71	Mr. H. Bland	Geological sequence in the Upper Calder Valley	Lowther Park Gate, Egremont.
16.5.71	Dr. G.H. Mitchell	Borrowdale Volcanics of the Upper Duddon Valley	Seathwaite, Dunnerdale.
19.6.71	Mr. T. Shipp	Carboniferous Limestone in the Blindcrake area	Blindcrake, Cockermouth
17-18-19 7.71	Dr. G.A.L. Johnson	Geology of Upper Teesdale	High Force Hotel, Teesdale.
22.8.71	Mr. S.H. Gate	The Eycott Lavas	Berrier
15.9.71		The Soiree	Workington Grammar
25.9.71	Mr. E.H. Shackleton	The Sale Fell Minette	Wythop, Bassenthwaite.
5.10.71	Prof. J.E. Hemingway	Evaporites	Richmond School, Whitehaven.
10.11.71		Extraordinary General Meeting followed by films	St. Joseph's School, Workington.
8.12.71	Dr. A.R.L. Jones	Modern Mining and the work of the geologist	Richmond School, Whitehaven.
12.1.72	Mr. T. Shipp	The glaciation of the Lake District	St. Joseph's School, Workington.
9.2.72		The Annual General Meeting	W. Cumberland College, Whitehaven.

Honorary Treasurer's Report

The Income and Expenditure Account for 1971 shows that we ended the year with a total balance of £76 (of which £58.20 was our balance at the bank on 1st January 1972, while £18.56 consisted of cash, cheques etc. which had not then been paid into the bank). This compares with a balance of £233 at the beginning of 1971 and with one of £257 at the beginning of 1970.

This startling change in our financial position is explained by the decision of your council to have the "Proceedings 1970-71" printed commercially instead of being produced laboriously in duplicated form by the Editor and a few members of council. The mere fact that we had accumulated a balance large enough to cover the heavy cost of commercial production was the result of the extreme economy with which earlier issues of the "Proceedings" and our other publications had been produced. It was felt that these laborious methods could not continue indefinitely.

The cost of printing 1000 copies of "Proceedings 1970-71" was £262, but it is hoped that part of this will be recouped by sales to the general public, especially in centres such as Keswick and Ambleside where numerous groups of students and schoolchildren are engaged every year in field studies. It should also be noted that the cost of stationery and materials has fallen from £95 in 1970 to a mere £7 in 1971, and these sums mainly represent the paper, ink, cardboard etc. which we used to buy for the production of our publications.

Most of the other items of expenditure are relatively trifling, though the fall in "Subscriptions to other societies" from £5 to £1 may be noted. We paid £4 annually to the Geologists' Association as Institutional Members, but when they raised their subscription to £8 from 1st January 1972, we decided that the advantages of membership were too small to justify this expense, and we have resigned our membership.

On the Income side of the accounts, a welcome increase in subscription income has taken place. The number of full members who paid during the current year has risen from 135 to 156, although there are fewer associate members (34 compared with 45 in 1970 and 60 in 1969). This continued decline in the number of our junior members most of whom come from local schools where geology and geography are important subjects, is rather disappointing. One can only speculate as to the cause.

The payment of subscriptions for 1972 (and even 1973) in advance produces an anomaly. Some of our members pay for two or three years at a time, and several of these sent subscriptions for 1972 at the old rate of 50p. before the recent increase to 75p. was agreed at the Extraordinary General Meeting on 10th November last. This explains why some members paid 50p. and others 75p. for 1972. It is to be hoped that the increase in subscription will not lead to a fall in membership.

The item headed "Donations" remains almost constant from year to year since it consists mainly of the generous gift from the Marchon Division of Messrs. Albright and Wilson which continues the tradition of a covenanted payment first made by Sir Frank Schon.

Sales of publications remain very steady, and a modest increase in 1971 compared with the previous year will be noted.

The Charles Edmonds Memorial Fund needs little comment. A well-deserved award was made to Dr. R.A. Smith, author of our best-seller, the Bibliography of Lake District Geology, and there is still a balance of £13 in hand.

The Statement of Assets and Liabilities shows that our stocks of publications are now valued at £350 compared with £104 a year ago. This increase represents the large stock of "Proceedings 1970-71" which we have in hand, and which we must hope will decline substantially during the coming year. In that case we can look forward to a more favourable financial position by this time next year.

Finally I should like to express my thanks to our Honorary Auditor, Mr. Mervyn Dodd, for several valuable suggestions and for the meticulous care with which he scrutinises our accounts.

H.A. WHITE
Honorary Treasurer.

The following Officers and Members of Council were elected to serve for the year 1972

President	– E.H. SHACKLETON, F.G.S.
Vice-President	– H. BLAND
General Secretary	– R.E.O. PEARSON
Treasurer	– H.A. WHITE, B.A.
Publications Secretary	– S.H. GATE, M.Sc.
Excursions Secretary	– Miss D. SLATER
Editor	– T. SHIPP, B.Sc.
Librarian	– M.F. BURTON
Auditor	– M.B. DODD, M.A.
Members of Council	– J.A. BARRAS
	– M.B. DODD, M.A.
	– J.D. HINDE
	– Rev. T.R.B. HODGSON B.D., A.L.C.D.

CUMBERLAND GEOLOGICAL SOCIETY

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDING 1 JANUARY 1972

1970 £	EXPENDITURE	£	1971 £
(95)	Stationery, materials, membership cards etc.		7.08
(34)	Postages		30.65
(5)	Subscriptions to other societies:		
	Lake District Naturalists' Trust Ltd.		1.05
(4)	Expenses of lecturers		1.00
(–)	Copy typing of material for publication		1.00
(–)	Cost of printing "Proceedings 1970-71"		262.40
(–)	Hire of rooms for lectures		3.50
(–)	Repayment of overpaid subscription		0.26
(–)	Reprint of Geological Society paper for Library		0.50
(–)	Advert in "Cumberland News" for meeting on 10/3/71		2.10
(2)	Bank Charges		1.25
(–)	Cash, cheques etc. in hand on 1/1/72		18.56
(233)	Balance at Bank on 1/1/72		58.20
		£387.55	

1970 £	INCOME			1971 £
(257)	Balance at Bank on 1/1/71			233.50
(91)	Subscriptions:			
	Arrears:			
		2 Full Members	1.00	
	1971 –	156 Full Members	78.00	
		34 Associates	8.50	
		8 Institutions	4.00	
	1972 & 1973 (in advance)			
		13 Full Members @ 50p	6.50	
		5 Full Members @ 75p	3.75	
		1 Part Payment	0.15	
		1 Over-payment	0.25	
				102.15
(10)	Donations			9.94
(–)	Collected for refreshments at Soiree on 15/9/71			0.80
(36)	Sales of publications, postcards etc. (including postages in many cases)			41.16
				£387.55

STATEMENT OF ASSETS AND LIABILITIES AT 1 JANUARY 1972

LIABILITIES	£	ASSETS	£
Subscriptions for 1972 & 1973, paid in advance	10.40	Balance at Bank on 1/1/72	58.20
		Cash, cheques etc. in hand on 1/1/72	18.56
		Duplicator (cost price £50, less depreciation)	10.00
		Typewriter (cost price £15, less depreciation)	5.00
		Estimated value of stock of publications, at 50% of nominal selling prices	350.00
		Sundry debtors	25.00
Balance, being excess of assets over liabilities	457.36	Stock of stencils	1.00
	£467.76		£467.76

CHARLES EDMONDS MEMORIAL FUND

Balance at Bank on 1/1/71	18.15
Interest for one year on 3½% War Stock (nominal value £146.25)	5.10
Bank Interest on Deposit Account	0.58
	23.83
Less cost of award to Dr. R.A. Smith	10.00
Balance at Bank on 1/1/72	£13.83

AUDITOR'S CERTIFICATE

I certify I have examined the accounts, the bank statements and cheque books, receipt books and other financial documents of the Cumberland Geological Society.

I further confirm I have found them in good order and correct in every particular.

30th January, 1972

(Signed) M.B. DODD – Honorary Auditor

The twelfth Annual General Meeting of the Society was held at the Whitehaven division of the West Cumberland College of Science and Technology on the 14th February 1973.

General Report

There were some memorable meetings held during the year. Members enjoyed three splendid lectures on geological topics connected with Northern Britain. The Soiree departed from the usual programme with an exchange of geological materials brought by members. The Annual Dinner was blighted somewhat by the action of the power workers; a scratch buffet supper was eaten by candlelight. A full programme of excursions was arranged to a number of interesting localities. Once again the Society is indebted to its Officers and Council for the work they have put in during the year, and to the lecturers and excursion directors who have made such an interesting programme possible. A heartening development has been the interest shown in our activities by the Institute of Geological Sciences and the Departments of Geology of some northern universities, and the willingness that members of staff of these institutions have shown in coming along to lecture or to lead excursions.

Calendar of activities for 1972

	Lecturer or Director	Title	Venue
25.2.72		The Annual Dinner	Eclair Restaurant, Whitehaven.
22.3.72	Mr. J.E. Wright	The Geology of the Western Approaches	Carlisle Technical College.
22.4.72	Miss D. Slater & pupils of Distington Junior School.	Whitehaven Coal Measures	Barngill, Distington.
6.5.72	Mr. E.H. Shackleton	Brockhole National Park Centre and the Brathay Quarries	Ambleside.–
10.6.72	Mr. E. Lawrence	Open Cast Coal Mining	Great Clifton, Workington
23-24-25 .6.72	Dr. D.A. Robson	Weekend excursion to the Cheviots	Wooler, Northumberland.
23.7.72	Miss D. Slater	Igneous intrusions below Burtness Combe	Buttermere.
26.8.72	Mr. E.H. Shackleton	The Embleton Granodiorite	Embleton, Cockermouth
17.9.72	Mr. A.J. Wadge	Skiddaw Slates and Borrowdale Volcanics in Matterdale Beck	Matterdale End.
11.10.72		The Soiree	W. Cumberland College Whitehaven
8.11.72	Mr. W.C.C. Rose	Geological History of the Duddon Valley	W. Cumberland College Workington
13.12.72		Programme of New Zealand Films	W. Cumberland College Whitehaven
10.1.73	Dr. A.G. Lunn	The Pleistocene of North Britain with special reference to the Pennines	W. Cumberland College Workington
14.2.73		The Annual General Meeting	W. Cumberland College Whitehaven.

Honorary Treasurer's Report

We began the year with £76 in hand and ended it with £198. This improvement in our financial position is explained mainly by the fact that the "Proceedings" were not published during 1972, and routine items of expenditure such as postages, stationery, hire of rooms for lectures etc. did not vary significantly from previous years.

It will be recalled that towards the end of 1971 1000 copies of "Proceedings 1970-71" were printed commercially at a cost of £262, and substantial stocks of this issue remain in hand for sale to the public.

On the Income side of the accounts we have felt for the first time the benefit of the increase in subscription to 75p for full members. During the year 135 full members, 8 institutional members and 23 associates were recorded. The comparable figures for the previous year were 156, 8 and 34 respectively. There is no evidence that the fall in membership was caused by the rise in subscription. However, the tendency for the numbers of associate members to decline has continued. This was mentioned in my report last year as a disappointing feature of our activities, and one that is surprising in view of the important place taken by geology and geography in many local schools. The number of associate members has fallen from 60 in 1969 to 45 in 1970, 34 in 1971 and a mere 23 in 1972.

The variety of amounts recorded under the heading "Subscriptions – Full Members" may seem puzzling. The member who paid 77p. is a Canadian whose subscription was sent in the form of 2 Canadian dollars; the amount of 50p. is from a member who pays by Banker's Order, and who has not yet altered it to the present rate; and the payment of 25p. is from a conscientious member who had paid in advance at the old rate and wished to make it up to the new amount.

The item headed "Donations" remains almost constant from year to year since it consists mainly of the generous gift from the Marchon Division of Messrs. Albright and Wilson which continues the tradition of a covenanted payment first made by Sir Frank Schon.

Sales of publications continue at a very steady rate.

The Trustees of the Charles Edmonds Memorial Fund did not make an award during 1972, and the amount in hand stands at £19.

Finally, I should like to express my thanks to our Honorary Auditor, Mr. Mervyn Dodd, for scrutinising our accounts with his usual meticulous care.

H.A. WHITE
Honorary Treasurer.

The following Officers and Members of Council were elected to serve for the year 1973:

President	– E.H. SHACKLETON, F.G.S.
Vice-President	– H. BLAND
General Secretary	– R.E.O. PEARSON
Treasurer	– H.A. WHITE, B.A.
Publications Secretary	– S.H. GATE, M.SC.
Excursions Secretary	– Miss D. SLATER
Editor	– T. SHIPP, B.SC., F.G.S.
Librarian	– M.F. BURTON
Auditor	– M.B. DODD, M.A.
Members of Council	– F.J. COCKERSOLE, M.B., CH.B., F.R.C.O.G.
	– G.S. GOWING, M.A., F.G.S.
	– J.D. HINDE
	– Mrs. E. ROBERTS, B.A.

CUMBERLAND GEOLOGICAL SOCIETY

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR 1972 ENDING 1 JANUARY 1973

1971 £	EXPENDITURE		1972 £
(7)	Stationery, materials, membership cards etc.		11.85½
(31)	Postages		29.90½
(1)	Subscriptions to other societies:		
	Lake District Naturalists' Trust Ltd. ..		1.05
(1)	Expenses of excursion leaders & lecturers ..		6.40
(3)	Hire of rooms for lectures & committee meetings		3.70
(262)	Cost of printing "Proceedings"		nil
(—)	Purchase of books for Library		0.75
(—)	Hire of film		5.00
(1)	Bank charges		0.50
(19)	Cash, cheques etc. in hand on 1/1/73		5.92
(58)	Balance at Bank on 1/1/73	£192.43	
	Deduct cheque not presented	0.75	191.68
			£256.76

1971 £	INCOME			1972 £
(233)	Balance at Bank on 1/1/72			58.20
(—)	Cash, cheques etc. in hand on 1/1/72			18.56
(102)	Subscriptions:			
	Arrears: 5 Full Members		2.50	
	1972: 135 Full Members			
	132 @ 75p		99.00	
	1 @ 77p		0.77	
	1 @ 25p		0.25	
	1 @ 50p		0.50	
	23 Associates @ 40p		9.20	
	8 Institutions @ 75p		6.00	
	1973 & 1974 (in advance)			
	3 Full Members @ 75p		2.25	120.47
(10)	Donations			11.19
(41)	Sales of publications			47.10
(—)	Sales of specimens on commission at soiree ..			1.24
				£256.76

STATEMENT OF ASSETS AND LIABILITIES AT 1 JANUARY 1973

LIABILITIES	£
Subscriptions for 1973 & 1974, paid in advance ..	2.25
Sundry creditors	10.00
Balance, being excess of assets over liabilities ..	408.35
	£420.60

ASSETS	£
Balance at Bank on 1/1/73	191.68
Cash, cheques etc. in hand on 1/1/73	5.92
Duplicator (cost price £50, less depreciation)	10.00
Typewriter (cost price £15, less depreciation)	5.00
Estimated value of stock of publications, at 50% of nominal selling prices	208.00
	£420.60

CHARLES EDMONDS MEMORIAL FUND

Balance at Bank on 1/1/72	13.83
Interest for one year on 3½% War Stock (nominal value £146.25)	5.10
Bank Interest on Deposit Account	0.19
Balance at Bank on 1/1/73	£19.12

AUDITOR'S CERTIFICATE

I certify I have examined the accounts, the bank statements and cheque books, receipt books and other financial documents of the Cumberland Geological Society.

I further confirm I have found them in good order and correct in every particular.

24th January, 1973.

(Signed) M.B. DODD – Honorary Auditor.

PUBLICATIONS OF THE CUMBERLAND GEOLOGICAL SOCIETY

The Society publishes Proceedings which contain, amongst other articles, accounts of the Society's activities, in particular, excursions in the Lake District. Also published are a bibliography and a description of the limestone series in West Cumberland. A complete price list including postage is given below.

TITLE

Proceedings (several early issues are now out of print)

Volume I	1963 part 1	Volume II	Part 1 (1966)
	1963 part 2		Part 2 (1967)
	1965 part 2		Part 3 (1968-9)
			Part 4 (1969-70)

Each part priced 47p.

Volume III Part 1 (1970-71) Priced at 66p
(to new Members: Council minute 14/6/72) Priced at 36p

Special Publications

The Limestone Series of West Cumberland by E.H. Shackleton, F.G.S. – Price 58p. To members: 50p

A Bibliography of Lake District Geology and Geomorphology by R.A. Smith, M.A., Ph.D. – Price 31p.

Post Cards (4 designs) 1½p each (Post free if ordered with other publications)

Geology/Geogr. Excursion Guides '72. Price 30p.

All the above are available from:

Mr. S.H. Gate, M.Sc., A.R.I.C., Publications Secretary,
"Four Winds", 8 West Spur, Moor Row, Cumberland CA24 3LG

CUMBERLAND GEOLOGICAL SOCIETY LIBRARY

The Society's Library is housed in the Whitehaven Borough Library.

A comprehensive catalogue (price 25p) may be obtained from the Society's librarian:
Mr. M.F. Burton, 47 Whinlatter Road,
Mirehouse, Whitehaven, Cumberland.
to whom all requests for books and periodical publications should be addressed.

The facilities of the library are available to members only. Postal charges must be borne by borrowers.

MATERIALS FOR PUBLICATION

Manuscripts should be addressed to the Editor. The material should be typed, with double spacings, on foolscap, quarto or A4 paper, leaving wide margins, and should not normally exceed 10,000 words. Line drawings should be submitted in Indian ink on good quality paper, captions should be stencilled, and any photographs must be of excellent definition. Photographs and line drawings should be capable of reduction to the format proportions of 12cm by 18cm. S.I. units should be used, although for the present Imperial units may be inserted in addition where they may be thought necessary for clarity.

Bethwaites Printers. Cleator Moor & Workington