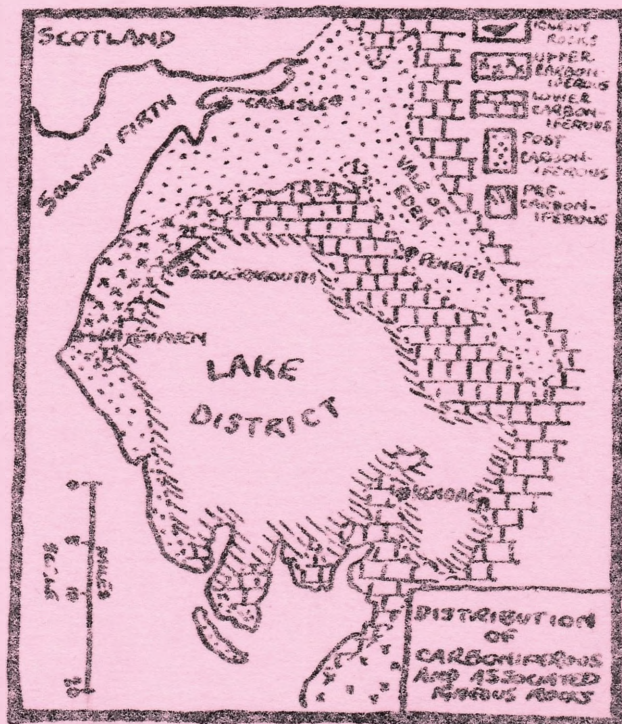


CUMBERLAND GEOLOGICAL SOCIETY



PROCEEDINGS

VOLUME 2 PART 4

1969-1970

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THE CUMBERLAND GEOLOGICAL SOCIETY

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Aspects of Glaciation in Northumberland

R. CLARK, B.A.

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Abstract

The survey incorporates the salient conclusions of some earlier writers and draws attention to the changed basis for interpreting various landforms. It also draws upon observations made by the present writer. The glaciation particularly considered is that equivalent to the Würm/Weichsel of Continental Europe. The extent, movement and surface form of this ice at its maximum extent is first dealt with, and some attention given to postulates on post-maximum ice margins in the county. Evidence of erosion, and the nature and landforms of till follows.

The major section is a description of deglaciation phenomena in the county; some new interpretations and speculations are introduced. The survey is concluded with a description of Late-glacial phenomena and their implications.

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Introduction

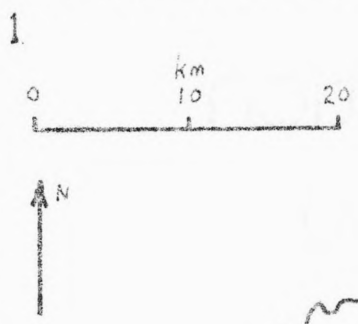
The long history of glacial studies in Northumberland has led to a fairly comprehensive knowledge of the distribution of certain glacial features, particularly drifts and striae. Besides the many local investigations, there have been reviews (e.g., Raistrick, 1931) of the regional picture which in their interpretations followed substantially the model developed by Kendall and applied by him (Kendall and Muff, 1901, 1902) and by Dwerryhouse (1902) at about the same time as the 'classic' Cleveland study (Kendall, 1902). The most recent short review (Hickling, 1949) conformed to this model.

Before the 1949 review, however, close examinations of glacial drift were leading to a broadening basis for interpretation (Carruthers, 1947, 1948, also 1953) which partly revived the views of Goodchild (1887) on the importance of static downwasting of starved ice sheets. More recently doubts cast on the adequacy of the orthodox view on melt-discharge channels (Peel, 1951, 1956) have been followed by the application to parts of Northumberland of newer views on the manner of ice loss, and melt water movement e.g., Hexhamshire (Sissons, 1958) and the same Cheviot area as examined by Kendall (Derbyshire, 1961).

It has been generally assumed that the county-wide evidence is of one glaciation although nearby in north Durham a more complicated sequence has

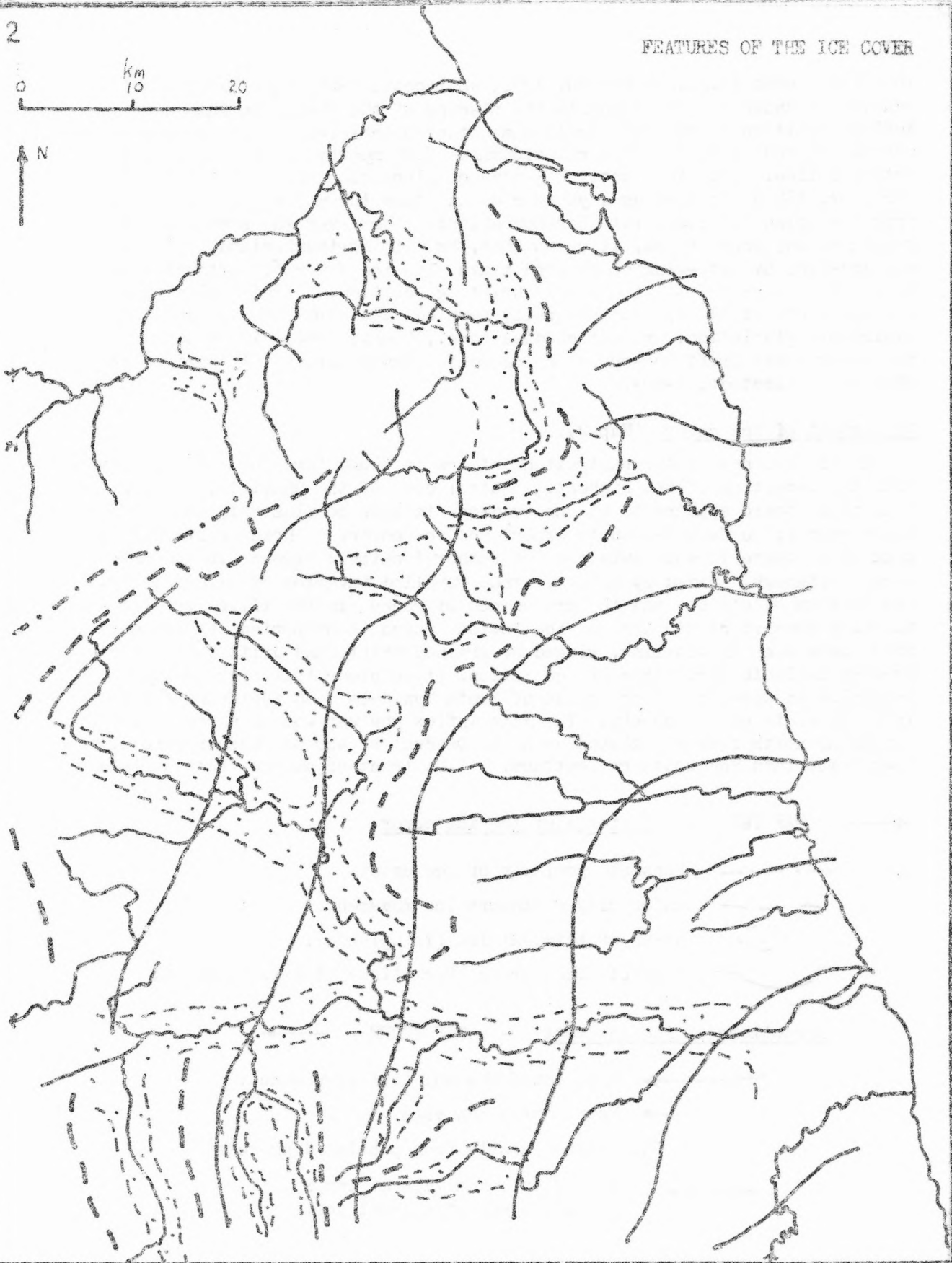
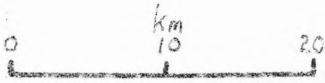


LOCALITIES DISCUSSED
IN TEXT.



2

FEATURES OF THE ICE COVER



long been known (e.g., Trechmann, 1931; Woolacott, 1905, 1906, 1907). With paucity of known datable deposits the placing of the phenomena into a well-defined position in the time scale has not been achieved; such progress as exists depends largely upon relationship with nearby areas, analogy and extrapolation. Thus the Scottish Readvance glaciation of the Carlisle area (Trotter, 1929) is seen as a younger event than the major movement of ice from the Irish Sea Basin into Northumberland. Whatever the status of this readvance may prove to be, it seems that, as with Northumberland, its area was ice-free by Late-glacial Allerød times. The ice cover of Northumberland is usually assigned to the Newer Drift glaciation. This glaciation, despite aberrant views, has generally been equated with the European Würm (Weichsel) glaciation; recent studies (e.g., Penny, 1964) give reasons for the major Newer Drift ice-sheet being contemporary with a late part of the Würm (cp. Woldstedt, 1960).

The extent of ice cover (Map 2)

Clear evidence of the past extent of ice is found throughout the county with the exception of the highest, central core of the Cheviots. Within this area there appears to be no evidence to show conclusively that these hills over 2,000 feet failed to experience ice cover. However it will be seen that there is some evidence of rather localised vigour in ice movement, although, aided by height, they repelled invasion by external ice. The pattern of striae and the provenance of rocks in the tills present a mutually consistent picture of ice motion which is supported by evidence from forms such as drumlins, ridged or grained drift, and drift tails, that broadly indicate directions of ice motion. It is clear that high ice masses nourished in uplands at the heads of South Tynedale and Weardale fed ice into the south of the county. The main influx however was on a broad front extending north from the Alston area to Deadwater across which passed ice from Cumberland and southern Scotland. The tract of upland between Peel

← MAP TWO - Features of the ice cover

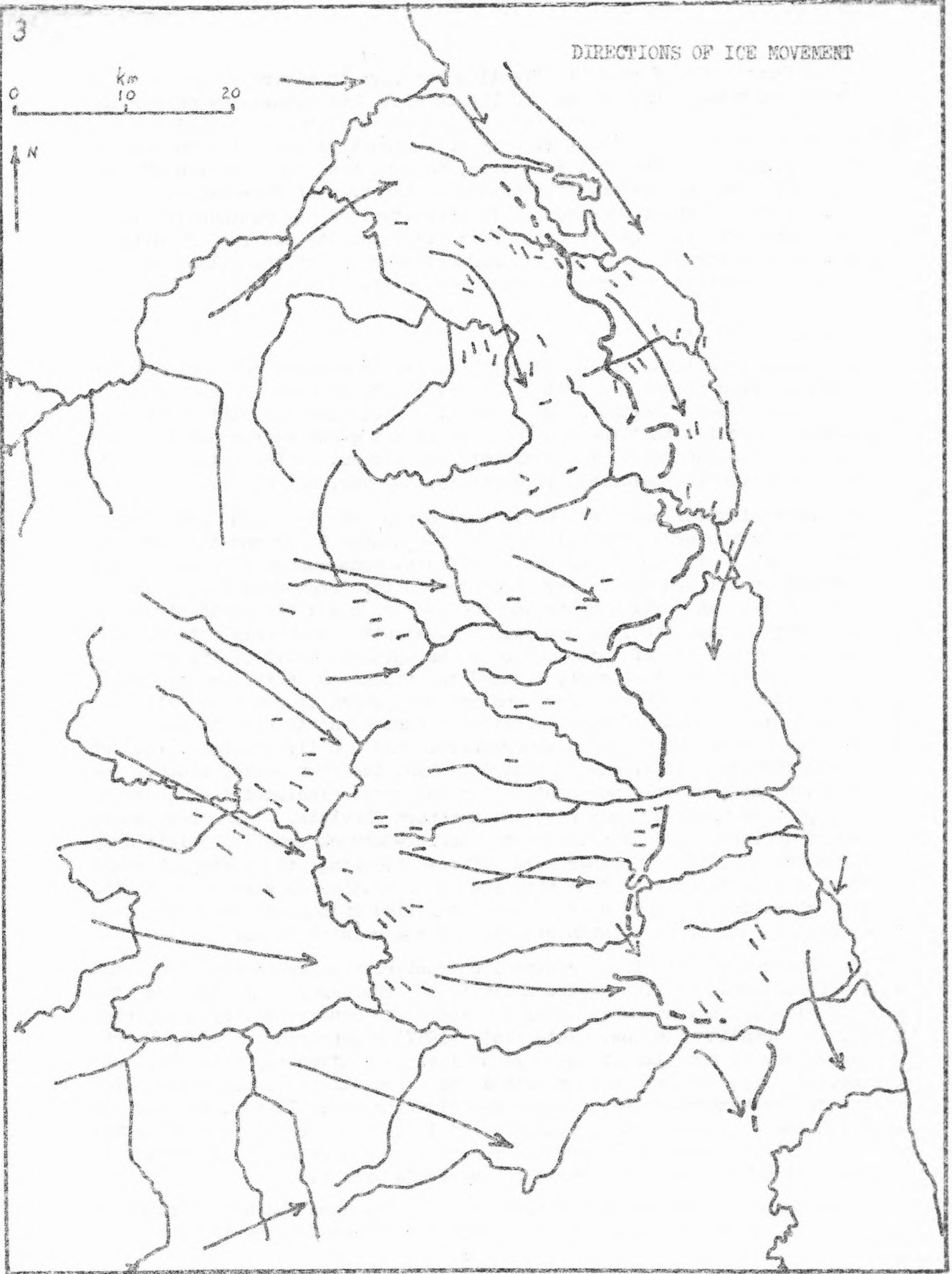
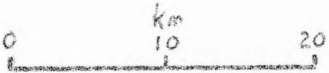
- · — · — · Possible position of ice crest.
- — — Major ridges athwart ice movement.
- (· ·) Areas of thickest ice (in uplands).
- — — Possible ice surface form lines at maximum cover.

Directions of ice movement - MAP THREE →

- From landforms and till provenance.
- From fabric analyses.
- — — Striae (mostly from published sources).
- — — Approximate position of inner limit of influence of coastal ice.

3

DIRECTIONS OF ICE MOVEMENT



Fell and Carter Bar formed an effective barrier to vigorous invasion but the crestline between Carter Bar and The Cheviot was crossed by deeper ice capable of some erosion and transport at heights of 1,800 feet (Thirlmoor). Nevertheless this part of the periphery of Northumberland, although covered by ice, appears, with the Peel Fell area, to have been the location of minimal ice invasion and action. In consequence the area of Tarsdale, Redesdale and part of Upper Coquetdale is characterised by dominantly local drift. Similarly the massive Cross Fell ridge and its own ice effectively excluded Lake District ice from the highest reaches of the Allendales and Derwentdale leaving them dominated by local drift.

Ice motion (Map 3)

A principal element in the pattern of ice provenance and movement is the confrontation of the generally easterly component over the county with a southerly movement in the coastal strip. Evidence of drift morphology and striae indicates that the zone of contact was quite narrow and that the coastal ice was generally the dominant ice stream. The nature of the resolution of the two movements in depth is, however, not clear.

The morphological contrast north and south of the main Tyne valley reflects the structural contrast between the Alston Block and the Northumberland Trough (Bott, 1967) and had significant consequence for ice motion. High ground overlooks the valley from the south, from Cold Fell east to Gateshead Fell, and only approaching the latter could the great stream of ice entering through the Tyne Gap gain a substantial southerly motion. Some diffuence or spread of this ice over the uplands south of the Tyne did occur but clearly the topography reduced the thickness of this sheet while the high ridge north of the Wear and the ice which it generated limited this movement. This effect was felt even further north for the basal ice coming from Dumfriesshire and Roxburghshire, and locally nourished ice of the Northumberland hills, was prevented by Tyne ice from moving south. Ice involved in the southerly movement along the coast included the Tweed ice stream, part of which transgressed the northern Cheviots. The very sharp southward deflection of this ice in the Lowick-Berwick area is explained by the presence a little further east of ice reaching the North Sea Basin north of the Lammermuirs. That this ice moved southwards very close to the present shoreline is shown by the occasional find of basalts from the Edinburgh region and of Caledonian granites in the coastal tills.

Southerly movement is a regional characteristic extending from the south of Scotland to the southern limit of the Newer Drift ice on the eastern side of England. This major ice sheet was constrained by a superior force, the Scandinavian ice. Valentin's (1957) reconstruction of the North Sea geography at the time of the maximum last glaciation supposes the eastern Scottish ice to have been confined to a breadth of about sixty miles off north Northumberland by stronger Scandinavian ice. In turn the eastern Scottish ice was competent to restrain and deflect the basal flow of Northumberland ice. Robinson (1968) has recently commented on the character of this relationship nearer the limit of the ice's extent.

Carruthers' (1948) interpretation of this situation led him to think of an 'inland' component to ice motion from Berwick to the ice terminus. In

Northumberland it has generally been supposed that the southerly motion was more strictly parallel with the present coast, and striae tend to confirm this. However there has been a suggestion (still to be examined in detail) of incorporation into the south-eastern tills of minerals derived from off-shore outcrops. The Scottish rocks in the local tills show some inland movement to have been likely. A small number of till fabric analyses confirm the parallelism with the coast at Scremerston (Berwick) but indicate an oblique movement in from the sea at Hartley in the south. The pattern of ice movement shows the Newcastle area to have been one of particular convergence and intense congestion with significant consequences for the area to the south.

It should be noted that reference to a coastline in this context is only a means of stating location, for the North Sea Basin would have been largely dry before the ice sheets contributing to the local glaciation met. On the world scale these sheets are peripheral to the area of the last major glaciation and much eustatic lowering of sea level would have been achieved earlier. The pattern of outcrops on the sea floor would affect the subsequent drifts just as the inland outcrops have so clearly done; from this point of view the present coastline is not important. The picture of North Sea geology shown by Kent (1967) is thus relevant to the interpretation of the east coast tills from Tweed to Wash, particularly the Hesse till (Carruthers, 1948, 1953; Penny, 1964; Catt and Penny, 1966).

Form of the ice cover

Knowledge of ice movement and distribution leads to consideration of the form of the ice surface. An indication can be derived from association of evidence for height of ice surface and for direction of movement. This however may give a conservative estimate. The reconstruction requires the application of the physics of ice-sheet forms. In this case the problem is rendered difficult by the gross irregularities of the surface over which the ice moved. If minimal gradients appropriate to the field evidence are applied a general picture is obtained which is of importance to analysis of the effects of the glaciation. The extent of the ice sheets and the minimal gradients needed to allow forward movement to the ultimate limits indicate a much greater thickness of ice than has previously been envisaged, and there could be little possibility of ice-free ground in any part of the area. An incidental consequence which might be explored is the isostatic effect and the possibility of differential response of structural units, e.g., the Northumberland Trough and the Alston Block.

The extent of the ice and the altitude of its surface demands consideration of the size of the alimantation zone which permitted the maximum advance. The general though implicit impression given in many local and regional studies is of ice sheets initiated and nourished in specific hill-areas. However the need for balance between accumulation and ablation, and the necessary shape of the ice surface show that alimantation must have taken place well beyond the locations of ice-sheet initiation (Clark, 1967).

Climatic implications have been studied particularly by Manley (1951, 1964) who indicated a marked eastward decline of snowfall and rise in snow-line matched by eastward decline in glacial vigour. Material in the drifts,

and studies of the area west of the Pennines, especially by Trotter (1929) and Hollingworth (1931), infer that at the time of maximum Newer Drift glaciation a high ice ridge extended from Galloway across the Solway to the Lake District, thence east to the Pennines. This crest, higher than any ice surface directly to the east was the parting between Irish Sea and North Sea ice-drainage and separated windward and lee slopes with respect to snow-bearing winds from the west. Manley suggested a firn line at about 1,100 feet in the Lake District during the Newer Drift glaciation. It is not known at what time in the build up of the ice that the relationship of precipitation to temperature was most favourable for accumulation. It may be noted that the firn line need not coincide with the altitude of the heaviest snowfall and that the relationship between the two variable altitudes would itself change during the course of the glaciation. However it is clear that the western area was for long one of great accumulation. The breadth and height of the western snow domes would be expected to produce rapid eastward decline in snowfall matching in pattern and probably exceeding in intensity the decline in present rainfall. Nevertheless a firn line several hundred feet higher in the east would have included much of Northumberland in the accumulation area.

A generalised scheme is presented of a possible form of the ice sheet needed to produce the observable morphological results and to carry the ice to its limits. This indicates great ice depth over Northumberland, particularly in valleys within the hills, with implications for the behaviour of the ice to be discussed below. A consequence of the eastward fall in ice levels and eastward rise in firn line would be a more rapid initial response to ameliorating climate in the east than in the west.

Ice margins

Sissons (1964, 1967) and West (1963, 1967) have drawn ice-margin positions for various late-Würm stages including stretches across Northumberland. West supposes a Scottish Readvance ice limit to pass from the St. Bees Head area into the Solway lowland, by Brampton, thence north east towards The Cheviot and then south east to the present coastline near Alnwick. He linked the features in the Kirkcowan area of Galloway to features of the northern Lammermuir slopes to form the succeeding Lammermuir-Stranraer ice margin. This alignment has been rejected by Sissons who placed the Stranraer-Kirkcowan features as part of a later Perth readvance occupying only the wetter western parts of the Southern Uplands. He linked the northern Lammermuir features to a line crossing those hills to their southern side thence enclosing the Tweed lowland and extending beyond the present coastline. From the Berwick area the postulated margin then ran south west apparently beyond Northumberland except for a salient including the Tyne basin above Hexham.

There has been little attempt to relate these postulated ice margins to features in the Northumberland landscape and it seems that they are largely extrapolated from beyond the county. Sissons (1964) has commented upon features in the Berwick-on-Tweed area as possibly marking his Lammermuir readvance, the Merse drumlin field, the Cornhill kettle moraine, and the unpitted delta in the Milfield plain. These forms will be considered below;

it is possible that they do not require marginal or readvance conditions for their creation.

Erosion

Great quantities of drift show that considerable erosion was achieved by the passage of ice. However spectacular landscapes of severe erosion are not widespread. Some hills and valleys in the northern Cheviots show signs of severe drubbing, and the Whin Sill is strongly shaped particularly in the hills near Budle Bay and in an almost scab-land landscape north of Colwell. Elsewhere the accentuation of sandstone and Whin Sill scarplands and mesas is notable especially where the directions of strike and ice-motion correspond, as between North and South Tyne, e.g., near the Roman Wall, and in the hills west of Belford. Combined erosional and depositional forms akin to crag and tail and rock-cored drumlins are by no means uncommon. The Shaftoe, Harnham, Berwick Hill, Saltwick and other examples lie west of Newcastle while in the north such forms occur in and south of the main Tweedside drumlin tract. Eroded rock basins survive as lake sites in the Roman Wall country west of the North Tyne, especially where they are isolated from major streams. Elsewhere eroded hollows are usually peat-filled like many basins in the drift.

Notable irregularities in the drift-rock interface are best documented in the coalfield and appear to take several forms. Anson and Sharp (1960?) located some forms which appear to be buried melt-water channels as well as broader depressions normal to the present coastline. Concealed valleys in the vicinity of the present Blyth and Wansbeck are still imperfectly known. The details of their interpretation as old river valleys depends on the future knowledge of possible erosive movement of ice from the west before Scottish ice achieved its maximum extent, and of the nature of sea level fluctuations in the glacial epochs. Understanding of the nature of a relationship between the Wear and Tyne systems depends upon an establishment of the altitude and location of the last interglacial coastline which probably lay inland from the present shore. Concentration of ice in the Newcastle area has largely obscured the local evidence by gouging out the Tyne trough above Newcastle and by causing deflection of ice south between Wickham and Gateshead effecting at least in part the Team Wash. It seems the question of where the Tyne and the Wear entered the sea before the last glacial period is by no means settled, nor is the question of whether they had first joined forces.

Tills

The provenance and nature of the tills of Northumberland has been described in general terms (Smythe, 1914; Raistrick, 1931; Hickling, 1949) and it has been noted that an upper reddish or brown till is characterised by more-travelled constituents than a lower, duller, tough, stony till. This bipartite sequence has been stressed as has the nature of the interface, variously described as an unconformity or as a gradual merging. In places, interbedded sands and gravels are conspicuous. However in some thick coastal exposures a gradation from base to top permits no separation into two tills while frequently either the more local or the more travelled till is absent. The upper till is usually the thinner. The degree of till cover

diminishes markedly from coast to inland areas where it is sometimes only a lower valley side deposit.

In places, especially on the coastal lowland, the upper till or, where thick, the highest part of this till has been described as a prismatic clay. There is some locational correspondence between this characteristic, the area of southward directed coastal ice, and a very subdued topography on the coastal plain. There have been suggestions that the low relief of the till sheet here was caused by a marine planation. There seems to be no conclusive evidence for this however. It appears more likely that the till lies on a generally little-accidented rock surface shaped partly by the youngest of a series of planations which have influenced the county's relief. In parts, particularly near the Tweed, the subdued till surface seems to terminate at a steepened inner margin which may correspond with an old coastal feature. It is also possible that the gentle relief is partly due to some fluid spread of a specially wet till in the low eastern parts of the county which received much melt water from the west during deglaciation.

The presence of sand and gravel layers within the tills has long been known, notably from between upper and lower tills, and consequently a multiglacial hypothesis has been advanced at times. At Ovingham and Ponteland channel fills in the till occur, some in association with major eroded melt water routes, some under a smooth till cover. It appears that some organized movement of water was taking place while much material which later built up the till was still held in the ice. The variety in location and development of the water-sorted sediments within the tills lends support to Carruthers' detailed arguments that the decay of a complex ice cover of one major glaciation would be adequate to produce the currently known features, though it obviously does not deny the possibilities of earlier glaciations.

Certain aspects of till topography have been noted. In addition to the drumlins a grained or corrugated drift surface is not uncommon inland from the coastal plain, the ridges matching in trend the movements of ice inferred from other evidence. The Merse drumlin belt is continued some miles to the east in this fashion, and the area south from the Simonside Hills to the Tyne is rather similar. These lineations have strongly directed the movements of melt water which the present streams follow almost faithfully. Drift tails to upstanding rock bosses are incorporated into the grained landscape. Where strong relief has lain athwart the movement of ice, the lee side is in many places a quite smooth till slope which produces or emphasises a marked asymmetry in many valley sections. It is clear that this form predates the final organised movement of meltwater in some areas. The dales south of the main Tyne, parts of Redesdale, and some dip slopes of the Fell Sandstone display this particularly well. In narrow upland valleys, particularly in the Cheviots, concave drift aprons on the lower slopes have been trenched by streams. The coarse stony drift often almost exclusively of local material strongly resembles slope-foot solifluction debris. Nevertheless it can be shown that the drift apron was in places cut laterally by subglacial melt water, and that in others the axial incision was cut by melt water. It is clear that much of this material predates Late-glacial periglacial activity and is a true glacial deposit.

Deglaciation (Map 4)

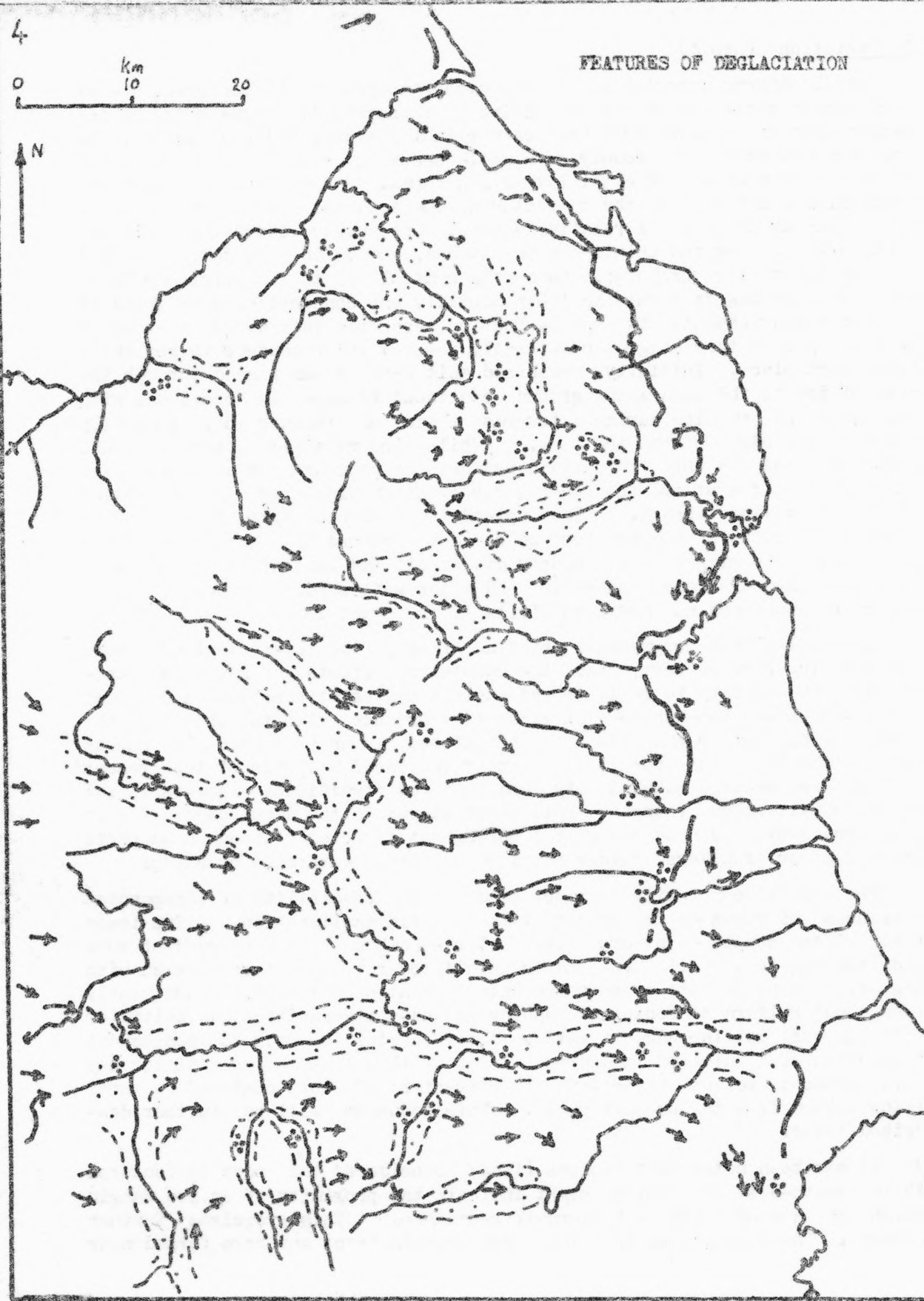
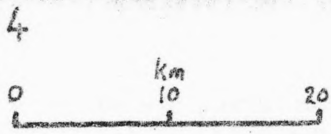
The landforms associated with the disappearance of the ice cover are of a character and distribution suggestive of a progressive downwasting of ice rather than an episodic retreat. Ice marginal features and proglacial forms are unimportant and the county as a whole seems to present a continuous and coherent arrangement of glacial landforms. Nevertheless there are complexities inherent in the character of the area and they appear to be of the following nature. A relatively simple ice surface concealed a diverse land surface. As the ablation zone widened, and as ice thinned, a unified mass of active ice broke up, under the control of the underlying relief, into areas losing or retaining their mobility and connections with areas of sustained nourishment. Eventually the ice separated into discrete stagnant masses. Before this stage was generally reached other changes in ice character took place. Initially, organised melt water which passed through the mass of ice to the underlying ground continued to move in accordance with the slope of the ice surface towards areas of thinner ice, generally towards the edge of the ice mass. While ice retained a thick, dense structure and was able to sustain hydrostatic pressure in englacial and subglacial melt systems, the general direction of discharge was independent of the underlying terrain. Thus uplands and ridges lying in any degree athwart the slope of the ice surface could be crossed by water moving under pressure. Many ridges in the county did so lie and innumerable examples of such crossings are found on minor and major watersheds from Newcastle to the extreme western and northern limits of the county.

Eventually with progressive thinning of ice, the development of a more complex ice surface form, and the cumulative effects of meltwater penetration, the ability to build up and sustain hydrostatic pressures was lost and water moved beneath ice in general accordance with the shape of the land. This latter phase is an important one in an area where ice sheets have melted 'in situ' for it means that the basic elements of the present pattern were created subglacially and that few significant elements in the drainage pattern are younger. Both these stages in the development of melt discharge systems can be recognised throughout the county though some parts lacking major transverse ridges display only minor watershed crossings.

The general complexity is increased by the possibility of independent responses of parts of the ice sheet to climatic amelioration. The lower part of the county east of a line Wooler - Hexham became starved of snow and incoming ice, while Tyne and 'coastal' ice retaining a connection with higher, wetter, western or northern uplands continued mobile. Consequently from about Belford to Ponteland southward and eastward directed meltwater from the west met the edge of thick, dense coastal ice with the consequent production of a suite of landforms. At about this time the coastal ice may have advanced inland affecting the character of this chain of features lying inland from the present shore. This sequence will be further described later.

It has been noted that Sissons (1964) considered that certain features to the south-west of Berwick might indicate the proximity of an ice margin which he equated with a Lammermuir readvance. This requires further comment. The suggestions that the Merse drumlin tract may have formed near


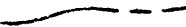


FEATURES OF DEGLACIATION



an ice margin loses force in so far as the tract merges evenly into grained till country and less strongly-moulded till spreads to the east and south without any ice margin features. The drumlins may reflect local ice behaviour within a broader ice cover but do not here appear to indicate the close proximity of an ice margin. The Cornhill kettle moraine was also postulated as an ice advance indicator but again this interpretation seems contestable. The moraine is a partly subglacial kame tract which can be fitted into a sequential development of glacial drainage in that area at a stage following the abandonment of the discharge of water from the Till-Breamish basin into the Aln valley. Progressive concentration of water movement into a subglacial Tweed involved the use and disuse of a series of channels between Lowick and Berwick at the same time as the Whitadder system north of the Tweed was becoming integrated. The Cornhill kames are a depositional correlative of a late part of this channel sequence from a period which saw the local change from a degree of ice-directed water movement to relief-controlled flow, and an associated change in ice-surface fall from south-east to north-east. The kame tract which locally overlies drumlins and, at least in its upper parts, formed under stagnant ice is thus not convincingly linked in time with the drumlins as diagnostic features. Its higher parts are related to the channels between Lowick and Berwick, and to the cutting of the Till gorge north of Heatherslaw. To the west the lower parts are associated with routes close to the Tweed north of Cornhill.

The unpitted delta of the Milfield Plain is part of a complicated area lying between the Wooler-Powburn kame tract and the Cornhill kame moraine. The former is largely the subglacial depositional product of the large regional melt system controlled by a south-east sloping ice surface discharging glacial water across from the eastern Cheviots and through the Till-Breamish basin into the Aln. However some of the deposits and channels can be shown to belong to a later stage of reversed northward drainage. The relief of the Fell Sandstone upland in this area allowed the Powburn channel to operate until and possibly, because of the intervening distance (17 miles), after the northern channels became operative. The formation of the Wooler-Powburn kame tract thus spans the period of drainage reversal and its youngest and mainly lower part is possibly contemporary with the Cornhill kames. Between the two lies the Milfield Plain where thick young sediments fill an excavation in the Cementstone Group outcrop which is at least a hundred feet deeper than the rock lip at Heatherslaw where the Till leaves the Plain. It can be shown that meltwater entered this area from all sides probably at one stage moving below the present level of alluvial infill. It appears likely that the delta was fed from an ice contact, accumulated, and was then cut to below the present level of Till alluvium

MAP FOUR - Features of deglaciation

-  Areas of thickest ice (in uplands).
-  Approximate position of inner limit of influence of coastal ice.
-  Selected meltwater routes crossing ridges.
-  Location of major glacifluvial surface deposits (generalised).

while ice remained adjacent. The general impression of this anomalous situation is of a feature produced beyond ice but substantially enclosed by ice. A possible explanation is based on an association of characteristics, a deep basin holding thick ice and having an ice base lower than that all round, a centripetal drainage system, and a way out which progressively lowered from over 200 feet to about 100 feet O.D. but which maintained high standing water levels in the ice. It is suggested that under those conditions ice in the Milfield basin was lifted, eventually fractured, disrupted, and disposed of, leaving an area to be occupied by fluvial and lacustrine forms yet surrounded by contemporary glacial forms. For the present purpose the outlines only of a complex situation are presented in an attempt to show that the delta was not necessarily formed at the outer margin of an ice sheet and that the case for a Lammermuir readvance margin existing in the area is not a strong one.

The evidence from the county as a whole is of ice wastage taking place simultaneously over a wide area with the development of both regional and local components in the pattern of melt movement. The regional pattern of ice flow and the general unimportance of local relief control upon ice movement together with the evidence for widespread contemporary melting, including the occurrence of fragile subglacial landforms, show that over large parts of the county the ice lost mobility while still very thick.

It has been inferred above that eroded channels and glacialfluvial deposits may be complementary parts of melt discharge systems and as such can be described together. However it is also useful to consider particular characteristics of the deposits and channels separately. It has been shown that traces of organised movement of water are found within the tills and that some channels lie alongside buried channel fills; it is clear that some melt routes persisted virtually throughout the period of ice loss, and that very many areas experienced a change from depositional to erosional environments at a time of advanced ice loss. Much of the glacialfluvial material, particularly prominent kames and eskers, show that ice was stagnant at the time of their formation though it is possible that some spreads in the mid-Tyne valley were formed before ice motion ceased and that early deposits were smeared and disfigured. Some of the major accumulations are related to important ice-controlled ridge-crossing channels and were built up beneath several hundred feet of ice on adjacent low ground. The upper part of the Wooler-Powburn kame tract is the major example of this class of feature in the county. An important characteristic which this area displays, a combination of many feeders and restricted outlet, is found in other major glacialfluvial areas in the county. Where the building of subglacial sediments took place under relief-controlled flow the restricted outlet was produced either by a lower valley constriction, or by a lower ice restriction where the drainage was towards an area of thicker ice, or by both. Such situations existed along the 'coast' and at times in the Tyne valley. Whatever the circumstantial details the result was to produce an effective sediment trap. In several places the sediments have been built up into quite smooth sheets to heights controlled by persistent outlet levels and resemble pro-glacial 'sandars' on a small scale, but their subglacial character is shown by the presence of occasional kames and eskers on their surface and/or by their subsequent incision by subglacial water.

It is clear that the extensive sheet flow under ice involved in the building up of sediments was succeeded in places by dominance of more specific paths of water movement. The Aln, Coquet, Font, and the East Allen valleys display those combined forms well. The first three appear to have been influenced by coastal ice. Their thick masses of sands and gravels which cannot be satisfactorily explained by relief situations alone are associated with southwards diversions of drainage that include some ridge-crossings. As the coastal ice lost its ability to impound and deflect, this phase was succeeded by direct discharge to the east characterised by incisions in the areas occupied by the coastal ice and by trenching of the sands and gravels. When this took place water passed beyond the present coast below present sea level, eustatic recovery being relatively little advanced. A restricted coastal strip south of the Aln is virtually free of surface fluviglacial deposits because after the coastal ice lost depth and coherence no sediment trap could be produced. This regional pattern explains how Cheviot materials characterise sands and gravels as far south as the Kirkley kames fed from the north, while the adjacent Dissington kames contain western materials, a contrast in content noted by Smythe (1900) and partially explained by him. It also produces a suitable context into which the reversal of drainage in the lower Coquet area can be fitted. It may perhaps be worth looking at the north Durham kames in these terms.

This coastal area includes the district from which Anson and Sharp (1960?) describe buried sections of deep channels trending normal to or parallel with the coast and incised up to 100 feet below present sea level. It may be noted that in addition to the explanations proffered by those writers, the channels (considered to be pre- or inter-glacial valleys and spillways respectively) can perhaps be accommodated in the sequence of events here suggested by the present writer. It should be noted that normal land drainage would be extended on to the sea bed as world-wide eustatic sea level lowering preceded local ice occupation and that 'pre- or inter-glacial valleys' may in fact be early-glacial. It would be valuable to examine this area further bearing in mind also the possible effect of an inland movement of coastal ice against thinning lowland ice crossed by major regional melt routes. The invasion of the lower parts of such routes would obstruct and direct southwards their waters, obliterate or obscure their lower channels and intervening landforms, and impose a further layer of drift over and perhaps incorporate the earlier deposits. On weakening, this coastal ice would allow the inland drainage to establish new eastward routes without any certainty that the older concealed ones would be revealed. Drainage from the western margin of coastal ice would be to the zone of southward diversion but dissipation would lead to drainage reversal and the development of a new young eastward drainage pattern.

The Bradford Kame, a controversial and spectacular part of a complex kame and channel tract traceable from Spindlestone to Shipley in the Aln valley, was studied in detail by Carruthers (1927) and his team, Burnett particularly, but its character is still incompletely elucidated. It appears to be compound, the southern part belonging to the period of thick coastal ice that permitted ice-controlled south-directed drainage to take water from the coastal plain into the Aln valley above Alnwick. Later development of the kame was restricted to the coastal plain. A clear relief

contrast exists between the parts of the coastal plain north and south of the Aln. The general morphology of the plain to the north suggests that ice impressed a strong and persistent southerly direction on melt movement throughout the dissipation of an ice cover which underwent a relatively simple downwasting and stagnation.

Some other areas of glaci-fluvial sedimentation deserve notice. Linear esker and kame systems lead east towards watershed channels near Elsdon and Hallington, the former as part of the Font system, the latter taking water to the Blyth discharge routes. On the slope southeast from the Simonside Hills traversed by several melt routes including the continuation of the Elsdon route there are many well-formed, even meandering, eskers and kame mounds, not easily related to any relief control. The kames of the Blyth subglacial catchment near Dissington, built largely of western-derived material, appear to have developed there because thick coastal ice immediately to the east produced a trap by diverting and directing drainage first across and then along the northern flank of the ridge which lies north of the Tyne. As this ice thinned water cut into the kames and flowed to the newly-opened subglacial Blyth which itself encountered another trap above the Stanington gorge, a late location of ridge-crossing.

The Whitley Chapel kames occur in an area studied by Sissons (1958) who concentrated upon the erosional features in revising earlier views, particularly those of Derryhouse (1902), and in offering an explanation of the humped long-profiles of important melt-channels to which Peel (1951) had drawn attention. It may be noted that Sissons' views now stand in need of revision particularly with respect to the interpretation of ice-margins and the significance of certain channels. Glaci-fluvial deposits extend for about four miles from south-west of Whitley Chapel to about Newbiggin. They appear to postdate the disuse of the major Beldon channel which took water into the adjacent Derwent valley, and to be contemporary with the period in which eastwards water movement across the watershed from the Devil's Water became increasingly concentrated in the East Dipton Channel. That the normal valley opening to the Tyne was not used, and that the East Dipton Channel was excavated by water moving under hydrostatic pressure shows the Tyne ice was still sufficiently thick and dense to repulse water. This suggests that West Dipton water and possibly even some from the Tyne ice itself used the East Dipton route until the Tyne ice admitted normal water flow causing the local cessation of hydrostatic flow, the deepening of older valleys and the trenching of the kames. For some of the time during which the East Dipton Channel acted as the major outlet for a very large area the Whitley Chapel district acted as a sediment trap.

The Tyne discharged water from its whole catchment only towards the end of the period of ice loss. Subglacially-produced landforms exist along the forty mile stretch of the main valley though whether the whole length ever operated as a subglacial route at the same time remains to be worked out. The magnitude of this great meltwater route was vastly increased by the inflow of water from the west. Meltwater entered the Tyne basin from the Butt Hill channel at the head of Geltsdale for forty miles to Deadwater on the North Tyne and also at the headwaters of the Rede. Many of the crossings were high (channel floors up to 1,500 feet) and belong to an early

part of the ablation period when ice surfaces were high and hydrostatic pressure responsible for directing much water movement. The low area between Cold Fell and Spadeadam became the zone for persistent and concentrated transfer of water into the Tyne system so long as ice surfaces to the west remained higher than the lowest point in the Gilsland col, the last path to be used before flow reversed when water pressure exceeded ice pressure at the line of thickest ice. A complex and extensive association of channels and deposits stretching for many miles north and south of Brampton tells of the convergence of water into the Tyne gap. Specific landforms suggest that water approached even the lowest col at Gilsland under pressure, that some of the incision of the Irthing valley above and below Gilsland was produced while water moved into the Tyne, that reversal of drainage took place under an ice cover, and that the present surface form of the deposits conceals a history of variations in paths of movement and accumulation. It should be noted that in this area no recourse is needed to ice margins, glacial lakes, and readvance conditions in discussion of the local deglaciation features at least until after the disuse of the Gilsland channel.

Many of the characteristics of both form and origin of local melt channels have been considered by writers already cited, the principal outcome being the gradual rejection of the 'lake and spillway' model and an adoption, hesitant despite early advocacy, of a 'wastage in situ' model with its implications. It is proposed to limit present discussion to certain points which have not received much attention. Derbyshire (1961) in particular has discussed the depth within ice to which meltwater can penetrate, suggesting that 300 feet is the approximate limit. He sought to apply this limit as a criterion for determining the relative ages of channels by altitude. He also assumed that subglacial col gullies formed under hydrostatic head tend to be the highest and earliest deglaciation features of a locality. It has been shown here that as a generalisation this assumption has significant exceptions. The reality of the limit requires further examination if only to refine the question. It would seem that there are two issues involved, the depth to which water penetrates into an ice cover and the depth to which it passes when in contact with the ice bed, having entered at an ice margin or met the ice bed in the course of penetration into the ice cover. With respect to the first issue it would seem that although in the earlier period of widespread ablation perhaps little water reached the underlying land the location of crevasse systems would be important in determining where water met land. When there were few if any nunataks and, consequently, ice margins, the correspondence of crevasses with ridges would favour the latter as sites for initiating subglacial drainage while they would clearly be early in intercepting englacial moving water and water tables in thinning ice. There is a large number of hillside channels which combine the characteristics of ridge-crossings or col-incisions with those of chutes. Many of these appear to contradict the 300 feet limit expounded by Derbyshire in descending hillsides to depths of between five and seven hundred feet. Consider the case of an east sloping ice surface concealing valleys running north to south and allow the bounding and intervening ridges to be accessible to melt water. Then, for certain stages of deglaciation, melt water meeting the

ground at the ridges would move east, some of the water from the west of the ridges being under pressure. East of the ridges water would descend the hillslope as far as possible. Field evidence shows that this was often almost to the valley floor. Consequently the pattern revealed by complete ice loss is asymmetrical with much greater concentration of valley-side channels on the 'up ice' side of the valleys and local minor ones only on the 'down ice' side. Such asymmetry is a widespread phenomenon in Northumberland, often in conjunction with the asymmetry due to differences in the form of till deposits discussed earlier.



Though 'in and out' channels have long been known from Northumberland little if any note has been taken of a similar characteristic found in many melt channels still occupied by streams as well as in some empty channels. This is a channel meandering greatly exceeding in size meanders of the present winding streams and generally occurring on sloping ground where free flow under ice would be likely. Paige (1956) and Loewe (1957) described meandering flow under ice, and the very large numbers of such forms in Northumberland ranging up to about a half-mile in wavelength suggest that the development of swinging paths by concentrated melt water under ice is not unusual. The Irthing displays these forms well. Its very large potholes starting well above the present channel and its numerous falls were also possibly initiated subglacially.

One of the most significant results of the deglaciation was the institution of a new stream pattern. Even in the upland many valleys are so drift encumbered that their streams have new reaches. However, a virtually fresh pattern was produced in the eastern area extending north from the Ponteland district where it is widest, past Alnmouth where it is very narrow, to Berwick where it is squeezed into the sea. The principal elements in this zone are those rivers which, as subglacial channels, extended directly to the North Sea basin as the coastal ice thinned. Some of these are continuations of older inland valleys, others are the lower paths of meltwater which crossed ridges from further west, but together they form a series of incised Rinnentaler or Tunneldales that owe little to postglacial processes.

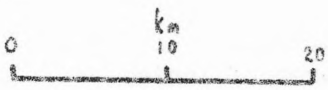
Late-glacial cold climates (Map 5)

There is abundant evidence that periods of great cold affected the area in the Late-glacial period after the loss of ice cover and it is clear that

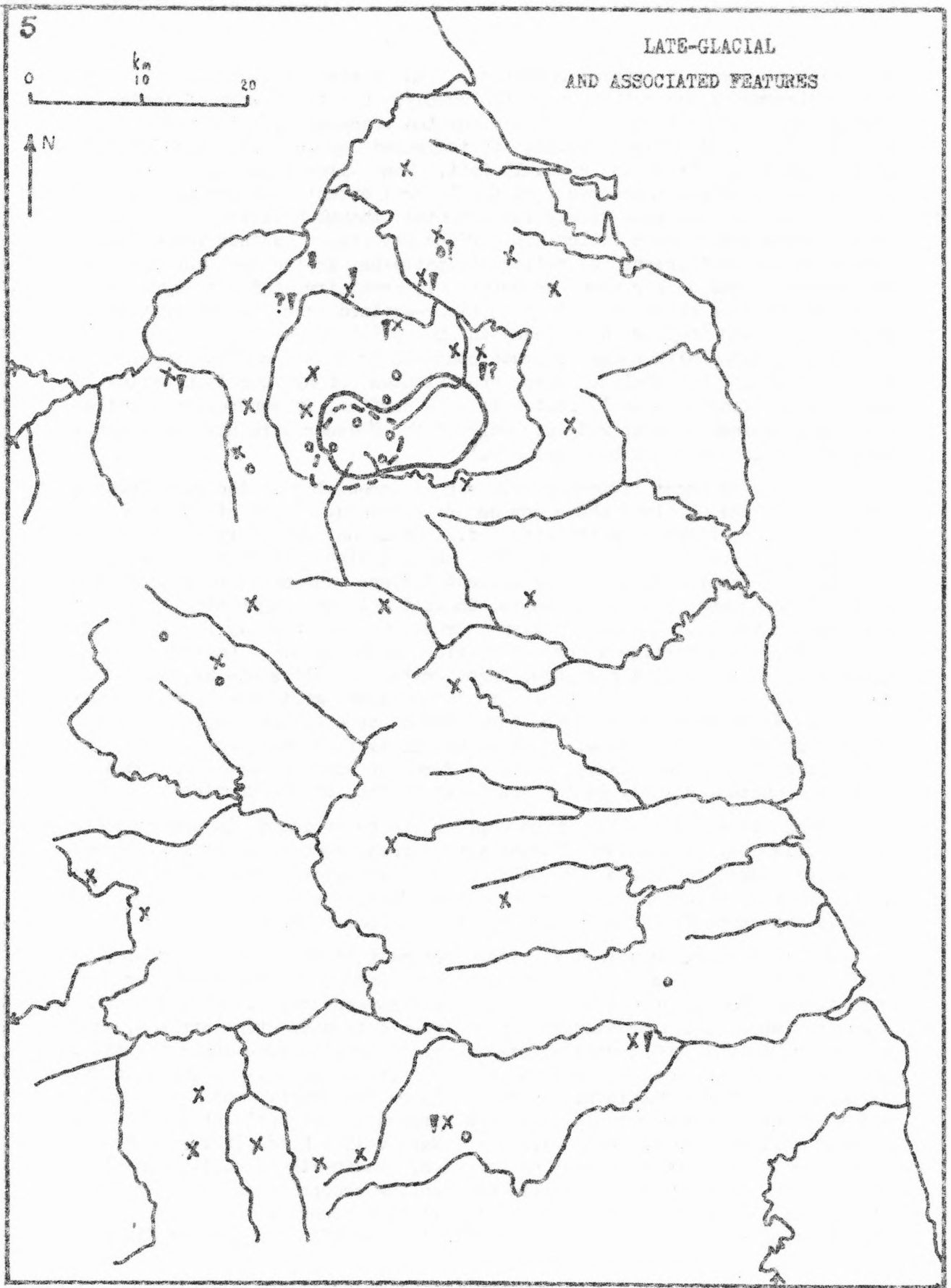
MAP FIVE - Late-glacial and associated features.

- X Selected locations of frost phenomena (scree, block-fields, head, bedded slope deposits, convolutions, etc.)
- ! Ice-wedge pseudomorphs.
- o Deep weathering profiles.
-  Principal area of tors and tor-like forms on Cheviot igneous rocks.
-  Principal area of Cheviot altiplanation and nivation features.

5



LATE-GLACIAL AND ASSOCIATED FEATURES



at times cold was of extreme severity. The various features telling of cold environments occur throughout the county, but the degree of landscape modification brought about by the associated processes is not well known. Deep and sustained ground freezing is indicated by ice wedge pseudomorphs some of which penetrate to 12 and 15 feet. Most sites known to the present writer are vertical exposures and the lateral extent and arrangement of these forms has not been widely investigated though a limited examination at two sites indicates a reticulate surface pattern. Rather vague indications on air photographs of reticulate patterns in the kame moraines in the Cornhill and Wooler area associate in proximity and site type with known occurrences which are mainly in finer-grained kame and higher terrace deposits, though they are also found in shales (Slaley area). Forms generally associated with wedges include contortions in the surface layers of kame deposits and shales, deep precipitates of hydrous iron oxides in horizons and lenses up to 12 feet below the surface, in concretions, and as cementing linings to deep wedges. Only at the Redscar site have syngenetic contortions in sediments been noted yet.

Forms due to frost riving are widespread especially in the closejointed andesites of the Cheviots where screes are numerous. The steep slopes of many glacial melt channels are affected. It is not necessary to invoke an exceptionally severe climate for scree accumulation but there is evidence of indurated layers in deeply translocated fines and of deep iron precipitates from exposures of scree in the Cheviot valleys suggesting they have been deeply frozen. Northumberland screes are essentially fossil forms, even if locally remobilised by overgrazing or burning. On more massive rocks such as the Fell Sandstones, Ingoe Grits, and Millstone Grits, block collapse has been usual. Where certain quartzose grit beds form the land surface, shattering and heaving have formed true blockfields, as on the moors west of West Allendale. It seems likely that even more blockfields could be hidden under blanket peat. Forms of similar type are found on Cheviot granites, notably on the southeastern face of The Cheviot.

Bedded slope deposits which appear to be produced in environments characterised by temperature fluctuations across freezing point have formed on slopes where the rocks are subject to a granular disintegration, and occur as the equivalent to scree on some Cheviot andesites. They are locally important from the Kale valley to the Wooler area.

Present winters can lead to minor sorting patterns (small polygons) in loose debris on the summit of Cheviot but larger fossil forms are not conspicuous though an exposure in the upper Bowmont valley showed a crude structure which could be ascribed to the degradation of stone stripes, and at Auchope Cairn on The Cheviot there are 'fossil' stone-banked terraces. Altiplanation terraces are recognisable if rather poorly-developed in the higher parts of the Cheviots, particularly on The Schill and The Cheviot, and there are quasi-horizontal nivation furrows at the heads of some of the highest valleys and hillside niches. Many valley heads in the Cheviots, even some below 1,000 feet have an expanded, basin-like quality suggestive of nivation enlargement, and there are shallow scoops in the sides of some hills, e.g., Hedgehope and The Cheviot. It is noteworthy that these become the location of deepest and most persistent snowdrifts in current winters.

However their forms are in many instances older than the last ice cover for not only do some hold regional till or are crossed by meltwater channels but they do not hold the deposits which would indicate significant Late-glacial enlargement.

Perhaps only The Bizzle on The Cheviot is a suitable site for true corrie development and only this site approaches a well-developed corrie shape. The other sites owe much of their form to local snow accumulations preceding regional ice cover in a more severe and long-lasting environment than any in the Late-glacial.

Disturbance of upper layers in the coarse stonier tills of the Cheviots is apparent but the effects of frost climates on the heavier textured lowland tills is little known though Anson and Sharp comment on periglacial landscape smoothing in lowland Northumberland.

Solifluction deposits are distinguishable in upland Northumberland; for example in upper Allendale two layers occur, the lower being the thicker. It is clear however that some landforms and materials require careful examination and sound criteria before distinction can be made between glacial and periglacial origins.

Similar care is needed over the interpretation of the numerous tors and tor-like forms found on the granites, on and near their aureole, and on the more massive sandstones and grits. Within the uplands and intermediate zone the forms in question are widespread. It would seem from present knowledge that recourse might be necessary both to a deep-weathering, exhumation model and to a more time-restricted periglacial model in order to explain all forms. Almost all occur where there is clear evidence that ice has been, though some of the most prominent east of Cheviot are essentially in a 'lee' situation and the highest occurrences on Cheviot were probably in an area of firm or of minimal ice erosion. Some occur in close proximity to sites of deep weathering (often c. 30 feet) where core stones and/or the basal weathering front is exposed. Most of these weathering sites are in the uplands where they occur in valley floor, hillside and hilltop locations. It can be shown that some Cheviot exposures of deeply weathered material have been cut by melt water and thus, as other evidence supports, the material is older than the glaciation. It might be argued that location in areas of minimal ice erosion has helped to preserve it, and that freezing before being ice-covered would also help. It is likely that the present occurrences are favoured residuals of a once more widespread cover. Certain tors in the Cheviots may well have a close approximation in form to upstanding parts of the earlier basal weathering fronts, and the presence of deeply weathered sandstones suggests that this may be true of some hillcrest tors in sandstones as for example south of Redesdale. However the characteristics of some tor-like forms show that their isolation and prominence is due to Pleniglacial and Late-glacial processes though the details of their modelling are more recent.

Personal knowledge of lowland sites is restricted to the lowest parts of a weathering zone on a Coal Measure sandstone west of Newcastle. If this reflects more than the intensity of fieldwork it may be the intensity of lowland ice erosion and the extent of concealing deposits. However if

deeply weathered zones are very old then the question of when lowland Northumberland became a terrestrial environment may become relevant.

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THE GEOLOGY AND METALLIFEROUS MINES
of the
BUTTERMERE AND LOWESWATER VALLEYS.

by

J. Moon, F.G.S. and J. D. J. Wildridge.

Introduction

The workings of these mines are situated in two of the most beautiful and lesser frequented valleys of the English Lake District. None of the mines is large; in fact all but two would today be regarded as little more than trials, which is what a number originally were.

The first record of mining is in the reign of Elizabeth I during which time German miners were brought into the Keswick area to improve the working of the mines. The Germans kept meticulous records which are still in existence in the archives at Augsburg.

Whilst dates are difficult to come by it would appear that no more work was done in the area until the early part of the last century. This continued spasmodically until towards the end of it.

Most of the workings are for lead, with three for copper, and two for iron, and many of them are difficult to find because there is no spoil visible or it blends in with the scree on the fellside. Many of the smaller workings were only located by talking to local people who had lived in the valleys all their lives and knew of odd holes in the fellsides.

Grid references are in some instances difficult to give and should only be regarded as approximate, but combined with the description should prove adequate.

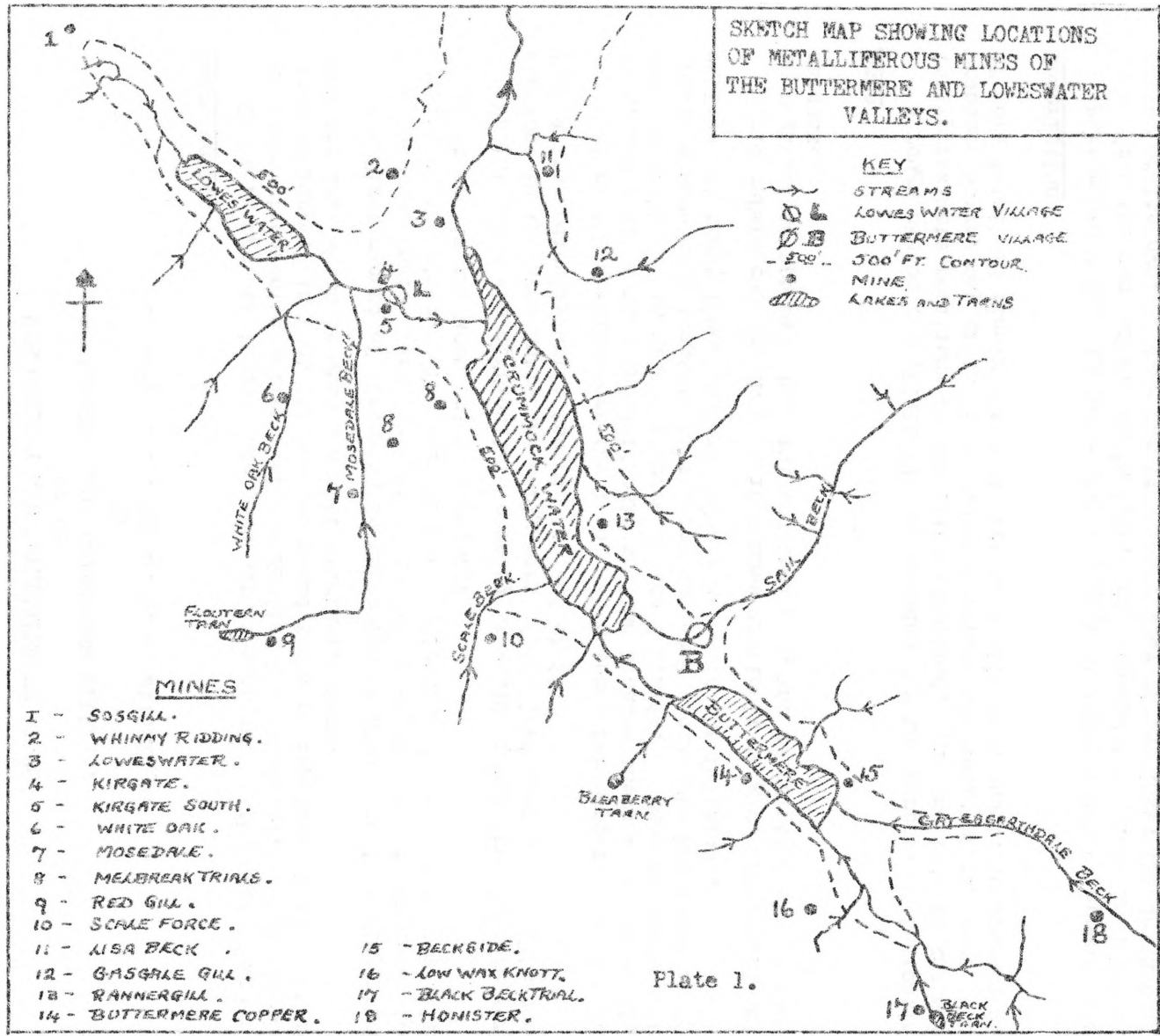
Maps

A rough sketch map (Plate 1) is included for the purpose of indicating the approximate positions of the sites described. The one inch to the mile Ordnance Survey map of the Lake District covers the whole of the area, but if more detail is required the 2½ inch to 1 mile maps should be consulted.

Description

Buttermere Valley is not really a valley of three lakes as appears when seen from the top of Fleetwith Pike, for Loweswater lies in a lateral valley of its own. Ages ago it was a valley of one lake; the delta built up by Sail Beck has gradually divided the lake into two.

Crummock Water has a more varied shoreline than any of its rivals in the western Lakes. Viewed from a point where the road runs past the flanks of Grassmoor one looks into the peaceful nook of Rannerdale where the fells are set back from the edge of the lake and allow room for a few green



meadows. Just beyond, the road passes round the rocky Hause Point, where it runs on a shelf above the lake, shortly to reach the village of Buttermere. On the western side the screes of Mellbreak (1676 ft.) sweep down to the water's edge ending in a little peninsular called Ling Crag, beyond which the valley of Scale Beck separates Mellbreak from the long range of the Buttermere fells of High Stile (2643 ft.), Red Pike (2479 ft.) and Starling Dod (2085 ft.). Scale Force is easily reached from the village; with a fall of 130 ft. it is the highest in the district and owes its impressiveness to its fine situation and the wonderful variety of rock plants and ferns draping the rocks.

On the eastern side of the valley are Grassmoor (2791 ft.), Whiteless Pike (2159 ft.) and Robinson (2417 ft.). The head of the valley is dominated by sheer precipices of Yew Crag and Honister Crag, both scarred by the tramways and tips of the 200 year old slate quarries, the slate from which is got out of long galleries driven into the hillside. The right-hand corner of the head of the valley contains the wonderful sweep of Warnscale Bottom flanked on the left by Fleetwith Pike and on the right by the rugged cliffs of Haystacks.

The seaward end of the valley opens out gradually into the coastal plain of the Solway Firth.

Geology

The area is formed in the main part of Skiddaw Slate rocks bordered on the south and east by the Borrowdale Volcanic Series, into which on the south-west side has been intruded the Buttermere and Ennerdale Granophyre. The whole of the bottom of the valley is for the most part covered with Glacial Drift, whilst the flatter ridges between the valleys are often covered with peat.

The valley probably formed originally along the prolongation of a fault running up from the Duddon Valley. This fault would form a line of weakness which would be followed by one of the rivers during the radial drainage period of the Lake District. The valley would then be further deepened and straightened during the Ice Age. Final shaping would then take place after the ice had melted up to the present day.

The lakes, at one time joined, are glacial in origin. They are now separated by the inwash delta from Sail Beck and lie in rock basins formed by glacial erosion of the Skiddaw Slate rock. The sides of the lakes show evidence of their origin due to blockage by glacial accumulation (terminal moraine) and their straightness except where interrupted by delta growth. The portion of the lake at the head of the valley (Warnscale Bottom) has been much foreshortened by delta inflow. On the west side of the stream joining the lakes can be seen the fault evidence. Here the Skiddaw Slates are exposed, shifted greatly to the south, in contact with the Granophyre.

Rannerdale Knott shows good evidence of truncation by the glacier as it cut out the valley.

Table of formations

The geological formations are given in the following table in descending order

Superficial formations

Recent and Post Glacial

- Peat.
- Alluvium.
- Deltas and fans.

Glacial

- "Upper" sands and gravels.
- "Upper" boulder clay.
- Interglacial peats.
- "Middle" sands and gravels.
- "Lower" boulder clay, moraines, etc.
- Gravel and boulder clay of earliest glaciations.

Solid formations

Ordovician

Borrowdale Volcanic Series (Llandeilian)

- Lower andesites.
- Mottled tuffs, dark tuffs with occasional conglomerates.

Skiddaw Slates (Skiddavian)

- Latterbarrow Sandstone (hard quartzite grit).
- Mosser Slates with Watch Hill Grit (slates may be striped, coarse grit in upper part).
- Kirkstile Slates (Lower Mosser Slates; soft dark slates).
- Blakefell Mudstones (hard, pale, grey-banded mudstones, flaggy sandstones with slates and grits).

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Intrusive igneous rocks

- Buttermere and Ennerdale Granophyre.
- Dykes of felsite and porphyrite.

Metamorphic rocks

- Hardened slates, spotted and chialstolite slates.

Ordovician

The oldest rocks of the area are the shales, mudstones and grits of marine origin - the Skiddaw Slate Series. They consist of repeated alternations of muddy and gritty sediments which differ not only in vertical distribution but also in lateral extent. Three major divisions have been recognised. A lower one presenting two different facies, Blakefell Mudstones and Loweswater Flags; the latter being alternations of shales or mudstones with sandstones and coarse grits. A middle one of Mosser Slates

(locally Kirkstile Slates), finely laminated shales, or shales and silts. An upper one of Latterbarrow Sandstone lying just to the south of Kinniside outside the area under discussion.

The predominant rock of the northern and western parts of the area is Skiddaw Slate in the form of three anticlines, one main and two lateral ones. They are composed of Blakefell Mudstones together with the Lowes-water Flags and Mosser Slates (Kirkstile Slates).

To the east the Skiddaw Slates are succeeded by tuffs, lavas, etc. of the Borrowdale Volcanic Series, whilst the central southern area is formed of the Buttermere and Ennerdale Granophyre.

The western end of the valley is covered in most places with glacial drift.

The Buttermere and Ennerdale Granophyre

This forms the major igneous intrusion of the district. It was shown by S. E. Hollingworth to be "a stock rather than a laccolite" and is probably of Caledonian age. The fine-textured pink coloured rock is made up of quartz and felspar. A microscopic examination shows it to consist mainly of micropegmatite with chlorite pseudomorphs after augite and biotite. It appears to have been intruded in some parts along the boundary between the Skiddaw Slates and the Borrowdale Volcanic Series.

Glacial and Recent deposits, etc.

A series of hanging valleys and combes is found on the south-west side of the main valley; the most conspicuous being Bleaberry Combe (containing Bleaberry Tarn), and Birtness Combe.

The glacial moraines and postglacial deposits carried into the lakes have already been mentioned.

Peat occurs whenever natural drainage is insufficient to carry off the surface water. These conditions are to be found on many of the flat ridges between the valleys; such as on Buttermere Moss and on top of Haystacks, also on the alluvial flats at the heads of the valleys and the low-lying valleys themselves such as Mosedale.

The peat on the ridges usually rests on glacial accumulation. There are various indications in parts of the district to show that the growth of peat has now ceased. Many of the "Mosses" are now shrinking and being traversed by cracks. Water collects into these cracks and wears away the peat forming large channels separating the peat into isolated blocks. The lapping of windswept water undercuts these peat blocks and causes their gradual destruction, with the result that infilled peat hollows are being slowly restored into tarns. One of the finest examples of this is the tarn on Haystacks.

Details of the Mines

In only two cases is the actual name of the mine or trial known (Lowes-water Mine and Buttermere Mine); in all others the name is that given when the fieldwork was done.

Iron

There is evidence of early working for iron in two bloomery sites, one at Cinderdale Common (Rannerdale) and the other at the upper reaches of White-Oak Beck. The reason for the location of the former is obscure as there is no source of supply in the immediate neighbourhood. With regard to the latter the ore was probably brought down from the early haematite workings to be found associated with the Scale Force and Red Gill Faults in the Flouter Tarn area at the top of Mosedale Valley. The veins lie along the faults which in places form the dividing line between the Granophyre and the Borrowdale Volcanic Series. In some places the two rock series form opposite walls of the workings, especially along the Red Gill Fault.

Scale Force Mine NY 152170.

The lode is N.-S. On the left of the Scale Force Gorge is a small tip. The entrance is completely collapsed. Nothing much is known about this working. It was said to be very promising, but the work was discolouring the water of Crummock Lake and the owner had the mine closed.

Red Gill NY 129167.

Up Mosedale, just before one reaches Flouter Tarn, Red Gill can be seen on the left. The workings are quite obvious on approach. The vein worked is a split vein which was also worked on the other side of the mountain at Clews Gill where it appears as a single vein. All the workings are in a state of complete collapse.

Mellbreak Trials NY 142192 and NY 148196.

Both these are very small and go into the mountain only a few feet. The former can best be seen high up on the west side of Mellbreak if one stands on the Little Dodd side of the valley. It appears as a black hole high up above an obvious track traversing the mountain, which is the best approach. The latter can be seen facing as one approaches Mellbreak from Low Park. There is little of interest in either trial.

Copper

The earliest working for copper seems to have been during the reign of Elizabeth I when German records at Augsburg record a mine at Buttermere. This would appear to be the only mine in the valley of which there is any recorded production.

Buttermere Copper Mine NY 181156.

The easiest way to locate the mine is to follow the western shore of the lake until one arrives at the tip. The entrance to the mine is blocked and whilst quite a large dig located the roof of the level, the workings are flooded to this height and access would only be possible after further considerable digging.

Extracts from the Keswick Journal of 1569 give the following information:-

"Shrovetide reckoning

Andre Tor has turned out at his tribute work 120 Kibbles of Massey ore, of which he has still to be paid for 40 kibbles at 2d. --- £4; also 100 kibbles of shally ore on which the balance due to him is £2-8-6.

Easter reckoning

Carriage of ore from Buttermere 128 Kibbles ----- £3-4-0."
(This would be transported probably to Copperheap Bay on Derwentwater, whence it would be taken to the furnaces at Keswick.)

"A. Thore, 8 Kibbles massey ore and 100 Kibbles of shally ore, £9-13-4.

Whitsuntide reckoning

M. Berger for last term and A. Torer for last term £4-3-4.
A. Torer £6 and for ore raised £4-6-8.

St. James Day reckoning

J. Dixon, carrying ore from Buttermere, bringing it up from the water side and putting it into sacks, £2-4-0."

The only other information is that the mine was still working in 1570.

Honister Try Level NY 220140.

From the top of Honister descend toward Buttermere, At about the large sign warning DANGER on the left, go down into the gill and follow it until the level is found. This short level goes under the road and follows a strong vein of quartz in a north-easterly direction for about 60 ft. The vein is mainly a mixture of quartz and specular iron with some small copper strings in the roof, and it is thought that this is the reason for the trial.

The vein has again been tried where it reappears in the crags half way up the spoil heaps of Rigghead slate quarries in Borrowdale where a level (very difficult to find) of about the same length was driven.

Low Wax Knott NY 188141.

To locate it, follow the path up towards Scarth Gap until it goes across the top of a small crag. This is Low Wax Knott. The vein goes along the base of the crag roughly east-west, and in places has been stoped up to grass. It may have been worked open at first and then a level driven to try it in depth. The entrance to the level is by a cross cut, the original entrance being covered with scree, which breaks in about half way along the now accessible part of the level. The total length of the level from the blocked entrance to the rushed stope is 48 ft. and the original extent of the working would not take it much beyond this point.

Exact dating would appear to be out of the question, but it was known to have been worked towards the end of the last century by two men who led a rough existence in a small hut near the workings and who when the weather was reasonable came down each night to the village local. Eventually they ceased to come and it was not until the body of one of them was found in a deep pool up Warnscale Bottom that it was presumed that one had done away with the other and the survivor had taken off.

There is no record of production.

Lead

This mineral seems to have been the only one to have been worked to any reasonably large extent, but apart from the two relatively major workings of Loweswater and White-Oak, the mines are little more than trials.

As far as present research has been able to divulge, most if not all of these workings were driven about the time when Loweswater Mine was in operation.

In Scalehill Woods (NY 149214), on the left after passing through the gate, there are a number of small overgrown workings of unknown origin. One of these, known as Batey's Cave, was thought to go right under the Scale Hill Hotel, according to local tradition. This is obviously not correct as the spoil tip for such a venture would be considerable, and very little is in evidence.

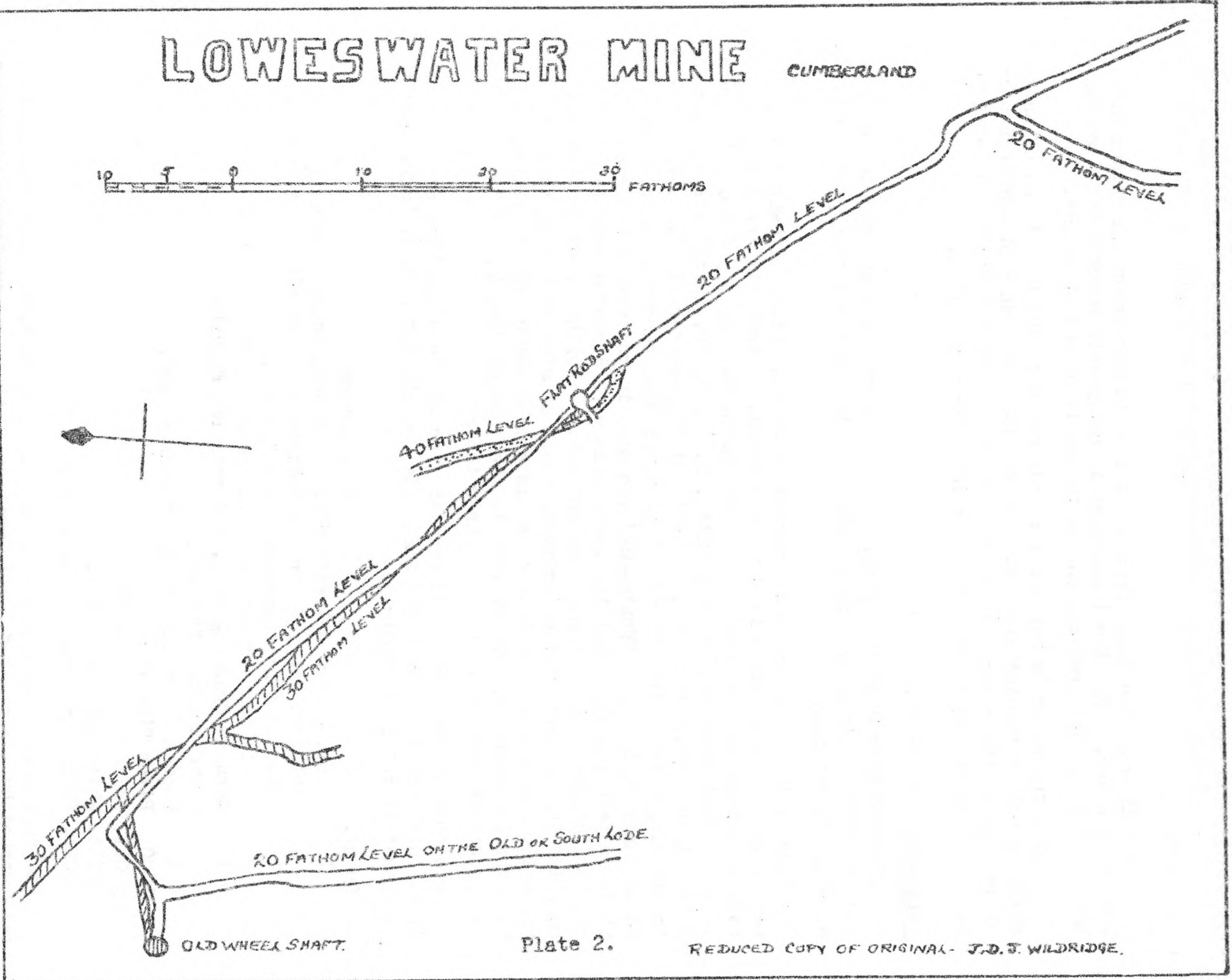
Loweswater Mine NY 146215. Plate 2.

The mine buildings were situated opposite Netherclose Farm at what is now Moss Cottage, which has been built out of the mine headquarters. The mine operated from about 1829 to 1841 and it would appear that all mining activity in the area stemmed from the one headquarters. It was on the estate of Skelton Wood of Godferhead. The ore was poor and the mine lost £6,000 during its period of life. A north west-south east vein was worked from three levels and according to Postlethwaite a considerable amount of ground was stoped out. Approximately 259 fathoms of level were driven at 20, 30 and 40 fathom levels. Whilst the 40 fathom level was driven from the bottom of the Flat Rod Shaft, as far as is known all the ore was raised at the Old Wheel Shaft near the mine building by a water wheel which was used for hoisting, pumping and dressing. Both shafts have now been filled, the last few feet of the Flat Rod Shaft fairly recently (1968). Prior to this the workings were known to be flooded.

The main spoil tip has trees growing on it, and in front of the main building was the smithy which is still there and used as a wash house. No trace has been found of the wheel pit. The water for the wheel was leated round Low Fell End from a dam high up Crabtree Beck. Some time after the mine closed this dam is reputed to have burst and flooded Crabtree Cottage, drowning two people. Whilst this may be true, no evidence can be found to substantiate it. No trace of a dam can be seen up Crabtree Beck, but what is thought to be the leat can be followed so far. Here the existing water

LOWESWATER MINE

CUMBERLAND



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Plate 2.

REDUCED COPY OF ORIGINAL - J. D. J. WILDRIDGE.

goes down towards Loweswater Lake when the leat would obviously go straight on. No further trace has been found but it is thought that the small stream marked on the map running past Moss Cottage was originally the lower part of the leat.

The vein was also tried from a level on higher ground on Whinny Ridding without success. The level entrance is completely blocked and a search of the spoil heap only produced one or two small pieces of quartz.

Beside the river is another tip but no trace has been found of another shaft or adit connected with it. There are also traces of workings on the other bank of the river but no connection has been established with this mine. They appear to have been earlier surface workings.

White-Oak NY 128196.

Situated near High Nook Farm. The tips can be seen from the road and the approach is obvious. It is advisable to ask permission at the farm to examine the remains.

Very little is known at the moment about this mine. It was supposed to be working in 1860, but this date is suspect. That all the machinery and buildings were sold in 1892 is a fact borne out by a printed sales catalogue of that year when on July 28th., R. Mumberson, Auctioneer, of Keswick sold all the equipment, etc., on site at "Loweswater Mine". The name is interesting because the original Loweswater Mine ceased to operate in 1841. As the only building at "White-Oak" included in the sale was a wooden house it would seem possible that the operations were directed from the original mine buildings at what is now Moss Cottage. Further food for thought is supplied in the fact that no smithing tools or similar mining tools were up for sale. Does this mean that there is some credence in the statement that "All the equipment was transferred to the Woodend Mine in 1895", and that this equipment was in fact these other tools?

A combined catalogue was printed for the Brandley Mine sale on the 27th. July and the Loweswater Mine sale on the 28th. July, 1892, and the equipment listed is as follows:-

Quant.	Description
1	40 ft. Waterwheel with 3ft. 6" breast, wrought iron axel. Cast iron ring, Centres & Pedistals, Pitch pine arms etc.
1	Blakes patent stone-breaker 15" x 19".
2	Triple compartment Jiggers, Pedestal, Brasses etc.
1	Cornish Crushing Mill, 30" rollers, Elevator leavers etc. Complete.
1	Wooden House with corrugated iron roof.
1000	Pitch Pine logs.
2000ft.	White pine deals 3".
2000ft.	White pine deals 1½".
100ft.	Pitch pine troughs and stands.

The vein worked is a parallel one to that in Loweswater Mine and has been worked by a series of levels vertically above one another. There are a number of small scratchings on the fellside to the right (looking up) and

to the left just above the stream there is another level, above which is a shaft about 20 ft. deep. It is not known whether the two connect as descent showed it to be blocked at the bottom. All the level entrances are blocked and in most cases cannot be seen because spoil has 'run' over them. The adit entrances were originally walled up to prevent fox hounds going in after foxes. At the side of the top level a pocket has been worked and it is possible to descend into it and gain access to the top level. This only goes a short distance and shows no trace of mineralisation.

The mine had its own dressing floor with a cornish crushing mill and a Blakes patent stone breaker powered by a 40ft. water wheel which was either overshot or high breast. As 100 ft. of troughs and stands were included in the sale the former type seems the more likely. The water for this wheel was leated from the beck about 300 yards upstream. From the amount of galena in the waste at the dressing floor the method of recovery seems to have been wasteful.

Above and to the right of the dressing floor about 40 yards away is a flat rectangular piece of ground. Was the wooden building listed in the sale catalogue situated on this level site? As someone (caretaker possibly) lived in this building with the corrugated iron roof what were the crushers housed in?

No record of production at this mine has been found, but Eastwood (Lead and Zinc ores of Lakeland) states that although a large amount of ore was raised the workings were not extensive.

Kirgate NY 140208.

On the north bank of Park Beck some 400 yards above Kirkstile Inn is a level 100 ft. long and running almost due north. In view of the fact that all the veins mentioned in this area are coursing north west-south east, this would seem to be a cross cut driven in the hope of cutting a vein. Anything brought out of the level in the form of waste has been washed away as in time of storm the level probably floods. No trace of mineralisation has been found.

Kirgate South NY 140207.

On the south side of Park Beck about 100 yards nearer Kirkstile, part way up the steep river bank is a short level coursing south. This leads to a vein following the same direction as the previous two. There is some doubt, but this is probably the one mentioned by Clifton Ward (Geology of the Northern Lakes) as being worked about 1866.

The level, bearing 240°, in 21ft. comes to a small hole beyond which is deep water. This is a 21 ft. deep shaft which is 6 ft. square and filled to its edge with water. This shaft is at the end of a level running along the vein, i.e., N.W.-S.E. and at 48 ft. turns sharply northwards to a roof collapse at the entrance to the level. The other side of this collapse can be seen outside about 50 ft. to the right of the present access level. It would appear that this present open level was driven for ventilation purposes.

Once more no trace of spoil or mineral was found outside. Inside the hanging wall of the vein can be seen.

Mosedale NY 137186.

There are a number of trials on the west side of Mosedale. They are reached by following the road (on foot) past Kirkhead until the open fells are reached. The trials can then be seen on the right.

The main working is on a quartz vein, the general trend of which is again N.W.-S.E. and could well be a continuation of the one worked at White Oak. It was probably found on the surface and worked open for the first 30 ft. The miners then went underground to work the vein for a further 26 ft. Another vein appears in the working and would appear to join up eventually with the first mentioned. Whilst some galena was found, the result must have been poor as very little can be seen either in the vein or on a small dressing floor beside a ruined building slightly to the south.

Above and to the right of this working is another open, about 30 ft. long. Slightly higher still and about 170 yards to the right is another small working.

Lisa Beck NY 164210.

On the east side of Lisa Beck there is a small working where a string of quartz with traces of galena in it has been tried.

Gasgale Gill NY 164210.

On the north side of Gasgale Gill is a small trial ten feet long. The best approach is from Lanthwaite Green. The level is up in the crags about 70 vertical feet above the stream. It is rather difficult to find. No trace of mineral was found.

Rannerdale NY 163183.

As the wall ends before going round Hause Point on the way to Buttermere a small trial will be seen in the crags. This takes the form of a hole about five feet square, going into the crag about six feet. At the face there are two small strings of quartz containing galena.

Beckside NY 192154.

Beside Buttermere Lake is a parking place for about five cars. This is the refuse from two small workings on the other side of the road. On the left over the fence is a grassy channel leading to a partially concealed level entrance. A battle with metallic debris and brambles reveals a short level about 30 ft. long which is flooded and runs in a northerly direction. There are traces of galena in the tip by the lake.

Above this level is another one behind a small waterfall. This level can be found by following the stream (not shown on the O.S. map), until traces of spoil can be seen on the right. The level is just above, in the back of the waterfall. Access is difficult without wading the pool. This

is a trial, 15 ft. long, and may have worked a pocket of quartz and galena running in an easterly direction, as no trace of string or vein was found at the forehead. There are abundant traces of galena in the small tip.

Blackbeck Trial NY201131.

This trial can be found by going to Blackbeck Tarn at the head of Buttermere Valley. Follow the stream down and almost immediately will be found vein material with traces of galena. The working can be seen by going further down the gorge; where it opens out the approach is obvious.

There is a small working in the form of a pocket. Much of the galena is mixed with country rock and could only be extracted by crushing.

Sosgill NY 106237.

Near the farm marked on the map as "Bramley" is a small area of marshy ground locally known as "Leady Moss". The mine is in this area. Enquiries of the 'locals' suggested a large mine with a row of tubs in it. It is in fact a trial about 10 ft. long partially filled with water. There must still be considerable lead contamination in the marshy ground around the trial because the farmer is unable to keep ducks, as they eventually die off with lead poisoning.

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Field Work

The field work was done by J. D. J. Wildridge, J. Moon, F. G. S., A. E. Cannell and M. Cannell, with occasional assistance by other members of the Northern Cavern and Mine Research Society.

Works of Reference

Very little of what has been written on these mines and trials has appeared in print before, but the following works have been found to contain something which has been of help:-

- History of Cumberland and Westmoreland - Whelan 1860.
- The Iron Ores of Great Britain and Ireland - J. D. Kendall 1893.
- Mines and Mining of the Lake District - J. Postlethwaite 1913.
- Lead and Zinc Ores of Lakeland - T. Eastwood 1921.
- Elizabethan Keswick - R. Collingwood.
- Geology of the Northern Lakes - Clifton Ward.

May 1968. Amended, December 1969.

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REPORTS OF FIELD EXCURSIONS AND MINE VISITS

VISIT TO HAIG COLLIERY, WHITEHAVEN

On Saturday morning, April 19th., 1969, sixteen members of the Society, accompanied by two N. C. B. officials, descended 1,150 ft. into the Haig Colliery on a tour of inspection of the workings.

From the shaft bottom a twelve minute ride took the party about three miles seaward and another few hundred feet down into the level of the Metal Band. Further along the roadway the distorted roof and side braces very clearly showed the power of the rock movements. The party had to stoop low at several places of local roof settlement, and shuffled through the lime-stone dust scattered over ground and walls to prevent the spread of flame.

At a lower level a working face was reached in the six to seven feet thick Main Band. The large number of hydraulic jacks supporting the roof made it difficult to worm along the 130 yard long face to the coal cutter. Here it was explained how the coal was cut back in 2 ft. slices, the jacks moved forward and the roof allowed to collapse behind. In this way all the coal in the seam could be removed. Some fossilised plant fragments were noticed in the roof rocks at the face.

The party made its way out and returned to the surface after nearly two hours underground. Thanks were expressed to the Manager and to the two guides who had given up their free time to show us round.

D. Livesey.

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WHITEHAVEN BRICKWORKS QUARRY, COAL MEASURES.

A recent fossil plant find in the Whitehaven Brickworks Quarry has been reported by W. F. Davidson of Penrith.

It was a sterile frond of *Crossotheca hoeninghausi*, so rare that it has been lodged in the fossil plant collection of the British Museum.

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VISIT TO TULLIE HOUSE MUSEUM, CARLISLE

Fifteen members met at Tullie House on Saturday afternoon, May 10th., 1969, and were received by Mr. Perriam who explained that the Curator, Mr. Hogg, was absent due to indisposition.

We were conducted to a room where a large number of specimens drawn from the Harkness Collection were laid out for our inspection, along with some of the very many papers written by Professor Harkness during his long and active career. One thing which caused surprise was the width of the collection, covering as it did many of the geological ages and formations. The whole was excellently displayed and our members were soon engrossed in an examination of fossils of all descriptions and ages. If fossils from the Lake District attracted many of us, others were equally interested in the magnificent fossil fishes from the Devonian of Scotland.

Of the many graptolites displayed what attracted attention as much as anything were the localities from which the specimens were drawn. Scale Hill, for example, seems to have provided some fine examples, but just where in the vicinity of Scale Hill would they have been found? It would seem that there is much that we could do both individually and as a Society in the investigating and pin-pointing of some of these old fossil localities. After all, good, well-preserved fossils in the Skiddaw Slates are not all that easily come by.

One of the exhibits, *Stella scolites*, and there were several specimens, caused much discussion. These peculiar rayed remains from the Skiddaw Slates have caused a great deal of discussion ever since they were found. It was indeed interesting to see actual examples of these "problematica" as they have often been described. Usually referred to the annelida, they still remain something of a mystery.

After studying the special display for some time we adjourned to the public gallery and only then realised what an extensive collection Professor Harkness had made. Much interest was shown and some small criticisms made about some of the exhibits, but all agreed that a very interesting afternoon had been spent. In thanking Mr. Perriam and Mr. Hogg for all the trouble they had taken, the President suggested that another visit might well be arranged in the not too distant future.

E. H. Shackleton, F.G.S.

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A general survey of the quarry confirmed the broad features of the exposures as recorded in the diagrams. The beds are relatively undisturbed dipping westwards at angles up to 20° without obvious signs of folding. Consequently, by entering the quarry on the east side and moving round the south end to the west side, the party gradually worked up the succession from the White Beds exposed at the quarry floor level on the east side to the Junceum Beds exposed at the top of the west wall. Identification of the individual beds of the succession was aided by appreciable weathering of the thin beds of shale separating them, but this also helped to increase the instability of the 20-30 feet high quarry walls, especially on the east side where the beds dip out of the walls. Because of this the party tended to avoid close approach to the unsound walls; instead extracting specimens from the fallen blocks.

On the east side the Rough Beds lie above the White Beds from which they are separated by the Girvanella Band in which occurs nodules of fossil algae and "stick-like" concretions, as could be seen on some of the fallen blocks. Notable finds along this section were an excellently-revealed *Productus giganteus* complete with ears, found by a young member, and examples of the beautiful *Lonsdaleia floriformis crassicanus*, known to occur in the Rough Beds but not previously identified by Dr. Nicholas in this quarry. Numerous *Davisiellae* could also be seen in section revealing that the layers do not run parallel to the shell outlines, a feature which the President explained distinguished them from *Productids*. *Lithostrotion junceum*, *L. phillipsi*, *Diphyphylloids* and *Foraminifera* were abundant.

Along the south wall the Rough Beds come down to the floor and the dark wavy bedding is easily discerned. Further along are the Spotted Beds, sometimes referred to as a pseudo-breccia, a generally pale limestone with dark spots. The origin of these spots is uncertain, but Dr. Nicholas attributed them to recrystallisation of calcite from the calcareous mud while it was still soft. Moving westwards in the direction of the dip, the Potholes Limestone is soon brought in at the top of the wall. Interesting finds among the blocks along the south wall included an example of a corallum of which the foot was easily observed with hundreds of individual corallites fanned radially from it. Among well-exposed solitary corals was found *Aulophyllum fungites cumbriense*.

Near the south west corner the *Orionastraea* Band at the top of the Potholes Limestone is brought in. This is a very interesting band containing a range of very beautiful corals. The west wall has collapsed over a length near its southern end which increases the difficulty of identifying the *Orionastraea* Band, but one consolation brought by the dismal weather was that the band was revealed as a paler streak on the wet walls and in some of the fallen blocks. In spite of failing light and increasing rain, some specimens of *Orionastraea* were obtained before the visit was ended.

Dr. Nicholas was warmly thanked for what, in spite of the conditions, had been a most instructive excursion.

W. E. Harrison, B.A.

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EXCURSION TO THE ARMBOTH DYKE, FISHER CRAG, THIRLMERE.

Sunday, 22nd. June, 1969.

Director; M. F. Burton.

The Armbboth Dyke is a quartz-porphyry dyke intrusive into the coarse ashes and breccias of the Borrowdale Volcanic Series. If Marr's (1916) regional divisions of the B.V.S. are accepted here, it occurs within the "Ullswater Basic Andesite Group".

J. Clifton Ward originally surveyed the dyke for the Geological Survey over an approximate distance of $1\frac{1}{4}$ miles (allowing for faulting), and found the width to vary between 20 and 30 feet. The Survey Memoir and 6" map of the area were published in 1876.

The excursion party visited only the southern part of the dyke. From a section immediately north of Fisher Gill it was followed in a generally southerly direction to a scarp adjoining the forest fence below the summit of Fisher Crag at around 1250-1300 feet O.D. The actual trend of the dyke is N.W.-S.E. The northern portion extends from Fisher Gill in the direction of Middlesteads Gill and is last seen on a fell top towards the head of Shoulthwaite Gill.

The dyke lies in a vertical position and the first sections visited were found to stand out in relief separate from the wall rock. Further south, however, sections of the dyke abut on to the latter, but on a brief investigation no sharp contacts were observed. The dyke in fact grades imperceptibly into the Borrowdale Volcanic Series in this locality.

Wrench-faulting has cut the dyke into several sections in the area visited. Fisher Gill apparently occupies one of the fault planes, the horizontal throw in this instance being of the order of 1200 feet. This was the greatest throw encountered; the normal lateral shift being only a matter of a few feet. It is interesting to note that the emplacement of the dyke antedates the orogenic movements responsible for the faulting.

In general appearance the dyke exhibits conspicuous crystals of quartz in a pinkish (sometimes greyish) felsitic matrix. Some of the feldspar phenocrysts of the matrix exhibit large shiny faces in broken specimens of the rock. There are also sparsely scattered small dark patches in the rock. X-ray powder diffraction tests have been made on two specimens from separate localities, individual crystals being singled out for tests, with the following conclusions:

Hard quartz-like crystals.....alpha quartz.
Soft dark material.....an orthohexagonal chlorite,
(greenish on powdering) having the formula:
$$\text{Mg}_{1.0}\text{Fe}_{3.2}\text{Fe}_{0.4}\text{Al}_{1.2}(\text{Al}_{1.5}\text{Si}_{2.5})_{10}(\text{OH})_{18}$$

Crystals from the matrix.....a mixture of orthoclase
and oligoclase.

X-ray spectrographic tests were made on the whole rock (minerals were not separated). Iron, manganese and a small amount of calcium were indicated. Potassium, silicon, aluminium, magnesium, sodium, boron, beryllium and lithium are not detected by the technique used. The photographs from the second specimen were identical with those from the first, suggesting that the material is uniform in composition. It should be noted that the specimens were taken from different sections of the dyke and had a differently coloured groundmass.

The general analysis shown below is taken from Walker's (1904) paper, after Harker.

SiO ₂	75.26%	
Al ₂ O ₃	12.85%	
Fe ₂ O ₃	0.17%	
FeO	1.36%	
MnO	0.22%	
CaO	0.83%	Specific gravity
MgO	0.04%	2.648 at 16.4°C.
K ₂ O	5.01%	
Na ₂ O	2.66%	
CO ₂	0.04%	
H ₂ O	1.04%	
Loss on ignition	(1.29%)	
	<u>99.48%</u>	

Rastall and Wilcockson (1917) made an investigation of the accessory minerals of the Armbboth Dyke along with those of the Low Rigg and Threlkeld Microgranites. Within the former they found garnet and pyrrhotite to be very common, pyrites frequent and zircon very rare. They concluded that, apart from garnet, the mineral assemblage of the dyke did not lend much support to any genetic connection with the St. John's and Threlkeld masses, since apatite was completely absent and zircon very rare. The zircons they did find in the dyke were of the short "stubby" variety whereas those of St. John's and Threlkeld were found to be long and "needle-like". The titanium-bearing accessories anatase, brookite and sphene which were found in the Threlkeld rocks were also notably absent in the dyke. Members of the party discovered small brown or red euhedral garnets in some of the specimens examined, but no magnetic tests were made for pyrrhotite.

Glacial action in the shape of retreating ice from the Thirlmere region has scattered boulders over a large area. The present position of perched blocks and boulders of the Armbboth Dyke serve to indicate the general direction of ice movement. They are to be found at intervals east of, and up to the watershed line all across Wythburn and Armbboth Fells. The

fact that perched blocks have been seen on the top of crags $\frac{1}{4}$ mile S.W. of Harrop Tarn at a height of over 1750 feet suggests that not all of the ice retreated northwards. Clifton Ward (1876) explains that though the lower ice occupying the Thirlmere valley moved northwards, some of the great mass of ice coming off the Helvellyn range shot over the ridge on the western side and partly escaped across the western watershed south of Arnboth Fell.

As one might expect, the greatest concentration of erratics is found N. and N.N.W. of the dyke, in the Shoulthwaite and Naddle Valleys. One perched block is located at a height of 800 feet on the north end of High Rigg, a little way S.W. of St. John's Church. Boulders have also been deposited in the following areas:-

- Keswick Vale: On the drift-covered tract between the north end of Castle-rigg Fell and Latrigg foot, and on Latrigg summit at 1200ft. Further westwards in Lyrrick Wood up to 1250 ft. on the S.E. flank of Dodd.
- Borrowdale: South end of Walla Crag, and small boulders at 1800 ft. on Bleaberry Fell.
- Mosedale: Near the hamlet of Mosedale, indicating that a lobe of Helvellyn ice went some way northwards up the higher part of the Glenderamackin Valley after crossing the Keswick-Penrith depression.

Many thanks are tendered to Mr. W.D. Smith for his X-ray spectrographic and powder diffraction analyses.

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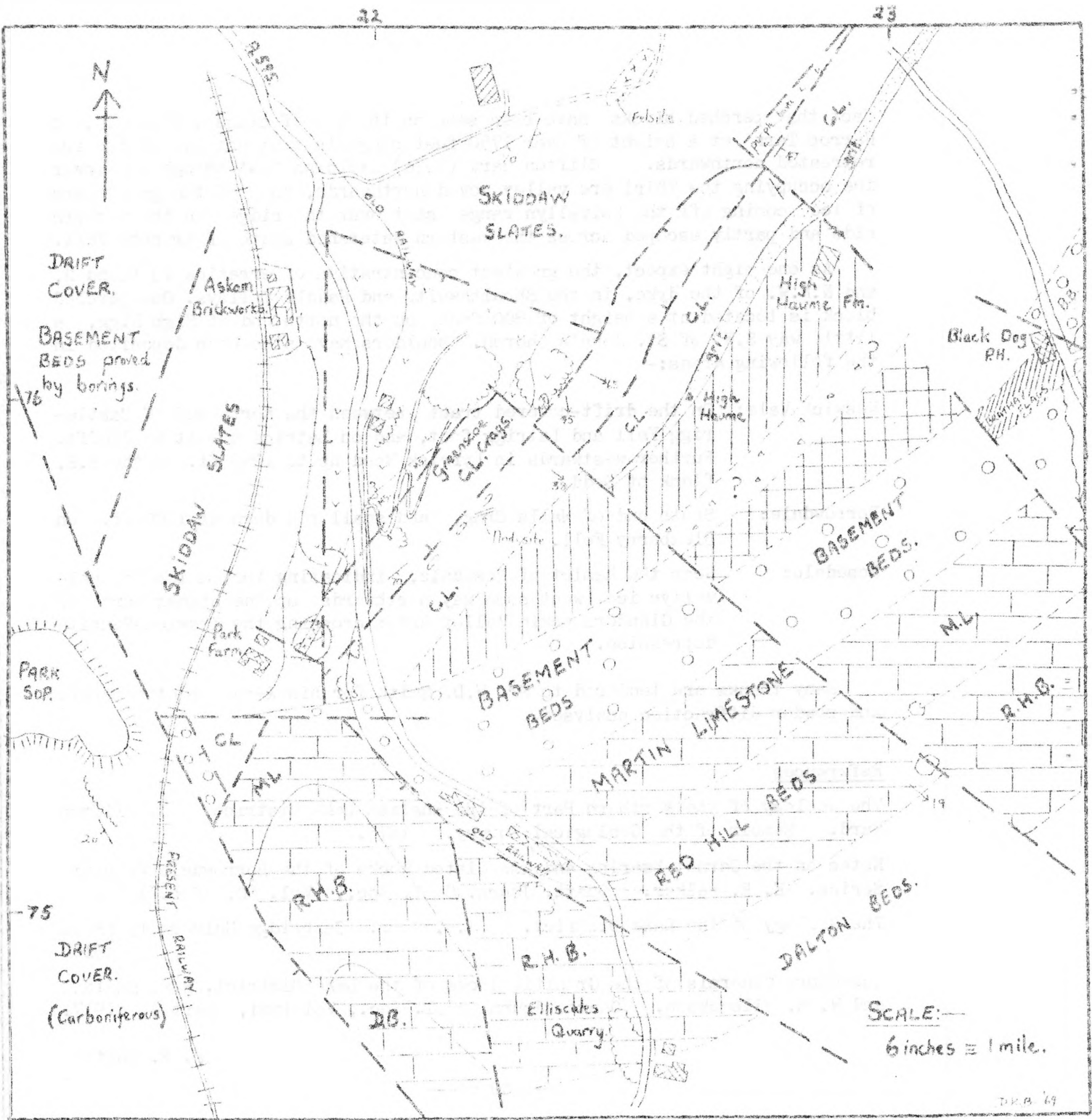
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




M. F. Burton.

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 B.V.S. m.s. - Mottled Shale.

 SKIDDAW SLATES.

 Bathing Figs. Wenlockian.
 Slates. Blandevary.
 Sparquade
 Shales grit
 C.L. Blue Limestone

CONISTON LIMESTONE SERIES.

 DALTON BEDS.
 RED HILL BEDS
 MARTIN LMST.
 BASEMENT CARBONIFEROUS

EXCURSION TO THE GREENSCOE AREA, DALTON-IN-FURNESS

(Lower Palaeozoics)

Sunday, 13th. July, 1969.

Director; D.K. Buckley, B.Sc.

The small Lower Palaeozoic inlier at Dalton-in-Furness appears to have been little studied. Nicholson (1868) refers briefly to it, whilst Bolton (1869) described some of the sections. Aveline mapped the area for the Geological Survey in 1873 and Marr (1892) described the Coniston Limestone. J. F. N. Green published a paper in 1912 but since then the only recent published work has been Dunham and Rose (1941) who concentrated on the Carboniferous and later rocks. Thus the only references concerning the Skiddaw Slates and Borrowdale Volcanics, known to the author, are the early papers of Sedgwick and that of Green (op. cit.).

About thirty members and friends assembled at the entrance to Greenscoe Quarry where the Director outlined the geology of the area and with the aid of maps demonstrated its importance in a regional context.

The excursion was directed towards the study of the stratigraphy and structure, and both can be well seen on the accompanying map. Like the majority of Skiddaw Slate inliers peripheral to the Lake District, this one owes its presence to a N.E.-S.W. anticlinal axis, here producing the High Haume ridge, but unlike other inliers the Coniston Limestone is exposed. Normally the Coniston Limestone, though shifted by dip faults, forms a linear outcrop across the Lake District, but here local folding has repeated it from the main outcrop.

The oldest beds are the Skiddaw Slates and these were visited first where they are well exposed in the brickpits near Park Farm. Lithologically they are blue-black mudstones without arenaceous beds, and are surprisingly soft, being readily scratched with the finger nail, unlike the majority of their representatives along the northern outcrop. After several minutes, graptolites in fair states of preservation were being found from the scree. Fragments of *D. hirundo* were collected, and the Director had brought along a specimen of *D. bifidus* which had been found previously, thus suggesting a high *D. hirundo* or low *D. bifidus* age, and a high level in the Series. Of interest was an andesite dyke which had caught up rafts of Skiddaw Slates during intrusion, whilst nearby in the corner at the top of the brickpit, the Coniston Limestone could be seen faulted against Borrowdale Volcanics.

The party then proceeded to the larger brickpit behind Park Farm. Here removal of the soft Skiddaw Slate for brickmaking has exposed the contact of the Skiddaw Slate with the Basement Beds of the Carboniferous unconformable above. It can be seen from the map that the Basement Beds overstep older beds successively south-westwards. They lie upon the Brathay Flags at the 'Black Dog', then upon the Llandoverian, upon different members of the Coniston Limestone Series, and eventually upon the Skiddaw Slates at Park Farm. The party then ascended Housethwaite Hill behind the farm on to

the Martin Limestone. This provided a good viewpoint of Black Combe, another inlier, and of the southern Lake District fells to the north. The sops of Furness, Park Sop, Rita Sop and Nigel Sop could be seen to the west towards Sandscale Haws. (Nicholas, 1963).

A short diversion along the old railway track followed, where the Director pointed out the Basement Beds backed by a good fault plane, whilst a little further on an excellent exposure of 'Crab Rock' proved a little confusing (lithified boulder clay), before a return to the cars was made and lunch taken.

After lunch the party crossed the road and examined the Borrowdale Volcanics in the Greenscoe 'Granite' Quarry. The B.V.S. here consists of agglomerates, quite spectacular in places, with subordinate lavas, tuffs and intrusives, all dominantly andesitic. From the sinuous quarry track the outcrop of the Coniston Limestone could easily be traced from the brickpits away along the High Haume ridge to beyond Ireleth, but the main interest was in the relationship of the Skiddaw Slates to the overlying Borrowdale Volcanics. Now that the 'Blue Shales' of Green (?Skiddaw Slates) have been reasonably proved as Skiddaw Slates by finds of contemporary graptolites, their relationship to the B.V.S. is important since relatively few localities expose the junction.

The junction at Greenscoe is exposed in the small disused brickpit below a scarp of Coniston Limestone, but unfortunately difficulty of access prevented the party from examining it. However the Director pointed out that the junction as exposed is sensibly horizontal with the Skiddaw Slates passing upwards into a mottled rock consisting of fragments of shale in a volcanic matrix, which the quarrymen would have called 'rain spot slate'. This is the 'mottled shale' of Green, but is perhaps better described as mottled tuff. The shale fragments are probably Skiddaw Slate which they match lithologically. Some of the fragments are six or more centimetres long, and angular. According to Simpson (1967) the Caledonian Orogeny in the northern part of the Lake District consisted of two paroxysms of activity, the end-Silurian orogeny, F_3 , and an earlier intra-Lower Ordovician orogeny of two separate fold styles F_1 and F_2 both predating the deposition of the Borrowdale Series, which are then unconformable.

Accordingly the shale fragments within the mottled tuff should at least show a cleavage at random orientation which does not continue into the matrix. At present a limited number of thin sections have failed to demonstrate any convincing pre-Borrowdale cleavage, although this does not rule out an unconformity. One could argue that the mottled tuff belongs to the Skiddaw Slates and that the junction lies higher up and perhaps demonstrates the cleavage required by Simpson's hypothesis. This division seems untenable and is unnecessary in postulating unconformity since the exposure is small; but on the other hand it may be conformable. At present there is no convincing evidence either way.

The mottled tuff by the track leading to the main quarry was examined and its similarity to the agglomerates was noted. The party then entered

the quarry where an instructive section anticipated by the Director now appeared some 30 feet up the quarry face. Nevertheless blocks of andesite up to 4 feet across were common and suggested proximity to a volcanic vent. The presence of agglomerate in agglomerate was noted. An important point was the strike of the B.V.S., here north of N.N.E. and steeply dipping, it contrasted with the more familiar N.E. to E.-W. strike. This has been correlated with initiation of the Black Combe structure which seems reasonable in view of the considerable south-westerly overstep of the Coniston Limestone.

The party then moved on to Greenscoe Crags to examine the Coniston Limestone. Here unusually pure, it is a blue limestone very similar to the Eilean Dubh Group of the Durness Limestone, and although fossils were rare, structurally it was rewarding, being repeated by strike faulting and thrown against agglomerates by a strong N.W.-S.E. dip fault well exposed in the quarry face. This concluded the excursion and the President, Mr. Shackleton thanked the Director for an interesting day's geology before the party dispersed.

Thanks are also due to Mr. Bill Grieve of Barrow who kindly obtained permission of the quarry owners, Messrs. Keirby and Perry, Ltd., and the Askam Brickworks Company, to whom these thanks must be extended.

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D. K. Buckley.

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EXCURSION TO BIGRIGG
(New Red Sandstone)

Saturday, 16th. August, 1969.

Director; The President.

The members of the party met at the Smith's Arms, Bigrigg, at 10-30am. The object of the excursion was to examine deposits of Permo-Triassic age in the area. The New Red Sandstone has had little attention from the Society, apart from visits to Barrowmouth Bay. At this well-known exposure on the coast south of Whitehaven there is a section as follows:

St. Bees Sandstone	up to 1100 feet.
St. Bees Shales, with gypsum and anhydrite	100-373 feet.
Magnesian Limestone	18 feet.
Brockram, unconformable on Carboniferous sandstone	6 feet.

When traced inland, these beds are found to change considerably in thickness. The Brockram, a breccia formed by desert weathering in Permian times, thickening immensely at the expense of both Magnesian Limestone and St. Bees Shale. In a borehole west of Park House Farm (the site of which was visited and old discarded cores seen) the following section was noted:

Brockram with sandy and marly beds	97 feet.
Limestone, red and grey	1½ feet.
Brockram, almost a coarse conglomerate at the base	50 feet.
The deposit resting on red-purple plant-bearing mudstones (Millstone Grit or Coal Measures).	

Something of these rocks was seen in Linethwaite Beck, both in the overgrown tangled wood behind Linethwaite Hall, and nearer its source at Park House Farm, where the Magnesian Limestone was discovered in the stream bank. The much-thinned St. Bees Shales were seen in an old quarry behind Park House Farm.

After lunch, taken in the cool bar of the Smith's Arms, the party made its way to a disused railway cutting behind Langhorn Farm where the Brockram rests unconformably on an unevenly eroded surface of First Limestone (Lower Carboniferous).

The next location visited was the Bank End Quarry, where, by kind permission of the Manager, Mr. Stoker, members were able to examine the strongly false-bedded St. Bees Sandstone, and the machinery by which it is fashioned for architectural purposes.

After collecting samples of false-bedded sandstone from the tip, as well as specimens of 'foreign' ornamental stones (speculations as to their natures and places of origin) the party dispersed.

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THE WEEKEND CAMP, GRASSINGTON, WHARFEDALE.

September 12-14th., 1969.

Nineteen members and friends attended, the weather being all that could be desired, and the programme interesting. The leaders for the excursions were Alan Butterfield, an industrial archaeologist, and Ian Metcalfe, a mineralogist. The programme was as follows:

Friday evening. Camp was established at Threaplands House Farm, Cracoe.
8-30p.m. An introductory meeting at the Devonshire Arms, Cracoe, where the proprietor very kindly loaned us a room to ourselves. Mr. Butterfield showed a good collection of minerals and fossils representative of the area.

Saturday. 9-30a.m. Members met at Grassington Top Car Park and visited the Grassington Moor Mining Road, Low Moor Pony Level, Cockbur Veins, Franklin Fold, Stool Mine, Ryson Veins and New Moss. At the last two locations good specimens of aurichalcite, rosasite and calamine were found.
2p.m. After lunch the party visited Moss Mine, where barytes was being worked for drilling slurry for North Sea gas exploration. The District Smelt Mill chimney and high winding wheel were also seen, the latter with flat ropes serving three mine shafts 2 miles apart. Finally a visit was made to Cyrlo Smelt Mill at Hebden Gill, the Union Shaft and Duke's water course, before arriving back in Grassington at 5-30p.m.
8-30p.m. Mr. Butterfield gave a lecture, illustrated by slides and specimens, by way of introduction of the programme for the following day.

Sunday. After assembling at Grassington Top Car Park, the party travelled in cars to Stump Cross Cavernas, which have stalactite and stalagmite formations superior, in my opinion, to those of the Cheddar Caves. Next the North Craven Fault, the Jackass Level, Cockhill Mine, Sam Son Level and Nidderdale Quarries. After lunch the Garnett Vein and Coldstone Quarry were visited. At the latter location some very good specimens of colourless fluorspar (up to 2" cubes) on massive barytes were found, also a 6" vein of galena:

Limestone & gritstone	Barytes 24"	Fluor 4"	Galena 6"	Fluor 4"	Barytes 24"	Limestone & gritstone
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A remarkable specimen from this vein was given to the Craven Teaching Museum at Ipswich. It consists of a 3" thick base of galena with perfect 2" cubes of greenish fluorspar on top bearing two large "cockscombs" of barytes. Another very good specimen given to the Craven Museum (by Mr. and Mrs. Cockersole) was a rich deposit of rosasite in barytes 6" x 4" x 3" from New Moss. This mineral is the result of secondary mineralisation and

is always found associated with malachite and aurichalcite. Its formula is $(\text{CuZn})_2\text{CO}_3(\text{OH})_2$ and it was first described from the Rosas Mine in Sardinia.

With the accent of the weekend on mines and mineralisation, there was no time to visit any of the numerous fossil localities, although crinoids $\frac{3}{4}$ " diameter x 9" long and productids were found.

Some attention was paid to the industrial archaeology of the area which contains such items as meer stones, bell pits, primitive adits and shafts, water wheel beds, etc. Stope and feather working is very much in evidence, while the "Sam-panty-oun-stone", a large mortar of 3' 6" internal diameter, was used in mediaeval times for the grinding of ore.

Thanks were given to Mr. Butterfield and Mr. Metcalfe, and are also extended to Dr. Arthur Raistrick for his ideas and help.

A resume of the minerals found during the weekend is as follows:

Ankerite	Glauconite
Aurichalcite	Hemimorphite
Barytes - cockscombs and rosettes plentiful Free crystals rare.	- two specimens
Calamine - many good specimens.	Limonite
Cerussite - associated with rosasite.	Pyromorphite
Fluorspar - 2-3" cubes, colourless and pale green. Also a small amount of blue fluor.	Rosasite
Galena - mainly massive. Very few free crystals.	Sphalerite
	Travertine.

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R. H. Hewitt.

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WINTER PROGRAMME 1969-1970

The indoor programme commenced, traditionally, with an informal SOIREE, held this year on September 24th. at Whitehaven Grammar School.

Dr. F. H. Day, who is no stranger to the Society, gave an interesting and informative lecture entitled "Some Mediterranean Volcanos" on Oct. 1st.

On November 12th., Dr. A. W. Phillips gave a talk, well illustrated by slides, on aspects of her present work on "Coastal Changes on Walney Island Barrow-in-Furness".

A 'travelogue' film on Iceland was shown on December 10th., with some very interesting and beautiful shots of scenery, vulcanicity and glacial features of the island.

Mr. Richard Gowing travelled down from Annan on January 7th. 1970 to show us some more of his superlative colour slides taken in Japan. Having dwelt on the vulcanicity of the country in his previous lecture, Mr. Gowing concentrated on aspects of the general geology and tectonics of Japan.

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THE NINTH ANNUAL GENERAL MEETING

The Annual General Meeting of the Society was held at the Whitehaven College of Further Education on Wednesday February 11th. 1970. The meeting was opened by the President who called upon the Officers of the Society to present their reports.

The General Secretary's Report

This has been a fairly good year for the Society. Membership stands at 261. Mr. White has kindly taken over the task of dealing with applications for membership and corresponding with new members.

Concerning the Society's programme; we have had some excellent lectures given by The President, Dr. Philips of the University of Lancaster, Dr. Day lately Vice-Principal of Carlisle Technical College, and Mr. Richard Gowing of Annan. The Soiree was held at Whitehaven Grammar School. The Annual Dinner, held once again at the Skiddaw Hotel in Keswick proved popular, the guests of honour being Dr. and Mrs. A.W. Woodland. Dr. Woodland, Assistant Director of the Institute of Geological Sciences, praised the largely unpublicised work being done by regional Geological Societies such as ours.

The Field Excursions were up to the usual high standard, and members will share my regret that Mr. Hewitt has decided not to seek re-election to the post of Excursion Secretary. Our thanks are due to him for arranging the many excursions held over the past few years. Our good wishes are extended to Miss Pimblett who has left the area and taken up a teaching appointment in Liverpool.

The replacement of retiring officers brings me to my yearly plea to ordinary members to volunteer their services to the Society. Officers and Members of Council alike would welcome a bit of competition at Annual General Meetings and suggestions and assistance in organising and running the many activities of the Society.

May I close my report by once again thanking all those who have given me their support during the past year. My free time has been sadly curtailed this year due to reorganisation at my place of employment. Only due to the hours of work done by the President, Mr. Shackleton and the Honorary Treasurer, Mr. White, am I able to produce this report. The Society owes a considerable debt to these senior officers. Mr. Shipp is to be commended on the high standard of the Proceedings. Mr. Burton has faced difficulties over the reorganisation of the Whitehaven Public Library, which houses the Society's Library. However, books and library lists are available to all members, on application to Mr. Burton. I wish to thank Mr. M. B. Dodd for auditing the accounts, and for arranging accommodation for Council Meetings throughout the year at Whitehaven Grammar School.

R.E.O.P.

The Honorary Treasurer's Report

The state of the Society's finances continues to be very healthy. Our total income from all sources during 1969 was £148.2.11 and our expenditure was £97,13.11, so that we ended the year about £50 better off than we began it. It must be remembered, however, that there was an outstanding account

at the end of the year of some £27 in respect of materials for the production of the "Proceedings" for 1968-9, and provision for this is made in the Statement of Assets and Liabilities under the heading "Sundry Creditors". It has since been paid.

Our income from subscriptions has risen to £99 compared with £84 in the previous year; at the end of the year we had a total of 261 members some of whose subscriptions were paid in advance and appear in last year's account. Sales of publications have fallen to £39 compared with £101 in 1968. Once again the welcome item "Donations" is chiefly made up of the generous annual gift from the Marchon Division of Messrs. Albright and Wilson, continuing the payments made under covenant for several years by Sir Frank Schon.

In spite of the rise in cost of materials and postages our subscription income appears to be just sufficient to cover our running expenses. This is only possible because of the extremely economical method of producing the "Proceedings" and other publications. Most of this work is done by the Editor, Mr. T. Shipp, and the Publications Secretary, Mr. W.E. Harrison, and the Society owes them a debt of gratitude for keeping expenses down to the absolute minimum consistent with efficiency.

With reference to the Statement of Assets and Liabilities, it will be seen that the nominal value of our duplicator, typewriter and stocks of publications have all been subjected to heavy reductions on account of depreciation, but even so, our financial position continues to be sound.

H.A.W.

Other reports

In the absence of the retiring Excursion Secretary the Editor commented on the variety and high standard of the excursions held throughout the year and thanked the Excursion Secretary for arranging for details of excursions to be made available for publication in the "Proceedings". Mr. Shipp gave a brief outline of the contents of "Proceedings", Volume 2 Part 4, which he said was very nearly ready for publication. After the unfortunate delay experienced with Part 3 it was a relief to be able to make this announcement. The current "Proceedings" terminate Volume 2, and Mr. Shipp stated that he would like to see the next volume printed professionally, as he was beginning to find the preparation of a batch of 50-60 rotary stencil skins for each part issue very time-consuming and burdensome.

The Publications Secretary, Mr. Harrison, stated that some back-numbers of our publications were sold out. He would be glad to provide members and others with such publications as he had in stock, and had printed a tariff.

The President, after commenting on the reports, then conducted the election of Officers and Members of Council. The following were returned unopposed for 1970:-

President,	Mr. E.H. Shackleton, F.G.S.	Council Members:
Vice-President,	Mr. H. Bland.	Mr. M.B. Dodd, M.A.
General Secretary,	Mr. R.E.O. Pearson.	Mr. G.S. Gowing, M.A.,
Excursion Secretary, duties to be performed		F.G.S.
by sub-committee, pro tempore.		Miss D. Slater.
Publications Secretary, Mr. W.E. Harrison, B.A.		Mr. T.G.P. Ziemba.
Editor,	Mr. T. Shipp, B.Sc.	
Librarian,	Mr. M.F. Burton.	

Before closing the Ninth Annual General Meeting, the President allowed Mr. K. R. Baker to say a few words on behalf of the newly-formed Whitehaven and District Lapidary Society.

After refreshments, a Mobil Oil film on the subject of drilling for North Sea Gas was shown.

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INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDING 1st. JANUARY, 1970.

<u>Expenditure</u>		<u>Income</u>	
1968		1968	
£.		£.	
(64) Stationery, stencils & materials for publications.	34 18 9	(121) Balance at Bank on 1/1/69	206 10 6
(32) Postages	32 16 2	(84) Subscriptions:	
(5) Subs. to other Societies		Arrears 1969, 127 members	4 0 0
Lake Dist. Naturalists Trust Ltd.	1 1 0	63 10 0	
Geologists' Assoc.	4 0 0	60 associates	15 0 0
(1) Catering for Soiree	3 0 0	7 Institutional	3 10 0
(2) Expenses - Lecturers & Excursion leaders	8 3 0	1970-1 in advance	
(-) Purchase of book for resale	2 0 0	25 members	12 10 0
(-) Cost of duplicating Proceedings 1968-9	5 0 0	4 associates	<u>1 0 0</u>
(-) Purchase of books & maps for library	5 0 0	(11) Donations	9 11 0
(2) Hire of films	- - -	(-) Sale of Book	2 5 0
(-) Cheque Book	10 0	(101) Sales of publications (including postages)	36 16 11
(1) Bank Charges	1 5 0		
(207) Balance at Bank 1/1/70	<u>256 19 6</u>		
	<u>£354 13 5</u>		<u>£354 13 5</u>

THE CHARLES EDMONDS MEMORIAL FUND

Balance at Bank on 1/1/69	14 8 2
Interest on 3½% War Stock (Nominal Value £146 4 11)	5 2 4
Bank Interest on Deposit Account	<u>11 9</u>
	20 2 3
Less cost of prize awarded to Miss Aynsley Shilston	<u>7 15 6</u>
Balance at Bank on 1/1/70	<u>£12 6 9</u>

STATEMENT OF ASSETS AND LIABILITIES AT 1st. JANUARY, 1970

<u>Liabilities</u>		<u>Assets</u>	
Subscriptions for 1970-1, paid in advance	13 10 0	Balance at Bank 1/1/70	256 19 6
Sundry creditors	27 0 0	Duplicator	10 0 0
Reserve for materials to produce Proceedings Pt. 4	40 0 0	Typewriter	5 0 0
Reserve for postages for Proceedings Pt. 4	10 0 0	Stock of stencils	2 0 0
Balance, being excess of assets over liabilities	<u>253 9 6</u>	Stocks of publications valued at 50% of nominal selling price	70 0 0
	<u>£343 19 6</u>		<u>£343 19 6</u>

AUDITOR'S CERTIFICATE

January 31st., 1970

I hereby 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.

(Signed) M. B. Dodd
(Honorary Auditor).

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