AN INVESTIGATION INTO THE ORIGIN AND NATURE OF SOME ORGANIC DEPOSITS OF THE INGLEBOROUGH REGION

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Contents

Photographs are at the end of the section to which they refer.

Summary.

Five sites were investigated in the Ingleborough region of Yorkshire, Helwith Moss, Thieves Moss, Scar Close, Moughton, and Howrake Rocks. Samples of peat were extracted by means of a borer, or taken from monoliths, and their structure and pollen content examined. Profiles and pollen diagrams were produced for each site.

Helwith Moss was found to have developed from a former lake which became invaded by aquatic mosses, then reed swamp, and finally raised bog. Peat formation began in zone V, and raised bog was initiated at the Boreal-Atlantic transition, when the climate became wetter. An important recurrence surface was found in sub-zone VIIb, where the peat changes noticeably from a relatively humified *Eriophorum-Sphagnum* type to light brown less humified *Sphagnum imbricatum*. As this did not coincide with the suggested position of the VII/VIII boundary of the pollen diagram, a transition zone was postulated from the recurrence surface at 235 cms. to the start of zone VIII at 120 cms.

Thieves Moss also was found to have developed from a former lake which became colonised by *Carex* swamp, *hypnoid* moss, and then *Sphagnum* bog. The upper layer is of a mixed peat including monocotyledonous material. Pollen is preserved from zones II to VII, the latter zone being the latest to which any of the peat belongs. The change from swamp to bog took place at the end of sub-zone VIa, when a lowering of the water table took place probably caused by the removal of a barrier at the southern side of the Moss. This would lessen considerably

the influence of calcareous drainage water allowing more acid conditions to develop with a corresponding vegetational change. The surface of the bog appears to be affected by erosion and peat formation is not actively taking place, probably because of the well developed drainage system of a limestone area.

At Scar Close the peat lies in a continuous layer on slopes above the limestone pavement, but only in patches on the pavement itself. Profiles and pollen diagrams from eight sites suggest that this peat cover was once continuous over the whole pavement area. The peat belongs to zone VIII. On the slopes above the pavement it has formed on a layer of drift which covers the limestone. The peat on the pavement is in actual contact with the limestone. It may have formed on a thin drift layer which has now been washed into the grykes, or directly on the limestone with a later widening of grykes under peat, because of an increase in the rate of solution of the limestone. The series of pollen diagrams from the upper to the lower sites show a progressive truncation from below. These may be interpreted, either as a gradual spreading of the peat onto the pavement from the slopes above, or the result of oxidation of the lower peat layers in contact with the limestone.

The information from Moughton and Howrake Rocks suggests that the peat on the limestone pavement at Scar Close has formed in situ, and has not slipped down from the slopes above.

Acknowledgements.

My grateful thanks are due to Dr. D.D. Bartley who has not only supervised my work for this thesis, but who has also carried out all my boring and assisted greatly in the field.

I am also indebted to Professor I. Manton, F.R.S., for allowing me to work in her department and for giving me every encouragement; to Dr. K.M. Clayton, Dr. R.J. Jones, Mr. J. Palmer Professor C.D. Pigott, Mr. C.A. Sinker, Dr. M.M. Sweeting, Professor H.C. Versey, for helpful advice; to Miss C. Lambert, for assistance in the identification of a pollen grain, and to Mr. I.T. Riddell for technical assistance.

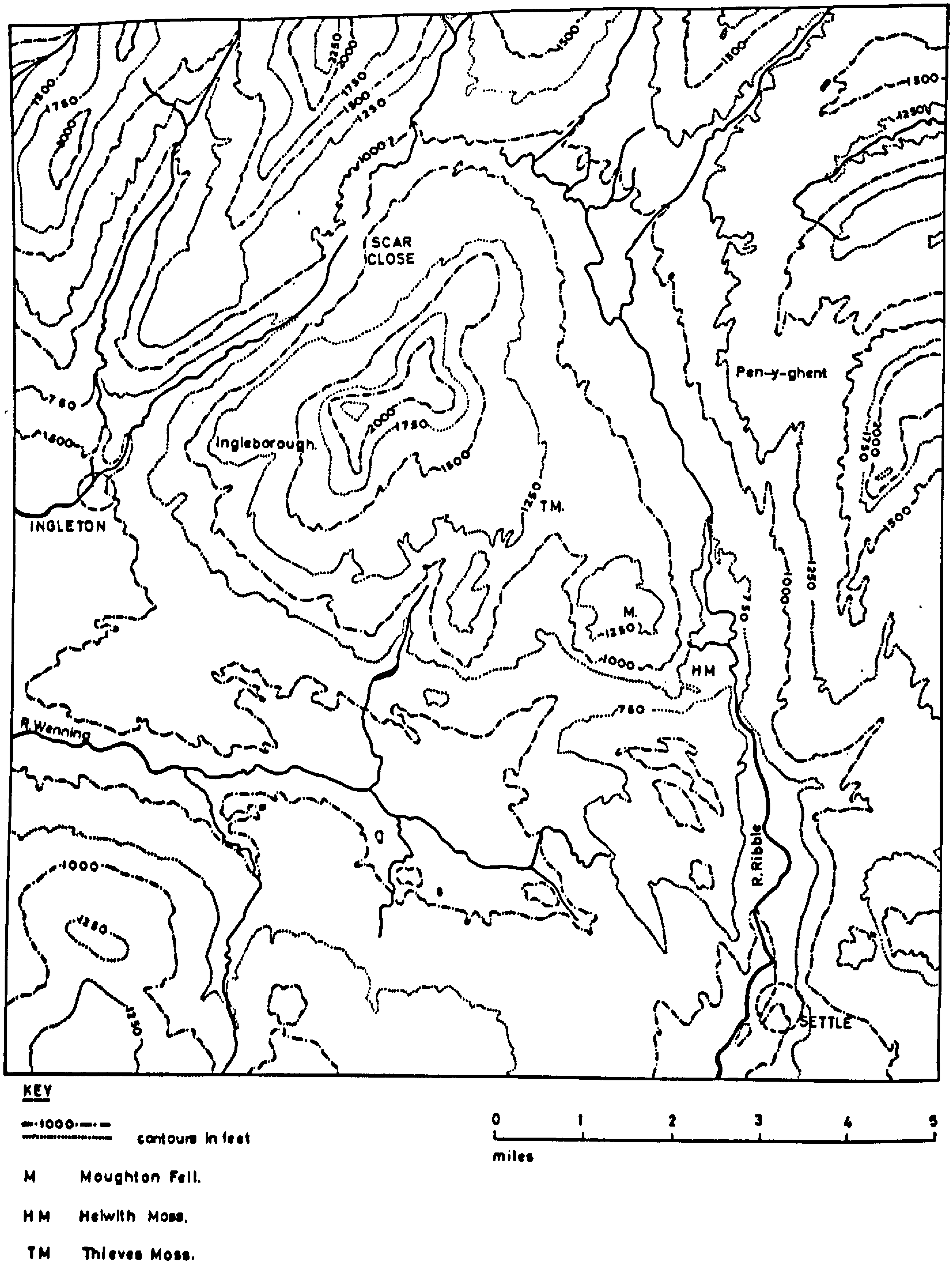


Fig. 1. The Ingleborough area.

Introduction.

The peat deposits of the Ingleborough area are particularly interesting in the variety of their position, and their relationship to topography. It therefore seemed likely that an investigation of them would be profitable, and might yield information about the vegetational history of the northern Pennines. Two main areas were chosen: (Fig. 1)

1. Helwith Moss (National Grid reference SD 805695), a good example of a raised bog,

2. Scar Close (SD 750773), a limestone area partly covered with peat bearing acidophilous vegetation.

These were chosen because they showed several points of contrast in altitude, position, and underlying rock. The investigation of Helwith Moss was relatively straight-forward, whereas Scar Close with its peat patches situated directly on limestone pavement presented many more problems. It was also hoped that the longer pollen diagrams from Helwith Moss might be useful in trying to date the shorter ones from Scar Close. To link these two sites smaller investigations were made of peat from Thieves Moss (SD 778730) at the head of Crummack Dale, and from the top of Moughton (SD 792710). Thieves Moss has developed from a former lake in a similar way to Helwith Moss, but with a different vegetational history, whereas the top of Moughton is an area of limestone pavement similar to Scar Close in its general characteristics.

Geography of the Ingleborough Area (Fig. 1). (Sweeting 1950).

The Ingleborough area is situated on the western side of the

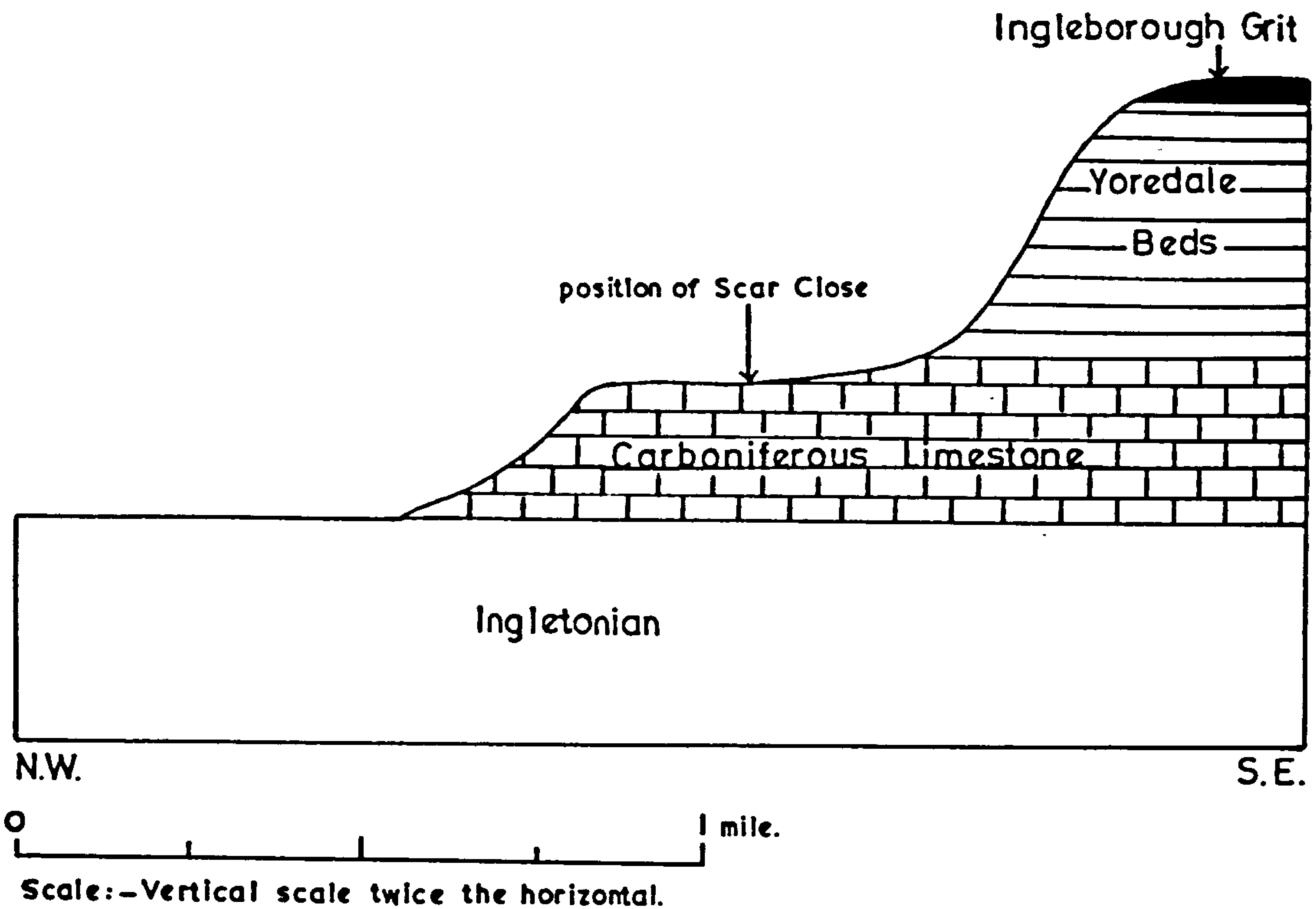


Fig. 2. A section through Ingleborough. (Based on Dunham et al., 1953.)

northern Pennines in the county of Yorkshire (SD 742746). It consists of an ancient erosion surface at approximately 2,000 ft. which has subsequently become dissected leaving the peaks of Whernside (2,419 ft.), Ingleborough (2,373 ft.) and Penyghent (2,273 ft.). At approximately 1,300 ft. there is a second erosion surface below which the rivers flow in deep valleys. This plateau is almost flat, often devoid of soil and consists in many places of limestone pavement. Though there is evidence to suggest that it is Pre-Glacial the feature has been well preserved as a result of the development of an underground drainage system.

Geology.

The geological history of the area is long and complicated. Ingleborough itself, (Fig. 2), consists of Carboniferous rocks resting unconformably on folded and truncated rocks of the Ingletonian Series which are considered to be Pre-Cambrian. The latter form the rigid basis of the Askrigg Block. The lowest of the Carboniferous layers is Great Scar Limestone which is about 600 ft. in thickness. It is the surface of this which forms the 1,300 ft. erosion surface mentioned above. Exposure to weathering has caused the development of "Karstic" features such as widening of joints to form grykes and clints, and the formation of pot-holes, caves, swallow-holes and underground drainage systems. Above the Great Scar Limestone are "Yoredale Beds" an alternating series of harder sandstones and limestone with softer shales which have weathered and eroded differentially giving rise to the characteristic step profile. Ingleborough is capped with Millstone Grit of a course texture. Although a number of faults developed in the Craven area during, and at the end of Carboniferous times, these beds have been disturbed very little. There is no folding but a gentle tilt to the north-north-east.

Moughton (1,402 ft.) is not as high as Ingleborough and consists of Great Scar Limestone at a similar altitude to Scar Close. In both Crummack Dale and Ribblesdale there are large inliers of Ordovician and Silurian rocks which have become folded and faulted. There is no direct evidence in the area of deposits of a Mesozoic or Tertiary age, and if they were laid down they must by now have been eroded away.

There is however considerable evidence that the area was glaciated during Pleistocene times. At its maximum the ice must have covered both hills and valleys though some of the higher peaks such as Ingleborough may have been left as nunataks. The dales such as Ribblesdale and Crummack Dale were occupied by glaciers which eroded their valleys to the characteristic U-shape. From the path of erratics, and the direction of scratches and roches moutonnées, it is evident that the ice was moving south or south-east. It scoured the country and on its retreat left behind irregular deposits of drift in the form of gravels or Boulder Clay, thickest in the valleys but also deposited at a considerable height. Some was left as morainic material which dammed the dales and caused lakes to develop, or as eskers and drumlins. The glaciation of the country caused much modification of the scenery and surface with a consequent effect on vegetational history.

<u>Rainfall.</u>

The rainfall of the area is fairly high as shown by the following data from the tables of British Rainfall. The three stations are situated to the north-east, south-east and south-west of Ingleborough, respectively.

Station.	Grid Reference.	Altitude.	Average Annual Rainfall.
Ribblehead (Station).	SD (34) 766789	1,025 ft.	78.7 inches.
Settle (Malham Tarn).	SD (34) 893672	1,297 ft.	60.3 inches.
Settle (Greet Bridge).	SD (34) 702589	825 ft.	72.7 inches.

According to Manley (1956), at Malham Tarn lower day time temperature maxima, due to altitude, are accompanied by more wind, greater cloudiness and decreased evaporation causing surface layers of soil over wide stretches to retain their moisture. This would have significance for peat formation.

Vegetation. (Pearsall 1950, Sinker 1960).

The complexity of the geology is reflected in the vegetation. The limestone being practically pure calcium carbonate, produces on weathering very little soil, so that limestone pavements tend to be bare except where covered by drift. The surface is exposed to extremes of wind, temperature and moisture and little grows on it. However the clints are sometimes covered with crustaceous lichens, and tiny pockets of soil may support plants such as Saxifraga tridactylites. In the deeper grykes conditions are more stable, cool, moist, and still and where humus has accumulated Mercurialis perennis, Geranium robertianum, Stachys sylvatica and Phyllitis scolopendrium may be rooted in the bottom, and Asplenium trichomanes occupy crevices in the wall. The wider and shallower grykes contain grasses such as Sesleria caerulea. Where soil does accumulate however it is normally rich in basic salts and the vegetation is correspondingly rich in species. Festuca-Sesleria grassland may develop associated with Anthoxanthum odoratum, Briza media, Cynosurus cristatus, Helianthemum chamaecistus, Thymus drucei. Where there is a more or less constant supply of lime-saturated water, marsh, fen or carr may be found. In a marsh there is little evidence of peat formation, but fen and carr are established on peat or organic mud. Marshes in this area are subject to disturbance by frost and trampling and the ecological situation is essentially dynamic. Hummocks carrying turf of Festuca ovina and Carex species associated with Primula farinosa, Pinguicula vulgaris and Sagina nodosa are separated by open patches of stony drift clay with runnels sparsely colonised by Carex lepidocarpa, Juncus articulatus and Triglochin palustre. Calcareous marsh vegetation is generally short in contrast to fen vegetation which is taller and more lush. Some characteristic fen species are Carex rostrata, Potentilla palustris, Mentha aquatica, Lychnis flos-cuculi, and locally Phragmites communis. Where carr develops the typical trees are Alnus glutinosa and Salix spp.

Where the soil is acid the vegetation is completely different. The acidity may be caused by excessive leaching of limestone soils or the nature of the parent material. For example Millstone Grit gives rise to a soil which, being sandy, becomes podsolised and deficient in basic salts. The downward movement of water carries away clay particles, humus colloids and iron depositing them lower to form impermeable pans. This impedes drainage, and where rainfall is high peat develops. The presence of drift may also give rise to areas which are badly drained, acidic and peat covered. The vegetation of such areas is either bog or moorland. Where conditions are very wet bogs develop with many species of Sphagnum, and Eriophorum, Erica tetralix, Narthecium ossifragum and Drosera rotundifolia. Moorland may be of several kinds dominated by different plants. Sedge-moors have Eriophorum vaginatum and Eriophorum angustifolium as the most conspicuous species, but where drainage is better Calluna vulgaris may predominate with Vaccinium myrtillus forming heather moor. Grass moorland may be present on soils similar to those of the heather moor though rather damper. Here Nardus stricta is often associated with Juncus squarrosus and Deschampsia flexuosa, Galium saxatile and Potentilla erecta. As compared with base rich soils however acidic habitats are relatively poor in numbers of species.

In the Ingleborough area there is very little woodland but a mature ashwood is growing on limestone pavement at Colt Park on the eastern side of Park Fell. A small wood is also present again on limestone pavement to the north-east of Scar Close at Howrake Rocks.

Techniques.

As the deposits at Helwith Moss are deep, the material was extracted by means of a Hiller Borer. This enabled cores to be removed from known depths. From the centre of the cores smaller samples were taken at regular intervals and placed in clean corked specimen tubes. On returning to the laboratory the corks were waxed to prevent drying out during storage. At Scar Close and on Moughton Fell it was possible to dig out complete monoliths of peat from which smaller samples could be taken in the laboratory. These small samples were investigated by two methods:

1. Macroanalysis
2. Pollen analysis

Both methods make use of the fact that peat forms under water-logged conditions where bacterial decay is extremely slow. As a consequence of this the material forming the peat, and any other structures such as seeds, fruits and pollen grains, which may be trapped in the peat are preserved for a very long period in a state in which they can be recognised and identified.

1. Macroanalysis.

Starting at the base of the deposit small quantities of peat were removed at 5 cm. or 10 cm. intervals according to the complexity of the layering, and digested in 10% nitric acid for approximately twelve hours, with occasional stirring. This treatment destroys the humus and breaks down the material. After thorough washing on a sieve it was then possible to examine the plant remains by means of a low power microscope. An attempt was made to ascertain the nature of the

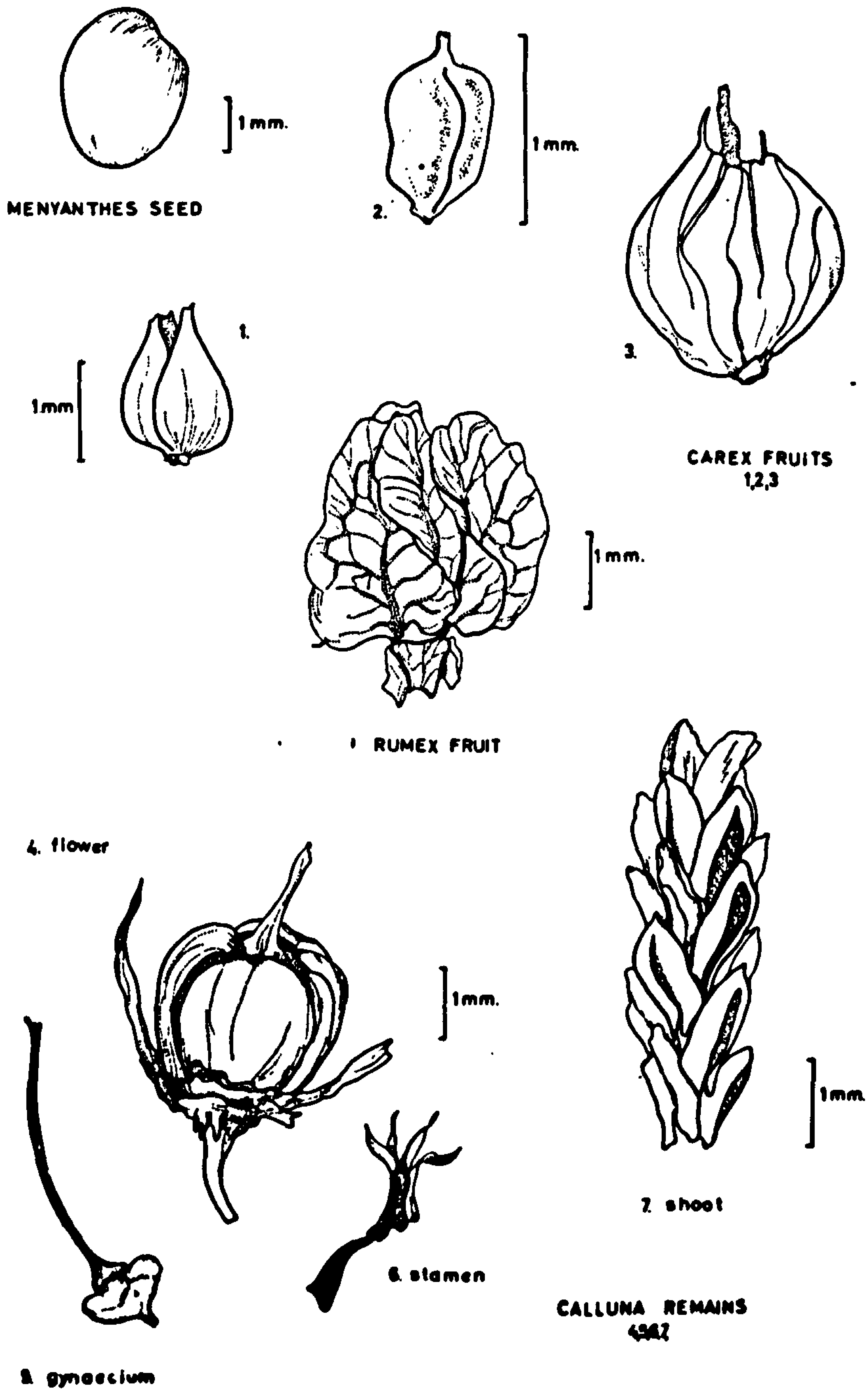


Fig. 3. Macroscopic remains found in peat.

main plant material forming the peat, and to identify any fruits and seeds which were present. From this information can be inferred the succession of vegetation types which have formed the peat. This information, together with field notes, is used to construct the peat profiles. The stratigraphy of a large area such as Helwith Moss is shown as a section constructed from a number of cores taken at intervals across the bog. Examples of some of the plant structures found by this method are illustrated in figure 3.

2. Pollen analysis.

Pollen grains are particularly resistant to decay because of the chemical nature of their walls. The exine, composed of sporopollenins retains its characteristic form and sculpturing provided the peat does not dry out. This makes it possible for grains to be identified (in some cases even to species level), and counted. The varying proportions of these different pollen types are then calculated as percentages of total tree pollen or total pollen. At any one level the proportions of the different types constitute a pollen spectrum, and a vertical series of such pollen spectra form a pollen diagram. Each pollen spectrum is a reflection of the vegetation growing in the neighbourhood of the bog when that particular layer of peat was formed. The changes in the pollen curves of the pollen diagram indicate the changes in vegetation which have taken place in the area during the formation of the whole deposit.

The samples were prepared for pollen analysis as follows:

1. About 2 ccs. of each sample were heated in 10% potassium hydroxide solution in a hot water bath for at least two hours.

2. The material was filtered through a sieve.

3. The filtrate containing the pollen grains was centrifuged and washed twice in distilled water.

4. The residue was stained with safranin and mounted on a clean slide in glycerine jelly.

When a large quantity of mineral material was present, it was removed by the Aceto-Bromoform Technique (Frey 1951):

1. About 2 ccs. of each sample were heated in 10% potassium hydroxide solution in a hot water bath for at least two hours.

2. The material was filtered through a sieve and the filtrate centrifuged in a pointed centrifuge tube.

3. The residue was washed once in distilled water and twice in acetone.

4. To each sample about 3 mls. bromoform (specific gravity 2.02) was added and stirred.

5. After centrifuging, the supernatant containing the pollen grains was poured into a clean tube and the centrifuging repeated.

6. The supernatant was added to twice the volume of acetone and centrifuged. The supernatant was then discarded.

7. Steps 4. - 6. were repeated twice more with the original material to ensure a complete removal of pollen.

8. The residue containing the pollen grains was washed once in acetone, twice in distilled water, stained and mounted as described previously.

Two slides were made of each sample and half of the required pollen grains counted from each slide using a high power binocular microscope with a mechanical stage. It is customary to continue counting until 150 tree pollen grains have been recorded, and then to calculate the proportions of all pollen types as percentages of total tree pollen. This is because forest has been the dominant vegatation type through much of the post-glacial period. As very little tree pollen was present in samples from Scar Close and Moughton, this method could not be used. Instead counting continued until a total of 500 pollen grains was reached, and values were calculated as percentages of total pollen. Although spores were also counted they were not included in the total of 500. In section B1 of Scar Close, however, and for the lowest part of the sample from Moughton, tree pollen was present in sufficient quantities for values to be calculated as percentages of total tree pollen as well. In the case of Helwith Moss, percentages were based on both tree pollen and total pollen.

If the stratigraphy and the results of pollen analysis are considered a picture of the vegetation can be built up. The stratigraphy indicates the vegetation which actually grew on the site, whereas the pollen diagrams indicate the nature of the vegation which grew not only on the site but also in a wide area around. This accounts to some extent for the discrepencies between the macroscopic remains and the pollen grains. Although pollen diagrams show the relative proportions of the genera and in some cases the species concerned, because they are expressed in percentages they cannot be interpreted as a direct quantitative measurement of the constituents of the vegetation. Also the amounts of pollen trapped and preserved in the deposit depend on several factors, e.g. pollen production of individual species, relative resistance to decay, facility for dispersal, direction of prevailing winds and situation in relation to the bog. The absence of pollen of a particular species does not necessarily mean that it was not present. However, with these considerations in mind it is possible to gain from pollen diagrams much valuable information regarding the general changes in vegetation.

Fig. 4. The geology of Ribblesdale. (Dunham et al., 1953.)

Helwith Moss.

Location.

Helwith Moss is situated at the foot of Moughton on the western side of Ribblesdale at a height of about 800 ft.

Geology.

The geology of the area is rather complex as can be seen by reference to figure 4. The valley floor is partly covered by patches of glacial drift. The bog has developed in a depression in a region of impervious Horton Flags which are overlain on the western side by Carboniferous Limestone forming the mass of Moughton.

General Appearance.

The Moss itself occupies a considerable area, being approximately half a mile across and roughly circular in shape. It is bounded on the northern side by a dike and on the south-eastern side ~~by~~ a stream, Black Sike, originates and flows into the River Ribble. The edges of the bog are eroded or cut in parts exposing a considerable thickness of peat (photograph 1. page 25a). The general shape is markedly convex, the central area being raised in some parts as much as four metres about the surrounding lower ground. The convexity can be seen clearly in photograph 2 taken from the south-eastern side with Moughton in the background.

Vegetation.

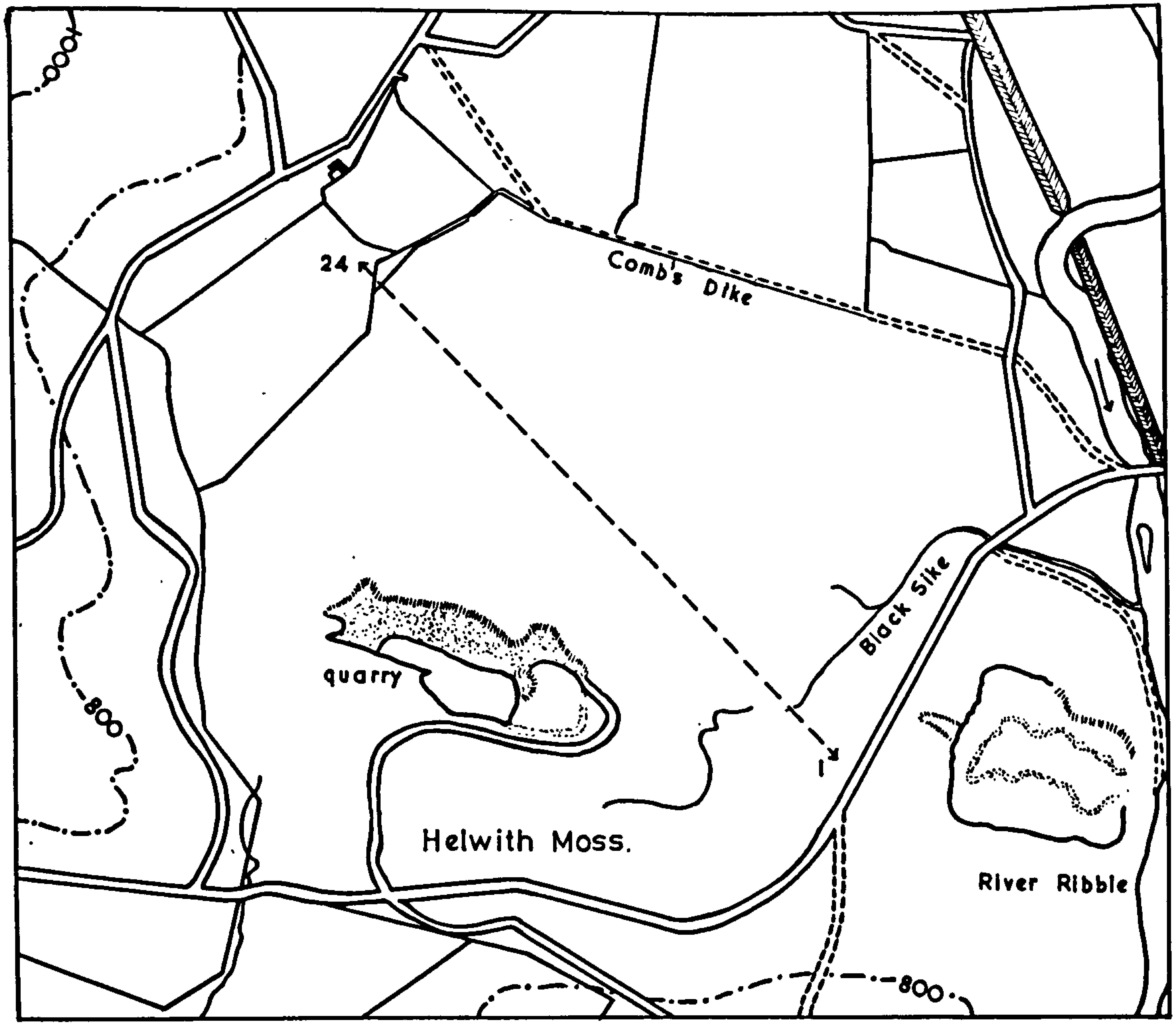
The raised surface is very irregular consisting of hummocks and pools (photograph 3). The vegetation is dominated by species of Sphagnum with Eriophorum vaginatum and Eriophorum angustifolium (shown in bloom in photograph 4). Many of the pools contain Sphagnum cuspidatum. Tussocks of Polytrichum commune and Polytrichum strictum are well developed and Calluna vulgaris is prominent round the edges where drying out has occurred. A list of some of the other species present is given below:

Andromeda polifolia	Molinia caerulea
Betula spp.	Narthecium ossifragum
Deschampsia flexuosa	Oxycoccus palustris
Drosera rotundifolia	Potentilla erecta
Erica tetralix	Trichophorum caespitosum
Festuca ovina	Vaccinium myrtillus
Luzula multiflora	

On the lower area surrounding the Moss the vegetation is very different. This is particularly marked on the south-eastern side in the region of the stream, where the water table is much nearer the surface and the dominant plants are Molinia caerulea and species of Carex and Juncus. Some of the most abundant species are listed below:

Carex nigra	Lychnis flos-cuculi
Carex rostrata	Mentha aquatica

Fig. 5.



Scale: 9 Inches to 1 Mile.

←‒‒‒‒→ line of peat borings —·1000—·— contours in feet

Juncus articulatus	Menthyanthes trifoliata
Juncus effusus	Potentilla erecta
Molinia caerulea	Potentilla palustris
Caltha palustris	Ranunculus flammula
Cardamine palustre	Ranunculus repens
Eriophorum angustifolium	Triglochin palustre
Galium uliginosum	Acrocladium cuspidatum
Holcus lanatus	Polytrichum commune
Hydrocotyle vulgaris	Sphagnum spp. (not S. imbricatum.)

Between the stream and the steep sloping edge of the central raised part of the Moss there is evidence of peat-cutting with large pools containing Eriophorum angustifolium and Carices. On the north-western side the area of lower ground between the raised bog and the dike is neither so large nor so wet but there is a similar though less well marked change in vegetation. Molinia caerulea is again conspicuous, growing where there is downward drainage from the bog to the dike.

Stratigraphy.

In order to trace the development of the bog, a number of borings were made along a line from the south-east to the north-west as shown in figure 5. By using a level the relative heights of the various profile stations were determined and from this information

Fig. 6.

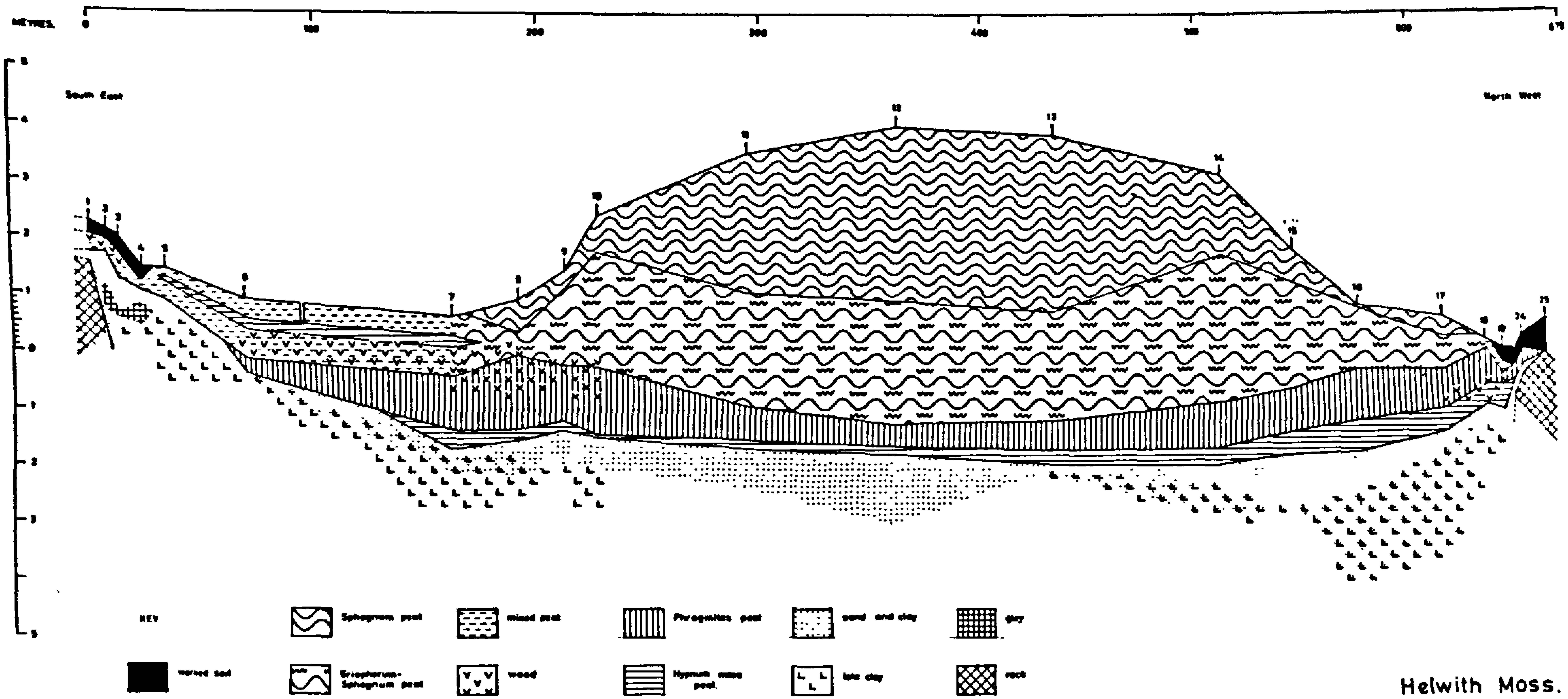


Fig. 6. Section through Helwith Moss.

and the macroanalysis data the section illustrated in figure 6 was constructed. A definite sequence of plant remains became evident, showing the type of succession which had taken place. This is illustrated clearly by the detailed stratigraphy of boring 11 near the centre of the Moss:

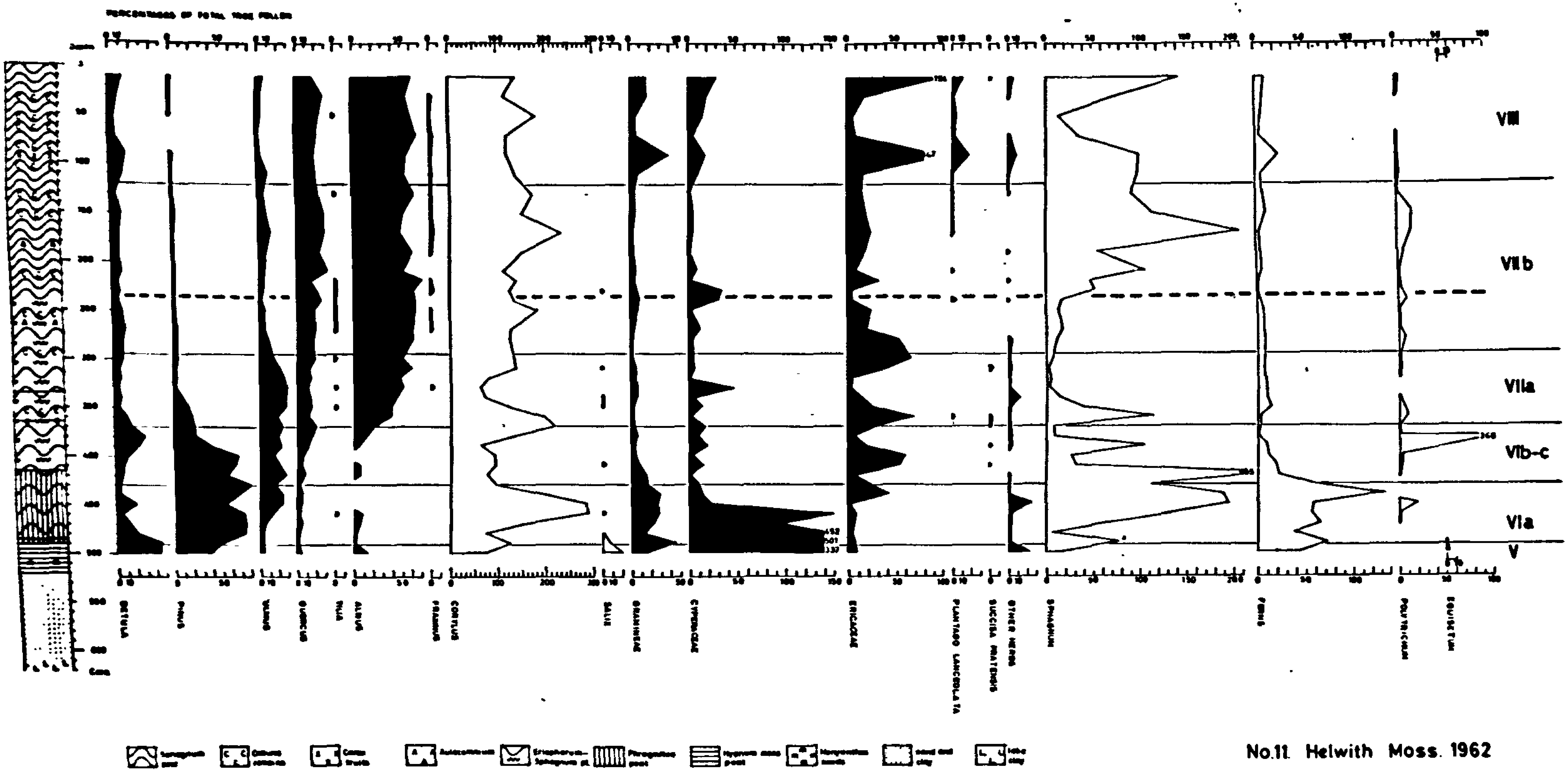
0 - 235 cms.	reddish brown peat, rather wet and only slightly humified, consisting mainly of Sphagnum imbricatum; Sphagnum plumulosum, Calluna vulgaris and occasional Carex fruits were also present;
236 - 410 cms.	smooth peat, rather fibrous, chiefly Eriophorum with some Sphagnum imbricatum, Sphagnum plumulosum, Calluna vulgaris and occasionally small quantities of Hypnum type moss;
411 - 485 cms.	a much more solid and drier peat, light in colour, mainly Phragmites but with a little Sphagnum plumulosum and Eriophorum;
486 - 520 cms.	Hypnum type peat with a few seeds of Menyanthes;

521 - 609 cms.	coarse sandy clay with a few oospores of Chara;
610 -	blue-grey clay.

It was not possible to continue boring below 621 cms. but the lake clay continued beyond this point.

It can be seen that Helwith Moss occupies a depression in the parent rock. The basal layer is a fine blue-grey lake clay, the upper part of which is mixed with a much coarser sand. The depression appears to have held a lake in which a Hypnum-type moss grew. This was succeeded by a Phragmites reed swamp, then Eriphorum-Sphagnum bog and finally almost pure Sphagnum imbricatum. The latter has grown most rapidly in the central part and this accounts for the marked convexity of the bog surface. The pressure of the mass of Sphagnum in the centre may also have caused compression in the Eriophorum peat, thus producing the concavity of its upper surface. Although Sphagnum imbricatum and S. plumulosum were-the only species of Sphagnum found in any quantity, S. cuspidatum, S. palustre and S. papillosum were also present in small amounts. Round the edges development has not followed the same pattern. After the reed swamp layer the peat is of a mixed type with no predominating constituent. It consists of remains of Sphagnum, Eriophorum and monocotyledonous leaves with some Calluna, Equisetum and Hypnum. In the reed swamp layer and immediately above, woody fragments of Betula are also present.

Fig. 7.



No.11. Helwith Moss. 1962

The Moss has developed asymetrically and at the south-eastern end there is a second layer of Hypnum-type peat about half a metre below the surface. There is no convexity as in the centre of the bog. At the extreme edge the surface layer is a worked soil to a depth of 20 cms.

Pollen Analysis.

The pollen diagrams are constructed from two borings, one at position 11 in the central raised area, and one at 6 in the lower marginal area. Figure 7 shows the pollen diagram of boring 11 based on total tree pollen. Details are given in table 1 of the individual percentages which are grouped together and shown as a single curve labelled "other herbs" in figure 7. The diagram has been zoned in the usual way for Great Britain and the sequence seems to be from zone V to zone VIII. Tree pollen in sufficient quantities to count was not present in the lower layers of the Hypnum-type peat, nor in the clay. Each zone shows certain characteristics which distinguish it. Some of the characteristics are general for Great Britain as a whole, and others are special features of this particular area:

Zone V (500 - 490 cms.)

Betula and Pinus predominate amongst the trees. The Corylus curve rises. Values for the Cyperaceae are very high and the Gramineae, Sphagnum and ferns are well represented. Equisetum is present and of the "other herbs" Filipendula accounts for 15% of total tree pollen.

Sub-zone VIa (489 - 430 cms.)

Pinus predominates throughout. Betula which is high at first falls rapidly and Ulmus values rise to 15% by the end of the sub-zone. The Corylus curve rises steeply and reaches its maximum of 288%. Gramineae, Cyperaceae, Sphagnum and ferns are well represented.

Sub-zones VI b and c (429 - 370 cms.)

There is no clearly marked boundary between these two sub-zones, so they are considered together. Betula and Pinus are still present but towards the end of the zone Pinus values fall while Quercus increases to 19%, and Alnus appears consistently for the first time. The Corylus curve has dropped noticeably at the beginning of the sub-zone but rises again at the boundary between this zone and zone VII. Amongst non-tree pollen the Ericaceae shows high values while fern, Polytrichum and Sphagnum spores are conspicuous.

Sub-zone VIIa (369 - 290 cms.)

The boundary between zones VI and VII lies where the rising Alnus curve and the falling Pinus curve cross. Alnus shows the highest values in tree pollen, with Ulmus, Quercus and Tilia, indicating the presence of alder and mixed oak forest. Betula and Pinus pollen falls to very low values and Corylus also falls considerably.

Sub-zone VIIb (289 - 120 cms.)

The beginning of this sub-zone is marked by the fall in Ulmus pollen. Betula and Pinus remain very low, while Alnus maintains values of 50%

Fig. 8.

No.11. Helwith Moss 1962.

and over. Quercus is the only other tree which is well represented, rising as high as 32%, though Tilia appears sporadically, and by the end of the zone, Fraxinus has established a continuous curve. Corylus shows a rise but this is not as high as in sub-zone VIa. Of the non-tree pollen that of the Ericaceae is the most conspicuous, and Sphagnum again reaches high values with some increase also in Polytrichum.

Zone VIII (119 - 10 cms.)

The boundary of this zone is difficult to define and other possibilities will be discussed later. Here it is drawn where Betula pollen increases but Ulmus decreases. Tilia is much less frequent than in sub-zone VIIb. There is a marked increase in non-tree pollen and Plantago lanceolata rises as high as 20%. Sphagnum values rise particularly towards the end of the zone.

The pollen diagram based on percentages of total pollen is shown in figure 8. This was constructed for comparison with the diagrams from Scar Close but it illustrates some more features of Helwith Moss not shown in figure 7. It was possible to obtain values expressed as percentages of total pollen from the Hypnum-type peat and the upper layer of coarse sandy clay where tree pollen was poorly represented. The main features of interest here are the high values of "other herbs", (table 2), 26% being pollen of Myriophyllum alterniflorum, and the exceedingly high percentage of Equisetum spores.

Fig. 9.

The column showing the proportions of tree, shrub and herb pollen shows a fall in non-tree pollen in zones V and VI, and a rise in zone VIII.

Similar information for boring 6 of Helwith Moss is given in figure 9 and table 3. Although the boring was made on the same site as number 6 in the section of Helwith Moss (figure 6) the Hypnum remains were more diffuse and did not form such a definite layer. The pollen diagram is clearly divisible into two parts. Below 85 cms. Pinus is the most abundant tree pollen whereas above Alnus predominates. From the high percentages of Pinus pollen it can be deduced that the lower layer belongs to zone VI. Similarly abundant Alnus pollen suggests that the upper layer belongs to zone VIIa, yet there are some points which throw doubt on this. Firstly, above 85 cms. non-tree pollen increases, particularly of grasses and sedges. Secondly, the presence of Plantago lanceolata rising as high as 20% would suggest that this layer has some of the features of zone VIII. On the other hand, Succisa pollen is also present and this appears to be a characteristic of zone VIIa on the main diagram from boring 11. It therefore seems that the peat in this area might have become mixed by alternating processes of deposition and erosion since the VI/VIIa transition. Thus the layer in the pollen diagram labelled VIIa shows features of both zone VII and zone VIII.

Discussion.

From its position in relation to the present bed of the River Ribble it seems likely that the area now covered by Helwith Moss was occupied by a drift-dammed lake. The earliest vegetation which has been preserved belongs to the Boreal period when the climate was comparatively warm and dry. The remains are those of mosses and other aquatic plants which could have become established in a lake. Large quantities of pollen of the Cyperaceae are present at this level and with it pollen of Myriophyllum alterniflorum, M. spicatum, M. verticillatum, Ranunculus peltatus type and Salix. Abundant spores of Equisetum, seeds of Menyanthes and oospores of Chara also suggest growth in a shallow lake. The amount of non-tree pollen compared with tree pollen is very high and though much of this is probably derived from plants growing in or around the lake, it nevertheless suggests that the surrounding forest may not have been very dense. During sub-zone VIa the area seems to have developed into a reed swamp still with a high pollen content of the Cyperaceae but also with many rhizome remains of Phragmites. Small amounts of Sphagnum were also present and from the great rise in Sphagnum spores towards the end of the sub-zone, it appears to have become increasingly important. At the end of zone VI this community was invaded by Eriophorum and members of the Ericaceae and a typical bog vegetation became established. The presence of large quantities of Polytrichum spores and ericaceous pollen and the drop in the values of Sphagnum spores may also indicate a rather lower level of the water table at that time. However, the major period of bog growth began at the transition from the Boreal to the Atlantic period near the boundary of sub-zones VIc and VIIa as at many sites in Great Britain. The climate was becoming increasingly wet and was very favourable for bog growth. It is from this time onward that the Ericaceae have been an important constituent of the vegetation as shown by the rise in pollen values and the frequent remains of flowers and shoots of Calluna. It was also the warm wet climate of the Atlantic period which apparently favoured the growth of Alnus in the surrounding region and enabled it to dominate over Pinus and Betula, the two most characteristic trees of the Boreal times.

There is a very marked change in the stratigraphy at 235 cms. where the highly humified Eriophorum - Sphagnum - Calluna peat is replaced by light-brown undecayed Sphagnum peat which continues to within 10 cms. of the surface. The presence of such a recurrence surface is a characteristic feature of a large number of raised bogs, e.g. Tregaron (Godwin and Mitchell 1938). It usually marks the boundary between zones VII and VIII when it is suggested that a climatic deterioration occurred and bog growth was stimulated. It is shown by a broken line in figure 2. The great increase in

Sphagnum is also reflected in the rise of the *Sphagnum* curve in the pollen diagram. From the results of pollen analysis, however, it seems more satisfactory for the boundary between zones VII and VIII to be placed at 120 cms. as shown by the continuous line in figure 2. Here there is a marked increase in non-tree pollen and *Betula* pollen also rises. The *Corylus* curve falls and values for *Sphagnum* decrease though they increase again nearer the surface of the bog. Towards the end of zone VIIb and throughout zone VIII there is a significant rise in the pollen of *Plantago lanceolata* and this, together with a rise in the pollen of grasses and sedges, is presumably indicative of prehistoric agriculture. A possible solution to the difficulty in marking the boundary between zone VII and zone VIII is to introduce a transition zone from 235 cms. to 120 cms., and for zone VIII to include only the peat from 120 cms. to the surface. Wherever the boundary is drawn the fact remains that from 235 cms. upwards the peat is composed almost entirely of *Sphagnum imbricatum* which is present throughout the whole of the Atlantic, Sub-Boreal and Sub-Atlantic periods. The disappearance of *Sphagnum imbricatum* in recent times has given rise to considerable speculation (Morrison 1959). It is an oceanic species which will only grow where conditions are very wet and it is sensitive to drainage and fire. It may be that the raised bog has reached its maximum vertical growth and precipitation no longer compensates for the downward movement of water. Whatever the cause the surface of the Moss today does not appear to be wet enough for Sphagnum imbricatum to grow. Sphagnum plumulosum is present throughout the same periods as Sphagnum imbricatum but at no time does this become the dominant element in the peat. Sphagnum cuspidatum, S. papillosum and S. palustre have also been identified but no definite pattern of occurrence has emerged which might suggest a regeneration complex. This is not surprising, however, as the borings were made in positions too widely spaced for the necessary detailed analysis to be made.

All the discussion so far has been concerned with the central area of Helwith Moss. The marginal areas are a different problem. From the stratigraphy it can be seen that after the reed swamp it is likely that the margin became wooded with Betula though the possibility of the woody fragments being washed in from the outer edges cannot be excluded. At the south-eastern side there appears to have been a second flooding resulting in the re-establishment of Hypnum. The rest of the peat is of a mixed type and although it contains Sphagnum remains it is nowhere dominated by it, but it is composed of considerable quantities of nocotyledonous leaves. The establishment of Sphagnum may have been prevented by the presence of a high mineral content in the water draining into the margins from the surrounding area. The evidence suggests that the development of a typical bog vegetation was retarded and modified. The unusual features, e.g.

20% Plantago lanceolata of the zone labelled VIIa in figure 4, are more characteristic of zone VIII in the centre of the bog and are indicative of considerable disturbance in this marginal area. It is interesting to note that flooding by calcareous water in the Somerset bogs (Godwin 1956) after the Late Bronze Age (zone VII) and in Romano-British times (zone VIII) induced the development of Cladium-Hypnum fens, and the climatic retrogression caused a recession in local agriculture giving rise to an increase in the pollen of weeds. Here at Helwith Moss, where evidence suggests that the peat is a mixture of zones VII and VIII, the Hypnum layer which may well have developed as a response to flooding, (a fact reinforced by the presence of Potamogeton pollen), is also covered by a layer of peat in which pollen of Plantago lanceolata, Taraxacum type, Senecio type and Ranunculus are well represented.

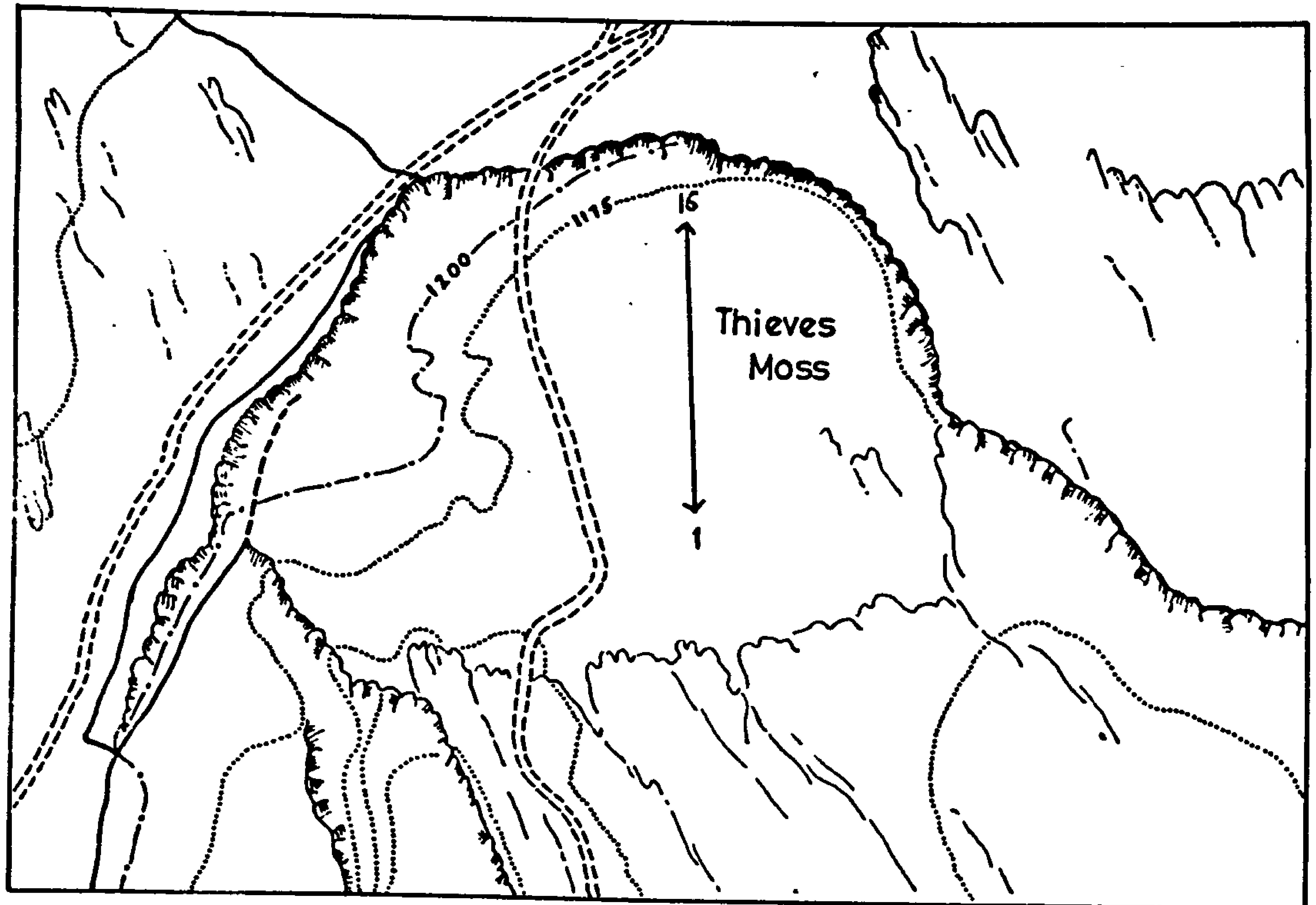
Phot. 1. Helwith Moss: the eroded margin.

Phot. 2. The raised surface of Helwith Moss, at the foot of Moughton.

Phot. 3. Detail of the surface of Helwith Moss showing _Calluna_, _Eriophorum_, and _Sphagnum_.

Phot. 4. Helwith Moss: _Eriophorum angustifolium_ in flower.

Fig. 10.



Scale: 12 inches to 1 mile.

⟷ line of borings

—·—·— contours in feet ········

Thieves' Moss.

Location.

Thieves Moss is situated at the head of Crummack Dale, on the south side of Sulber above Moughton Scars, at a height of about 1,140 ft.

Geology. (Figure 10).

The Moss lies in a depression in the Great Scar limestone. It is bounded on its northern side by a semicircle of limestone cliffs which rise to a height of 50 ft. (photographs 5 & 6). To the south the limestone is exposed and has been weathered to form well developed limestone pavement which is higher than the present bog surface.

General Appearance.

Thieves Moss is oval in shape and it is approximately 80 metres across at its narrowest. There is no permanent stream entering the Moss but the drainage system collects into a stream (crossing the section at A) which runs off the Moss (photograph 7) and disappears into the limestone. The surface is considerably eroded and dissected (photograph 8) and rather concave in section as can be seen in figure 12.

Vegetation.

The vegetation consists chiefly of tussocks of *Eriophorum vaginatum* with *E. angustifolium*, *Calluna vulgaris*, *Polytrichum commune*,

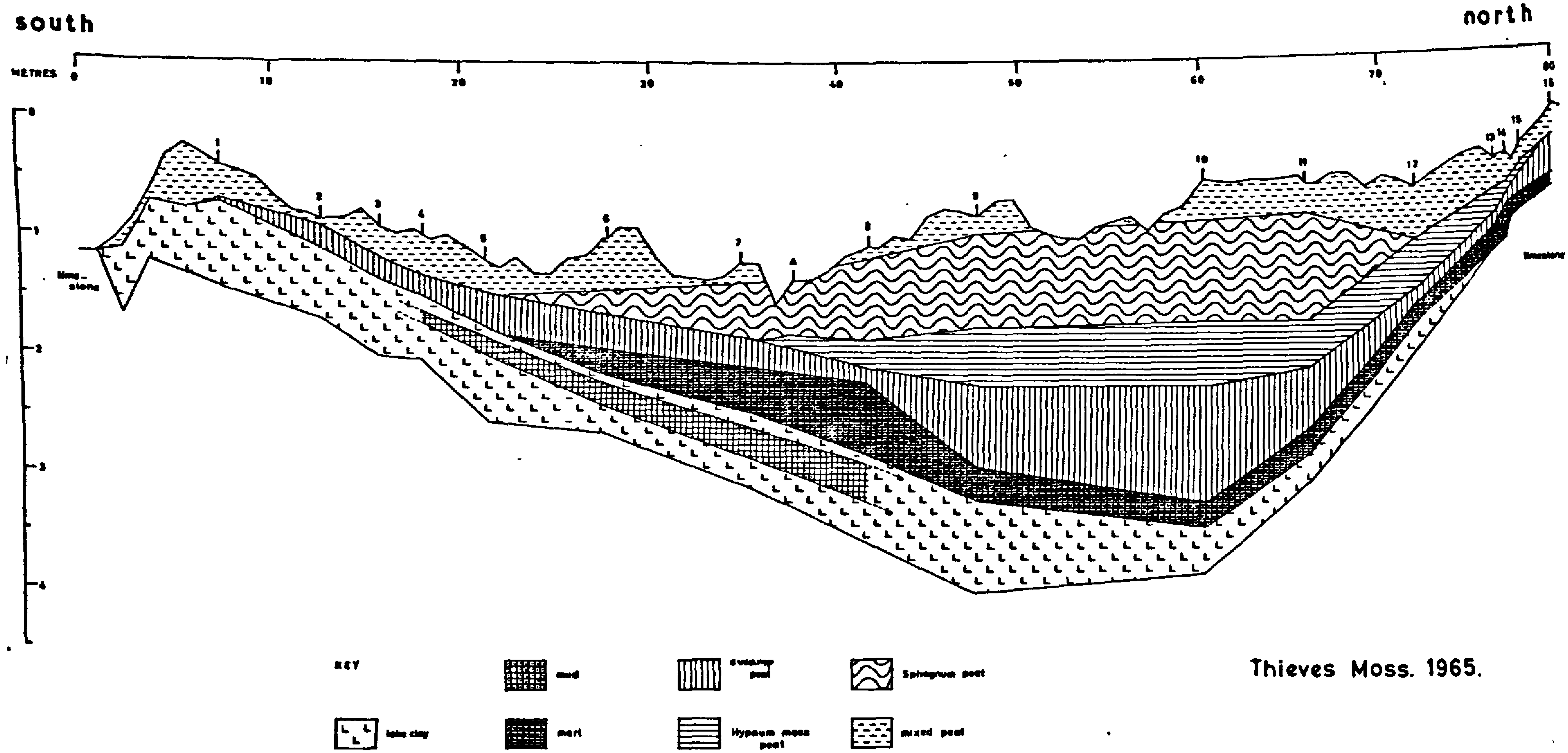
PEAT LAYER	BORINGS 1	2	3	4	5	6	7	9	10	11	12	13	14	15	16
MIXED PEAT					Dr.				Dr. Er.	Er. Sp. Cs.	Er.	Dr. Er.			
SPHAGNUM PEAT							Ml.	Ml.		Ml. Ap.					
HYPNOID PEAT									Dr. Df.	Dr. Pl. Ap.	Ml. Mn.		X		
SWAMP PEAT	Ch.	Ch.	Ch.	Ch.	Ch.	Ch. Cr. Sl.	Ch. Nm.	Ch.	Ch. X Sl. Ps. Bf. Pt.	Ch. X Ca. Sl. Dr. Ac.	Ch. X	Ch. X	Ch. X	Ch. X	X Ms. Bw.
MARL						Ch. Dr. Sl.	Ch.	Ch. Ms.	Ch.	Ch. Dr. X	Ch.	Dr.			
CLAY					Sl.										
MUD					Ch. Sl.	Ch.	Ch.								
CLAY															

KEY

- Ac. Acrocladium cuspidatum.
- Ap. Acrocladium palustre.
- Bf. Betula fruit.
- Bw. Betula wood.
- Ca. Carex acutiformis fruit.
- Ch. Chara oospore.
- Cr. Carex rostrata fruit.
- Cs Campylium stellatum.
- Df. Drepanocladus fluitans.
- Dr. Drepanocladus revolvens.
- Er. Erica tetralix leaf.
- Ml. Molinia leaf.
- Mn. Mnium type moss.
- Ms. Menyanthes seed.
- Nm. Nymphaea seed.
- Pl. Polytrichum leaf.
- Ps. Paludella sqarrosa
- Pt. Potamogeton pyrene.
- Sl. Sphagnum palustre.
- Sp. Sphagnum papillosum.
- X. Carex fruit.

Fig. 11. Thieves Moss: Details of stratigraphy.

Fig. 12. A section of Thieves Moss.



and many lichens. Those parts of the surface which are lower and therefore near the water table have a rich covering of *Sphagnum* with *Trichophorum caespitosum* and *Erica tetralix*. *Eriophorum vaginatum* is also growing in the pools. A flatter area (photograph 9) to the east of the line of borings is dominated by *Juncus effusus* with *Polytrichum commune*, *Sphagnum sp.*, *Aulacomnium palustre*, and *Dicranum scoparium*.

Stratigraphy.

Sixteen borings were made in a line running north and south across the bog (figure 10), and a section constructed (figure 12) in the same way as for Helwith Moss. The profile at boring 10 will serve to show the stratigraphic sequence of the deposits in the deeper, central part.

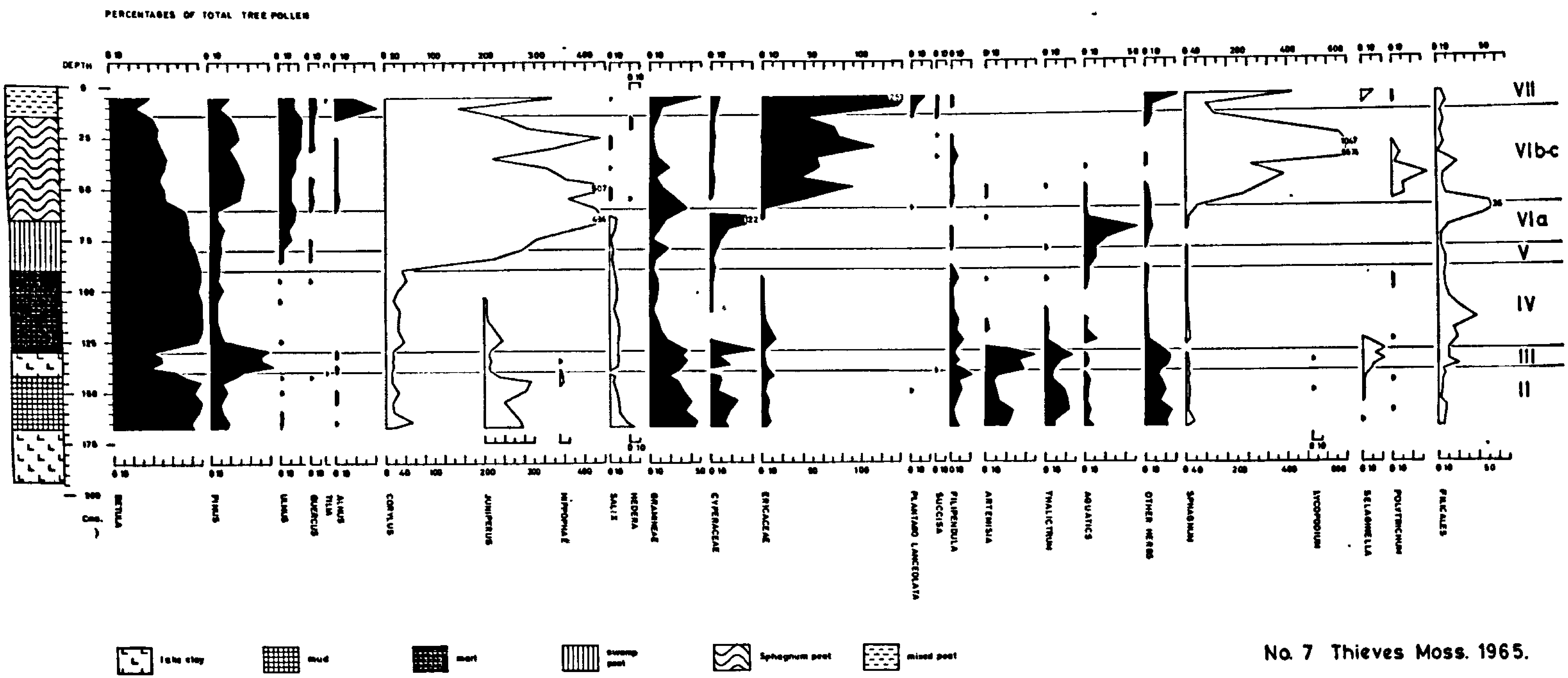
0 - 35 cms.	brown peat of a mixed type with monocotyledonous leaves, *Sphagnum plumulosum*, *Drepanocladus revolvens*, and leaves of *Erica tetralix*.
36 - 120 cms.	lighter colour peat consisting mainly of *Sphagnum plumulosum* with occasional wood fragments and some hypnoid moss.
121 - 176 cms.	finer more fibrous peat composed of hypnoid moss with a small amount of *Sphagnum plumulosum*.
177 - 275 cms.	swamp peat with detritus including many oospores of *Chara*, *Carex* fruits, hypnoid moss, *Acrocladium cuspidatum*, a little *Paludella squarrosa* and a

276 - 296 cms.	lake marl with shells, Chara oospores and some monocotyledonous remains.
297 - 337 cms.	grey clay.

The distribution, throughout the section, of plant remains other than the chief peat constituents, is shown in figure 11. A large tree trunk of Betula was found in boring 16 from 46 - 55 cms.

From the section it can be seen that Thieves Moss lies in a concavity in the limestone with a steep northern side, and a more gradual southern slope, because of the dip of the rock strata, so that development has been assymetrical. The hollow is lined with blue-grey lake clay which is interrupted on the gentler southern slope by a band of mud gradually merging into clay at its lateral margins. The clay has very little organic content, but the mud band contains fragments of moss, and oospores of Chara. Above the clay is a layer of calcareous marl, which in the deeper central part contains pieces of shell. This layer does not extend to the present southern extremity of the Moss and at its northern end appears to grade into ground limestone. On the marl a swamp vegetation developed, dominated by species of Carex, evidence of which is now preserved as fruits and leaf fragments. There must have been open water as seeds of Nymphaea and pyrenes of Potamogeton are present in the peat. The swamp was succeeded first by an abundant growth of hypnoid moss, possibly growing in shallower water, and then by Sphagnum plumulosum,

Fig. 13.



No. 7 Thieves Moss. 1965.

as bog conditions developed on the surface. The early *Sphagnum* bog has subsequently been replaced by a mixed vegetion of monocotyledonous plants with some *Sphagnum plumulosum*, and *S. papillosum* as well as *Erica tetralix*, possibly *Calluna* and mosses, such as *Drepanocladus revolvens*. The surface has obviously been subjected to much erosion, and instead of having the convex outline of a typical raised bog, the centre has been dissected and cut away so that it is now lower than the outer edges.

Pollen diagrams.

Two pollen diagrams have been constructed, one from boring 7, almost in the centre of the Moss, and the other from boring 16 at the extreme northern edge. In both cases, for comparative reasons, there are two versions, one based on percentages of total tree pollen, the other on percentages of total pollen. Figures 13 and 14 are the diagrams for boring 7 with details of herb pollen in tables 4 and 5, and figure 15 is the diagram for boring 16 with details in tables 6a and 6b. All the pollen diagrams have been zoned in the usual way.

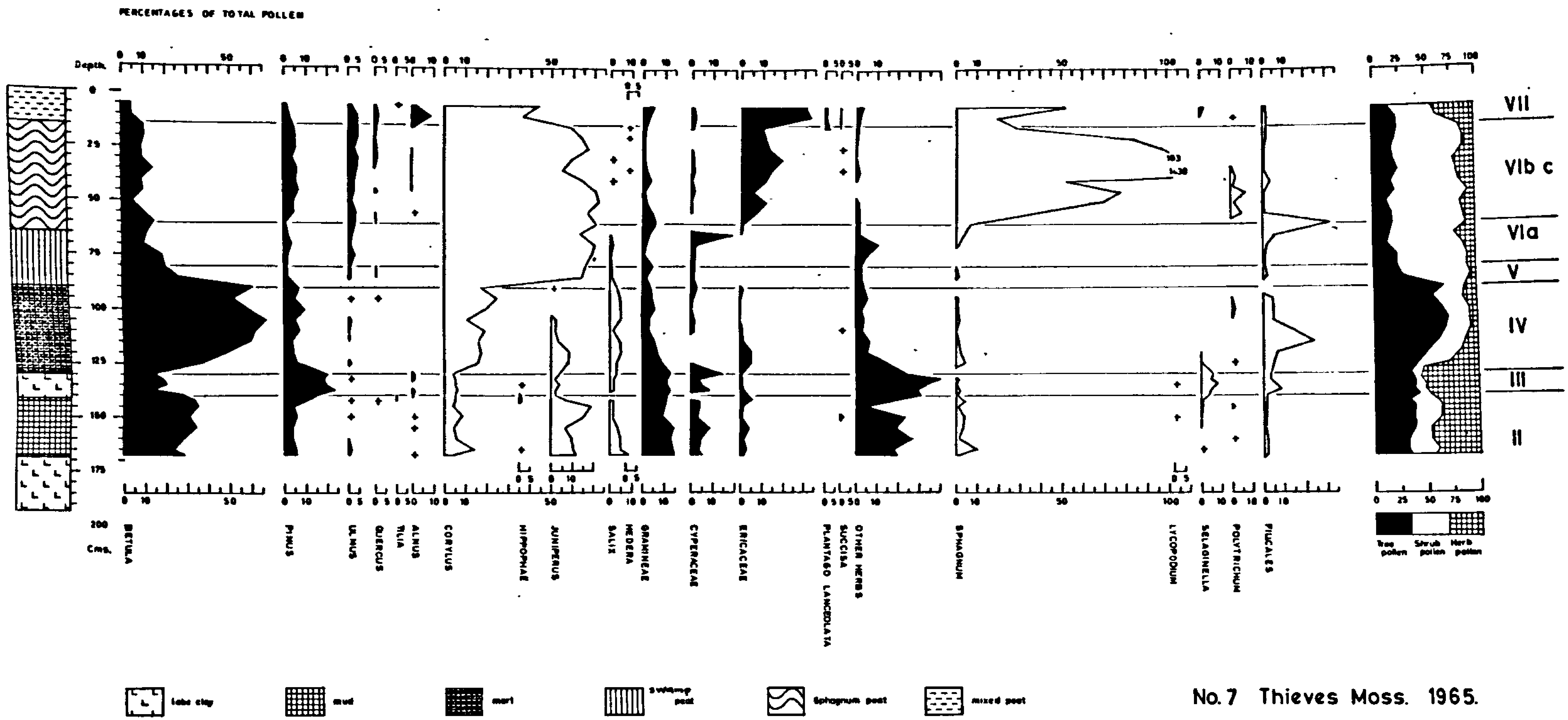
For No. 7 the sequence is from zones II to VII. Using figure 13 based on percentages of total tree pollen the outstanding features of the respective zones are as follows.

Late Glacial Period.

Zone I. (193 - 167 cms.)

Lake clay. No pollen is preserved.

Fig. 14.



No. 7 Thieves Moss. 1965.

Zone II. (167 - 143 cms.)

Betula is the most abundant tree pollen with small amounts, up to 10%, of Pinus. Corylus is present in some quantity, but this is regarded as the result of contamination in the Hiller borer. There is 40% of Juniperus pollen and up to 5% of Hippophaë, with Salix at a maximum at the beginning of the zone. The proportion of herb pollen to tree pollen (figure 14) is quite high and apart from Gramineae the herb pollen total is chiefly composed of those herbs characteristic of the Late-Glacial period, e.g. Artemisia, Thalictrum, Filipendula, Rumex type, and Helianthemum.

Zone III. (142 - 131 cms.)

In response to the onset of a colder climate, the ratio of herb pollen to tree pollen shows a marked increase. Pinus rises to 60% and predominates over Betula, but whether this is a genuine rise in pine, or merely over-representation, because of differential preservation in clay, is debatable. Values for Juniperus and Hippophaë decline but Selaginella reaches its peak.

Post-Glacial Period.

Zone IV. (130 - 91 cms.)

Betula rises to its maximum and once more exceeds Pinus. Juniperus, after an initial rise, declines and disappears. The ratio of herb pollen to tree pollen falls sharply, a reflection of the change from tundra vegetation of the Late-Glacial period to the woodland of the Pre-Boreal period.

Zone V. (90 - 81 cms.)

Betula pollen values remain high and Corylus rises spectacularly. Ulmus and Quercus appear continuously for the first time.

Zone VI.

Sub-zone VIa. (80 - 61 cms.)

In this sub-zone Betula values fall and Ulmus increases. Corylus reaches very high percentages. There is a rise in Cyperaceae presumably because of local reed-swamp, and in the pollen of aquatics. Maximum values are reached in spores of Filicales because of the high total for Cystopteris.

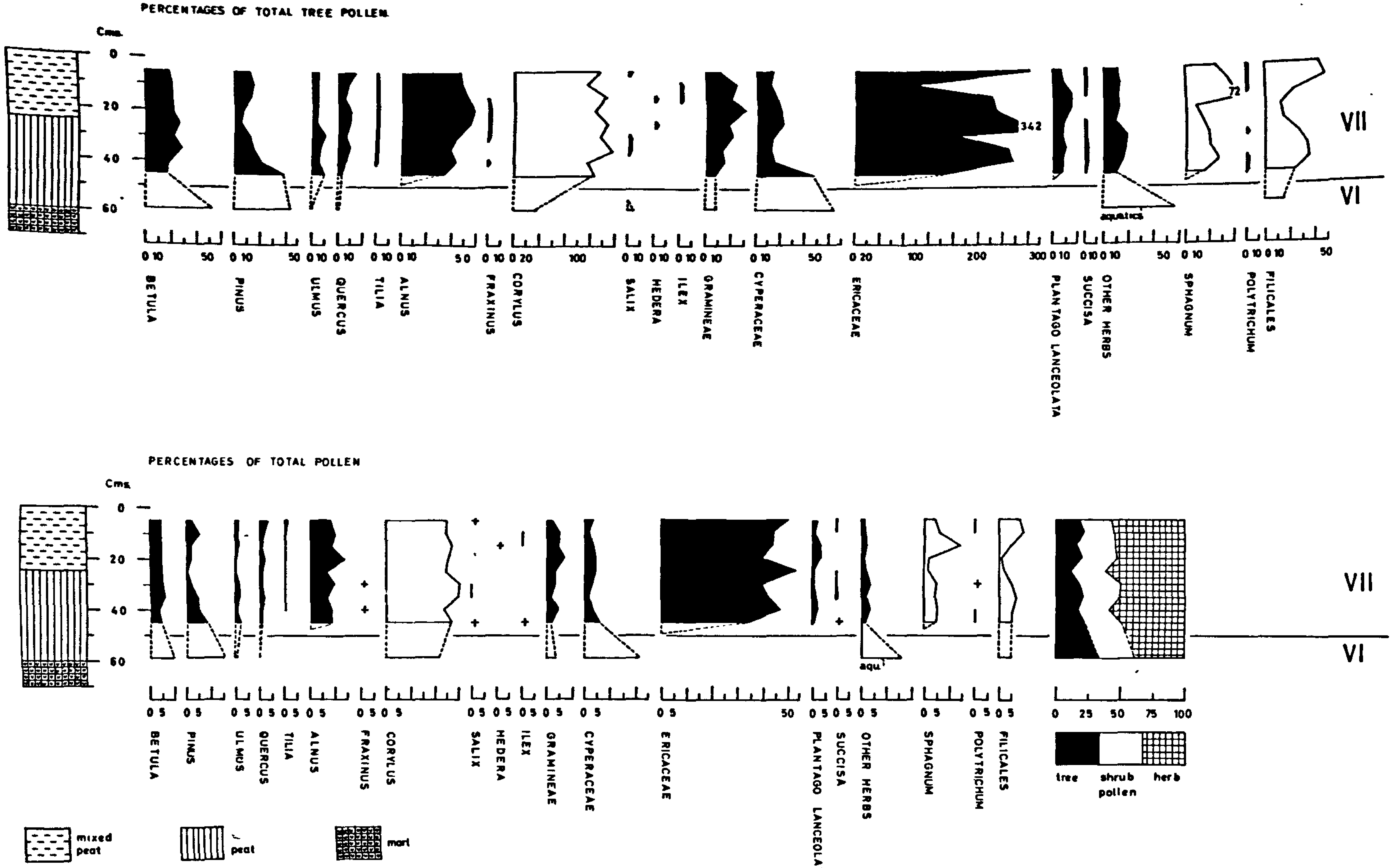
Sub-zone VI b-c. (60 - 16 cms.)

There is not sufficient evidence for separating these two sub-zones, so they will be considered together. The Betula curve continues to fall, but Betula is still the predominant tree pollen. Pinus values increase and also those of Ulmus and Quercus. Alnus appears consistently, though sparsely. Corylus oscillates but still maintains high values, and there is a great increase in ericaceous pollen, Polytrichum and Sphagnum spores, coincident with the development of Sphagnum bog.

Zone VII. (15 - 0 cms.)

The surface peat of Thieves Moss belongs to the early phase of zone VII. Alnus increases markedly, up to 41%. Betula and Pinus curves fall, but rise again, values for Ulmus fall slightly, and

Fig. 15.



No.16 Thieves Moss. 1965.

Quercus remains more or less constant. The *Gramineae* curve rises and, after an initial fall, so do those for *Ericaceae* and *Sphagnum*. *Plantago lanceolata* reaches 14% and values of other herbs increase, including *Succisa*, *Rosaceae*, *Potentilla* type and *Ranunculus*.

The pollen diagrams for boring 16 are much shorter (figure 15). Sufficient pollen to count was not found between 46 and 57 cms. but a count was obtained at 58 cms., and its value joined to those at 45 cms. by a dotted line. It is clear from the high percentages of *Betula* and *Pinus* that the lower part of the peat must be earlier than zone VII. The values of *Betula* and *Pinus* suggest zone VI, if compared with the pollen diagrams of boring 7. The presence of comparatively high values of *Cyperaceae* and aquatics also supports this. The small amounts of pollen of *Ericaceae* and *Sphagnum* suggest sub-zone VIa of the pollen diagram for Thieves Moss, boring 7. The upper part of the diagram has many of the characteristics of zone VII, with values of *Alnus*, as high as 60%, the presence of *Ulmus* and *Quercus*, the consistent appearance of *Tilia*, as well as *Plantago lanceolata* and *Succisa*.

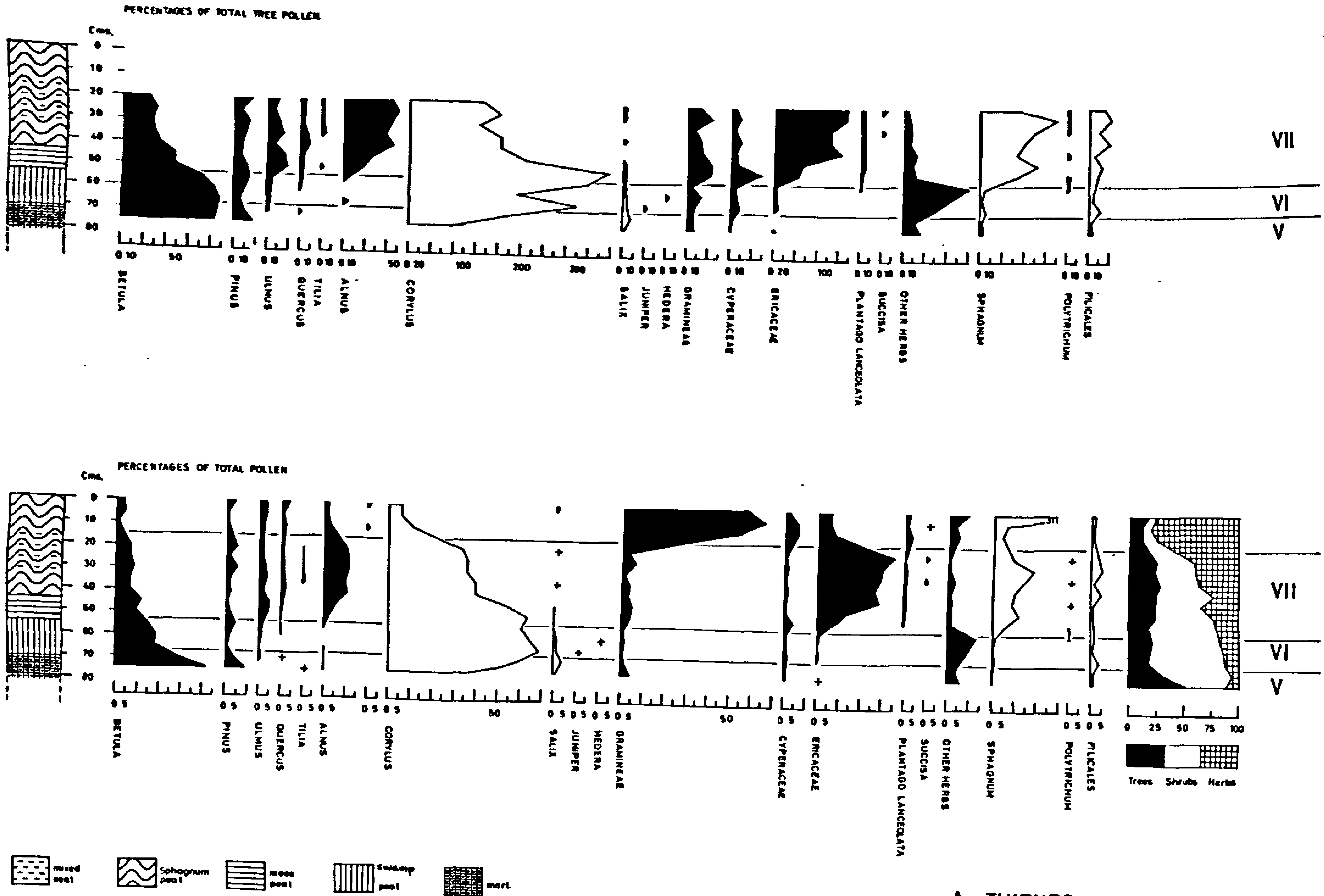
Discussion.

From the stratigraphy and pollen data a more complete vegetational history of Thieves Moss can be formulated. No organic material has been obtained which could be attributed to zone I, the beginning of the Late-Glacial period. Grey lake clay, almost devoid of organic material, was deposited in the depression as a result of the erosion of open soils.

Climatic conditions were severe, and considerable solifluxion occurred so that it seems likely that any vegetation which may have grown in the area would be sparse. During the milder Allerød period, pollen is preserved and its composition suggests an open vegetation with such herbs as Thalictrum, Artemisia, Helianthemum and Rumex, with some trees of Betula, possibly Pinus, and shrubs of Hippophaë, Salix and Juniperus growing round the lake. At the same time an aquatic vegetation of Potamogeton, Myriophyllum alterniflorum, M. spicatum, and Nymphaea was growing in the lake. Deterioration of the climate at the end of the Allerød period caused a corresponding change in the vegetation. Once more grey clay was deposited, but unlike the zone I clay, some pollen was preserved, though little else of an organic nature. The pollen shows an increase of herbs at the expense of shrubs, and the ascendancy of Pinus over Betula, though the implications of this are doubtful as has been explained previously. After the Late-Glacial period at the start of zone IV the climate again improved and marl was deposited in the lake, thus indicating calcium rich water with a flora and fauna now represented by many Chara oospores, pollen of Nymphaea and Potomogeton, and shell fragments. Around the lake woodland developed, mostly of Betula with Salix and Juniperus, the latter showing an expansion before the final increase of birch to form birch forest. N A P (non-arboreal pollen) was very much reduced, as a consequence of the spread of woodland conditions. With the drier climate of the Boreal period a reed swamp became established with Carex, Typha and Menyanthes, and open water in which Nymphaea and

Potamogeton were growing. As it became shallower because of drying out, hypnoid moss occupied the central area. It is apparent that the water table must have been considerably higher than it is now because of the deposition of lake clay at the southern end up to within only 70 cms. of the highest point of the present Moss surface, and also because of the presence of material of aquatic plants, and reed swamp (pollen of *Nymphaea*, *Potamogeton*, *Myriophyllum*, *Typha*, fruit of *Carex* and seed of *Menyanthes*), in the basal peat of boring 16, again only 60 cms. below the surface. This high water table suggests that up to this time a barrier existed to the south which kept the lake dammed up. The limestone pavement now to the south, as mentioned previously, is considerably higher than the present bog. If this was drift-covered or the limestone had no lines of weakness so that it was relatively impervious this could have ensured the persistence of a lake in such a position. If however the limestone was exposed and subjected to weathering, it could have become pervious allowing the dammed-up water to drain away in the direction of Crummack Dale with a subsequent drop in the water table. This could be an alternative to the climatic drying out, as previously mentioned, or the two processes could have worked in conjunction, the climatic drying exposing the margins to erosion. If, for whatever reason, the water-level fell, then the influence of calcareous drainage water on the surface of the peat would decrease and allow the development of a *Sphagnum* bog. From the pollen diagram of boring 7 (figure 13) it seems feasible that this drop in water level took place towards the end of sub-zone VIa because the pollen of aquatics drops suddenly and the later peak of <u>Cyperaceae</u>, (which could suggest a change from open water to denser reed swamp), also declines at the end of the sub-zone. This consequent drying out of the edges of the lake may also account for the poor preservation of pollen in the basal layers of boring 16. The <u>Sphagnum</u> bog continued to grow until the end of the Boreal period. Around the lake thermophilous trees such as <u>Ulmus</u> and <u>Quercus</u> had started to grow, and <u>Alnus</u>, though not in any quantity. <u>Corylus</u> was very abundant throughout the whole period. With the onset of the wetter Atlantic time <u>Alnus</u> increased considerably, possibly growing on drift on the limestone, and <u>Sphagnum</u>, which had only become established in any quantity in the central area, became mixed with monocotyledonous plants and hypnoid moss. The pollen data from the edge, boring 16, suggests that peat formation continued well into zone VII through this is not evident from the central boring. There is no marked recurrence surface on the VI/VII boundary but a slight change from a lighter to a darker peat, and an increase in humification. The shape of the profile suggests that Thieves Moss was once a raised bog which has been arrested in development and reduced by erosion to its present shape. There seems to be little peat of recent origin and the general appearance of the Moss does not give the impression that active peat formation is proceeding

Fig. 16.

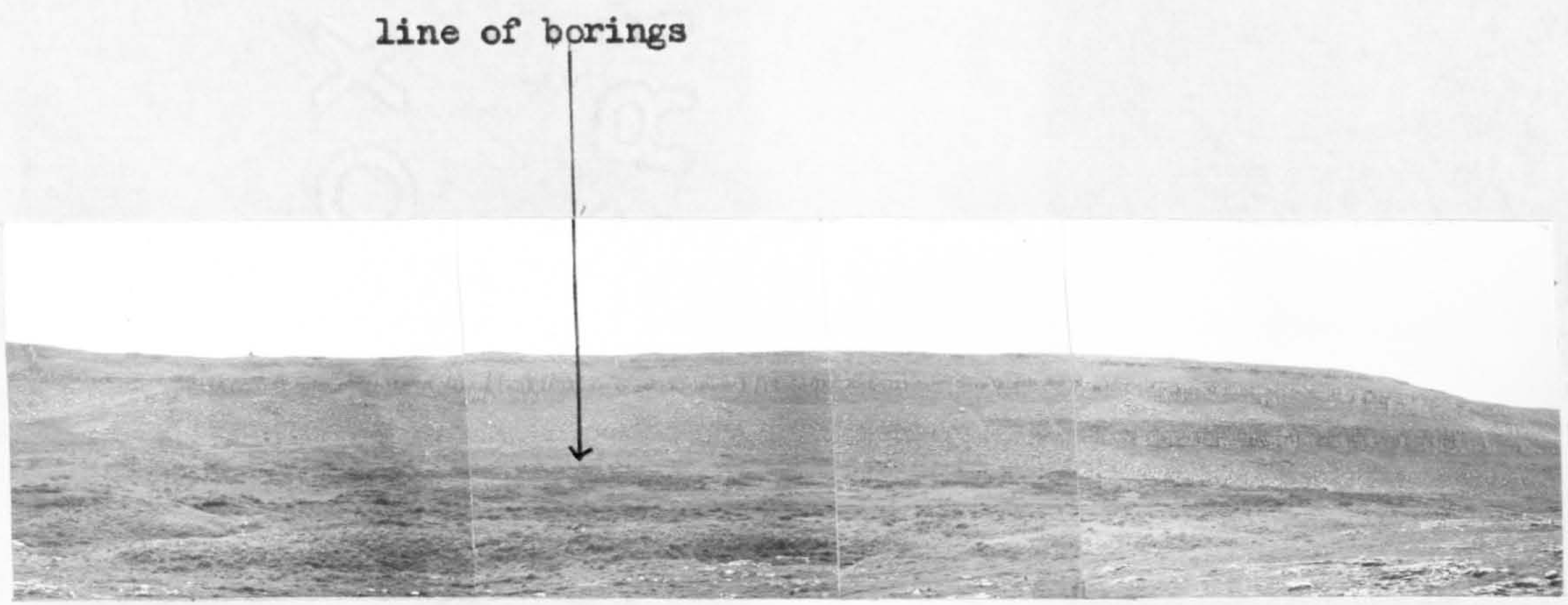


A. THIEVES MOSS 1965.

now.

A third boring for pollen analysis was at A the top of which is low on the bog surface. The pollen diagram is illustrated in figure 16, and shows that the *Sphagnum* peat is not of exactly the same age as that in 7 since its formation does not begin until zone VIIa. Zone VI of this diagram shows very low percentages of *Ulmus*, *Ericaceae* and *Sphagnum* which suggest that it is sub-zone VIa and that the moss layer began to form in zone VIIa followed quickly by *Sphagnum*. The uppermost layer of *Sphagnum* (0 - 20 cms.) at A is much less humified than that below it, and there is also a change in pollen content indicating a spread of herbaceous vegetation at the expense of shrubs and trees. It seems that there has been erosion, possibly caused by the stream already mentioned, with a later colonisation of the eroded surface. It follows then, that the upper limit of *Sphagnum* in the section is not synchronous. The extent of erosion of the bog surface could be elucidated by further pollen analysis at different points, but it was felt that this was not relevant to the present study.

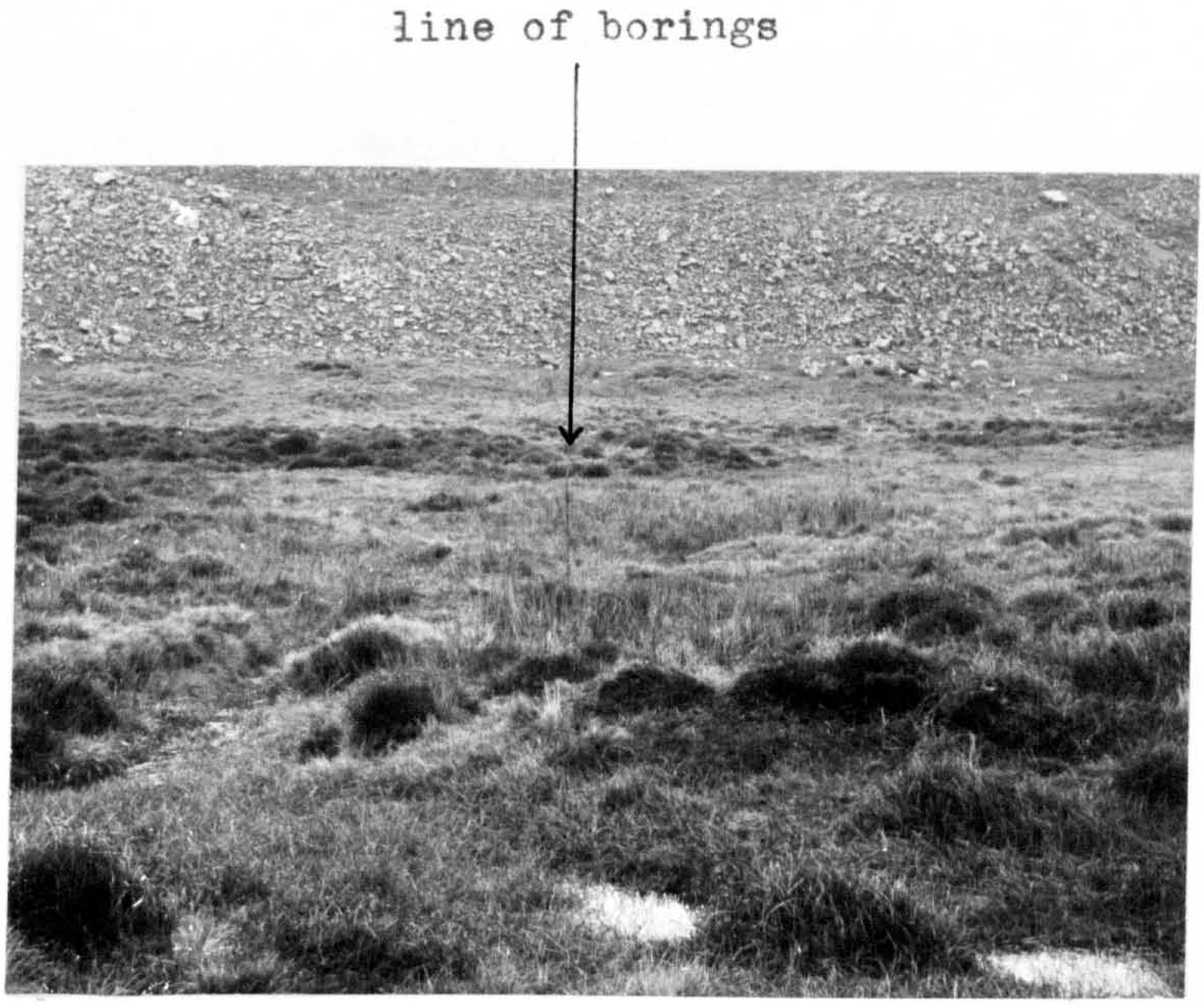
It is possible that the upper layers of the diagrams are extremely contracted. In that of No. 16 (figure 15) a line could be drawn at 24 cms. where elm declines, and this might be interpreted as sub-zone VIIb. There is also an indication in No. 7 (figure 13) of an increase in grasses, *Plantago* and other herbs which may be part of the same phenomenon as the top of A. However it is obvious that these upper layers are not easily elucidated on present evidence. It is possible that the very good drainage through the limestone at the edge of the Moss, results in unusually good drainage from the surface of the peat, so that it is very liable to drying and erosion, and the development of any depth of *Sphagnum* peat is precluded.



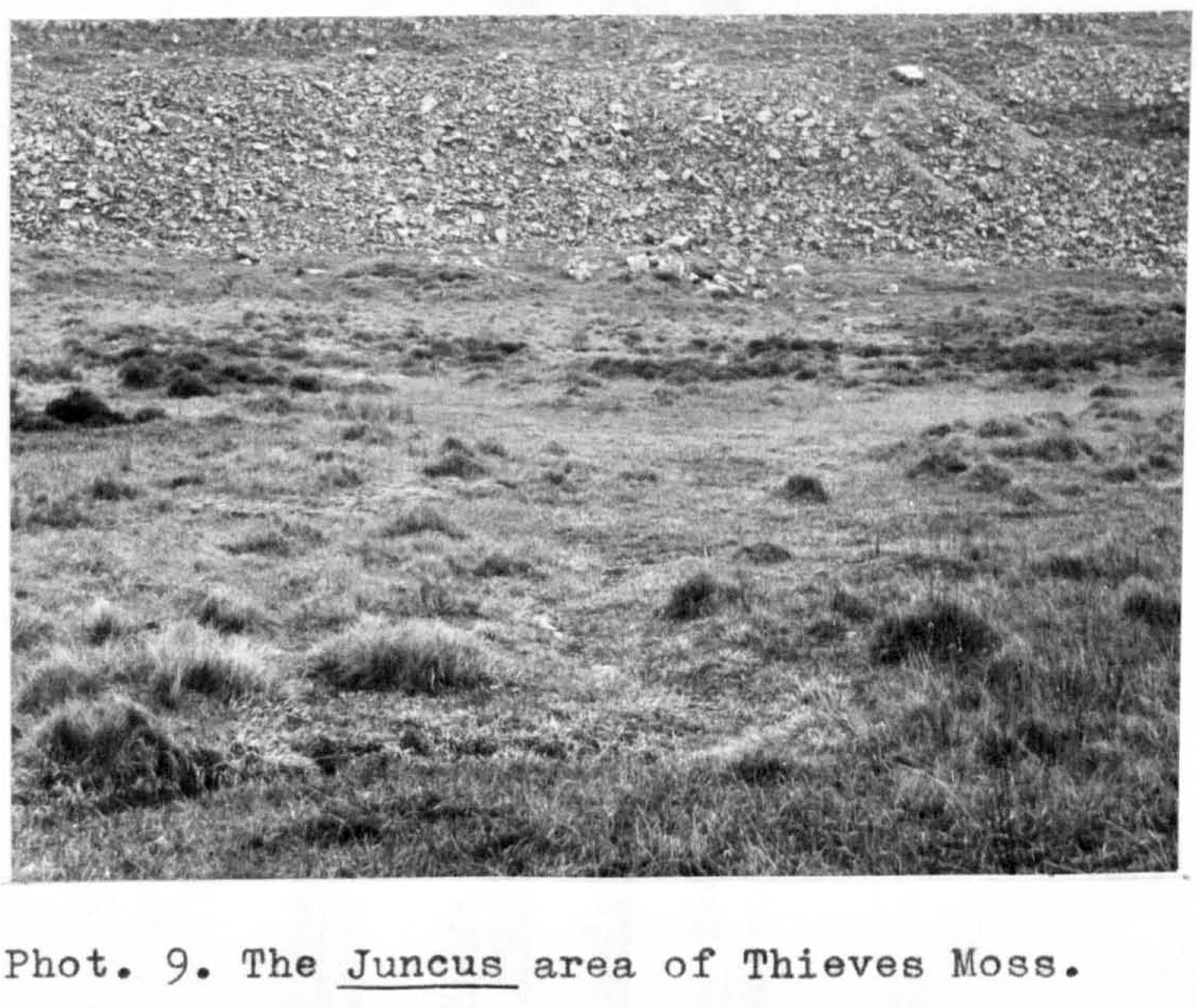
Phot. 5. Thieves Moss from the south.

Phot. 6. Thieves Moss from the east.

Phot. 7. Thieves Moss: the eroded stream margin.



Phot. 8. Thieves Moss: tussocks and pools.



Phot. 9. The Juncus area of Thieves Moss.

HELWITH MOSS.	TARN MOSS.	THIEVES MOSS.
Position. In valley of R. Ribble at 800 ft.	S.W. margin of Craven Pennine upland at 1,230 ft.	Head of Crummack Dale at 1,150 ft.
Geology. On Silurian Horton Flags with Great Scar limestone adjacent but higher.	On Silurian slates with Great Scar Limestone adjacent.	On Great Scar Limestone.
General Appearance. Convex raised bog.	Convex raised bog.	Concave eroded bog. (formerly raised?)
Stratigraphy. *Sphagnum imbricatum* peat.	*Eriophorum-Sphagnum* peat.	Mixed peat (monocotyledons, *Sphagnum* hypnoid moss).
Eriophorum-Sphagnum peat.	*Sphagnum imbricatum* peat.	*Sphagnum plumulosum* peat. hypnoid moss peat.
Phragmites peat. Hypnoid moss peat.	fen peat with *Phragmites* + wood.	Swamp peat with *Carex*.
	calcareous marl.	calcareous marl.
sand. lake clay.	lake clay.	lake clay. mud. lake clay.
	sand.	

Pollen Analysis.

Zone II.	(silt and clay). Pinus exceeds Betula. Salix, Juniperus, Hippophaë. Many herbs, e.g. Gramineae, Artemisia, Thalictrum. Open herbaceous vegetation.	(mud). Betula exceeds Pinus. Salix, Juniperus high, Hippophaë. Many herbs, e.g. Gramineae, Artemisia Thalictrum. Open herbaceous vegetation.
Zone III.	(laminated silt and clay). Betula exceeds Pinus. Salix and Juniperus rise, Hippophaë. Herbs increase.	(clay). Pinus exceeds Betula. Salix, Juniperus falls, Hippophaë. Herbs and Selaginella increase.
Zone IV.	(marl). Betula exceeds Pinus. Corylus; Salix and Juniperus fall, Hippophaë. Herbs decrease, ferns increase. NAP/AP falls.	(marl). Betula exceeds Pinus. Corylus, Salix; Juniperus falls. Herbs decrease, ferns increase. NAP/AP falls.
Zone V. (hypnoid moss peat). Betula equals Pinus; Ulmus, Quercus. Corylus rises, Salix. Gramineae and Cyperaceae high. Fern values high.	(marl). Betula exceeds Pinus; Ulmus. Corylus rises, Salix and Juniperus fall further. Herb values low.	(swamp peat). Betula exceeds Pinus; Ulmus, Quercus. Corylus rises, Salix falls. Herb values low.

Zone VI. Sub-zone VIa. (Phragmites peat). Pinus exceeds Betula; Ulmus rises, Quercus, Alnus. Corylus high, Salix. Gramineae, Cyeraceae high, Ericaceae. Ferns high, Polytrichum.	(marl, then fen peat + wood). Pinus exceeds Betula; Ulmus rises, Quercus, Alnus. Corylus high, Salix. Cyperaceae high, Ericaceae. Ferns rise.	(swamp peat then Sphagnum plumulosum). Betula exceeds Pinus; Ulmus rises; Corylus high, Salix. Gramineae rise, Cyperaceae and aquatics high. Ferns rise.
Sub-zone VI b-c. (Phragmites peat, then Eriophorum-Sphagnum peat). Betula rises, Pinus high, Ulmus; Quercus rises, Alnus. Corylus falls then rises, Salix falls. Gramineae fall, Cyperaceae fall, Ericaceae rise. Ferns fall, Polytrichum high.	(fen peat then humified Sphagnum peat). Betula rises, Pinus high, Ulmus falls, Quercus rises, Alnus. Corylus rises, Salix very low. Gramineae rise; Cyperaceae fall, Ericaceae rise. Ferns fall.	(Sphagnum plumulosum peat). Betula high but falling, Pinus rises, Ulmus falls then rises, Quercus, Alnus. Corylus high, Salix low, Hedera. Gramineae fall, Cyperaceae fall, Ericaceae rise. Ferns fall, Polytrichum high.
Zone VII. Sub-zone VIIa. (Eriophorum-Sphagnum peat). Betula falls, Pinus falls, Ulmus rises, Quercus falls, Tilia; Alnus rises, Fraxinus. Corylus falls then rises, Salix low, Ilex. Gramineae low, Cyperaceae rise then fall, Ericaceae fall then rise, Plantago lanceolata and Succisa low, herbs rise. Polytrichum falls.	(Sphagnum imbricatum peat). Betula falls, Pinus low, Ulmus falls, Quercus rises then falls, Tilia; Alnus rises, Fraxinus. Corylus falls then rises, Salix very low. Gramineae and Cyperaceae rise then fall, Ericaceae fall then rise, Plantago lanceolata.	(mixed peat). Betula falls then rises, Pinus falls then rises, Ulmus falls, Quercus rises, Alnus rises. Corylus falls then rises, Salix very low. Gramineae rise, Ericaceae fall then rise, Plantago lanceolata, Succisa, Herbs rise. Polytrichum falls. NAP/AP rises.

Sub-zone VIIb.	
(Eriophorum-Sphagnum peat then Sphagnum imbricatum peat).	(Sphagnum imbricatum peat then Eriophorum-Sphagnum peat).
Betula low, Pinus low, Ulmus falls, Quercus rises, Tilia; Alnus high, Fraxinus.	Betula low, Pinus low, Ulmus rises and falls very low, Quercus rises, Tilia; Alnus high, Fraxinus, Fagus.
Corylus falls then rises, Salix, Ilex.	Corylus falls then rises, Salix, Ilex.
Cyperaceae rise then fall, Ericaceae fall, Plantago lanceolata very low.	Gramineae and Cyperaceae rise then fall, Ericaceae fall then rise, Plantago lanceolata.
Polytrichum rises.	
Zone VIII.	
(Sphagnum-imbricatum peat).	(Eriophorum-Sphagnum peat).
Betula rises, Pinus low, Ulmus falls, Quercus, Tilia; Alnus high, Fraxinus.	Betula rises, Pinus low, Ulmus rises then falls, Quercus rises, Tilia: Alnus high, Fraxinus rises then falls, Fagus Carpinus.
Corylus falls then rises, Gramineae, Cyperaceae and Ericaceae, Plantago lanceolata, Succisa and other herbs all rise.	Corylus falls then rises, Salix, Ilex, Gramineae, Cyperaceae, Ericaceae, Plantago lanceolata, and other herbs all rise.
Ferns rise.	Ferns rise.
NAP/AP rises.	NAP/AP rises.

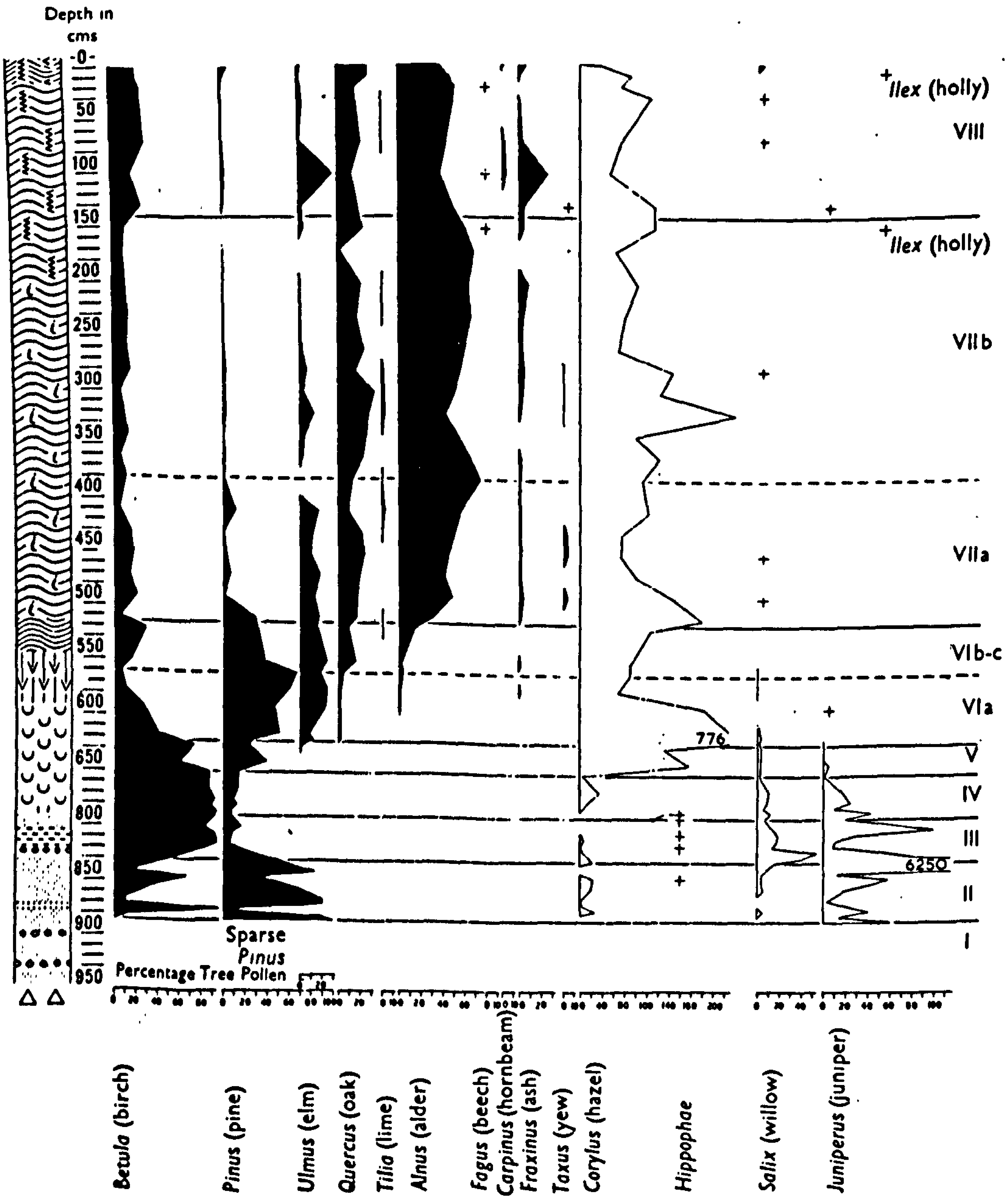


FIG. 2

Pollen diagram for Tarn Moss, Malham. The diagram is composite: the upper part is from a boring near position F on the long north to south transect and the basal part is from a deeper boring nearby. Stratigraphy symbols as in Figure 4.

Fig. 17. (From Pigott, 1959.)

Comparison of Helwith Moss and Thieves Moss with Tarn Moss, Malham.

It is interesting to compare Helwith Moss and Thieves Moss with Tarn Moss (Pigott and Pigott, 1958, 1963), which is situated in the Ingleborough area on the Craven Pennine upland. In order to make comparison easier a table has been compiled (pages 38 - 41) which sets out the data for ~~each site~~ Tarn Moss and the two sites under investigation regarding ~~its~~ position, appearance, stratigraphy and pollen content. In the section concerning the pollen diagrams the chief constituents of tree, shrub, and herb components are underlined twice. Where a species is listed without comment it indicates its presence either in small quantities or in the same amount as in the previous reference. Amongst herb pollen, and spores only the more significant have been mentioned by name. The pollen diagram of the trees and shrubs of Tarn Moss (figure 17) has also been included to facilitate comparison.

When these three sites are considered several differences become apparent as well as some remarkable similarities. No pollen has been preserved at Helwith Moss before Zone V whereas at both Tarn Moss and Thieves Moss it is present from Zone II onwards. This lack of early pollen may have been caused by the position of Helwith Moss in the Ribble Valley at the foot of Moughton Fell. The basal clay layers are mixed with coarse sand and have a high content of mineral material which could have been washed down into the lake from the neighbouring slope composed largely of Silurian rock. Because of the greater aeration of sand compared with fine clay, oxidation would prevent the preservation of any pollen. By contrast neither of the other two bogs has sandy material above the clay and preservation of pollen has taken place. Both Tarn Moss and Thieves Moss had calcareous marl deposited in Zone IV when the Post-Glacial period began. This together with high numbers of Chara oospores suggests that the sites were subject to calcareous drainage water and Pearsall (1940) has found that this is true of the area adjacent to Thieves Moss now, as also at Tarn Fen. On the other hand Helwith Moss has no calcareous marl, few oospores of Chara and shows little evidence of calcareous drainage water except round the edges. This is not surprising as it lies upon Silurian rocks forming the base of Moughton which is only capped by a layer of limestone some considerable height above the Moss. Helwith Moss and Tarn Moss have followed the same general development from lake deposits through swamp and fen peat with Phragmites to raised bog. In both the initiation of bog took place towards the end of Zone VI and the greater part of bog formation has occurred since the Boreal-Atlantic transition though the detailed stratigraphy is different. At Tarn Moss the change from highly humified Sphagnum peat to less humified Sphagnum peat took place at the Boreal Atlantic transition, and later in sub-zone VIIb changed again to Eriophorum-Sphagnum peat. At Helwith Moss the first change was from highly humified Eriophorum-Sphagnum peat to less humified Sphagnum peat at a later date, at the beginning of the VII/VIII transition zone and the Sphagnum peat has continued to form almost to the present surface. In both cases the species of Sphagnum forming the vast bulk of the peat is *Sphagnum imbricatum*. It is likely that the change to *Eriophorum-Sphagnum* peat at Malham was induced by drainage caused by human interference, or by drying during Sub-Boreal times. Such *Eriophorum* peat is characteristic of the standstill phase of raised bogs. At Helwith Moss however if the transition zone is incorporated in Zone VIII when the cooler and wetter Sub-Atlantic period began it is quite feasible that the growth of *Sphagnum imbricatum* would be stimulated. A similar change is seen at Heslington Moss, Westmorland, (Smith, 1959), where sub-zones VIIIa and VIIIb compare with the transition zone and zone VIII respectively at Helwith Moss. In its lower layers, Thieves Moss also shows a similar development, though its swamp peat has little evidence of *Phragmites* and is largely formed of *Carices*. The later changes though are rather different. As discussed previously it appears to have become drained in sub-zone VIa resulting in a change from swamp to bog at that time, which is earlier than in either of the other two sites. This suggests that it was caused by local conditions rather than a major climatic change. Here the main peat-forming *Sphagnum* is *S. plumulosum* which does not require such wet conditions as *Sphagnum imbricatum* and growth has not been so active. The mixed peat which has formed on the surface also suggests a decline in active peat formation and this may be a result of further increased drainage. There is little evidence of recent peat formation of zone VIII. This could of course mean that it has been formed and subsequently eroded but the change from *Sphagnum* to mixed peat suggests rather that it has entered a standstill phase. There was no evidence in stratigraphy of identifiable *Eriophorum* remains but it is growing on the bog surface now.

The pollen diagrams of Helwith Moss and Tarn Moss are very similar. Both show a pine maximum in zone VI as was also found at Linton Mires (Raistrick and Blackburn, 1938), with pine exceeding birch in pollen values. This was not so at Thieves Moss where birch persisted in quantity for a much longer period. In this respect the pollen diagram for Thieves Moss is more like that of Skelsmergh Tarn, Westmorland (Walker, N. 1955) though the rise in pine pollen in sub-zone VIb is more marked. There is also a similarity between pollen diagrams for these two sites in the high values of *Selaginella* in zone III. These two factors together may suggest that conditions were harder for plant life at Thieves Moss than at Helwith Moss or Tarn Moss. *Plantago lanceolata* is present at both Tarn Moss and Thieves Moss in sub-zone VIIa though these are not necessarily comparable because it can be seen from the pollen diagrams and the table that the uppermost peat of Thieves Moss has some features of the uppermost peat of the other two Mosses suggesting that later pollen has become incorporated.

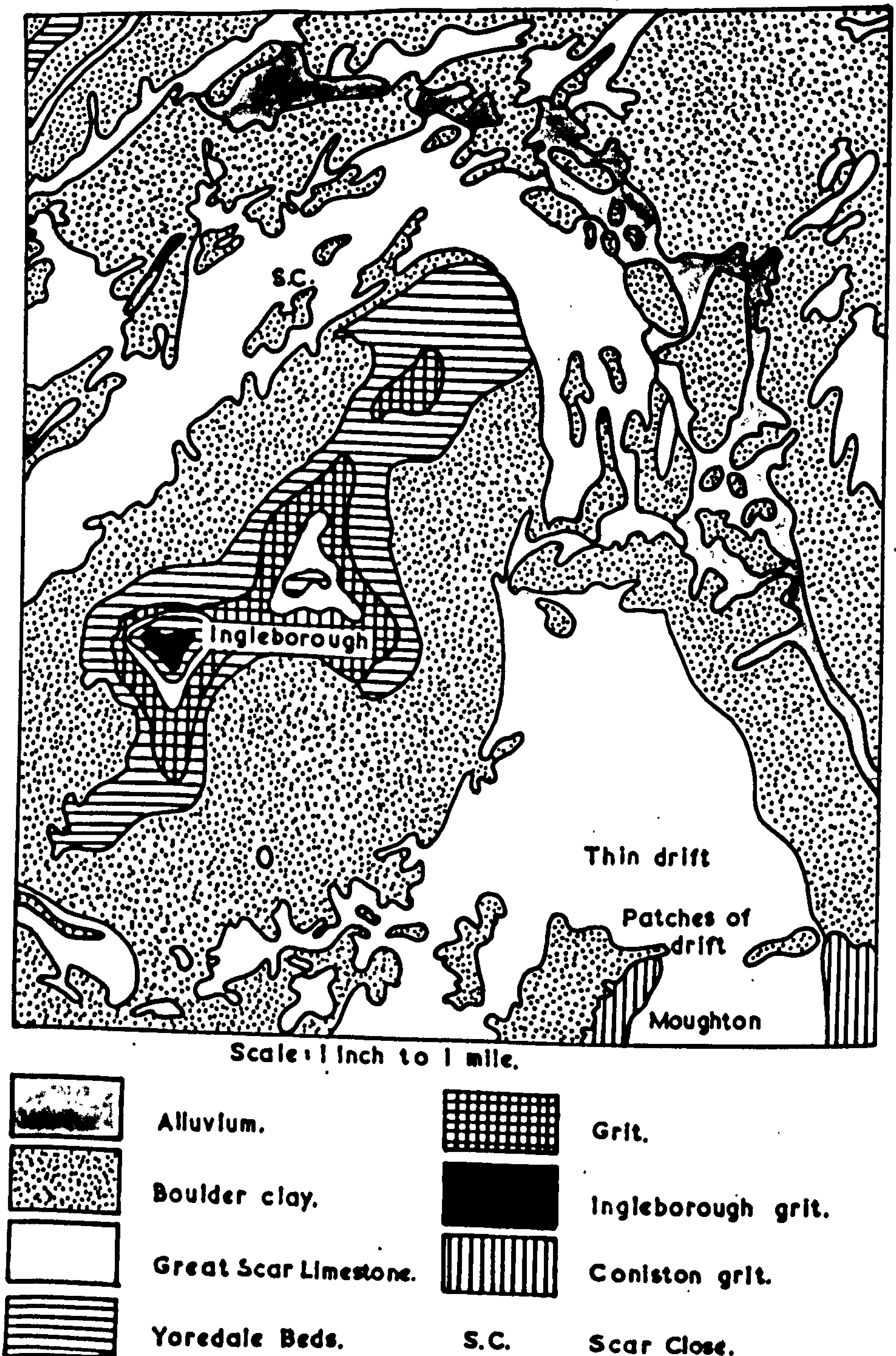


Fig. 18. The geology of the Ingleborough area.

Scar Close.

Location.

Scar Close is situated at the foot of the north-west side of Park Fell, near the steep northern face of Ingleborough (figure 1 and photograph 10), at about 1,000 ft.

Geology.

The geology of Ingleborough and its surroundings is shown in figure 18 which illustrates the surface features, and in figure 2, a section through the Ingleborough mass. From these it can be seen that Scar Close is situated on a shelf of Great Scar Limestone weathered to form pavement and overlain in parts with glacial drift. Immediately above the shelf, the hill is composed of rocks of the "Yoredale Series" also overlain to some extent by drift, and the boundary between these rocks and the limestone is marked by a row of swallow holes. (photograph 11).

General Appearance.

An impression of the whole area can be obtained from figure 19, which is drawn from an aerial photograph, and from photograph 12, taken from the summit of Ingleborough. High on the slopes of the hills the surface is covered with continuous peat. This thins out on the lower slopes and in parts entirely disappears, the soil beneath the vegetation being a coarse clay with boulders as seen in the exposed

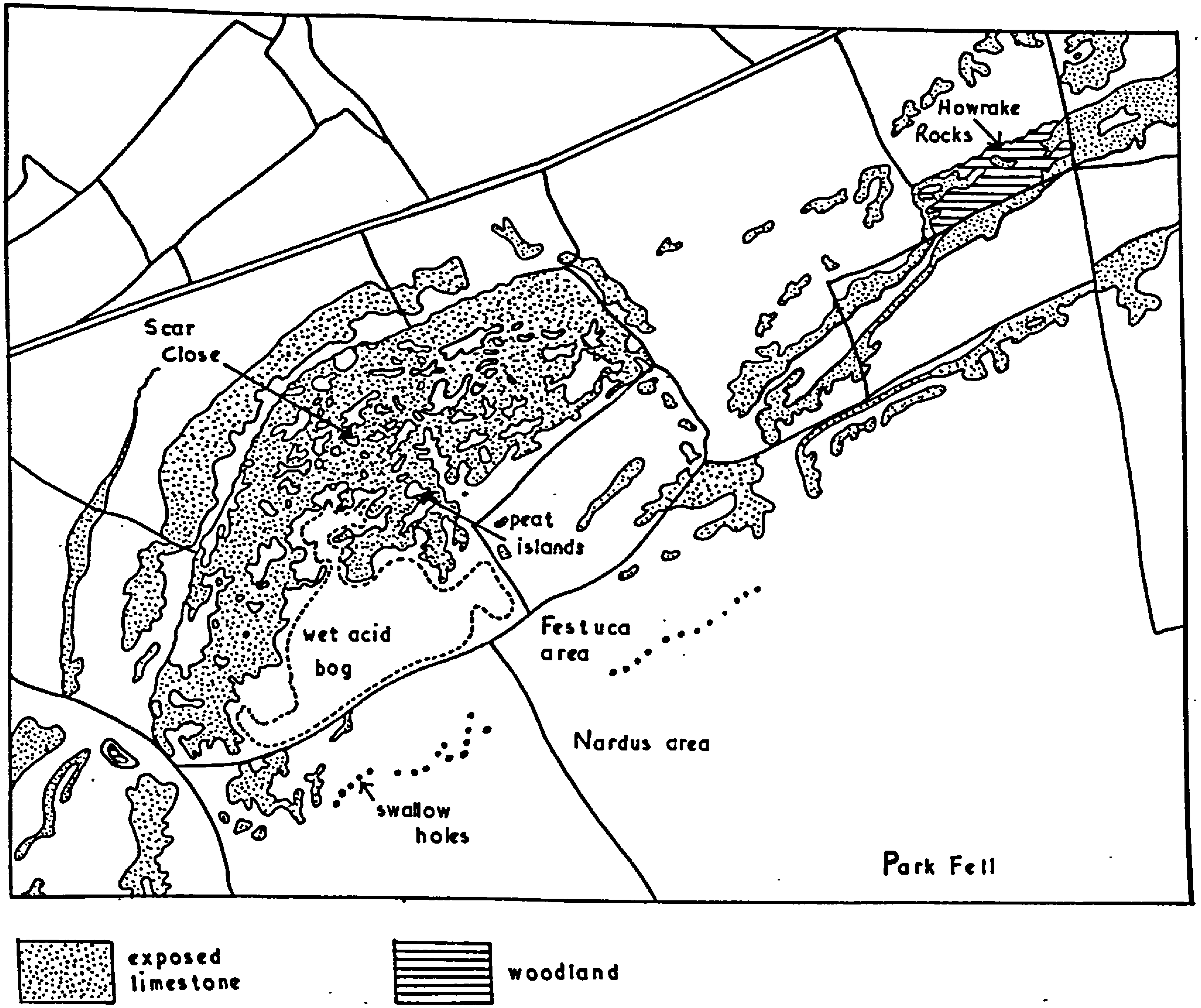


Fig. 19. Scar Close and Howrake Rocks, based on aerial photograph.

face in photograph 13. Between these lower slopes and the exposed pavement, the peat is thicker and wetter, and where the underlying surface is uneven or where erosion has taken place, peat slips have occurred. The peat cover becomes progressively thinner and more broken nearer to the pavement, and on the pavement itself a considerable amount of the limestone is fully exposed. Photograph 14 is a general view of Scar Close taken from the swallow holes, looking down over the pavement area. More detail is shown in photograph 15, where small islands of peat lie over the top of weathered limestone. There are occasional drainage channels (photograph 16) which are at a lower level and have a clay soil. They are very different in appearance and vegetation from the rest of the limestone.

Vegetation.

The vegetation shows considerable variation depending on the underlying material and its position in relation to slope and drainage.

On the "Yoredale series" above the swallow holes the vegetation as a whole is relatively poor in species and is dominated by Nardus stricta and species of Juncus such as J. squarrosus, and J. effusus. Examples of other species present are:

Festuca ovina	Plagiothecium undulatum
Galium saxatile	Pleurozium schreberi
	Polytrichum commune

Below the swallow holes a definite change occurs; Nardus stricta decreases and Festuca ovina becomes dominant. Growing with these are:

Eriophorum vaginatum	Campylopus flexuosus
Juncus conglomeratus	Hypnum cupressiforme
Juncus effusus	Plagiothecium undulatum
Juncus squarrosus	Polytrichum commune
Vaccinium myrtillus	Sphagnum spp.

Between the region dominated by Festuca ovina and the exposed pavement is an area of wet, acid bog. The surface is very uneven, the hummocks covered with Calluna vulgaris, Eriophorum angustifolium, Eriophorum vaginatum, Vaccinium myrtillus and some Sphagnum, and the hollows filled with standing water in which Sphagnum cuspidatum is growing luxuriantly. Other species present are:

Deschampsia flexuosa	Plagiothecium undulatum
Erica tetralix	Polytrichum commune
Juncus effusus	
Potentilla erecta	

This area can be seen beyond the limestone outcrop in photograph 17.

On the pavement there are four distinct plant habitats, the peat islands, the surface of the clints, pockets of soil in crevices and grykes, and the drainage channels.

The peat on the pavement is drier than in the area above, and has growing on it a mixture of calcicoles and calcifuges such as:

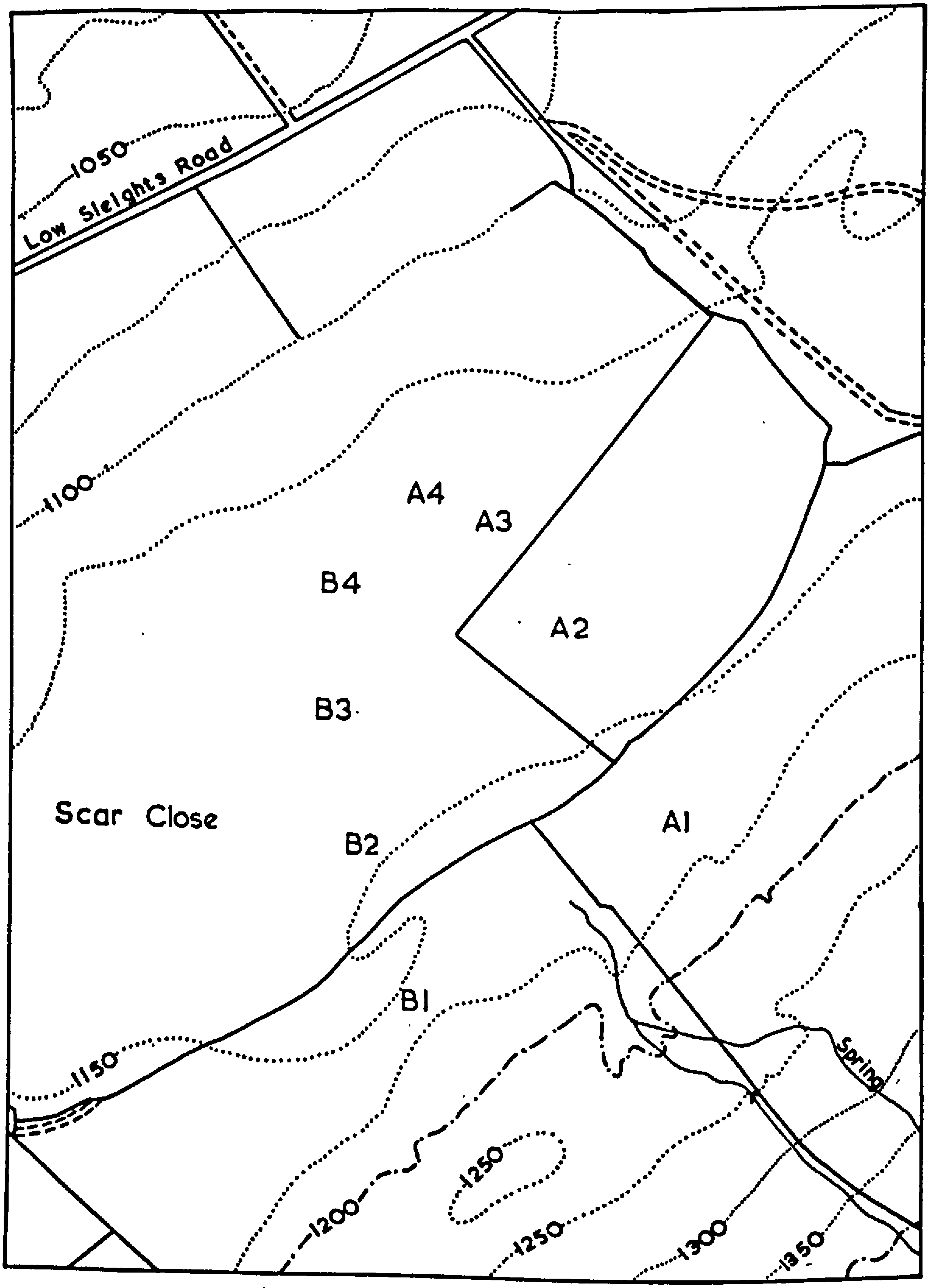
Calluna vulgaris	Vaccinium myrtillus
Cirsium heterophyllum	
Convallaria majalis	Dryopteris filix-mas
Geranium sanguineum	Phyllitis scolopendrium
Potentilla erecta	Polypodium vulgare

Each peat island has a fringe of mosses including species such as Rhytidiadelphus squarrosus, Pleurozium schreberi, Cratoneuron commutatum.

On the surface of the clints, apart from the peat islands, are small patches of mosses such as Tortella tortuosa, and a cover of crustaceous lichens.

In the crevices and grykes a number of plants have become established including trees such as Acer pseudo-platanus, Fraxinus excelsior, Sorbus aucuparia and Betula, with occasional bushes of Corylus avellana. The trees range in size from 1 metre to about 4 metres in height. Many species of fern grow prolifically in the grykes and some plants such as Mercurialis perennis which are more typical of woodland. Some of the species growing in the grykes are:

Actaea spicata	Sieglingia decumbens
Carex panicea	Trollius europaeus
Geranium lucidum	
Geranium robertianum	Asplenium ruta-muraria
Geranium sanguineum	Asplenium trichomanes
Lathyrus montana	Asplenium viride



Scale: 9 inches to 1 Mile.

A1 Position of samples

-·-·- ··1100····· Contours in feet

Fig. 20.

Potentilla crantzii   Phyllitis scolopendrium

Primula vulgaris

On the clay soil of the drainage channels, the vegetation cover is continuous and Pteridium aquilinum is prominent. Some of the limestone has not been weathered substantially and has remained as a smooth surface devoid of soil and vegetation.

Stratigraphy.

In order to elucidate the present distribution of peat, 8 monoliths were extracted in two lines as shown in figure 20, starting just above the wet peaty area and finishing in the peat on the pavement. From the results of macroanalysis profiles were constructed and are illustrated in figures 21 and 22. In each case the parent rock below the monolith was reached and it is shown as a horizontal line at the base of each profile. In the A series all the peat is underlain by coarse clay, the lower layers of which are heavily iron-stained. This can be seen clearly in the soil profile, photograph 18. A number of pH readings were made of the various sites investigated and the results are summarised below:

The pH of sites in the Scar Close Area.

Peat island

Peat on clint	Depth in cms.	pH.
	1	4.2
	10	4.4
(touching clint)	16	6.6
Peat above gryke		
	1	3.9
	16	5.9

Soil profile of peat overlying clay drift.

	Depth in cms.	pH.
dark fibrous peat	1	4.0
greyish peat	13	3.6
Very dark peat	23	3.9
grey clay drift	32	4.2
iron stained layer	39	6.7

Small moss patch on clint.

	Depth in cms.	pH.
	1	6.5
(touching clint)	4	7.0

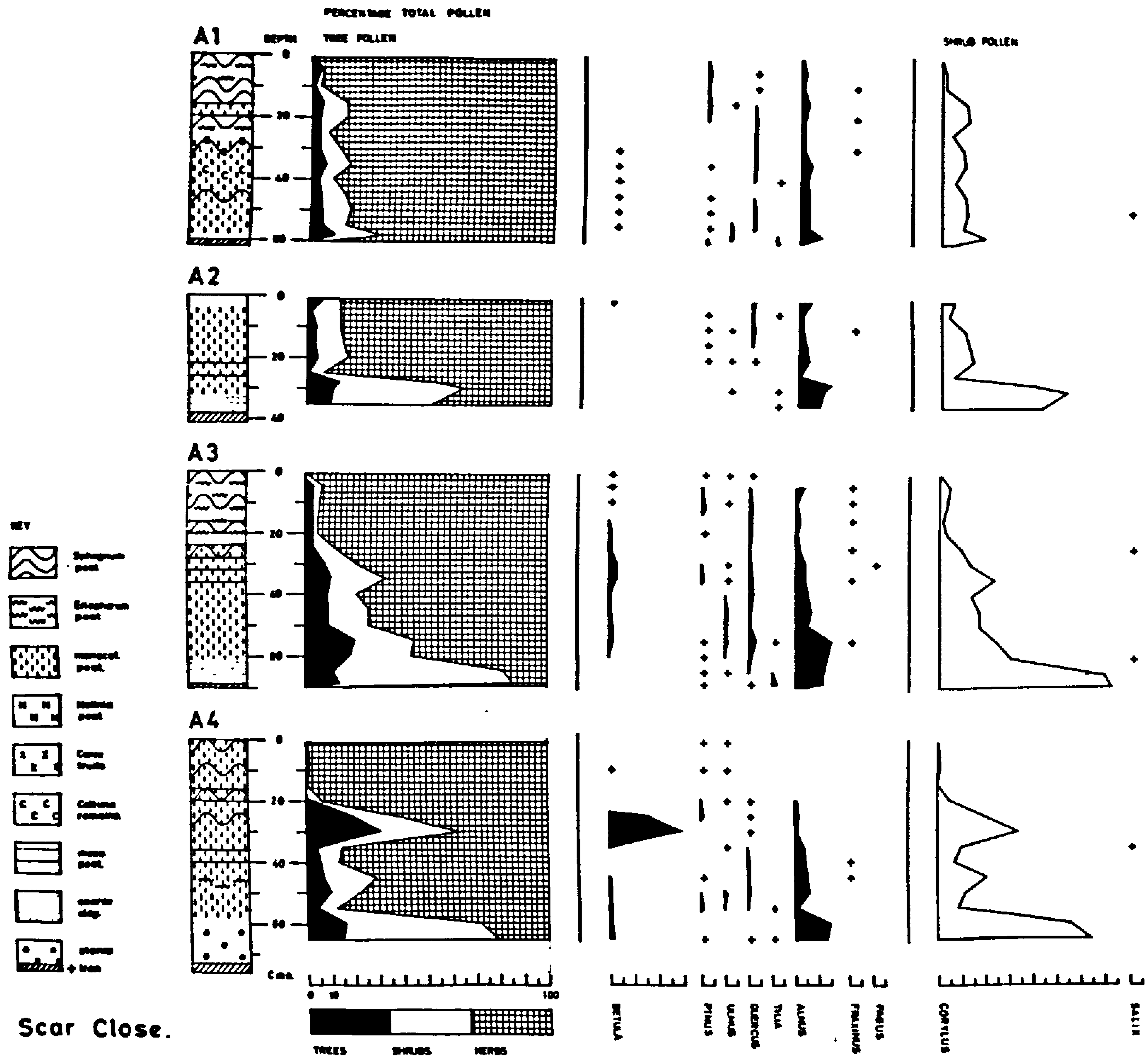
Most of the peat is composed of monocotyledonous remains with some Sphagnum in the upper layers and in the case of A1 and A3 some Eriophorum. Calluna remains were found in A1. A4 was situated on a rather larger area of peat than B4, dominated by Juncus effusus and not typical of the peat islands. In the B series the peat becomes progressively shallower from B1 to B4. In B1, 2 and 3 the lower layers are clay but in B4 no trace of this is present, the peat lying directly on the limestone pavement. As compared with the A series the peat contains much less monocotyledonous material but considerably more Sphagnum. In the highest of the B series the uppermost layer contains Eriophorum and this is present though in very small quantities in B2. Calluna remains were found in all four, Carex fruits in B1 and B4 and in B1, 2 and 3 small amounts of Molinia are also present.

From these profiles it would appear that the plant cover must have been of the mixed moorland type dominated by grasses, Calluna, and Sphagnum, with species of Carex and some Molinia. The growth of Eriophorum is more recent. No definite pattern emerged from the samples examined, but the general sequence of vegetation in the area seems to have been monocotyledonous types followed by Sphagnum then Eriophorum.

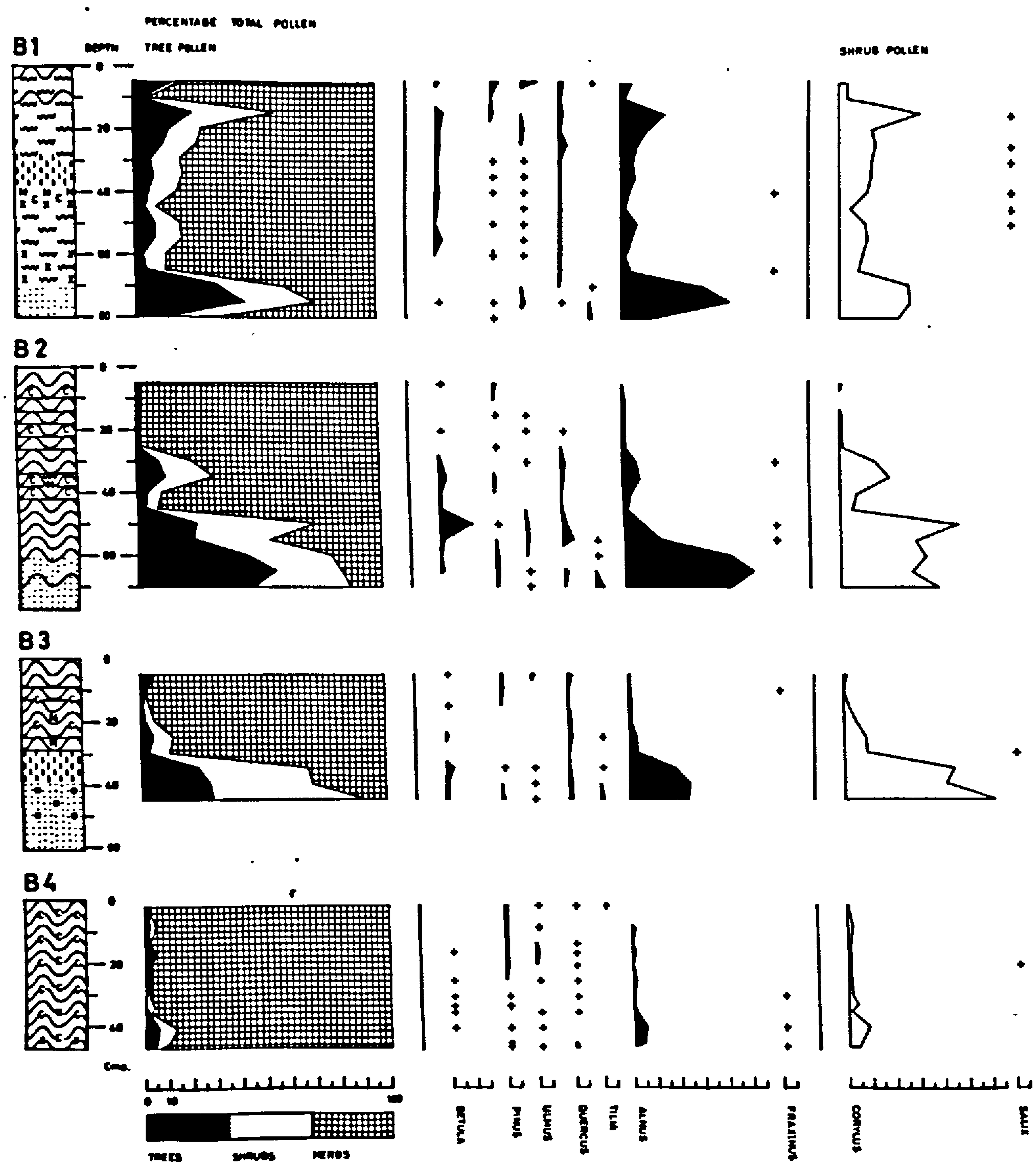
Pollen analysis.

The pollen diagrams from all eight sites are shown in figures 21 - 24 with details in tables 8 - 11. Because tree pollen was so scarce these diagrams are based on counts of total pollen. However, one site, B1, had sufficient tree pollen for it to be possible to construct a diagram based on percentage of total tree pollen and this is shown in figure 25 with details in table 12. From this an attempt was made to ascertain the age of the peat by zoning the diagram in the usual way and comparing it with the Helwith Moss tree pollen diagram. It is clearly divisible into two parts, one below and one above 70 cms., the level at which active peat growth appears to have started. Below 70 cms., in the clay, there is less non-tree pollen than above and the values of the Gramineae, Cyperaceae, Ericaceae and Plantago lanceolata are low. Of the non-tree pollen Succisa pratensis is an important constituent (up to 306%), and fern spores also reach very high percentages, (up to 738%). Alnus pollen is

Fig. 21.



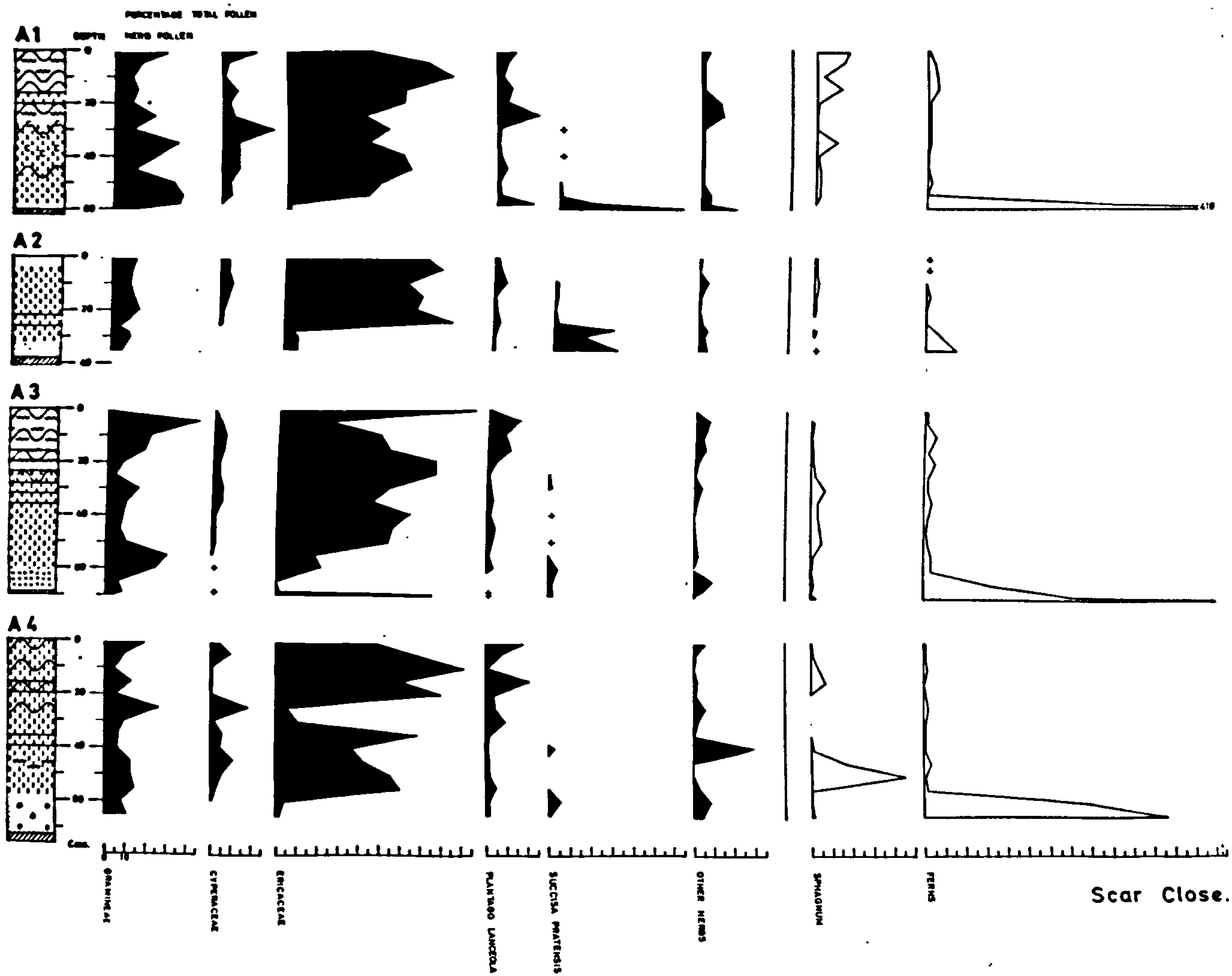
Scar Close.

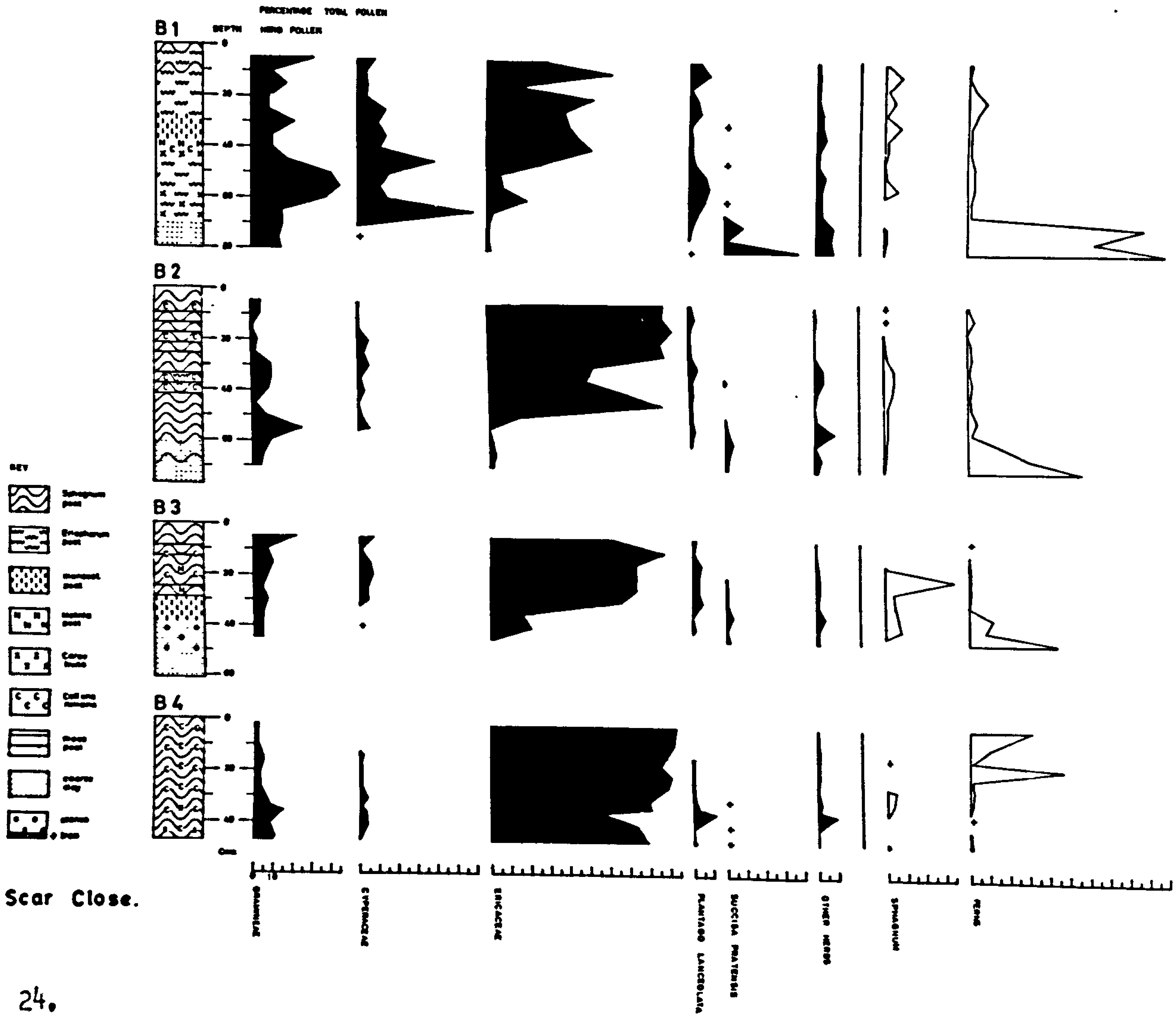


Scar Close.

Fig. 22.

Fig. 23.

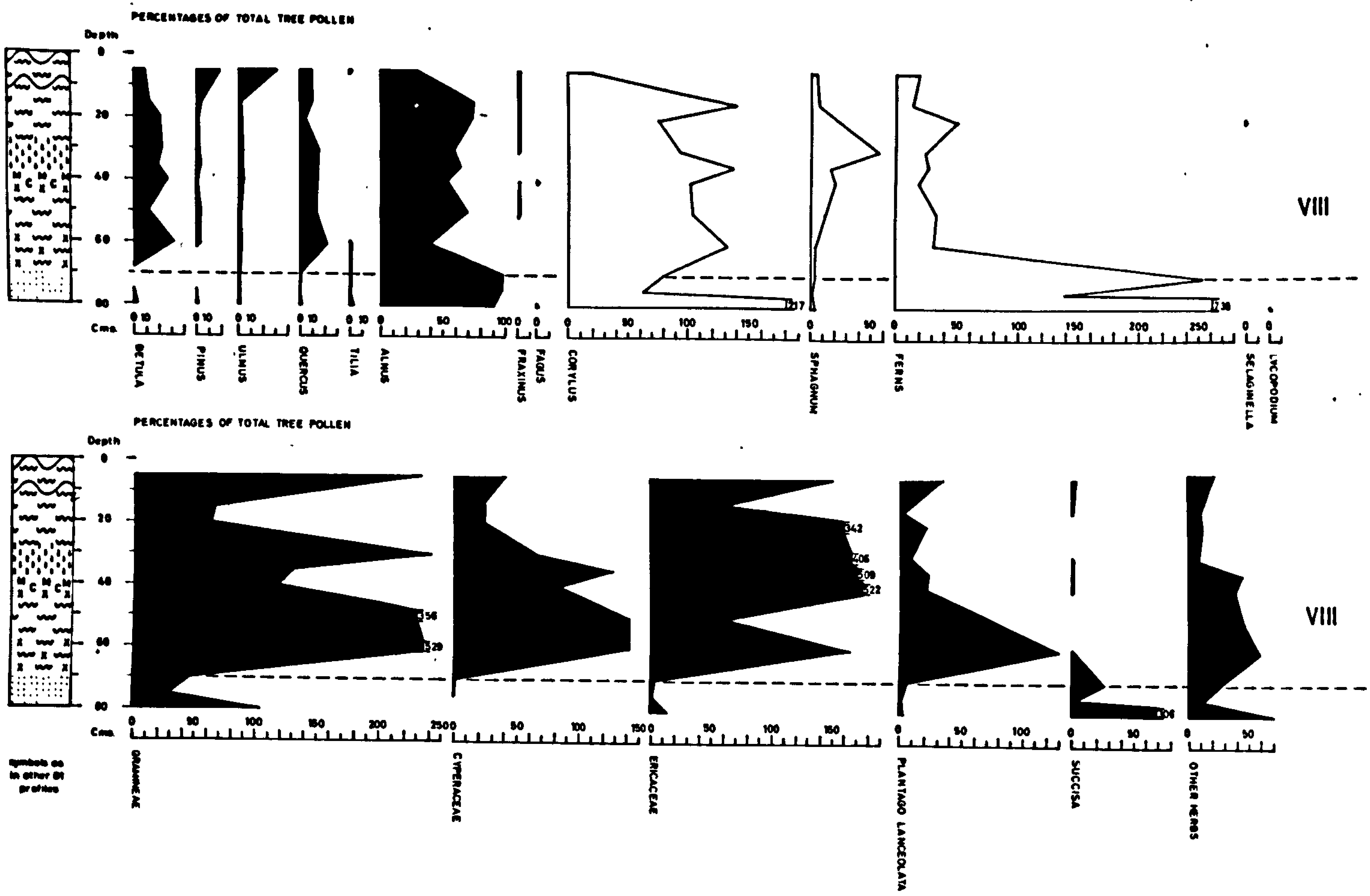

PERCENTAGE TOTAL POLLEN
DEPTH
HERB POLLEN
A1
A2
A3
A4
Cm.
GRAMINEAE
CYPERACEAE
ERICACEAE
PLANTAGO LANCEOLA
SUCCISA PRATENSIS
OTHER HERBS
SPHAGNUM
FERNS
Scar Close.



Scar Close.

Fig. 24.

Fig. 25.



B1. Scar Close. 1962.

the most conspicuous of the tree pollens. The high pollen content of the clay indicates that it is a downwash clay rather than a boulder clay. Above 70 cms. values for Betula, Pinus, Ulmus and Quercus all rise and Alnus values drop correspondingly though it is still the dominant tree pollen. Fraxinus is present in small amounts and there is an occasional pollen grain of Fagus. The amount of non-tree pollen increases tremendously, especially of the Gramineae, Cyperaceae, Ericaceae, Plantago lanceolata and other herbs (e.g. the Caryophyllaceae reach 27%). If this diagram is compared with the corresponding diagram of Helwith Moss (figure 7), the zone above 70 cms. at Scar Close resembles closely zone VIII of Helwith Moss with high percentages of pollen of the Gramineae, Cyperaceae, Ericaceae and Plantago lanceolata. The presence of Fagus pollen also suggests that this peat belongs to zone VIII. If this is so the deposit below 70 cms. would appear to belong to sub-zone VIIb, though this is not clearly comparable with sub-zone VIIb of Helwith Moss. If, however, the diagram is considered in relation to a similar one from Tarn Moss (Pigott and Pigott 1959) (figure 17), there is a marked resemblance between the 70 cm. level of Scar Close and the transition between zones VII and VIII of Tarn Moss. It seems justified then to suggest that the peat of Scar Close belongs to zone VIII. It may be unwise, however, to lay too much emphasis on the quantitative changes in pollen from the clay layer to the peat layer. Although obviously considerable changes in conditions are likely to have taken place at that time causing the development of peat to begin, nevertheless some of the quantitative differences may be due to differential preservation of pollen in clay and peat.

From the diagrams based on total pollen (figures 21 - 24) several points of interest can be noted. A constant feature at the base of all diagrams except that of B4 is the presence of _Succisa pratensis_ in some quantity and high values of fern spores. With the exception of the diagram for A4 and B3 _Sphagnum_ spore values are always below 16%. The pollen of _Polygala_ was found in four of the monoliths and a spore of _Lycopodium annotinum_ at 80 cms. in B1. One type of pollen grain with features similar to those of the _Papaveraceae_ occurred frequently in the lower layers but it was not possible to identify it with certainty. Despite differences in the stratigraphy of the peats, the strong similarity between all the pollen diagrams makes it difficult to avoid the conclusion that these peats all belong to the same formation.

Discussion of Scar Close will be left until two minor sites Moughton, and Howrake Rocks have been considered in order that information may be available from a wider area.

Phot. 10. The Scar Close area at the foot of Ingleborough.

Phot. 11. The row of swallow holes above Scar Close.

Phot. 12. Scar Close with limestone pavement, and the wood of Howrake Rocks, from the top of Ingleborough.

Phot. 13. Exposed boulder clay in the area dominated by Nardus, above Scar Close.

Phot. 14. Scar Close from the row of swallow holes, looking towards Whernside.

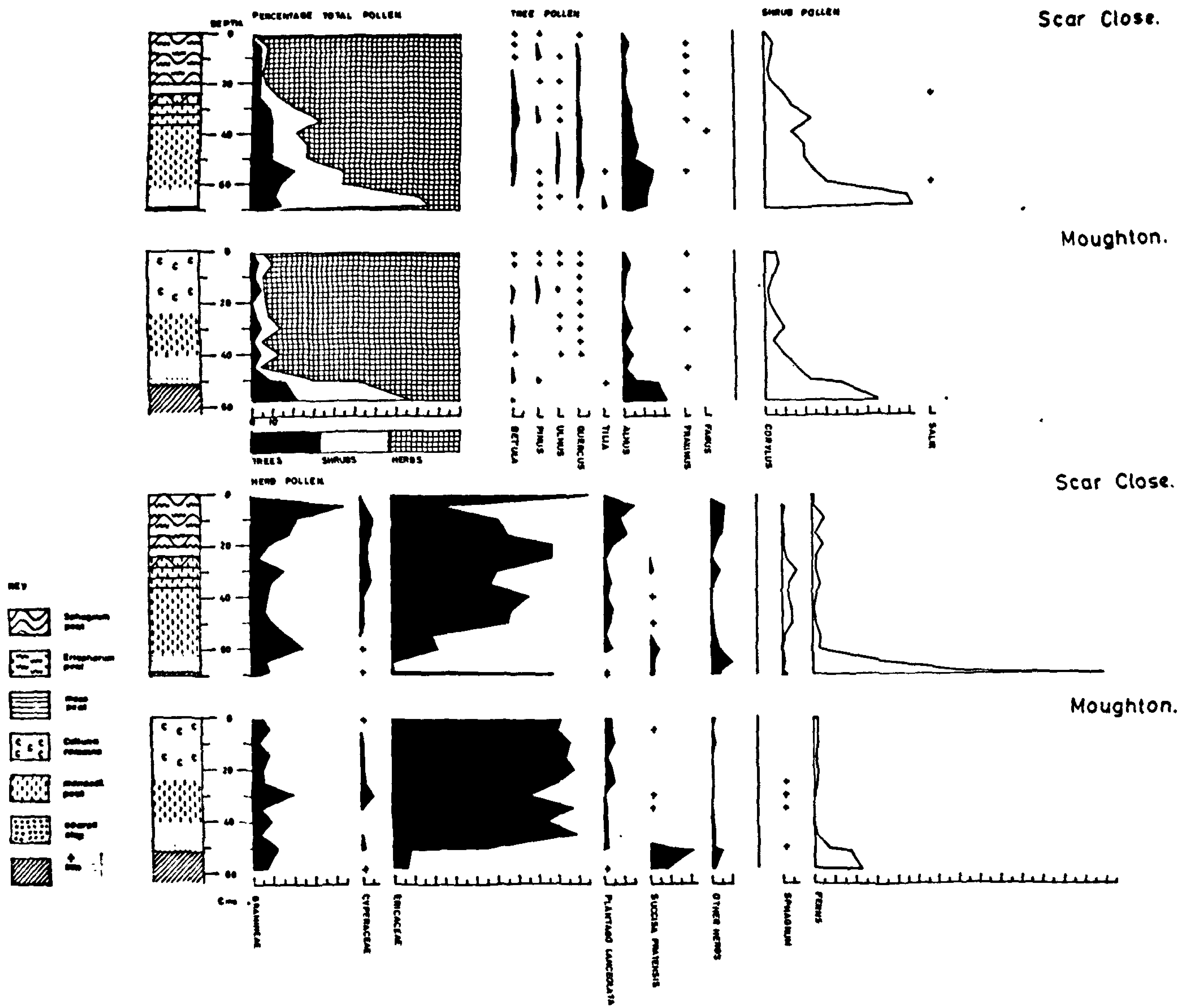
Phot. 15. Scar Close: detail of limestone pavement with patches of peat.

Phot. 16. Scar Close: a drainage channel in the limestone pavement.

Phot. 17. The upper part of Scar Close with Eriophorum vaginatum.

Phot. 18. Scar Close: soil profile.

Fig. 26.



Scar Close.
Moughton.
Scar Close.
Moughton.
DEPTH
PERCENTAGE TOTAL POLLEN
TREE POLLEN
SHRUB POLLEN
HERB POLLEN
TREES
SHRUBS
HERBS
BETULA
PINUS
ULMUS
QUERCUS
TILIA
ALNUS
FRAXINUS
FAGUS
CORYLUS
SALIX
GRAMINEAE
CYPERACEAE
ERICACEAE
PLANTAGO LANCEOLATA
SUCCISA PRATENSIS
OTHER HERBS
SPHAGNUM
FERNS
KEY
Cm.

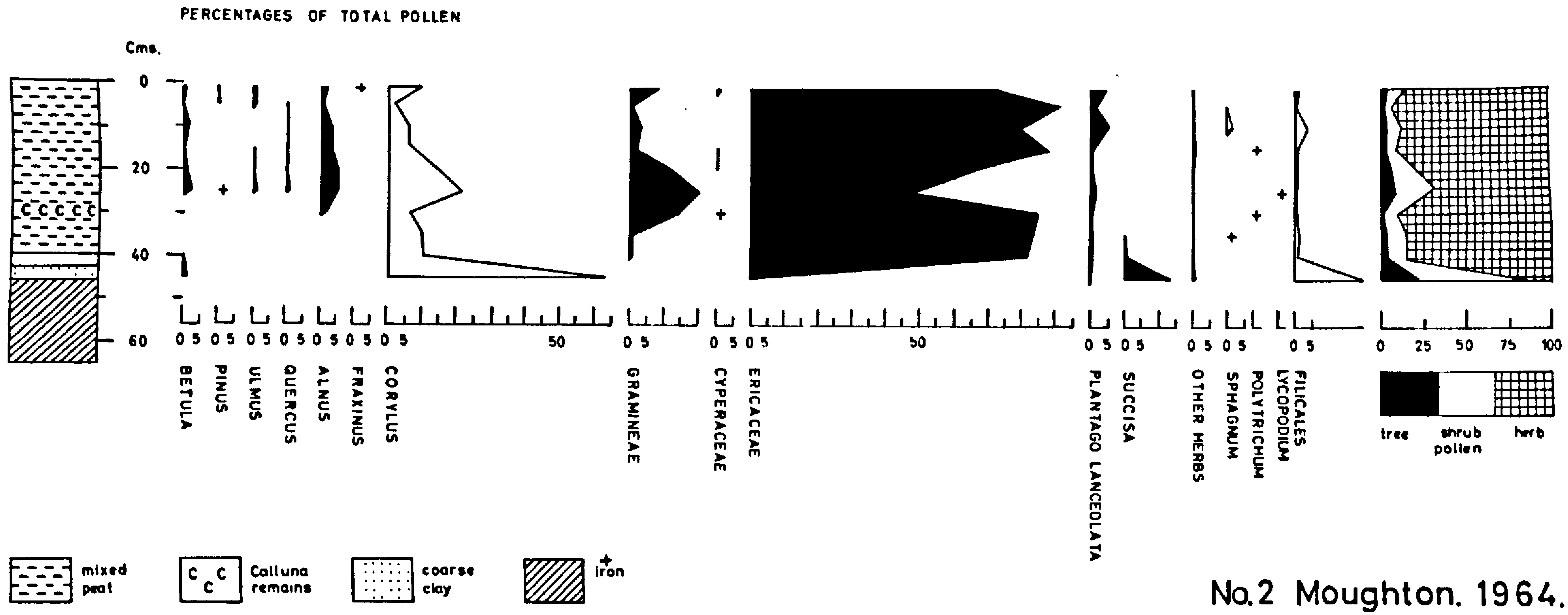
Moughton.

Two peat monoliths were removed from Moughton, a limestone plateau above Helwith at about 1,250 ft. Here there is a peat cover similar to that of Scar Close, but somewhat more continuous, (photograph 19). Blocks of peat were removed for analysis, and the soil profile so exposed, at the first site, is shown in photograph 20. This profile displays similar features to that of Scar Close with a basal iron stained layer covered by clay and above this, peat. The details of stratigraphy and the results of pollen analysis of the two sites are shown in figures 26 and 27, with details in tables 13 and 14. In order to facilitate comparison, the same information for Scar Close site A3 is included in figure 26 and table 13. All three sites are very similar in broad outline and are obviously contemporaneous. The pollen indicates that both Moughton and Scar Close had many species in common, e.g. *Polygala*, and *Centaurea nigra* type. A little pollen of *Poterium sanguisorba* was found at 20 cms. in Moughton 1. Very little tree pollen was present on either of the Moughton sites but sufficient was found in the lower layers to construct a diagram based on percentages of total tree pollen for the first site, and this is shown in figure 28. This diagram corresponds closely with that of Scar Close figure 25.

Discussion.

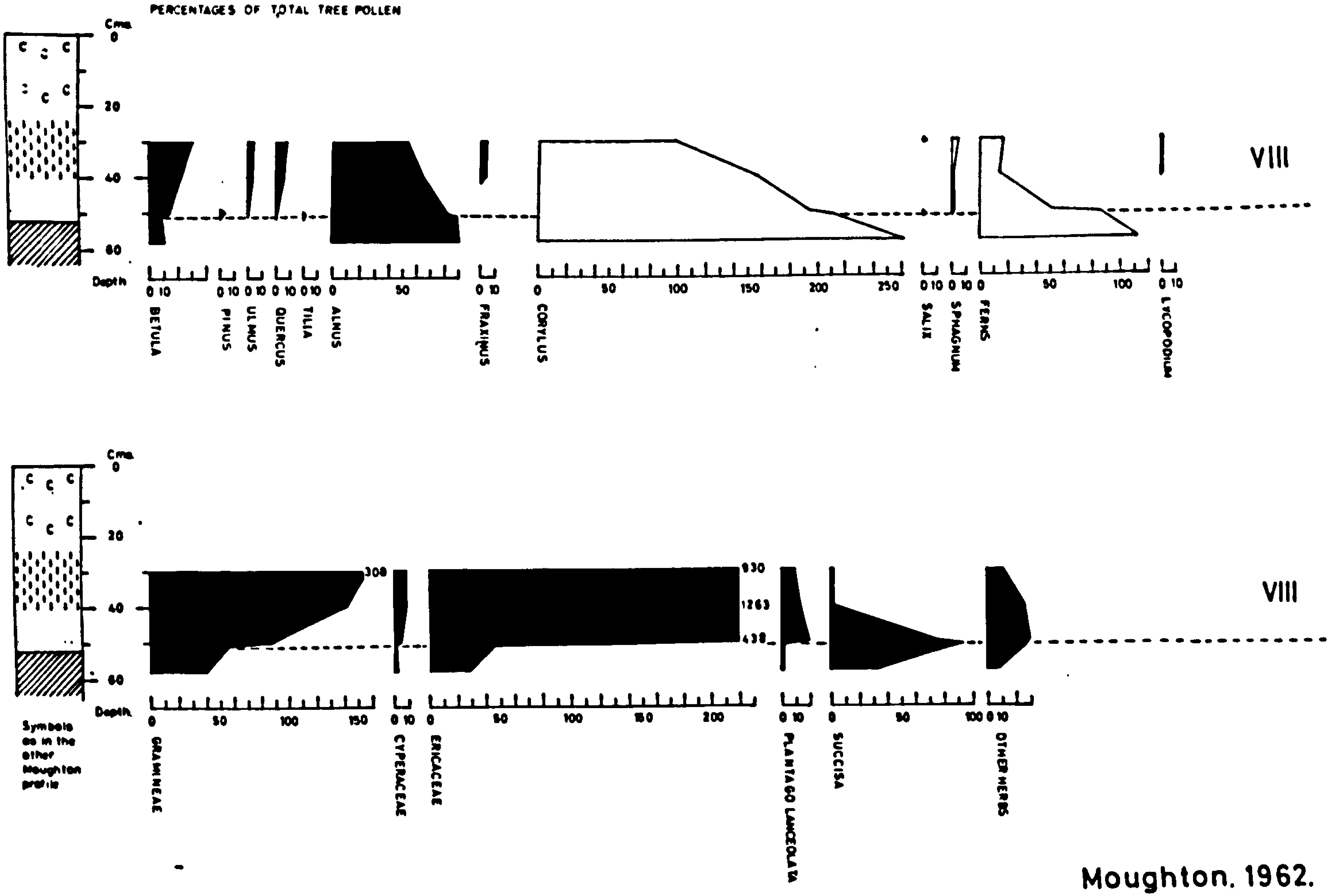
Cheetham 1947, has suggested that there was an ice-bound lake present in glacial times on the top of Moughton because the ice cap

Fig. 27.



No.2 Moughton. 1964.

Fig. 28.



Moughton. 1962.

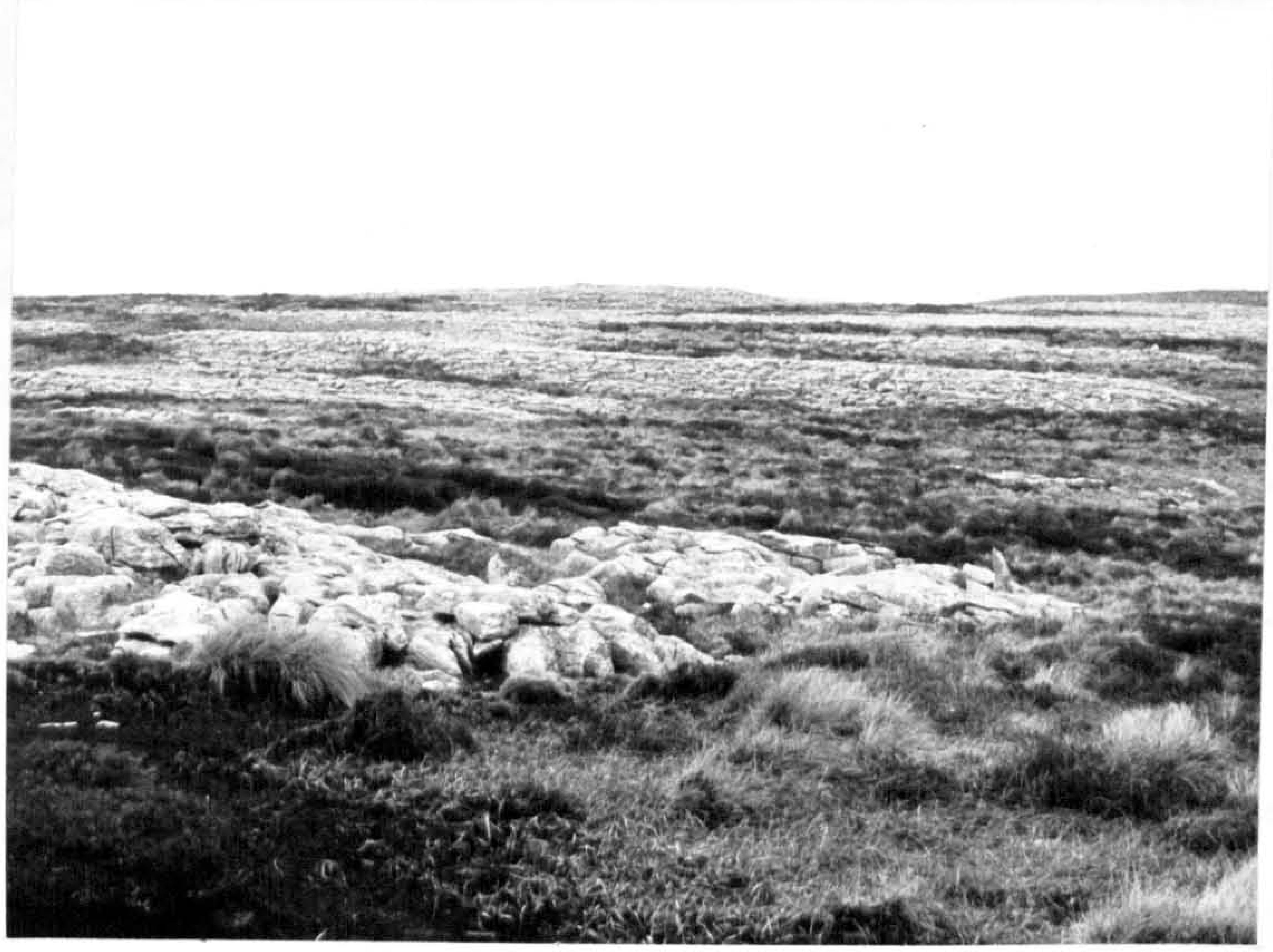
which covered it melted before the surrounding glaciers. Into the lake glacier water carried fine material which filled the interstices of the limestone making it impervious. He considers that the lake was later invaded by rushes, seeds of which he has found in the soil below the peat. The area was next colonised by Eriophorum and in the drier parts this was succeeded by Calluna. From the results of macroanalysis of both the Moughton sites investigated there was no evidence of a previous aquatic vegetation, although the peat was highly humified and it was not possible to identify with certainty any of the material from which it was formed. Its general appearance was that of Eriophorum peat but where identification was possible monocotyledonous material and pieces of Calluna were the only things discovered. The layering does in fact support Cheetham's suggestion of the more recent vegetational changes, at any rate at site 1, but it seems impossible that a lake was present here when the peat was forming because it is situated on a slope from which any large body of water would drain away.

Gilligan, (1918), also attributes the siliceous soil below the peat to ice-borne material which was washed in by melt water. He divided it into three layers -

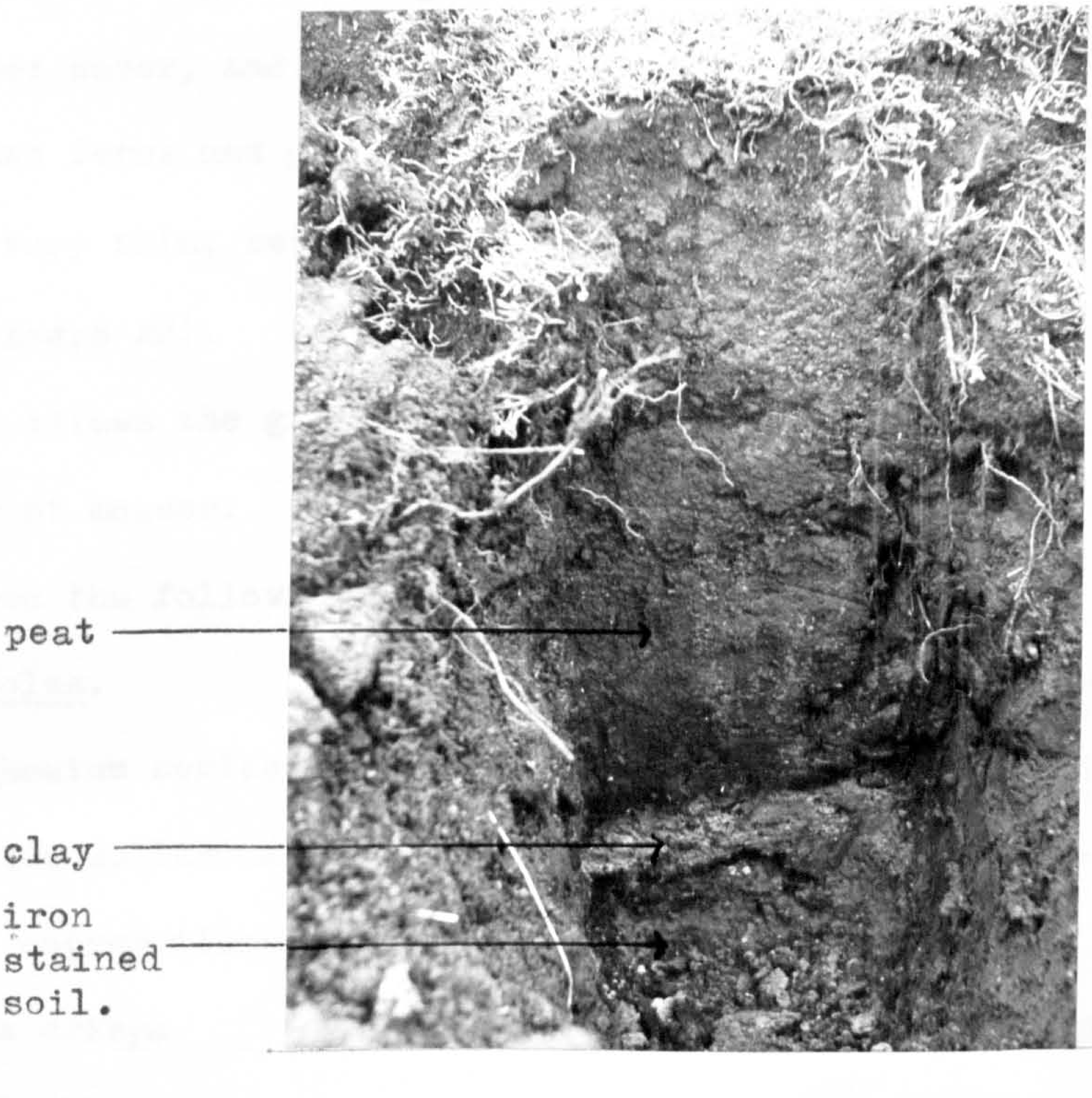
1. about 2" of grey soil full of roots immediately beneath the peat,
2. iron pan about $\frac{1}{4}$" in thickness,
3. Ferruginous sandy bed of considerable depth, up to 4 ft. or more.

He investigated the ferruginous layer in some detail, and discovered that it contained no carbonates. It was therefore not formed of limestone but was rock flour composed of grits sandstones and shales and was similar to that discovered in the bottom chambers of Gaping Ghyll, though here it contained much less ferruginous naterial. The iron pan he explained as resulting from oxidation of iron in solutions rising by capillarity from the sandy layer below. He considers the pan to have formed as soon as conditions were favourable for the establishment of vegetation in the swamp and that it has not been penetrated by roots of later vegetation. Nevertheless, from its appearance, the profile could be interpreted as the result of normal podsolisation.

This suggested development of the various soil layers may also be appropriate for Scar Close since the peat constituents, the pollen content, and the soil profiles of both the Moughton sites and those of Scar Close are so similar that it seems reasonable to suggest that both peat areas have formed at the same time and in the same way.



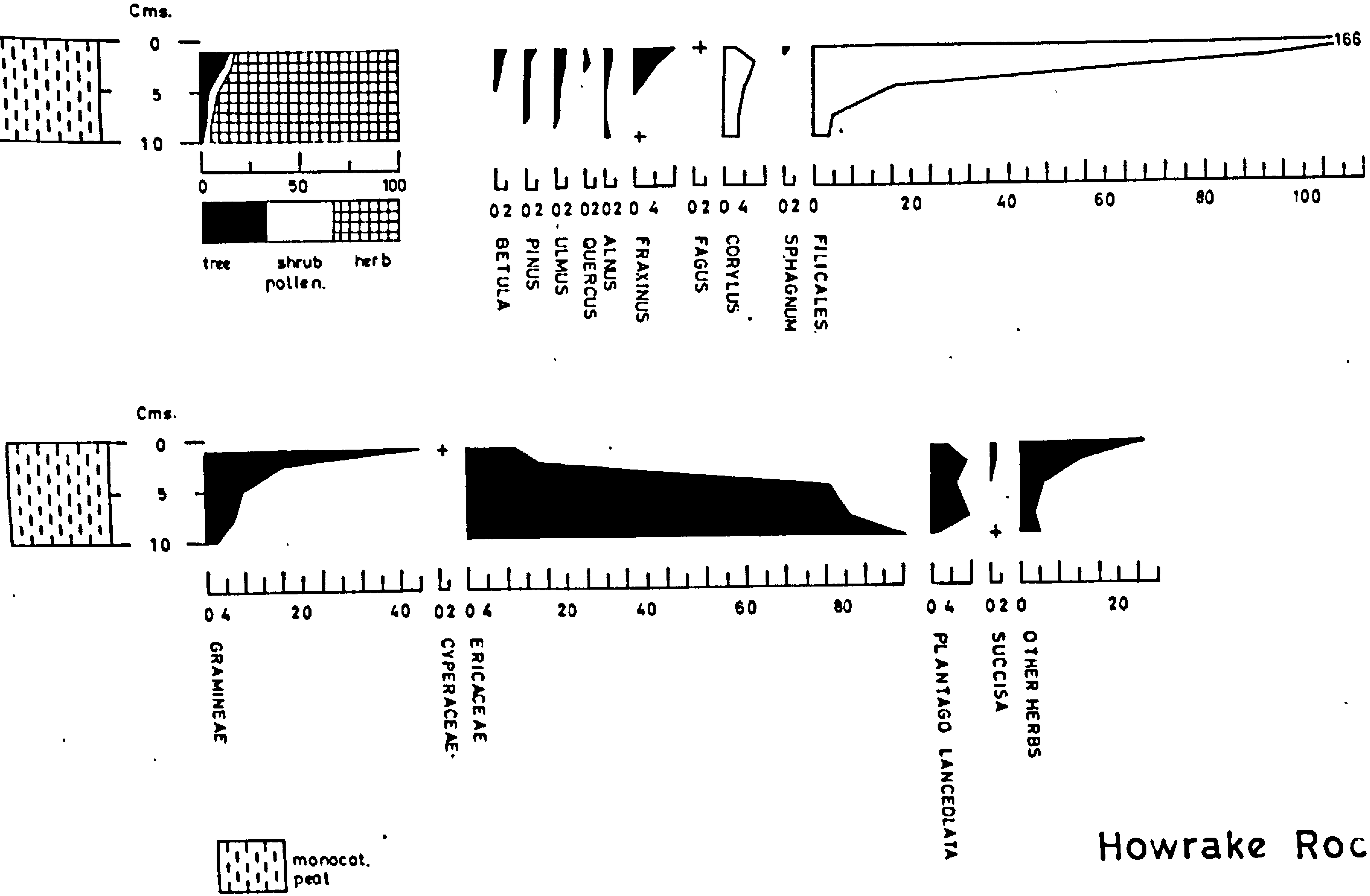
Phot. 19. Moughton: peat lying on limestone pavement.



Phot. 20. Moughton: soil profile.

Fig. 29.

PERCENTAGES OF TOTAL POLLEN.



Howrake Rocks. 1965.

These are a mixture of mosses requiring a basic substrate, growing in close contact with the clint surface, and others of neutral or more acid requirements which are growing on the accumulated humus.

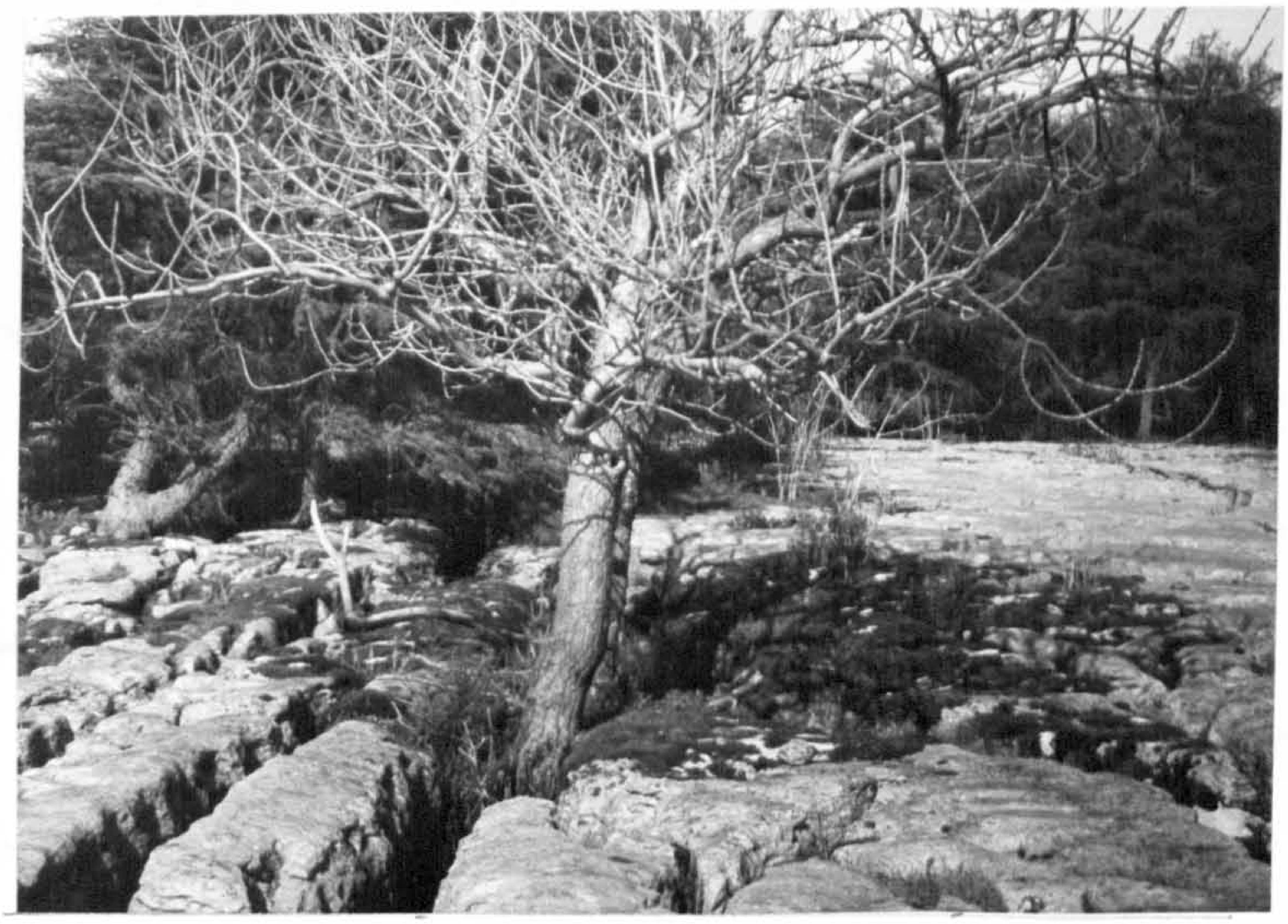
One small monolith was removed from peat above a clint, although it was part of a patch of peat which also extended over a gryke about 8" wide. (photograph 24). This monolith was analysed and the results are shown in figure 29, with details in table 15. From macroanalysis very little information can be obtained as the peat is highly humified and amorphous. The only identifiable material is monocotyledonous with roots possibly of Calluna. In another part of the same patch, a well marked layer of Dicranum cf. scoparium is present 2 - 3 cms. below the surface, and a woody layer 7 cms. down containing pieces of Prunus sp. The results of pollen analysis are more informative and show a change in the vegetation about 5 cms. below the surface from a former Calluna-dominated community to grass-dominated. At the same time ferns and ash show a marked increase suggesting a change from moorland type to woodland vegetation. The presence of up to 8% of Plantago lanceolata, and Fagus indicate that the peat belongs to zone VIIb or later.

Discussion.

If compared with the results from the various monoliths of Scar Close a number of resemblances can be seen. The percentages of tree pollen are similar to the upper layers of A1, A3, B2, and B4 with the exception of Fraxinus which may well be a local feature. The small quantity of Corylus pollen is also found in B4 as well as the rise in Filicales in the surface layer. A rise in Gramineae with a corresponding fall in Ericaceae is present at both Howrake Rocks and Scar Close B3, the smaller rise in the latter possibly explained by surface erosion. The presence of Succisa pratensis and Plantago lanceolata is characteristic of all the Scar Close sites as well as at Howrake Rocks. The general features are so similar that it seems likely that, like the peat of Moughton, this peat is also contemporaneous with that of Scar Close.

Phot. 21. Howrake Rocks: increase in vegetation under tree cover.

Phot. 22. Howrake Rocks: grass covered peat overlying grykes.



Phot. 23. Patch of mosses growing on limestone pavement under an ash tree, Howrake Rocks.

Phot. 24. Howrake Rocks: peat over a gryke.

Discussion of Scar Close with particular reference to Moughton and Howrake Rocks.

It has already been suggested that the peats at Moughton, Howrake Rocks and Scar Close are so similar that they must have been formed at the same time, and under similar conditions. Information derived from work at Moughton and Howrake Rocks will therefore also be used in an attempt to explain the present condition and distribution of peat at Scar Close.

A general survey of the Scar Close area immediately suggests that it can be divided into two main parts; 1, the upper, lying between the exposed limestone, and the 'Yoredale' rocks and 2, the lower, consisting of the pavement area itself. In the first of these a cover of more or less continuous wet acid bog (figure 19) is underlain by a layer of drift material which has become podsolised as at Moughton. From the profiles (figures 21 and 22) it can be seen that the peat is about 60 cms. deep, and macroanalysis reveals that it has some similarities with blanket peat of the southern Pennines (Conway 1954) in that it consists of *Sphagnum* and *Eriophorum*, with monocotyledonous remains (perhaps *Molinia*) and some *Calluna*, but it is not so highly humified, ~~and~~ *Eriophorum* does not form such a major part, and *Carex* is also present. The pollen diagrams show that peat accumulation only began in zone VIII, the Sub-Atlantic period, when temperatures were lower and increasing cloudiness caused a corresponding decrease in evaporation (Manley 1951). Pollen and spores are, however, preserved in the clay material beneath the peat, and indicate that a marked change took place in the vegetation surrounding Scar Close, and possibly on the drift itself, at the start of the zone. The change seems to have been from open alder woodland, with hazel bushes and abundant ferns, to a typical mixed moorland of heather, grasses and some sedges. It is interesting to note the consistent presence of Succis pratensis, especially at the transition from clay to peat. Its present distribution indicates that it is a species tolerant of a wide range of soil conditions, and that as well as growing in deciduous woodland, fens and bogs, it is frequently found on disturbed ground and in areas of open vegetation (Adams 1955). It is very likely that just such conditions as the latter prevailed at Scar Close at this time, before it became dominated by a more closed heather-grassland community.

The distribution of peat on the second area presents a much more difficult problem, and it is closely connected with theories of development of limestone pavement. It is evident from the pollen diagrams that the continuous peat and the 'islands' belong to the same zone, zone VIII, and are therefore of more or less the same age. The peat islands could be the remnants of a layer of blanket peat which slipped down the slope from the drift covered area described previously, and was subsequently eroded to leave small isolated patches. This seems unlikely however as, on consideration of the pollen diagrams where the curves are similar in both areas, the peat shows no evidence of disturbance because of movement, and this explanation would not be applicable to Moughton where there are no slopes higher than the pavement itself. Another alternative is that the peat has formed in situ. There is no indication now that drift has been present below the peat, which is touching the clint surfaces. However Webb (1947), has described the development of peat directly on a limestone surface at Carrowkeel in North western Ireland. He considers that impeded drainage is not essential where precipitation is sufficiently high, and that peat will develop in well drained situations because of the absence of the inhibiting effects of calcareous flush waters. A level surface particularly favours peat formation. He concludes that at Carrowkeel high rainfall and low evaporation must permit peat formation in situations where it would not develop elsewhere, and that saturation must work in some way other than by causing oxygen deficiency because in the early stages the peat is so thin that the lack of oxygen could not be severe. The rainfall at this Irish site is about 55 inches, and at Scar Close about 70 inches, so that high precipitation here might also encourage peat formation directly on the limestone itself. The fact that peat does not form in any quantity now at Scar Close may possibly be explained by differences in humidity. Where however persistence of moisture is increased, as for example under tree cover at Howrake Rocks (photographs 21 and 23), colonisation of the limestone pavement has been possible, particularly by mosses.

But at Scar Close the basal layer of the peat touching the limestone at the present time is not specifically moss material. The pollen diagrams could be interpreted as indicating a gradual encroachment of peat over the limestone from the mountain-side outwards, as the outermost ones especially in Series B seem to be equivalent to the upper layers of the innermost profiles, and therefore the whole series from 1 - 4 represents stages in decreasing age. This suggests the initiation of peat formation to have been in the first area discussed. It would be possible to accept the theory of peat formation as at Carrowkeel if the 'islands' were confined to large clints with an unbroken and continuous surface, and in fact there are small accumulations of plants in just such situations today, which has led to suggestions that the pavement is in a state of colonisation. However it does not explain how peat could develop in the situation shown in photograph 25, where it overlies a wide gryke. It can be seen from the pH figures presented earlier that even here over a gryke the dissolved bases from the parent rock are adsorbed onto the peat and raise the pH of the lower layer. Whatever theory of pavement development is accepted such grykes would already be formed by the time this peat accumulated even though they have become widened by later solution. Pigott in his paper on Tarn Moss and in two other papers (1962 and 1965) suggests that limestone pavements are preglacial and are a result of stripping to different levels during the last glaciation, so explaining the varied forms of clint and gryke. He thinks that old deposits on the surface of the limestone were removed by the activity of later glaciers and that exposed pavements such as this are only found in areas within the New Drift boundary. Any drift in Late-Glacial times would be rapidly washed down into the grykes leaving bare limestone. If this were so then the peat here must have formed in the same way as at Carrowkeel. The situation in photograph 25 may have arisen because the grykes were filled with drift to the pavement surface during the last glaciation. But, if grykes were already formed it seems unlikely that this drift material would have persisted until the Sub-Atlantic period. If the gryke was very narrow the peat might have formed by overgrowth as seen at Howrake Rocks today, and this would be acceptable provided that it consisted of plant material such as Sphagnum, which is able to absorb and hold water. Estimates suggest that limestone is eroded only very slowly, e.g. Williams (1963), has worked out that with a mean annual rainfall of 49.5", only 2" of limestone is removed from the basin of the Fergus River, Co. Clare in 1,000 years. However, higher precipitation, and more rapid solution below acid peat may have increased erosion and widening of grykes at Scar Close resulting in the situation shown in photograph 25. Without postulating this widening of grykes since peat formation it seems unacceptable that peat was formed directly on limestone by overgrowth if grykes existed of the order of 12 inches or more.

There is a possible alternative. Where the exposed pavement and the drift covered limestone meet, the peat is shallow and lies on an accumulation of stones and pebbles which have the angular appearance of ice-borne material (photograph 26). This seems to indicate that the finer clay material has been washed away (photograph 27), leaving only the bigger rock fragments below the peat, suggesting a receding drift cover. It therefore seems feasible to advocate the presence of a layer of drift, over the pavement area, which remained after the last glaciation, but is now in the process of removal. The presence of large erratics scattered over the pavement is further evidence of the deposition of glacial material. Jones, (1957), considers the drift to be receding and thinks that tree roots, such as that seen in photograph 28 at Howrake Rocks, must once have grown in soil which has now disappeared. Jones considers that limestone pavement is post-glacial and has developed beneath a thin drift cover bearing vegetation, the latter being a source of biological acids. Cvijic (1924) also thinks that continental lapiés, which resemble our pavements in many respects, are post glacial, but he suggests that a vegetation cover does not speed up development, but rather forms a protective layer and therefore delays the effect of weathering. Parry, (1960), considers pavement formation was peri-glacial and resulted from differential solution by meltwater rich in carbon dioxide, resulting from the disappearance of snow banks with the Post-glacial rise in temperature. He agrees with

Moisley (1954) on the part played by solution in pavement development. Parry states that solution by meltwater continued as late as the Pre-Boreal period, Zone IV, about 7,500 B.C., and that the large grykes date from that time. With the amelioration of climate, pavement formation slowed down, and it became colonised by grasses, the vegetation cover being more extensive at the "climatic optimum" than now when the pavements are in a state of decay.

If Scar Close is considered with reference to these theories the following ideas may be put forward as a possible alternative to explain the history of the pavement area. During the last glaciation any surface irregularities of the limestone shelf were planed by the glacier occupying the valley. When it receded a layer of drift was left behind which was subject to erosion as soon as it was exposed. This drift layer which became thinner because of weathering processes, was eventually colonised by vegetation, and below it pavement developed in the way described by Jones. Evidence of such pavement formation below a superficial cover can be seen onan exposed face at the side of a swallow hole (photograph 29). The drift was podsolised and eventually a peat layer accumulated in the same way as in the first area discussed. Erosion continued and the pavement became modified by chemical ahd sub-aerial weathering. As the grykes widened the drift was washed down into them leaving peat in contact with the limestone. Because of the rise in pH caused by solution of the limestone surface bacterial activity increased and oxidation of the lower peat layers would take place (Waksman, 1927).

This is a possible explanation of the truncated pollen diagram of profile B4. The present distribution of peat would then be explained as the remnants of a former more continuous cover which has been eroded and not as isolated patches of vegetation which are actively spreading by colonisation. There is evidence of erosion at Scar Close in the upper part where there are exposed surfaces left by peat slips, and also at Moughton (photograph 30). Jones has also demonstrated that there are lichen free margins to the peat islands indicating recent exposure by decrease in the area of peat.

There seems then to be at least two possible explanations of the pavement area at Scar Close:

1. Direct formation of peat on the limestone as at Carrowkeel with later widening of grykes.

2. Peat formation on a drift cover which has subsequently disappeared.

The first is only acceptable if the solution of limestone is more rapid here because of high rainfall and acidity than in other limestone areas investigated. Otherwise grykes would appear to have been too wide when peat was forming at the start of the Sub-Atlantic period, for overgrowth to have been possible.

The second alternative would be more acceptable if direct evidence of drift, such as the presence of angular stones, were found beneath the peat, but so far this has not occurred, and as Webb explains at Carrowkeel it does not seem that any normal soil development ever took place, at any time, on the limestone surface, before the formation of peat.

Phot. 25. Scar Close: peat lying over a wide gryke.

Phot. 26. Scar Close: stones left from the erosion of drift.

Phot. 27. Fine drift being washed out from under a cover of peat at Scar Close.

Phot. 28. Howrake Rocks: exposed tree root.

Phot. 29. Scar Close: grykes on the edge of a swallow hole, covered by a substantial depth of soil.

Phot. 30. Moughton: erosion of peat.

General Discussion.

In order to see how peat formation at Helwith Moss, Thieves Moss, Scar Close, and Moughton fits into the general vegetational history of northern Britan, and Ireland, these sites will be compared with several others drawn from a variety of situations.

Helwith Moss is a classical example of a raised bog and has many similarities both in stratigraphy and pollen content to the Tregaron bogs (Godwin and Mitchell, 1938), those described by Jesson (1949), and Mitchell (1951), in many Irish sites, Heslington Moss in Westmorland, (Smith 1959), and the group of Scottish bogs examined by Durno, (1956). Unlike many of the Irish raised bogs, however, Helwith Moss lacks the layer of brush wood peat, so frequently found in the upper fen peat and indicating the development of carr. At Helwith only a very small amount of Betula wood is present in the area surrounding the Moss proper. In the Scottish peat bogs referred to above, the mire at Fallahogy, Co. Derry (Smith, 1958), and at Thieves Moss, peat started to accumulate in the Boreal period. This was swamp or fen peat, and the transition to more acid raised bog took place before the Boreal period ended. Helwith Moss like Chat Moss, Lancashire, (Birks, 1964), has a basal layer of Hypnum peat, probably aquatic, but in many of the other sites reedswamp or fen peats were the first to form. In practically all the bogs mentioned, the bulk of the Sphagnum peat is composed of Sphagnum imbricatum, which seems to have been very widespread throughout Atlantic, Sub-Boreal and Sub-Atlantic times. This *Sphagnum* peat is often mixed with *Eriophorum* and some *Calluna*. Thieves Moss also, from its shape in section and from its stratigraphy, appears to have developed along the same lines as these raised bogs but, either it has not completed development because of local conditions already discussed, or it has become so eroded that its former state is difficult to recognise. In most raised bogs peat formation is still continuing, but at this particular site, there is very little above the Boreal-Atlantic transition.

At Helwith Moss pollen is only preserved from zones V-VIII, but at Thieves Moss pollen has remained from Late-Glacial times. If the pollen diagrams from the two sites are taken together, a more or less continuous picture of the vegetational changes in the area is obtained. The similarity of these two sites with Tarn Moss has already been pointed out. The Late-Glacial period at Thieves Moss has the usual features with a high percentage of NAP and the presence of *Juniperus* and *Hippophaë*. As far as the Post-Glacial period is concerned, in sub-zone VIIb and in zone VIII, at Helwith Moss, there is the usual sign of human activity, a rise in herb pollen, especially of *Plantago lanceolata*, and other weeds such as *Taraxacum officinale*, *Artemisia* and *Matricaria*. This increase in weed pollen is clearly seen at Heslington Moss, as well as at many other sites.

However, for the interpretation of the nature and distribution of the various peat deposits around Ingleborough, the changes in stratigraphy and pollen curves from zone VIIa onwards are the most significant. In all pollen diagrams from the start of zone VII an increase in wetness is indicated by the rise in alder, and this is accompanied by higher percentages of Gramineae, Ericaceae and Cyperaceae. This increase in the three herbaceous species which is so conspicuous at Tarn Moss, or the Scottish and Irish sites, such as Cannons Lough, (Smith 1961), is not so pronounced at Helwith Moss or Heslington Moss, but at Thieves Moss there is a sharp rise in the Ericaceae near the top of the diagram. This period, from the Boreal-Atlantic transition onwards, was the time of most active growth in raised bogs throughout the British Isles. It was also the time of initiation of the blanket bogs of the Southern Pennines (Conway 1954). Such blanket peat was earlier considered to be composed almost exclusively of Eriophorum vaginatum, (Woodhead and Erdtman, 1926). However Conway found that although it formed the major bulk of the peat at low altitudes such as at Woodhead (1,200 ft.) where Sphagnum was present in only small amounts, at higher altitudes Sphagnum became more important, and Eriophorum less so. For example at Kinder VI (2,050 ft.). She found the following sequence of peat types starting from the base:

1. a layer of compact fibrous material containing monocotyledonous remains, probably Molinia, which began formation at the Boreal-Atlantic transition.

2. a moderately humified peat with *Eriophorum vaginatum* and much Sphagnum.

3. fresh red-brown *Sphagnum* peat banded with more humified layers of *Eriophorum* and *Calluna*.

The surface today is dominated by *Eriophorum vaginatum*. The change from the humified middle layer to the less humified upper layer Conway considered significant for the southern Pennines, and designated it the C2 horizon. It was dated tentatively and thought to be about the same time as the start of Godwin's transition zone VII-VIII, and well before the familiar Grenzhorizont of lowland raised bogs. Conway found no obvious change in stratigraphy which would indicate the later Grenzhorizont, but in the pollen diagrams it was marked by a fall in arboreal pollen and a rise in the *Ericaceae*, and she called this level C3. Helwith Moss appears to be similar to the southern Pennine blanket bogs in this respect. At 235 cms. (figure 7) there is a distinct change in stratigraphy from a fibrous peat of *Eriophorum* and *Sphagnum*, to a much less humified *Sphagnum imbricatum* peat and it has been suggested that this should perhaps be called the start of a VII-VIII transition zone. However the changes in the pollen diagram at this point do not seem to be of great significance. At 120 cms. though, there are much more definite changes in the pollen content of the peat, with a rise in *Gramineae*, *Cyperaceae*, *Ericaceae*, and NAP and this seems to be the VII/VIII boundary, the accepted position of the Grenzhorizont. Like Conway's peats there is no corresponding stratigraphical change, and it may be that Pennine sites such as these were more sensitive to the earlier climatic change than that of the VIIb/VIII transition.

In the Irish sites however it was at the start of the Sub-Atlantic period that the change took place from soligenous to ombrogenous bog, with a great spreading of blanket peat as well as a renewal of growth of raised bogs. On the latter the dried surfaces became waterlogged and woodland and Calluna vegetation was replaced by Sphagnum, which has remained relatively unhumified. It is the boundary between the drier standstill phase and the active Sphagnum growth of the wetter period, which is equivalent to the Grenzhorizont of Granlund, or Conway's C3. It was only during this period of maximum climatic deterioration both cooler and wetter, that peat first formed at Scar Close and Moughton and these areas appear to have been unaffected by conditions causing Conway's C2 horizon. The material of which the peat at these two sites is composed is however comparable with the southern Pennine blanket peat, as also is its eroded condition. Conway considers that erosion has occurred since 500 B.C. on her sites at altitudes of over 1,500 ft. It is interesting to note that Succisa which is so consistently present in the Scar Close and Moughton peats is also present in the equivalent peat of zone VIII at both Heslington Moss and Fallahogy Mire. It is probable that peat formation before Sub-Atlantic times was prevented at both Scar Close, and Moughton by the well developed drainage, characteristic of limestone regions, which would not allow waterlogging to take place.

In general, the differences in peat growth in various areas may be caused by local differences in climate, altitude, topography and human interference. However the information gained by this investigation suggests that local topography and the nature of the underlying material are very important in establishing the pattern of peat development, in the Ingleborough area.

Conclusions.

1. Helwith Moss is a raised bog which developed from a lake. No pollen is preserved before Boreal times in the coarse sandy clay which forms the basal material. Peat started to accumulate in the Boreal period and from this time onwards pollen is preserved right up to zone VIII. The vegetational succession has been from an aquatic hypnoid type to a *Phragmites* reed swamp, an *Eriophorum-Sphagnum* bog, and finally a *Sphagnum* bog.

2. Thieves Moss is the eroded remnant of a 'raised' bog, which also developed from a former lake. The basal material is a lake clay, and the pollen record begins in a zone II mud layer laid down in this clay. The aquatic succession is continued by deposition of further lake clay, followed by marl in the Pre-Boreal period. In the Boreal period deposition of peat begins with the formation of *Carex*, and later, hypnoid peats. A lowering of the water table seems to have occurred towards the end of sub-zone VIa with a decrease in the effect of basic

drainage water, and a change to ombrogenous Sphagnum bog. The upper layers are of mixed peat belonging to zone VII which appears to be being eroded rather than accruing at present. The failure to develop into a normal raised bog may have been caused by the well formed drainage system of adjacent limestone.

3. Scar Close can be divided into an upper and a lower area. The upper area is on a slight slope and is underlain by drift. It is covered with more or less continuous blanket peat formed in the period of maximum climatic deterioration, ~~of~~ the Sub-Atlantic. ~~period.~~ The lower area is limestone pavement. There is no evidence here of drift at the present time though erratics suggest its presence in the past. The pavement has peat islands which seem to have belonged to the same blanket peat which covers the upper area. The islands are therefore the eroded remains of a once more continous cover. The peat on the pavement either formed on a thin drift layer which has subsequently been washed into the grykes, or it formed directly on the limestone and the grykes beneath it have later become widened by solution. The base of the peat in contact with the limestone is now being oxidised.

4. The peats on Moughton and at Howrake Rocks are similar to those of Scar Close. The Moughton peat has formed on drift as in the upper Scar Close area, and the Howrake peat is now in direct contact with the limestone as in the islands of the pavement area.

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Zone.	Depth in Cms.	Ilex aquifolium.	Artemisia.	Umbelliferae.	Filipendula.	Drosera.	Taraxacum type.	Chenopodium.	Senecio type.	Valeriana.	Epilobium.	Caryophyllaceae.	Rumex type.	Cruciferae.	Rosaceae.	Ranunculus.	Matricaria type.	Potamogeton.	Lysimachia.	Polypodium.	Pteridium.
	10				1	1	1			1											
	30						1										1			1	5
V111	50											1							1	1	2
	70						1												1	4	1
	90			1		1	2		1											1	2
	110																1	1		2	8
	130															1				2	1
	150															1				5	
	170						1													6	
	190															1				2	1
	210																1			3	1
	220																			1	2
V11 b	230															1				1	1
	240	1																		1	
	250																			2	1
	270																			5	1
	280			1																3	1
	300															1				3	
	310								1					1						4	
	320															2				3	
	330				1									1			1			2	
V11 a	340		1	1				1					3	3		1	1			4	
	350			1									1							3	
	360			1																6	1
	370			2																1	1
	380				1										1	1				3	
	390			3									1							1	3
V1 b-c	400																			1	
	410																			1	3
	420							1													1
	430								1											2	1
	440													1							
	450				1								24								
	460					1	1				1	1									1
V1 a	470			1					1	1										1	
	480							1												2	
	490			1	1		1														
	500		1	2	15	3															
V																					

Table 1. Helwith Moss 11; Percentages of Ilex, pollen of "other herbs", and fern spores, based on total tree pollen.

Table 2. Helwith Moss 11: Percentages of Ilex, "other herbs", and fern spores based on total pollen.

Depth in Cms.	10	30	50	70	90	110	130	150	170	190	210	220	230	240	250	270	280	300	310	320	330	340	350	360	370	380	390	400	410	420	430	440	450	460	470	480	490	500	510	520
Pteridium.	1	1	+	1	2	+			+	+	+	+		+	+	+					+	+	+	+		+	1	+	1	+	1			1						
Polypodium.	+	1	1	+	+	1	2	3	1	1	1	+	+	1	2	1	1	1	1	1	2	1	2	+	1		+	+	+		1					+		+	1	1
Lysimachia.		+	+																																					
Matricaria.	+				+																																			
Potamogeton.					+					+																														
Rosaceae.				+		+	+		+			+					+		1		1	+				+														
Ranunculus.		+		+	+					1	+	+	+			+	1	+		1		+				+					+									
Cruciferae.																		+		+		1										+								
Rumex type.																						1	+				1						5							
Caryophyllaceae.		+								+											+													+						
Senecio.type.		+			+														+												+				+					
Drosera.	+				+					+																											+	+		
Menyanthes trifoliata.																																						1		
Umbelliferae.		+			+												+					+	+	+	1		1	+			+			+	+		+	+	+	
Taraxacum type.	+	1		+	+				+																			+						+						1
Valeriana.	+																																+					3	3	9
Filipendula.	+																				+	+				+	+						+							1
Artemisia.																						+																+		1
Chenopodium.																						+								+						+				1
Rubiaceae.																																							+	1
Myriophyllum alterniflorum.																																							1	26
Myriophyllum spicatum.																																								4
Myriophyllum verticillatum.																																								1
Ranunculus peltatus type.																																								1
Epilobium.																																								1
Thalictrum.																																								1
Ilex aquifolium.													+						+		+																			

Depth in Cms.	Ilex aquifolium.	Sambucus.	Taraxacum type.	Cirsium type.	Rumex type.	Matricaria type.	Ranunculus.	Umbelliferae.	Chenopodium.	Filipendula.	Rosaceae.	Potamogeton.	Rubiaceae.	Senecio type.	Artemisia.	Caryophyllaceae.	cf. Papaveraceae.	Drosera.	Potentilla type.	Centaurea nigra type.	Polypodium.	Pteridium.
30			1				2	1	1				1	1			2		1		5	1
40		1	3				5	1	1		3	35		5		1	3		4	1	8	2
50							1					10	1	3		1	1				8	3
60			1			1	6		1		2	1		2		1					4	1
70			1		1		5	2	1				3	1		1	3	1	1		4	1
80			2				1				3			1	1	1	1				5	2
90			1		1		1	1						1							1	1
100							1			4			1								1	1
110										4	1	1									10	
120	1		1	1	1	1	1	1	1												4	
130			2																			

Table 3a. Helwith Moss 6: Percentages of Ilex, Sambucus, pollen of "other herbs", and fern spores, based on total tree pollen.

Table 3b. Helwith Moss 6: Percentages of Ilex, Sambucus, pollen of "other herbs", and fern spores, based on total pollen.

Depth in Cms.	30	40	50	60	70	80	90	100	110	120	130
Pteridium.	+	+	+	+	+	1	+	+			
Polypodium.	1	2	2	1	1	1	1	+	3	1	
Centaurea nigra type.		+				+				+	
Potentilla type.	+	1			+						
Drosera.					+						
cf. Papaveraceae.	1	1	+		1	+					
Caryophyllaceae.		+	+	+						+	
Artemisia.					+	+					
Senecio type.	+	1	1	+	+	+	+				
Rubiaceae.	+		+		1	+					
Potamogeton.		9							+		
Rosaceae.		+	3	1		1			+		
Filipendula.								2	1		
Chenopodium.	+		+	+	+					+	
Umbelliferae.	+				+		+			+	
Ranunculus.	1	2	+	1	2	+	1	+		+	
Matricaria type.				+						+	
Rumex type.					+		+			+	
Cirsium type.									+		
Taraxacum type.	+	1		+	+	1	+			+	1
Sambucus.		+									
Ilex aquifolium.										+	

Spores.

Depth in cms.	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125	130	132.5	135	137.5	140	142.5	145	150	155	160	165	167.5
Cystopteris.													112	15																							
Dryopteris.				1			2	1	8	1	1	3	2	2	3	1			3	1	3	2	30	15	7	1			2			1		1	1		
Pteridium.																											1		1								
Polypodium.		1	2							1	1	1		1	1					1							1	1	4		1	1	1				1
Papilionaceae.		1	1																																		
Potentilla type.		3		1																																	
Cruciferae.		1										1																									
Armeria.																										1	1										
Epilobium.																												1	1								
Littorella.																															1						
Poterium sanguisorba.		1																												2		1					
Cirsium type.				1																											1		1				
Polygonum.																																		1			
Lysimachia.																																		1			
Plantago media.																											1						1		1		
Mentha type.														1																					1		
Rosaceae.	9	1								1		6	4	2	1										1		1				1		1	1	1		
Helianthemum.											1			1	1													1	1	5	3	4	4	1	1	1	1
Umbelliferae.	3		1							1		1						1						1		2	1	1	1		2	3	3	3	3	1	3
Ranunculus.	4	3	2	1			1				1							1	1	1		1			1	3	2	1	1		1	1	2	2	1	2	1
Caryophyllaceae.	1							1																	1	7	7	10	8	6	1	1	1	2	3	3	1
Rubiaceae.	1										1		1	1									1			1	2	1		1	2	3		1	2	1	3
Rumex type.																		1	1						1	3	3	1	4				3		8	7	8
Matricaria type.			1																								1	2	1	1			1		1	1	1
Senecio type.	1	1		1				1		1				1		1										1	1	1	2				1	1	1		1
Taraxacum type.																					1					1	1	1	1		2	3		2	3	3	1
Plantago major.															1												1				1		2				1
Chenopodium.	1												1	1													3	3	2						1	1	1
Nymphaea.								1		1	1	1	1	2	45	18	8	8	1				1	1	1										1	1	
Myriophyllum spicatum.																									1							1				1	
Myriophyllum alterniflorum.																									1	1		1	1			2	1			1	
Typha.														4	1	1		3					1		1	1						1	1			1	
Typha/Sparganium.															2	2	2				1			1			1	3	1			1		1	3	1	1
Potamogeton.														3	1		1	1	3	1			1										1		2	1	5

Table 4. Thieves Moss, 7: Percentages of herb pollen and spores based on total tree pollen.

Table 6. Thieves Moss 7: Percentages of herb pollen and spores based on total pollen.

Depth in cms.	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85
Cystopteris.												21	3				
Dryopteris.			+			+	+	2	+	+	1	1	+	1	+		
Pteridium.																	
Polypodium.	+	+							+	+	+		+	+			
Papilionaceae.	+	+															
Cruciferae.	+																
Potentilla type.	+		+														
Armeria.																	
Epilobium.																	
Littorella.																	
Poterium sanguisorba.																	
Cirsium type.			+														
Plantago media.															+		
Mentha type.																	
Rosaceae.	1	+										1	1	+	+		
Lysimachia.																	
Umbelliferae.	+										+	+					
Ranunculus.	1	1	1	+							+						
Caryophyllaceae.																	
Rubiaceae.											+						
Rumex type.																	
Senecio type.	+	+		+			+	+		+				+		+	
Taraxacum type.																	
Matricaria type.			+														
Plantago major.																	
Helianthemum.														+	+		
Chenopodium.													+	+			
Nymphaea.											+	+	+	8	4	2	2
Myriophyllum spicatum.																	
Myriophyllum alterniflorum.																	
Typha.														+	+		+
Typha/Sparganium.																+	
Potamogeton.														+	+		+

Depth in cms.	90	95	100	105	110	115	120	125	130	132.5	135	137.5	140	142.5	145	150	155	160	165	167.5
Cystopteris.																				
Dryopteris.		1	2	1	1	18	6	3	+			1			1		+	+		
Pteridium.										+		+								
Polypodium.		+					+			+	1	2		+	+	+				+
Papilionaceae.																				
Cruciferae.																				
Potentilla type.																				
Armeria.									+	+										
Epilobium.											+	+								
Littorella.														+						
Poterium sanguisorba.															+					
Cirsium type.								+						+		+				
Plantago media.				+						+						1		1		
Mentha type.																		+		
Rosaceae.								+		+						+	+	+	+	
Lysimachia.																			+	
Umbelliferae.	+			+			1	+	1	+	+	+		1	1	1	1	1	+	1
Ranunculus.	+	+	+		+			+	1	1	+	+		+	+	1	+	+	1	+
Caryophyllaceae.								+	3	5	4	3	2	+	+	+	1	1	1	+
Rubiaceae.						+			+	1	1		+	1	1		+	1	+	1
Rumex type.	+	1		+				+	1	1	+	2			+	1		3	2	3
Senecio type.									+	+	+	1		+	+	+	+	+		+
Taraxacum type.				+					+	1	1	1		1	1		1	1	1	+
Matricaria type.										1	1	+	+	+		+		+	+	+
Plantago major.											+	+		+		1				+
Helianthemum.			+								1	1	2	1	2	1	+	+	+	+
Chenopodium.										1	1	+			+			+	+	+
Nymphaea.	1	+					+	+										+	+	
Myriophyllum spicatum.						+		+							+					
Myriophyllum alterniflorum.								5			+	1			1	+			+	+
Typha.								+							+	+				+
Typha/Sparganium.	2			+						1	1	+			+		1	1	+	+
Potamogeton.		+	+													+		1	1	2

Table 6a. Thieves Moss 16: Percentages of herb pollen, and spores based on total tree pollen.

Depth in cms.	5	10	15	20	25	30	35	40	45	58
Dryopteris.									1	
Pteridium.	7	5	4	2	3	5	2	7		
Polypodium.	15	16	5	3	5	3	8	4	3	
Mentha type.		1								
Drosera.				1						
cf. Papaveraceae.				1	1	1				
Poterium sanguisorba.			1			1				
Matricaria type.					1					
Cirsium type.		1				1	1			
Centaurea type.							1			
Lotus type.								1		
Chenopodium.								1		
Artemesia.						1		1		
Potentilla type.	1				1	2	1	1	3	
Ranunculus.	1		1	2		1	1	1	1	
Rosaceae.	1	1	5	1	1	3	3	3	1	
Taraxacum.	1	2	1	1	1	1	2	1	1	
Rubiaceae.	1	1		1	1		5	2		1
Caryophyllaceae.	1	2				1				1
Thalictrum.				1			1			1
Senecio.	3	2	1	1		2	3	1	1	4
Helianthemum.		1			1	1		1	1	1
Umbelliferae.	1	3	1	1	1	3		2	1	2
Filipendula.	1		1	1		1			1	18
Myriophyllum alterniflorum.										1
Typha latifolia.										5
Typha/Sparganium.										22
Nymphaea.										1
Potamogeton.										1
Menyanthes.										

Table 6b. Thieves Moss 16: Percentages of herb pollen, and spores based on total pollen.

Depth in cms.	5	10	15	20	25	30	35	40	45	58
Dryopteris.									+	
Pteridium.	1	1	1	+	1	1	1	1		
Polypodium.	2	2	1	1	1	+	2	1	+	
Mentha type.		+								
Drosera.										
cf. Papaveraceae.				+	+	+				
Poterium sanguisorba.			+			+				
Matricaria type.					+					
Cirsium type.		+					+			
Centaurea type.							+			
Lotus type.										
Chenopodium.								+		
Artemisa.						+		+		
Potentilla type.					+	+			1	
Ranunculus.			+	+			+		+	
Rosaceae.	+	+	1	+	+	1	1	1	+	
Taraxacum.	+	+	+	+	+	+	+	+	+	
Rubiaceae.		+		+	+		+	+		+
Caryophyllaceae.		1				+				+
Thalictrum.										+
Senecio.	1	1				+	+	+	+	2
Helianthemum.		+						+		+
Umbelliferae.		+			+	+		1	+	1
Filipendula			+						+	5
Myriophyllum alterniflorum.										+
Typha latifolia.										1
Typha/Sparganium.										7
Nymphaea.										+
Potamogeton.										+
Menyanthes.										+

Table 7a. Thieves Moss A: Percentages of herb pollen, and spores based on total tree pollen.

Depth in cms.	20	25	30	35	40	45	50	55	60	65	70	75
Cystopteris.							1	1		1		
Dryopteris.							4	1	1	1		2
Pteridium.	1	2		2		1		1				
Polypodium.	3	1	1	1	1					1		
Taraxacum.												
Cirsium type.			1									
Chenopodium.					1							
Helianthemum.			1	1	1							
Potentilla type.					1		1					
Rubiaceae.							1					
Menyanthes.							1					
Caryophyllaceae.	1				1			1				
Ranunculus.		3	1	1	5	2			1			
Rosaceae.	1	1	1			1		1	1			
Senecio type.	2	1	1	1	1				1	1		
Thalictrum.										1		
Artemisia.				1				1		1		
Umbelliferae.			1	1	1		1		1		1	1
Filipendula.		1	1	1			3	1	1	1	1	5
Rumex.												1
Myriophyllum spicatum.											1	
Myriophyllum alterniflorum.							1					1
Typha latifolia.								2	1			
Typha/sparganium.											1	3
Nymphaea.						2	4	54	37	25	7	3
Potamogeton.						2			1	1	1	3

Table 7b. Thieves Moss A: Percentages of herb pollen, and spores, based on total pollen.

Depth in cms.	1	5	10	20	25	30	35	40	45	50	55	60	65	70	75
Cystopteris.											+		+		
Cryopteris.									1	1		+		1	
Pteridium.	1	1	+	+	1		1								
Polypodium.				1		+	+						+		
Taraxacum.			+												
Cirsium type.		+				+	+								
Chenopodium.			+					+							
Helianthemum.						+		+							
Potentilla type.	1	1	2					+		+					
Rubiaceae.	7	1	1												
Menyanthes.										+					
Caryophyllaceae.															
Ranunculus.		1	+		+	+	+	1	1			+			+
Rosaceae.															
Senecio type.															
Thalictrum.													+		
Artemisia.	1						+				+		+		
Umbelliferae.						+	+	+		+		+		+	+
Filipendula.			+		+	+	+			1	+	+	+	+	2
Rumex.															+
Myriophyllum spicatum.														+	
Myriophyllum alterniflorum.															+
Typha latifolia.											1	+			
Typha/sparganium.														+	2
Nymphaea.									+	1	12	8	6	2	1
Potamogeton.									1			+	+	+	1

Table 8a. Scar Close A1: Percentages of herb pollen and spores based on total pollen.

Depth in cms.	1	5	10	15	20	25	30	35	40	45	50	55	58	60
Pteridium.	1	2	3	3		+	+			+	1			1
Polypodium.												+	2	177
Thalictrum.	+													
Chenopodium.			+											
Artemisia.		+		+										
Rumex type.	1	+		+	+	+								
Cirsium type.	+	+				1					+			
Rosaceae.	+	+		1	1	3	+	1	1	+	+	1		
Umbelliferae.	+	+		+				+		+	+	1		
Rubiaceae.		+		+	1	2	+	+				1		
Centaurea nigra type.			+	+						+	+	+		
Filipendula.				+			+	+			1	+		
Papilionaceae.												+		
Ranunculus.	1	+	+	+	+	2	1		+	+			+	
Taraxacum type.	1	1	1	1	6	1	+	+		1	+	+	1	
Senecio type.		1	1	+	1	2							+	
Matricaria type.	1				1		+	+	+	+			+	
Polygala.					+	+							+	
Caryophyllaceae.			+		+			+		+		+	3	6
cf. Papaveraceae.												1	1	11

Depth in cms.	Pteridium.	Polypodium.	Thalictrum.	Chenopodium.	Artemisia.	Rumex type.	Cirsium type.	Rosaceae.	Umbelliferae.	Rubiaceae.	Centaurea nigra type.	Filipendula.	Papilionaceae.	Ranunculus.	Taraxacum type.	Senecio type.	Matricaria type.	Polygala.	Caryophyllaceae.	cf. Papaveraceae.
5									+					+					+	
10	+	+		1						+					2	1				
15	+						+	+	+					+		+				
20	+	1			+		+	1							+					
25		+					1			+	+			+	1			1		
30	1						1	1			+			+						
35					+			2	1		1				1					
40	+	+			1		+	2						+	+					
45		+		+				2												
50	2				+			2							+					
55	2		+	+				5						+	+					
60	2					+		3						+	+					
65	1	+	+			+	+	3						+	+				+	
70	1	8				+		3	1					1			+		4	3
75	1	5					+		1					1					3	3
80	+	46							1	+		+		1					4	3

Table 8b. Scar Close B1: Percentages of herb pollen and spores based on total pollen.

Depth in cms.	Pteridium.	Polypodium.	Polygala.	Rubiaceae.	Senecio type.	Taraxacum type.	Rumex type.	Chenopodium.	Umbelliferae.	Papilionaceae.	Matricaria type.	Rosaceae.	Cirsium type.	Ranunculus.	cf. Papaveraceae.	Filipendula.	Centaurea nigra type.	Caryophyllaceae.
1		+										1						
5	+	+				+									+			+
10	+	+	+		+	1						3	+	+			+	
15	+	2	+						+			6					+	
20	+											+		+				
25		+				+						+		+				+
28		1		+	+				+					1				3
30		2																3
35		7									+		+		1			3

Table 9a. Scar Close A2: Percentages of herb pollen and spores based on total pollen.

Depth in Cms.	5	10	15	20	25	30	35	40	45	50	55	60	65	70
Pteridium.	1	2	+	1	1	+	1	+	1	1	+	+	+	
Polypodium.						+	+				1	6	20	37
Polygala.						+		+						
Rubiaceae.	+	1		+	+			+						
Senecio type.								+						
Taraxacum type.	+	+			+	1	+	+	+		1			
Rumex type.										+	1			
Chenopodium.		+									+			
Umbelliferae.						1					+	+		
Papilionaceae.												+		
Matricaria type.				+		+		+					+	
Rosaceae.	+	+	+	+	+	2	3	1	+	1	8			+
Cirsium type.					+			+			+	1	+	+
Ranunculus.					+		1	1	+	+	+		1	1
cf. Papaveraceae.							+				+	1	2	1
Filipendula.							+					+		+
Centaurea nigra type.														+
Caryophyllaceae.												2	2	2

Table 9b. Scar Close B2: Percentages of herb pollen and spores based on total pollen.

Depth in Cms.	1	5	10	16	20	25	30	35	40	45	50	55	60	65	69	70
Pteridium.		1	1	1	1	1		1		+	+	1		+		1
Polypodium.			+		+		+	+			+	1	1	21	47	136
Labiatae.				+												
Rumex type.				+												
Cirsium type.																
Helianthemum.																
Centaurea nigra type.																
Matricaria type.	+		+	+	+	+		+								
Senecio type.	+	3		2	+		+	1								
Umbelliferae.		1	+	+		+	+			+						
Rubiaceae.		+	+	1							+					
Chenopodium.	+			+							+	+				
Artemisia.			+		+		+		+	+		+				
Filipendula.			+						+			+				
Taraxacum type.	+	1	3	+	+	+	3		+		+		+			
Rosaceae.	+		1	1	+		+	+		+	1	2		+		
Ranunculus.		2	1	1	1		+		+	+	+	+	+	1	1	
Cardamine.															+	
cf. Papaveraceae.													+	2	+	
Geranium.															+	
Caryophyllaceae.										+		+		5	1	1

Table 10a. Scar Close A3: Percentages of herb pollen and spores based on total pollen.

Table 10b. Scar Close B3: Percentages of herb pollen and spores based on total pollen.

Depth in Cms.	5	10	15	20	25	30	35	40	45
Pteridium.	+		1	1	+			+	1
Polypodium.					+	+	1	1	22
Labiatae.									
Rumex type.			+						
Cirsium type.				+					
Helianthemum.						+			
Centaurea nigra type.		+			1	+	+		
Matricaria type.			+						
Senecio type.	+		1		+				
Umbelliferae.			+		+		1	1	
Rubiaceae.	+		+						
Chenopodium.						+		+	
Artemisia.	+				+	+	+		
Filipendula.					+		2	+	+
Taraxacum type.		+		+	1	1		+	+
Rosaceae.			+	2		+			
Ranunculus.							+		+
Cardamine.									
cf. Papaveradeae.						+	1	+	
Geranium.									
Caryophyllaceae.			+			+	+	+	1

Table 11a. Scar Close A4: Percentages of herb pollen and spores based on total pollen.

Depth in Cms.	1	5	10	15	20	25	30	35	40	45	50	55	60	65
Pteridium.		+	+		1	+	+		1	1		1		+
Polypodium.	1					1		+		+			12	81
Thalictrum.														
Rumex type.					+									
Matricaria type.						+								
Centaurea nigra type.	+				1		1	+	1					
Filipendula.							+	+	18					
Epilobium.									+					
Papilionaceae.									5					
Senecio type.														
Scrophulariaceae.									1					
Cirsium type.									+					
Artemisia.								+		+				
Helianthemum.	2							+	+		+			
Rubiaceae.						1			+	+	+			
Taraxacum type.	1	+		+	+	1	1	+				+		
Chenopodium.						1						+		
Rosaceae.	+	+		+	+	1	+	+		+		2		+
Ranunculus.	1	+		1	+	+						1	+	1
Umbelliferae.	1					1	+		3	+			1	1
Caryophyllaceae.					+				+				6	1
cf. Papaveraceae.						+	+						2	1
Geranium.													+	+
Valeriana.														

Table 11b. Scar Close B4: Percentages of herb pollen and fern spores based on total pollen.

Depth in Cms.	2	9	14	17	21	26	31	34	36	41	46	47
Pteridium.	+							+		+	+	+
Polypodium.	+			+			+					+
Thalictrum.							+					
Rumex type.												
Matricaria type.	+				+							
Centaurea nigra type.												
Filipendula.					+				+	+	+	
Epilobium.												
Papilionaceae.												
Senecio type.		+		1				+	+		+	+
Schophulariaceae.												
Cirsium type.												
Artemisia.								+	+		+	+
Helianthemum.							+					
Rubiaceae.	+							+	+			
Taraxacum type.		+			+	1	1	1	6			+
Chenopodium.				+	+		+					
Rosaceae.						+	+	+	1			+
Ranunculus.		+				+	+	+	2			
Umbelliferae.					+	+					+	
Caryophyllaceae.				+					+			
cf. Papaveraceae.	+			+				+				
Geranium.												
Valeriana.												+

Table 12. Scar Close B1: Percentages of herb pollen and spores based on total tree pollen.

Depth in Cms.	5	15	20	30	35	40	50	60	70	75	80
Lycopodium annotinum.											1
Pteridium.	5	1	2	1	6	1	27	17	2	1	
Polypodium.	1	3	1	1	3	1		2	22	10	307
Senecio type.	3	1									
Polygala.			1								
Artemisia.		1		3	3						
Centaurea nigra type.				1	4						
Chenopodium.	1			1		1	2				
Cruciferae.	1						1				
Potentilla type.	1			17	9	13	5	27			
Taraxacum type.	1	1	2	5	1	1	3	4			
Rumex type.			1		1	1		2			
Thalictrum.								2			
Cirsium.type.		1	2		1			1	1		
Ranunculus.	5	1	1	2		2	1	4	3	1	7
Rosaceae.	3	4	1	25	17	20	28	22			1
Umbelliferae.	1	1	1		7		1		2	1	5
Filipendula.	1		1		1	1					1
Caryophyllaceae.	1			1			1		11	6	27
Rubiaceae.			1	3							1
Matricaria type.			1						1		1
cf. Papaveraceae.							1		8	6	26
Valeriana.											1

Depth in Cms.	1	5	10	15	20	25	30	35	40	45	50	51	57	30	40	50	51	57
	Based on total pollen.													Based on total tree pollen.				
Selaginella selaginoides.		+																
Lycopodium selago.		+																
Polytrichum.		1					+							2	1			
Pteridium.	1	+	1	1	1	+	+	+		1	1		1	7	1	5	1	3
Polypodium.											2	7	7	1	1	11	33	32
Ranunculus.															2			
Thalictrum.														5	1			
Drosera.																1		
Chenopodium.		+	+															
Centaurea nigra type.						+	+							2				
Helianthemum.						+			+						2	1		
Rubiaceae.									+						3			
Potentilla type.										+								
Polygala.											+					1		
Filipendula.											+				1	1	2	
Cirsium type.	+										+	1				1	3	
Taraxacum type.		+	1			+		+	1		+	1			12	3	3	
Matricaria type.		+	+									+		1			1	
Rosaceae.		+	+							1		+			2		1	
Caryophyllaceae.											+	1	+			5	1	1
Senecio type.	1		+	+	+	+							1		1	3	3	1
Umbelliferae.	+		+					+			1	2	1	2	2	5	11	1
cf. Papaveraceae.																8	4	5
Ilex.																1		

Table 13. Moughton 1: Detail of percentages of Ilex, herb pollen, and spores.

Depth in Cms.	Umbelliferae.	Caryophyllaceae.	Rosaceae.	cf. Papaveraceae.	Helianthemum.	Taraxacum.	Ranunculus.	Senecio type.	Chenopodium.	Rubiaccae.	Centaurea nigra type.	Polypodium.	Pteridium.
1	+					+		+			+		1
5	+						+		+	+			+
10			+			+	+	+					2
15						1							1
20	+		+										1
25	+				+							+	1
30				+	+								1
35	+			+									1
40			+										
45	+	1										14	

Table 14. Moughton 2: Percentages of herb pollen and spores based on total pollen.

Table 15. Howrake Rocks: Percentages of herb pollen and spores based on total pollen.

Depth in cms.	1	2.5	5	8	10
Cystopteris.	1				
Dryopteris.	70	11			
Pteridium.	1	1	+	+	1
Polypodium.	+	+	+		
Rubiaceae.	1				
Potentilla type.	4	+			
Artemesia.		+			
Rosaceae.	10	1			
Mercurialis.	5	1			
Filipendula.	+		+		
Cirsium type.	+	2	+	+	
Caryophyllaceae.		+	+		+
Chenopodium.	1	1		+	+
Ranunculus.	1	+	+		+
Umbelliferae.	+			1	+
Taraxacum type.	1	1	1	+	2
Senecio type.	2	7	4	2	1
Centaurea type.					1
Matricaria type.	+				+
cf. Papaveraceae.					+