A study of some Peat deposists of the sunbiggin Tarn area, near Orton, Westmorland

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Contents.

Maps and Diagrams.

I. Introduction.

Sunbiggin Tarn and its surrounding area, see Map 3 are situated in Central Westmorland, see Map 2, an upland area of moderate elevation that links the hills of the North Pennines to those of the south-eastern part of the Lake District, see Map 1. The area outlined consists basically of an escarpment of higher elevation to the north reaching up to about 400 m. in height which overlooks a lower, more undulating area to the south of around 250m. in height. The escarpment to the north is formed of Carboniferous limestone as is the lower area to the south, but in the latter case, it is overlain by variable amounts of glacial deposits.

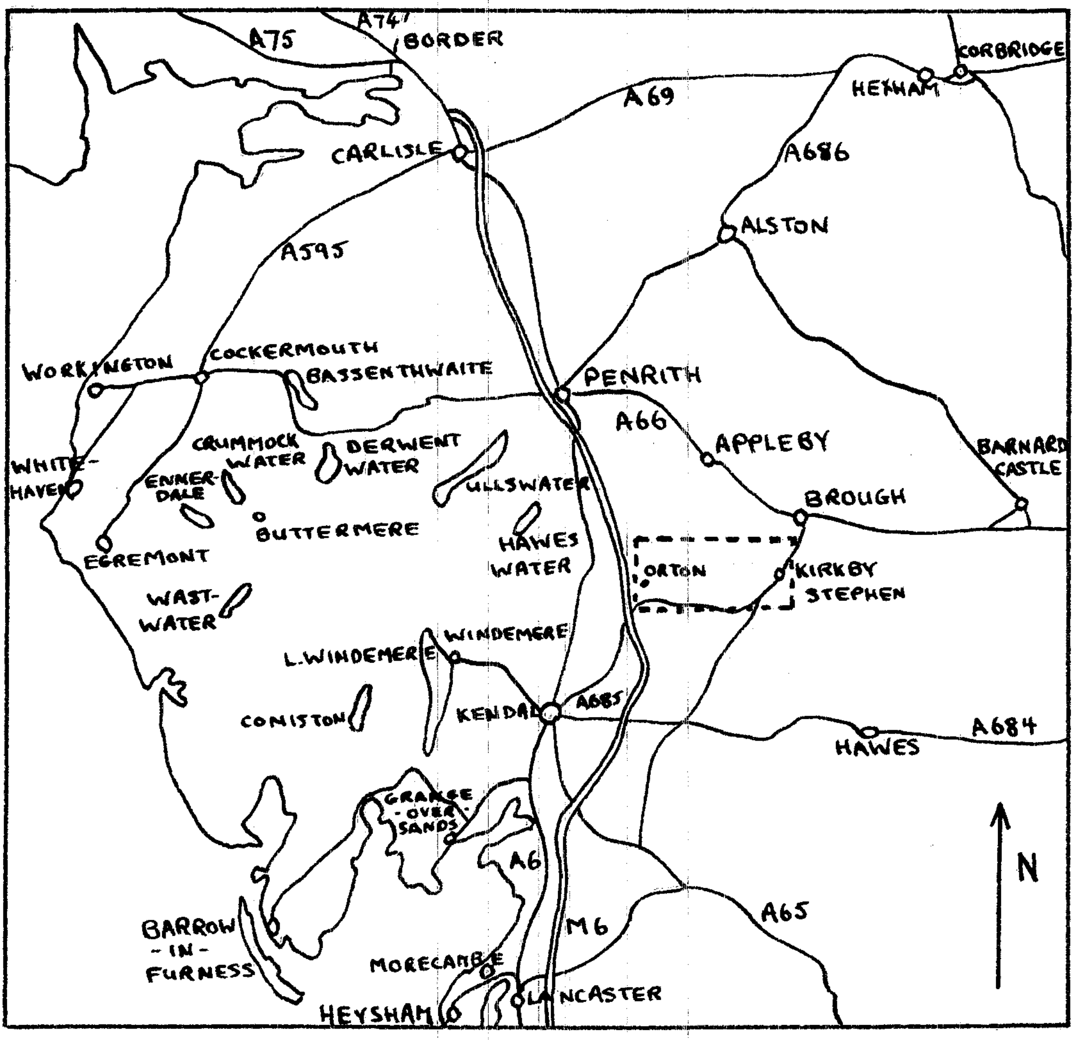
The area in which this investigation took place has also been the subject of two papers by Holdgate (1955). The first of these papers deals with the vegetation of some springs and wet flushes on Tarn Moor. This is described as an area of undulating moorland lying to the west of Sunbiggin Tarn, in the parish of Orton in Central Westmorland (Nat. Grid Reference NY/6707, lat. 54° 28'N long. 2° 30' W). The second paper is concerned with areas of 'rich fen'. Some of these occur in the area immediately surrounding the Tarn and Cow Dub, an irregularly shaped pool to the south of the Tarn, but also in some areas to the west of the Tarn.

The geology of the area is described by Holdgate as mainly of Carboniferous limestone locally interrupted by bands of sandstone and covered by a variable amount of drift, this information being taken from Dakyns, Tiddeman, Russell, Clough and Strahan (1891). This forms an uneven plateau about 250m.(825 ft.) above Ordnance Datum. The drainage upon these rocks and deposits is complex with numerous springs and swallow holes. To the north and south of this plateau are ridges rising to just over 300m.

Using data form Wilson (1938) and the Climatological Atlas (1952), Holdgate describes the climate as wet, with an annual rainfall of about 55 in. (1375 mm), with rain falling on about 225 days in the year. The mean annual temperature is approximately 44°F. (6.6°C.), July averaging 55°F. (12.8°C) and February 35°F. (1.6°C.). Snow-cover may be expected on about twenty-five mornings, and the 'growing season', when the mean monthly temperature exceeds 42°F. lasts from April to October (inclusive).

The moor is common land, being used for the grazing of sheep and cattle, the rights for this being based on a system of 'stints'. It supports a fluctating population of rabbits and is also preserved as a grouse moor, for which reason the drier parts are burnt periodically.

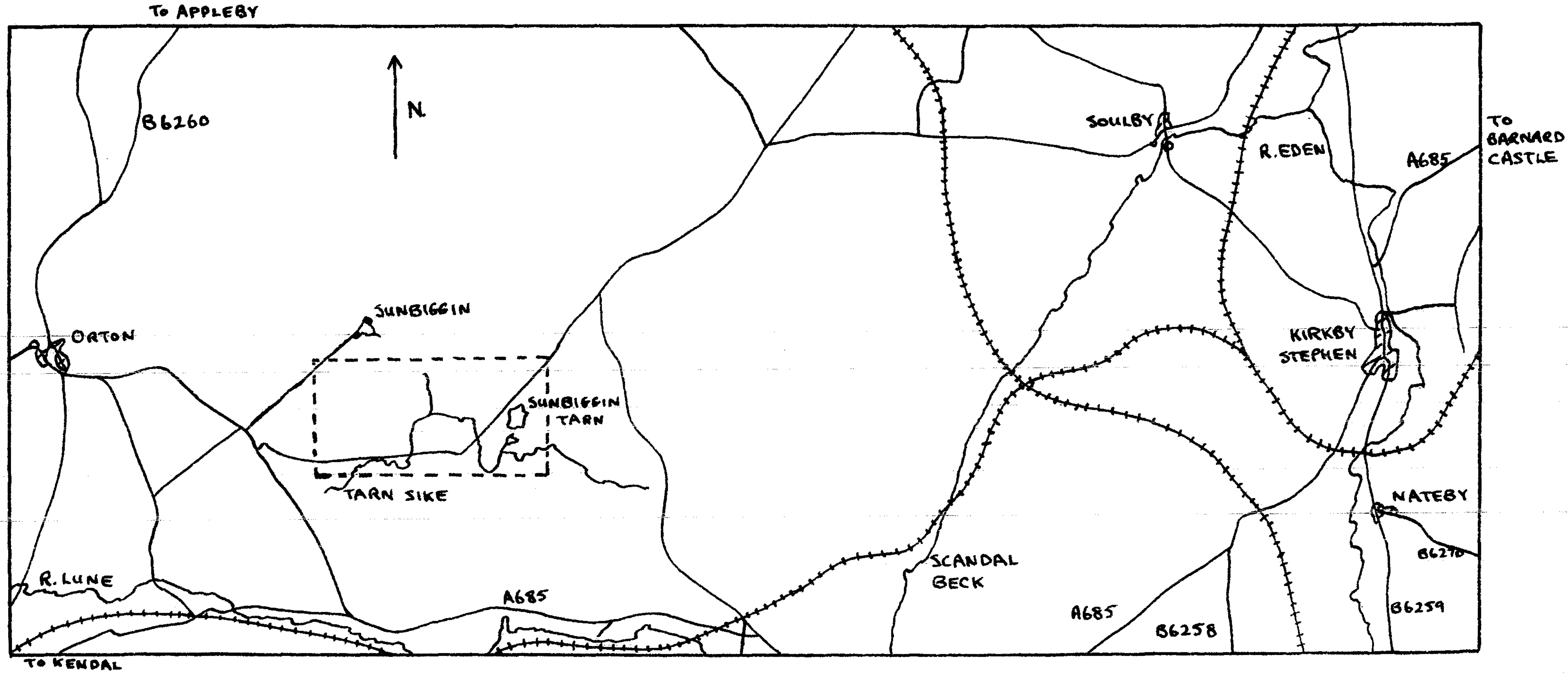
Glaciation has had a marked effect on the detailed topography of the moor, the summits of the low hills and ridges being drift covered. On such areas, Calluna vulgaris is dominant, being generally associated with Nardus stricta



Map 1. Showing the location of the general area of study, (inset), in the north-west of England.

Scale - approx. one inch to thirteen miles.

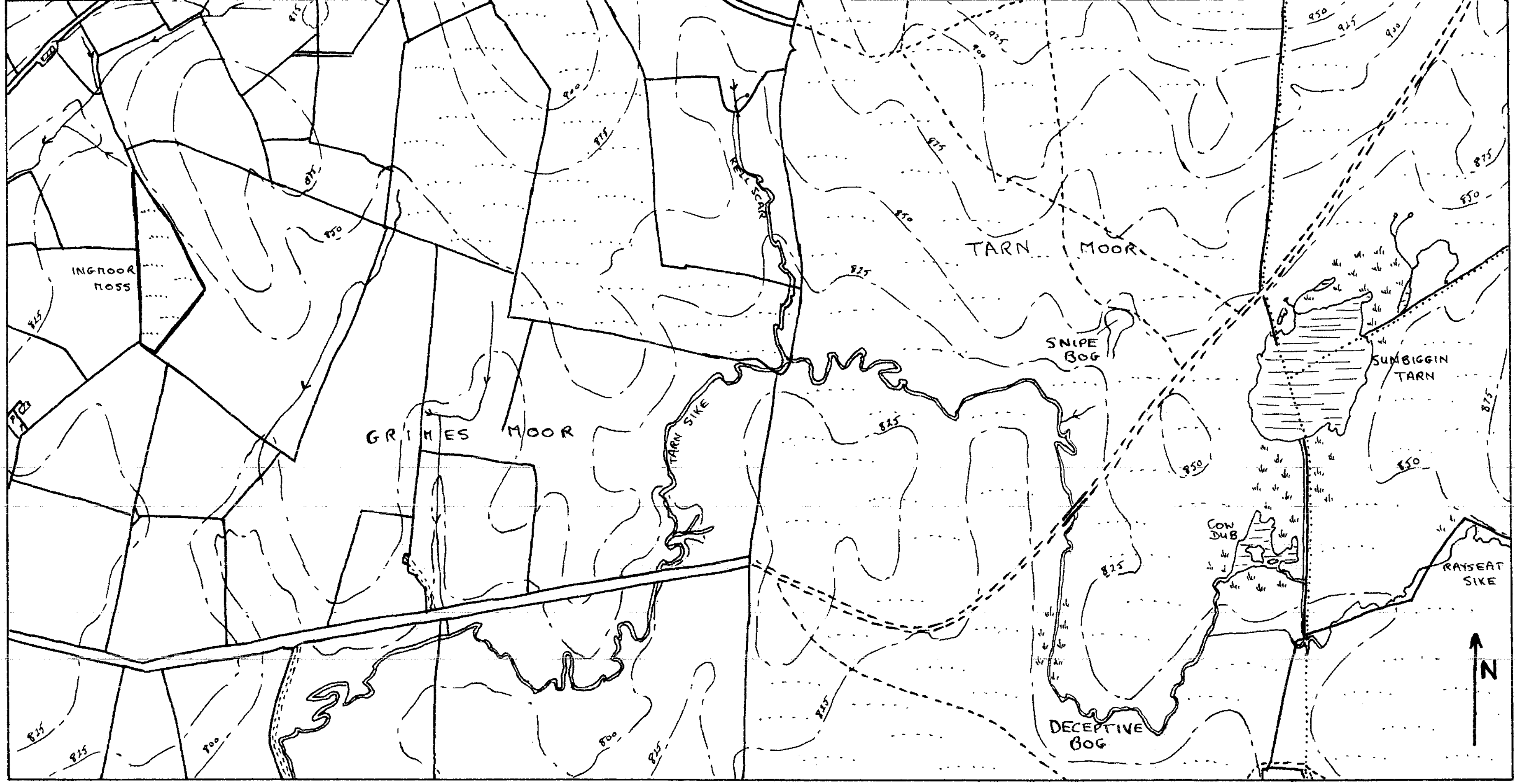
For enlargement of inset, see Map 2.



MAP 2. SHOWING THE POSITION OF THE PRECISE AREA OF STUDY IN RELATION TO THE POSITION OF KIRKBY STEPHEN.

SCALE - ONE INCH TO ONE MILE.

FOR ENLARGEMENT OF INSET, SEE MAP 3.



MAP 3. TOPOGRAPHY AND LANDUSE OF SUNBIGGIN TARN AREA SHOWING POSITIONS OF THE THREE BOGS STUDIED, SNIPE BOG, DECEPTIVE BOG AND INGMOOR MOSS.

SCALE - SIX INCHES TO ONE MILE.

- FENCED ROADS
- UNFENCED ROADS
- FOOTPATHS AND ROUGH TRACKS
- MAIN STREAMS
- RISES AND MINOR STREAMS
- 850 - CONTOURS - FIGURES IN FEET
- FENCED PASTURE
- ROUGH PASTURE, HEATHER AND MOOR
- MARSH
- OPEN WATER
- BUILDINGS

in the drier parts, while in wetter areas it is associated with Sphagnum spp., Polytrichum commune, Trichophorum caespitosum and Molinia caerulea. In more local areas where the drift is thinner, patches of more calcicolous species occur. Where the drift is absent altogether and the limestone outcrops, there is typical limestone grassland.

Between the low hills and ridges are numerous hollows and these Holdgate though might contain deep peat, supporting mires ranging from acid (ombrogenous) bogs to extremely alkaline fens.

Between these two areas of the Calluna moor and valley mires are belts dominated by small Carex spp. (e.g. C.panicea, C. lepidocarpa), and it is upon these belts that Holdgate's first paper is based, being the areas in which the springs and wet flushes occur. Basically these are areas where seepage of relatively enriched water of high alkalinity occurs, giving rise to a vegetation that falls under the heading of rich fen.

However, in the present study, it is the valley mires and the peat they contain that are of interest. It was thought that stratigraphical and palynological investigation of some of these deposits might prove interesting, mainly for two reasons.

Firstly, when one looks closely at the present day vegetation of the area, one notices how relatively rich the flora is. This is mainly attributable to the presence of the Carboniferous limestone which as mentioned gives rise to relatively rich ground water of high pH. The drainage of this water being very complex, it comes to the surface by seepage and springs in many places giving rise to a rich flora. Knowing this, and by means of palynological studies it was hoped to be able to spotlight the effects of the limestone on the vegetational history of the area.

The second point of interest concerns the extent of Sunbiggin Tarn itself. It was a theory of a member of staff within the Department that the Tarn was once much larger extending into an area to the south-west, which is now just a channel containing fen peat. Through this channel now flows Tarn Sike, a stream draining from the Tarn which meanders away to the west. In the second paper on the area, Holdgate gives evidence that the Tarn once covered a different area from that of today. This is thought so because borings to the south of the Tarn, between it and Cow Dub, and around Cow Dub itself, reveal open water deposits, showing that these two areas of water were probably once one. The objective of this part of the study was therefore to see if the Tarn once extended further still. By studying peat deposits in and adjacent to the channel to the south-west, and by determining the date at which formation started it was hoped to gain some idea of whether the Tarn did ever extend over a larger area and if so, how large an area and at what rate it receded to its present position.

Therefore, in selecting peat deposits to be studied, both these points were considered in attempting to find ones that would prove suitable.

The actual sites,studied are shown on Map 3. After a preliminary survey around the Tarn two sites were chosen. The first was named Snipe Bog, as at the time of study a Snipe was nesting on the bog surface. This is a small area of peat lying about 300m. to the west of Tarn. It has formed in a depression in the drift and at its southern end a peat-filled channel leads from it down towards the main channel in which Tarn Sike flows away to the west. The bog lies between the 825 ft. and 850 ft. contours.

The second site chosen was just under a half-a-mile to the south-west of the Tarn. This is in the main channel leading from the Tarn which at one time may have been submerged by the Tarn if it ever extended any further. The site lies just below the 825 ft. contour.

Thus two sites relevant to the aims of the study were chosen. Both were within a mile of the limestone pavement and also in areas affected by the drainage of the alkaline water. As regards the past extent of the Tarn, the second site at present lies below the level of the Tarn and thus would be expected to show evidence of open water it it ever covered that part. Snipe Bog was chosen because it lay just outside the main channel but at a greater height than the site in the channel. The aim of this was to see if the Tarn had once filled the channel, whether it had reached the level presently occupied by Snipe Bog. In fact when determined by means of a surveying level and staff the surface of the bog in the channel was found to be only about 13 feet below the surface of Snipe Bog, measured from the lowest transect points of each bog. It is therefore conceivable that both sites may once have been covered by the same body of water. In the original survey it appeared that there was a much greater height disparity between the bog surfaces and for this reason the second site was named Deceptive Bog.

At a later stage in the study it was considered necessary to look at another site in order to make the overall study more thorough. Fortunately there was an area about a mile to the west of the first two sites. This areas was discovered by studying a six-inch map of the area where the peat deposit, named Ingmoor Moss, was marked. Although it lay to the west of Tarn Moor, and was therefore not included in the area described by Holdgate, its general position was very similar, lying in approximately the same position in relation to the limestone escarpment on the same undulating plateau as Tarn Moor. Furthermore it showed the same type of drainage system so that it was felt that it would show a vegetational history similar to that that would be expected at the other two sites. Regarding the other point it was realised that it would have no value in determining whether the Tarn was once larger. This was considered not to matter as it was hoped that the original two sites would prove sufficient for this.

II Methods.

a) Fieldwork.

After the preliminary survey when the sites were chosen, another survey of each site was done to decide how best to treat each. In each case it was attempted to lay transects to cover the deepest part of the peat. This was done by a purely visual assessment when by looking at the nature of the slopes around the peat, it was hoped to be able to estimate correctly where the lowest part of the basin in which the peat was forming lay. When the positions of these were decided transects were laid right across the surface of the peat to the points where a change in slope from the peat surface to the surrounding slopes occurred. The transects were then continued for a sufficient distance up these slopes so that when levelled they would show up clearly on a profile the true slopes of the basin in which the peat was forming.

To start the laying of the transect two canes were pushed into the peat along the line required for the transect. Care was taken to make sure the canes were vertical. Using one of these as a base point other canes were then inserted along the line. The interval used between them was usually 5 metres but on the transect at one site 10 metre intervals were used. The measuring was done with a metre tape, care being taken to make sure that this was not slack to give a false measurement. The alignment of the stakes was done by eye and this proved completely satisfactory and no deviation of any of the transects occurred.

When finally in position a bearing was taken along each transect. In one case where a second transect was laid on the same bog, this was done at right angles to the first.

The next job in every case was to level along the transects as they were laid. This was done to measure the changes in height of the surface along the transect. The figures obtained were later to be used to draw up a profile of the surface at each transect. Also, in order to be able to correlate the stratigraphy it was essential to have some idea of relative height differences of the tops of the borings that were made along the transects.

The levelling was done by using a staff marked at half-centimetre intervals and a surveying level. At first the level was positioned on the exact position of one of the stakes while the staff was placed at other stakes, the base of the staff resting gently on the bog surface at the foot of the stake. To obtain accurate results, care was taken to ensure that the level was completely horizontal and that the staff was vertical. Readings were taken by looking through the level, where the middle of three horizontal lines within the level coincided with a reading on the staff. This was the correct figure.

However, it proved easier to take readings in another way. With the level positioned above one of the stakes, allowance had to be made for the height of the eye-piece of the level above the surface. This figure had to be substracted from all other readings in order to bring the stake at the position of the level into accordance with the others. Where the surface was changing considerably in height and the position of the level had to be changed often this resulted in complex figures. When the level was moved reference was always made from the new position to a stake whose relative height had been determined, before measuring those of new stakes. Thus it was possible to tie up figures right across the transect.

The alternative to this was to place the level in a position independent of the transect. Care was taken to select positions that would not necessitate frequent moving of the level. In this way, with the level positioned to the side of the transect, readings were obtained for the consecutive stakes for as long as readings could be taken through the level. The staff was again held vertically and special care was taken to see that the level remained horizontal as it was swung round to get the different stakes into view. The only extra calculation that took place in this way was when the position of the level was changed. Then a second reading was taken, as before, for the last stake used at the last position of the level. This enabled the figures right along the transect to be tied together. No figures needed to be taken of the height of the eyepiece above the ground as the level was independent of the transect. The heights of the surface at each stake could be calculated in relation to one another without this and this made the final plotting of the profiles much easier.

After completing the levelling at each site the stratigraphy of the deposit was then examined by use of boring equipment. In all cases any boring done was carried out at the stakes used in the levelling. In some cases where it was felt it would show the stratigraphy better boring was done at 5 metre intervals, but in others 10 metre and even 20 metre intervals were considered sufficient.

Two types of borer were used. While penetration was possible for it a Russian borer was used. At each boring 50 centimetre samples were taken. Starting with the top 50 centimetres, samples were taken lower and lower until penetration was no longer possible. For the samples deeper than 50 centimetres extension rods were fitted to the borer. Two holes were used at each stake both being situated closely adjacent to it. These were used alternatively to avoid taking a continuous sample from the same hole. This would have proved unsatisfactory as the point of the borer below the sampling chamber disturbed the top of the peat in the next 50 centimetre column below. By virtue of its action the Russian borer brought up an uncompressed and relatively undisturbed column of peat at each sample, which, when pieced together gave a complete representative column of the stratigraphy at the point of sampling. When penetration was no longer possible for another 50 centimetre depth, care was taken to measure how much further the borer had penetrated as the borer would have again taken some of the peat just sampled previously. This was discounted before continuing to note the stratigraphy.

When the Russian borer would penetrate no further, yet there were still deposits beneath, a screw auger was used. This had the disadvantage of compressing the deposit but still gave a sufficiently accurate picture of the stratigraphy. This was again used in alternate boreholes, bringing up 30 centimetre samples at a time, and was continued with until it would bore no deeper.

When noting the details of the stratigraphy as the cores were examined several points were watched for. Firstly any obvious differences in the type of peat and its colour were noted, and at what depths the changes from one sort to another occurred. Also recorded was whether these changes occured abruptly, or gradually and almost imperceptibly. This done the various layers were then pulled to pieces when the texture of each could be determined. At this stage a note was also made of the degree of humification. Attempts were made to identify any plant remains, especially in relatively undecomposed layers. Any remains of good structure that were not identifiable there and then were placed in air-tight specimen tubes, fully labelled, and taken back to the laboratory for identification. A special search was also made for other more discrete macro-remains such as seeds, leaves and pieces of wood which were also labelled and taken back to the laboratory.

Much inorganic material was also found in the peat, mainly at the first two sites. A note was made of what type was present, and how big a proportion it formed in the peat.

After completion of the stratigraphical investigation, when the position of the deepest peat was determined, cores were taken for pollen analytical studies. The procedure for this was exactly the same as before, but extreme care was taken to keep any contamination to an absolute unavoidable minimum. Before the first boring and between subsequent ones the borer was thoroughly washed in clean water. Then as each sample was pulled up, before opening the chamber the borer was cleaned of any peat stuck to it. Then on opening the chamber, the peat core was cleaned of any contaminating peat. A piece of clean plastic guttering, 50 centimetres in length was then placed over the peat which was slid off the blade of the borer. The guttering containing the peat, after having been fully labelled was then placed inside a clean polythene bag and wrapped up to prevent loss of moisture from the peat. Each sample was treated in this way until the whole depth of the core had been taken. Only the Russian borer was used. No samples for pollen analysis were taken by the screw auger.

All that remained to do in the field was to make brief sketch maps of the sites. No detailed study was done on the vegetation on and around the bogs, but the main areas, dominated by certain types of vegetation were mapped.

These are shown in maps 4,5 and 6 which show sketches of the three sites. Also included are the transects laid across the sites.

(i) Snipe Bog.

Map 4 is of Snipe Bog. The bog is surrounded mainly by Calluna moor, the Calluna being associated mainly with grasses and also Erica tetralix in the wetter areas. Many other species occur, but do not play a significant part in the vegetation. The vegetation of the bog itself is of a fen type being dominated by many species of sedges, mainly Carex spp., and Juncus spp. Again other species of minor importance occur such as Lady's Smock, (Cardamine pratensis) and the Bird's-eye Primrose, (Primula farinosa). To the east of the bog between the fen vegetation and the Calluna moor is a wide belt of grassland. This probably occurs where the drift thins and better drained conditions occur so that soil rather than peat has formed. A sward of very fine grass covers this area, probably heavily grazed by sheep. Associated with it are low-growing species including the Cowslip (Primula veris), Primula farinosa and the Early Purple Orchid, (Orchis mascula). This belt of grassland extends right along the northern edge of the bog and is followed by a rough track. Possibly this narrow strip of grass occurs because of human influence in the laying of the track. Equally possible is that the trackway was put here where an area of a drier nature occurred.

Two transects were laid across the bog. The first was at North 206^{o} and ran from the Calluna moor through the bog to where, at the southern end, it passed obliquely from the channel leading from the bog, back on to the Calluna moor. The second transect runs at right angles to the first at North 296^{o} and runs again from Calluna moor at the eastern side, through the grassy belt and across the bog surface before passing up onto the Calluna moor again on the western side of the bog.

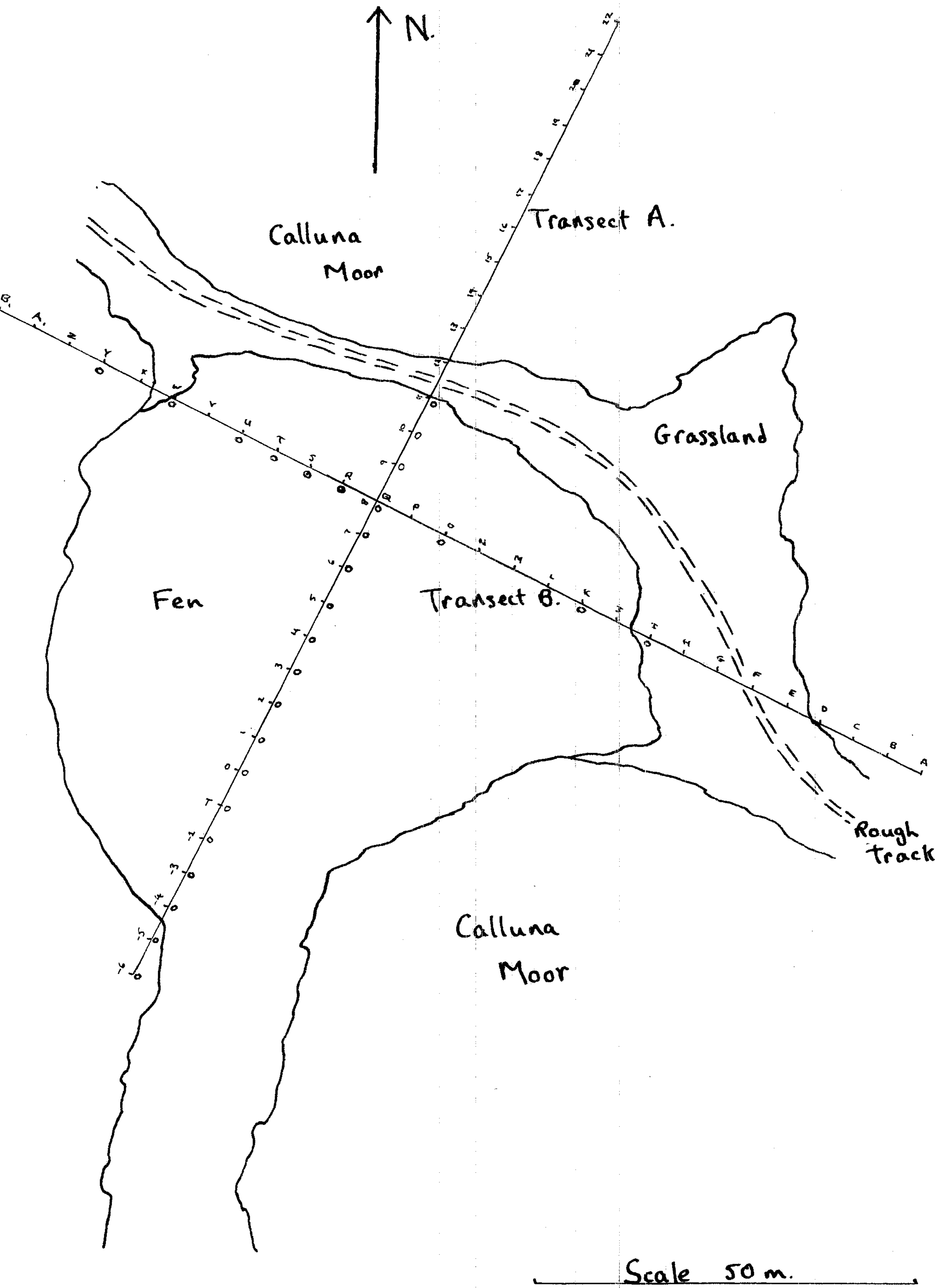
The position of the transects are shown on map 4 which also shows the zones of vegetation. The positions of the stakes are shown and also indication is given of at which stakes boring was carried out.

A similar procedure was carried out for the other two bogs.

(ii) Deceptive Bog.

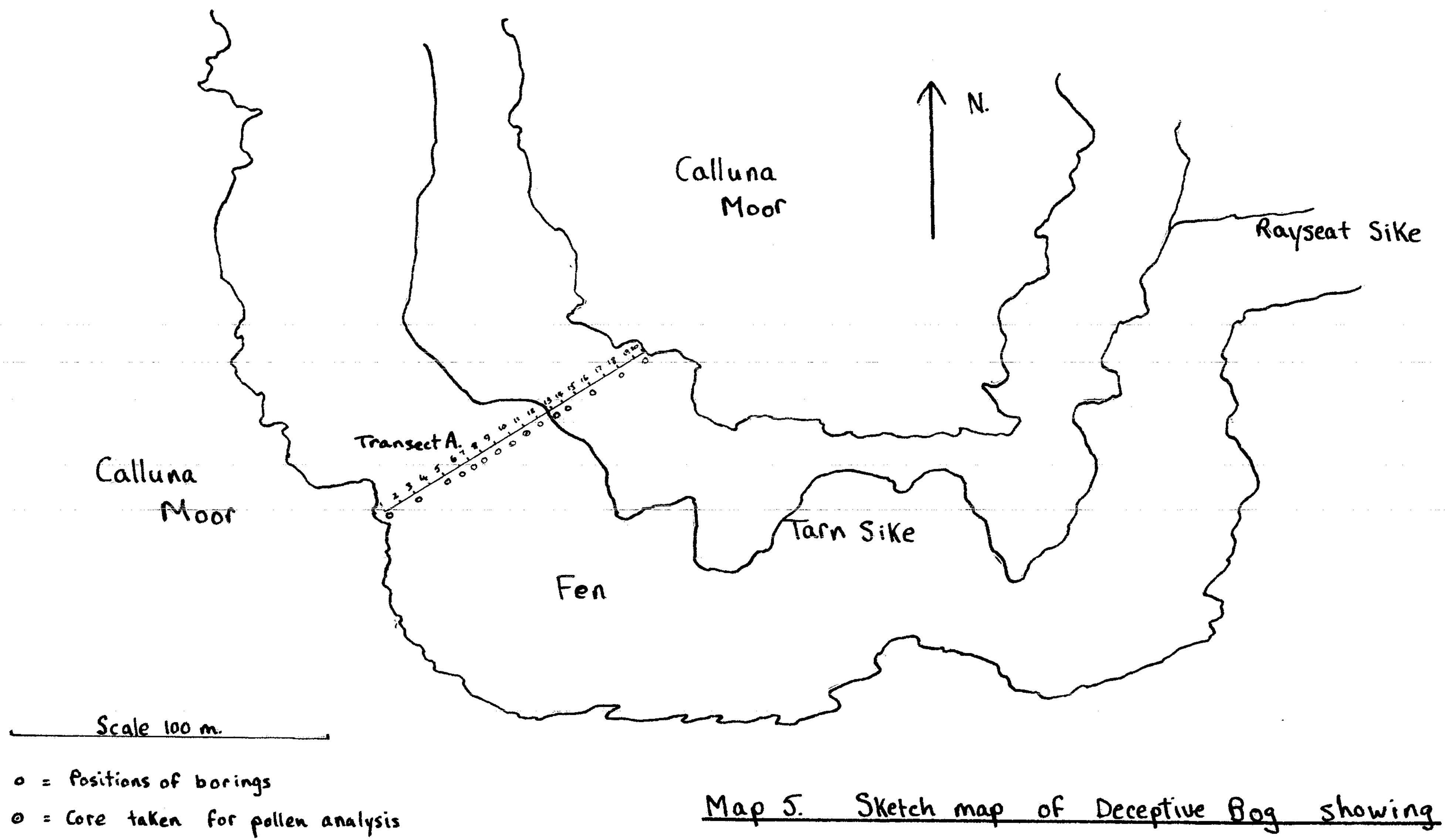
Map 5 shows the vegetation and position of the transect at Deceptive Bog. The channel here is also covered by a fen type of vegetation, similarly dominated by sedges but with a greater variety of other plants. Some grass is present mainly Holcus lanatus and Phragmites communis; also around Tarn Sike Meadow Sweet, (Filipendula ulmaria) and the Marsh Marigold, (Caltha palustris) are common. Many other typical fen species also occur.

Map 4 Sketch map of Snipe Bog showing vegetation and position of transects A and B.



o = Positions of borings

⊙ = Core taken for pollen analysis



Map 5. Sketch map of Deceptive Bog showing vegetation and position of transect A.

In a few slightly higher areas on the bog surface Sphagnum is becoming evident so that the area may possibly just be starting transition to raised bog. On either side of the bog where the ground rises the vegetation changes to Calluna moor, similar to around Snipe Bog, being associated chiefly with species of grass.

Only one transect was laid passing from the Calluna moor on the northern side through the bog to the Calluna on the southern side. It was laid roughly at right angles to the stream at a bearing of North 238°.

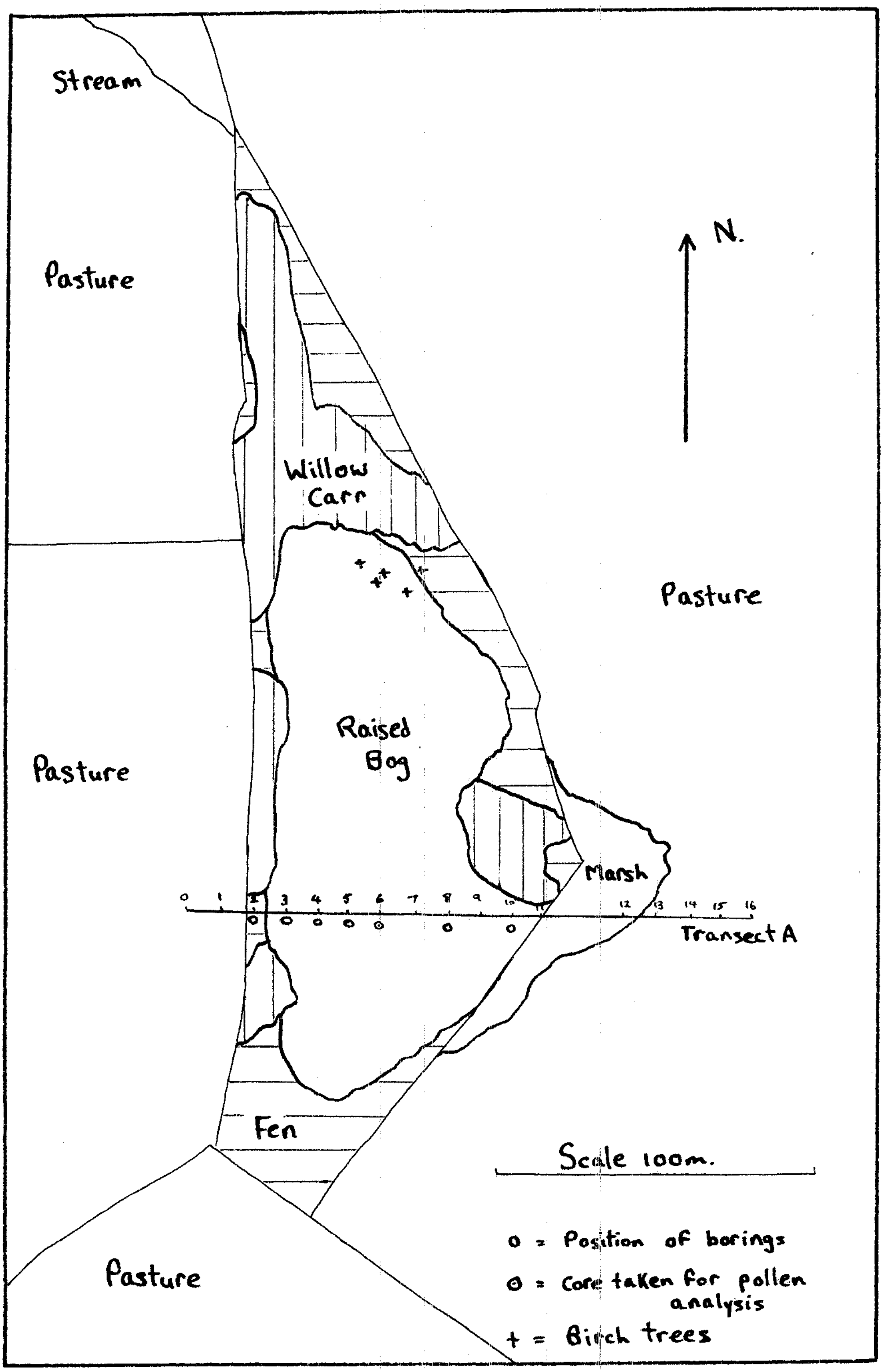
(iii) Ingmoor Moss.

At Ingmoor Moss shown in map 6, the nature of the site is quite different. The whole area is enclosed, being separated from the surrounding pasture by stone walls to the south and west and a wire fence to the east. It is assumed that this is purely to keep stock from the area as the surface of the bog is quite treacherous. Topographically the surrounding area is very similar to that around the other two sites being very undulating. However, the vegetation is very different. Whether the area was once similar, supporting Calluna moor on a thin peat cover which has been improved or whether the grassland was always present, the area now supports a fairly good pasture. Only in very low areas with bad drainage does the vegetation become poorer, being dominated mainly by Juncus spp.

Ingmoor Moss itself supports three main types of vegetation. Around the periphery patches of typical fen vegetation are found, dominated by sedges, but with some grasses and many other species including Filipendula ulmaria, Bogbean (Menyanthes trifoliata), Marsh Marigold (Caltha palustris), Potentilla palustis and in some places the Globe Flower (Trollius europaeus). Between the areas of fen vegetation are areas where what once must have been fen have now gone over to willow carr. These areas are dominated almost exclusively by Salix spp., with only an occasional tree of Hawthorn (Crataegus monogyna) at the extreme periphery of the site.

The centre of the site consists of a raised bog and is covered by a typical vegetation dominated by Calluna vulgaris, Eriophorum vaginatum and Sphagnum species. The latter species indicate a water table near the surface, as does the presence of the Cross-leaved Heath (Erica tetralix), and the Cranberry (Vaccinium oxycoccus). Also in evidence on the bog surface are the Bog Asphodel (Narthecium ossifragum) and Potentilla erecta. Occasional pools occur containing Menyanthes trifoliata with Potentilla palustris around them. A lichen, possibly Cladonia, is also common on the bog surface. A few birch trees were also present at the northern end of the raised bog.

Only one transect was laid, this being almost exactly from east to west across the site extending right across the bog and surrounding 'lagg' onto the pasture at each side of the bog. It was positioned to pass through the highest



Map 6. Sketch map of Ingmoor Moss showing vegetation and position of transect A.

point of the bog. The possibility of laying a transect through the same highest point at right angles to the first was considered. However borings at 40 metre intervals showed no difference in the basic stratigraphy or the depths of the main layers so a full scale investigation was not considered necessary.

b) Laboratory Work.

The first thing to do in the laboratory was to cut up the cores for pollen analysis. In all aspects of this, precautions were taken to see that no contamination occurred. All cutting surfaces used were wiped carefully between each cut and all tools used for handling the peat were also thoroughly cleaned after each time of use. When cutting of the peat was done cubes of material of roughly 1 c.c. were obtained. At each depth where a sample was required a piece was cut out of the core representing 1 centimetre's height of the core. This was then trimmed to remove the peat that had formed the outer parts of the core, leaving the 1 c.c. cube. As each specimen was prepared it was placed in an airtight, fully-labelled, specimen tube. When all the required samples from each core were completed, they were placed in a cool dark place until such time as they were wanted. Any peat not used for preparing samples was pulled to pieces and searched for any macro-fossils present.

When pollen analysis was to be started, samples were chosen to cover the complete core. Four samples were prepared at a time so that to start with one was taken from the bottom of the core, one from the top and two at regular intervals between. Subsequent samples were chosen to fill in these intervals evenly so that ideally, when completed, analysis of a complete column of levels, all the same vertical distance apart resulted.

The method used for preparation of pollen for counting was basically that described by Faegri and Iversen (1964). The sample was firstly broken down by boiling for a time in 10% potassium or sodium hydroxide, the mixture being immersed in a boiling tube in a boiling bath, and stirred occasionally with a glass rod. The mixture was then filtered through a fine mesh sieve, the filtrate being retained. The material retained in the sieve was washed and retained for subsequent macroscopic investigation. The filtrate was then washed with distilled water to remove the hydroxide and then dehydrated with glacial acetic acid. At each stage and between all subsequent stages the sample was centrifuged and the supernatant liquid poured off. Next acetolysis was carried out in order to remove the cellulose of leves, rootlets and such material. 10 c.c. of acetic anhydride and 1 c.c. of concentrated sulpharic acid were added and the mixture heated in a boiling tube in a water bath for 1 minute. After centrifuging and pouring off the supernatant it was washed again with a few drops of glacial acetic acid and distilled water and a few drops of caustic alkali was added to the final washing with distilled water before being ready to mount.

In addition to this standard preparation it was necessary in some cases to give additional treatment. In samples with a high content of calcium carbonate, this was first dissolved by treatment with cold 10% hydrochloric acid. This was done before heating with caustic alkali. In samples with a high content of siliceous materials such as clay, silt or sand it was necessary to remove this as such materials on a slide make counting difficult. These were removed by boiling for about two to three minutes in 40% hydrofluoric acid in a platinum crucible, taking suitable safety precautions for this reagent. After centrifuging, the solids were heated with 10% hydrochloric acid to remove colloidal silica and silicofluorides and centrifuged while hot. No samples needed to be treated a second time. This treatment was done after heating with the caustic alkali, and before the acetolysis.

To mount, molten glycerol jelly containing safranin was added to the pollen, about twice as much jelly as pollen present being added. The sample was stirred thoroughly and kept molten and then one drop was placed on a clean 3" x 1" microscope slide and covered with a 22 millimetre coverslip. The jelly was spread to cover the whole area of the coverslip by heating over a hot waterbath. As they were mounted, the slides were checked to ensure that they would be suitable to count, decreasing or increasing the amount of mixture on each slide as necessary. Finally, when the jelly was set the slides, four prepared at every level, were fully labelled.

Counting was done with a normal microscope by moving the slide across the microscope stage so that continuous transects were counted from one edge of the slide to the other. Care was taken to ensure that at least one diameter's width of the field of view was left between all transects to avoid any possibility of counting the same grain twice. Transects were counted across the whole width of the coverslip to overcome irregular distribution of pollen grains. All pollen grains and other microspores were counted, except those which were not identifiable. Frequent reference was made to a key, (Faegri and Iversen 1964), to run down grains not immediately recognizable and the assistance of a trained palynologist was asked for to confirm grains that had been run down and to give some guidance on real problem grains. Reference was also made to a collection of mounted material.

The total of pollen counted depended on the proportions of pollen types present on the slide. In all cases the original count aimed at was 150 tree pollen grains with whatever other non-tree pollen grains and microspores were counted in reaching this total. If however a total of tree and non-tree pollen of 500 was reached before 150 tree grains then this total was used. Spores of ferns and mosses were not included in this total of 500. On slides with very sparse pollen, as often happens with slides such as those prepared from late-Glacial deposits a total of 200 grains was used. This was not thought to be as accurate as if 500 grains had been counted but as such slides were extremely time-consuming the limit was drawn at 200 grains.

The macroremains from the sieving after treatment with caustic alkali were studied with the aid of a low-power binocular microscope. A note was made of any recognisable remains indicating the presence of certain genera and species. Some Sphagnum species and some other bryophytes in good condition were run down with keys. Any seeds present were also identified. The same was done with other macrofossils extracted during the fieldwork. Any pieces of wood found were thinly sectioned transversely to enable them to be identified.

III Results.

a) Stratigraphy.

The results of the stratigraphical investigation of the bogs are represented diagrammatically in figures 1 to 4 inclusive. Each figure shows firstly a profile of the bog along the corresponding transect with a line drawn in to represent the base of the organic deposits. This is at the point where the deposits change from being predominantly organic material to mainly inorganic material. Beneath each profile is an exploded diagram of the stratigraphy. The symbols for this are based mainly on those given by West (1969) but where these are not entirely satisfactory they are modified slightly using those shown in Faegri and Iversen, (1964), or other improvised ones.

(i) Snipe Bog.

The findings from the two transects across Snipe Bog are shown in the diagrams in figures 1 and 2 which represent transects A and B respectively. On transect A stakes 17 to 22 shown on the sketch map in map 4 have been missed out from the profile. These did nothing more than confirm that the slope above the bog continued to rise at the same angle. A quick look at the profiles of these transects shows that the peat has formed in a fairly typical basin which has a channel leading from its southern end. This hollow is formed in glacial deposits that have been laid down over the area. These are evident when one looks at the basal deposits of the boreholes where various admixtures of clay, sand, silt and stones are present, mixed with the bottom organic deposits in places. These deposits have undergone some water sorting, with deposits of finer silt and clay on the flatter parts with coarser sand and angular stones on the steeper slopes of the basin. Evidence of the presence once of open water is shown in transect B, where to the western part of the bog, fine blue-grey lacustrine clay has been laid down in a deeper hollow in the glacial deposits. These deposits form a lens of clay, slightly silty in places between the underlying glacial till and the organic deposits forming on top.

Figure 1. Transect A Snipe Bog. Bearing N 206°

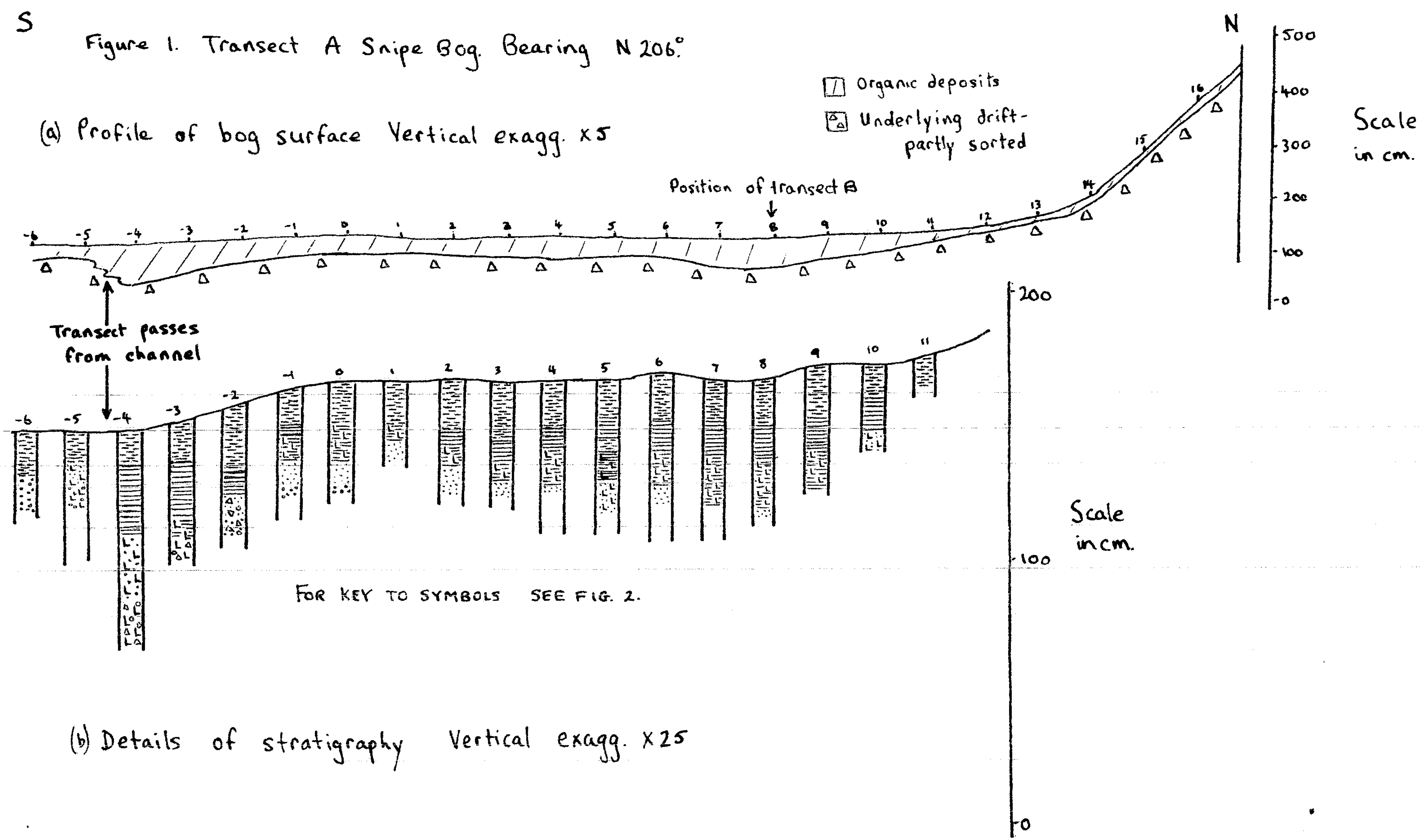
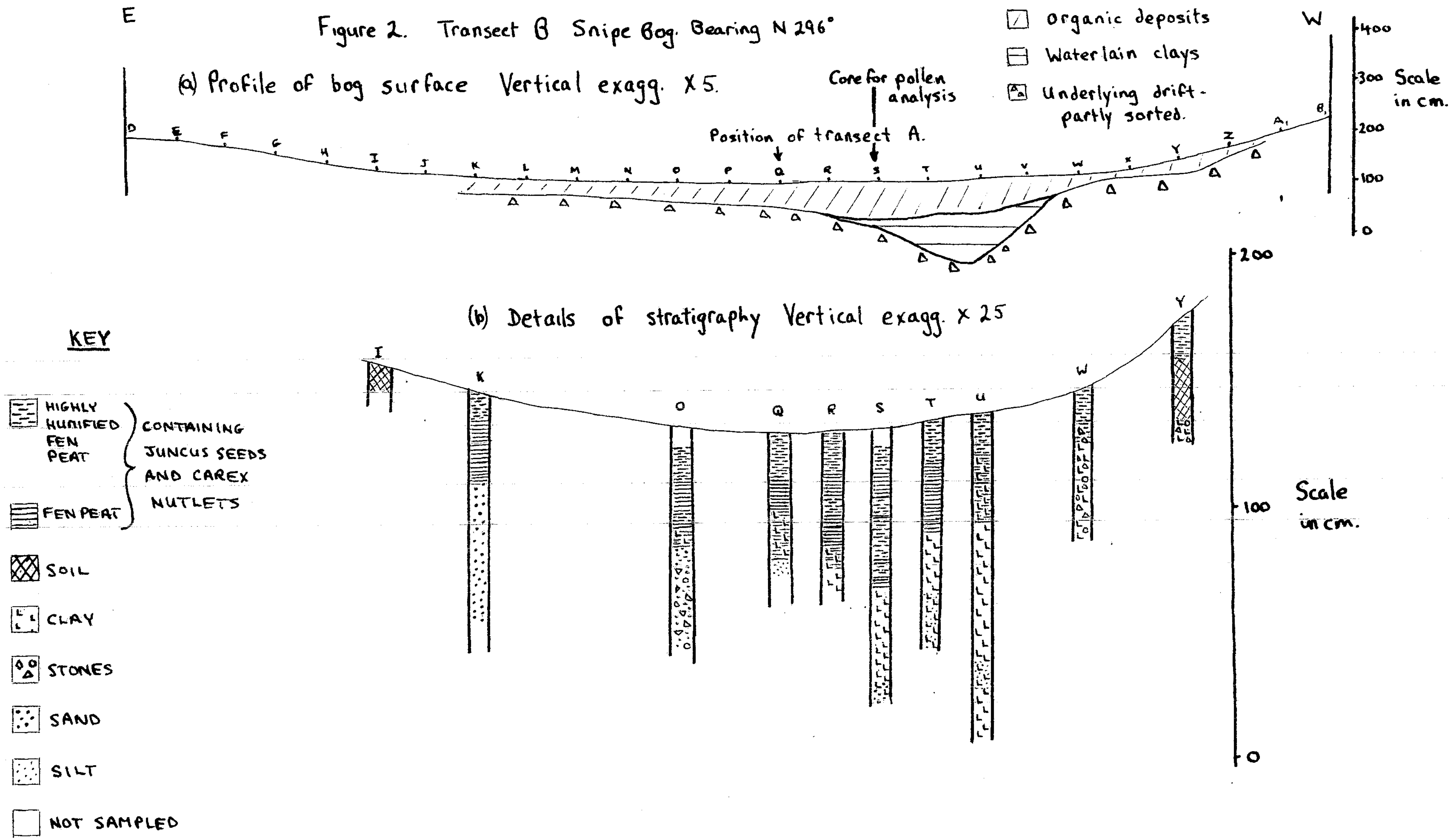


Figure 2. Transect B Snipe Bog. Bearing N 296°



The organic deposits consist basically of three layers:-

a) a lower peaty clay,
b) a peat of moderate humification above this,
c) an upper well humified peat.

All levels contained nutlets of Carex spp., and seeds of both Juncus articulatus and Juncus effusus so it is probable that the peat is very much all the same, a type of fen peat, the differences being accounted for by the amounts of inorganic material, the size of organic particles and the degree of humification of the peat.

Variations of this above pattern do occur as at some boreholes certain bands are missed out. Also difficulty in differentiating the layers was experienced at some holes due to variable humification of the peat having occurred. Stakes -5 and -6 on transect A are also not regarded as representative as it was at this point that the transect passed out of the channel onto the Calluna moor. The stratigraphy here just represents the blanket peat lying directly above the sorted drift. The details, including the information from the macrofossils are included on the diagram.

(ii) Deceptive Bog.

Figure 3 shows the same details for Deceptive Bog. In the profile stakes 1, 2 and 20 shown on the sketch map have been missed out for the same reason as at Snipe Bog. The profile shows the channel to be a flattish round-bottomed valley within which peat deposits have formed. The nature is very similar to at Snipe Bog. The channel is carved out of the glacial deposits which to some extent have been water sorted. The organic deposits however are much more difficult to correlate. In general they follow loosely the same general pattern. In the lower layers there is much mixing of organic and inorganic materials. Only does the very top layer of modern, well humified peat appear continuous across the stratigraphy. The details of the borings are shown in figure 3 but no attempt is made to correlate them.

(iii) Ingmoor Moss.

The stratigraphy of Ingmoor Moss shows a great deal more of interest than the first two sites. The details are shown in figure 4. Good regularity is shown throughout the deposit.

The base of the deposit consists of layers of blue-grey clay and calcareous gyttja, the latter grading into a detritus mud in places. At all boreholes where both were reached the gyttja was overlying the blue-grey clay. At stakes 3 and 4 a second layer of calcareous gyttja was found beneath the blue-grey clay. Comparing these with other boreholes it is likely that this layer would have been reached in other cases if deeper boring had been possible. The blue-grey clay contained no macrofossils except for one piece of fossil coral, probably derived from the limestone in the area. The clay was light-coloured and fairly soft at the top but became darker and stiffer towards its base. Occasional large, ($1\frac{1}{2}$ centimetre diameter), angular stones were found within it. The upper layer of gyttja was especially interesting as it contained numerous

Figure 3. Transect A
Deceptive Bog.

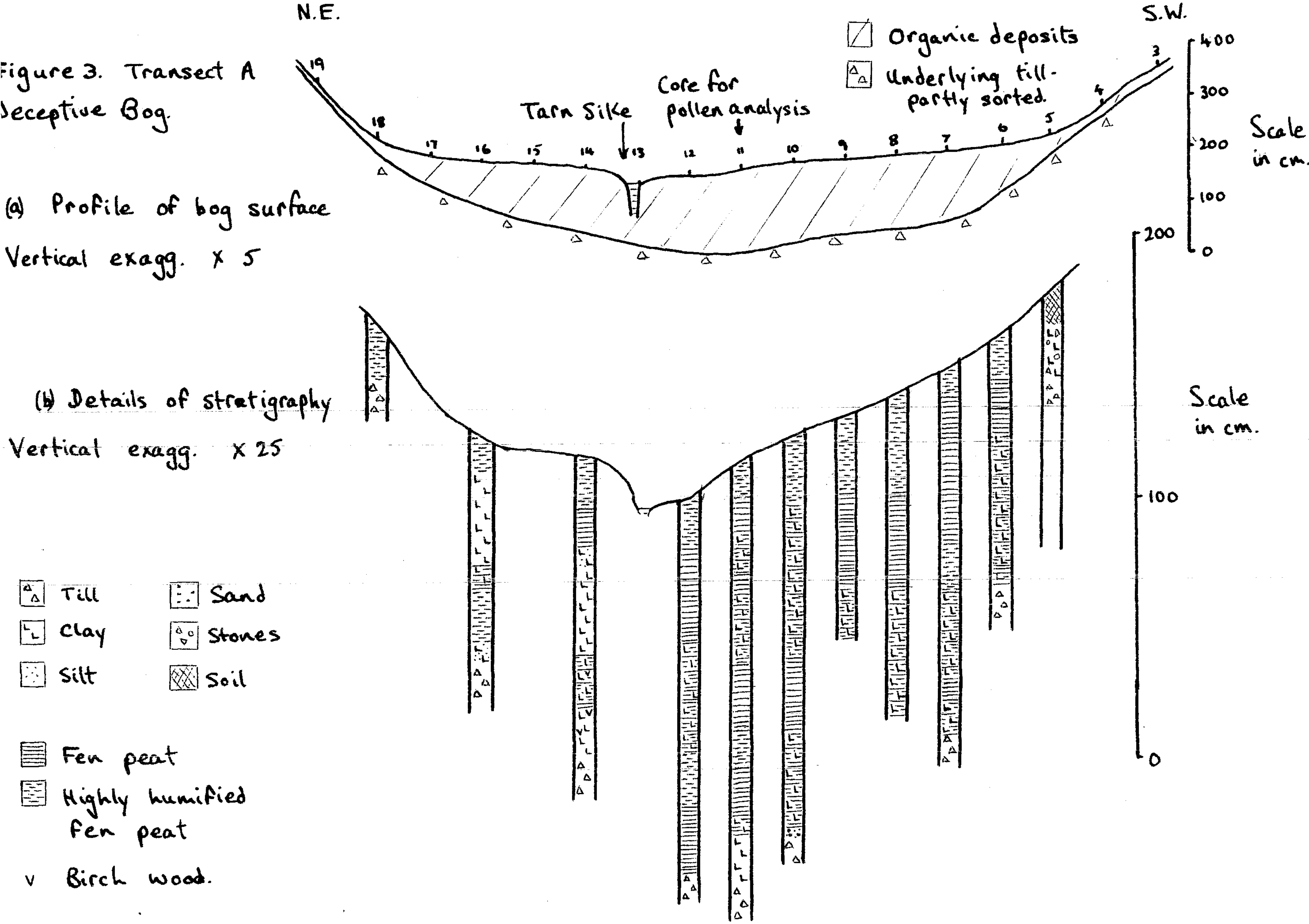
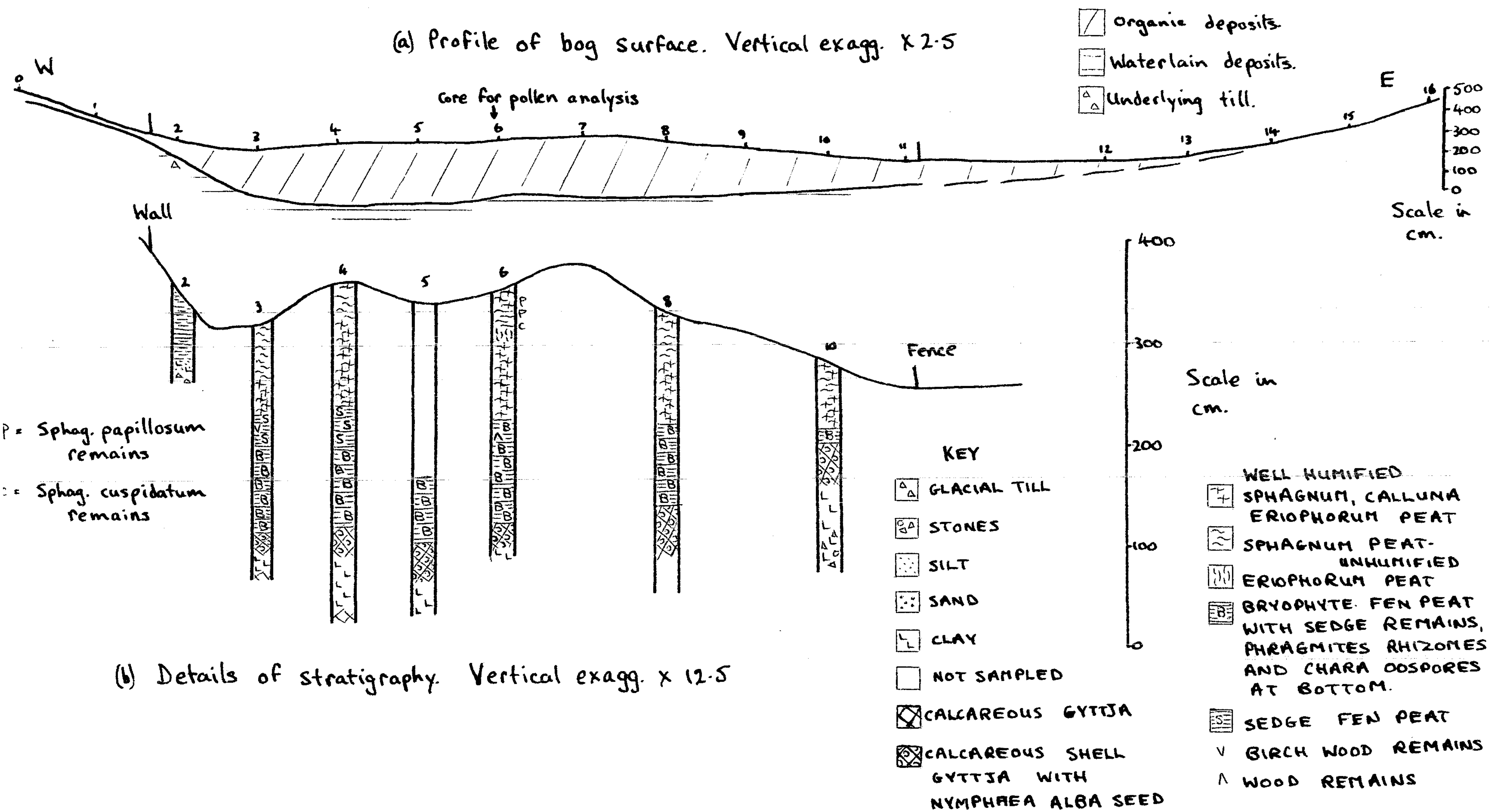


Figure 4. Transect A Ingmoor Moss. Bearing N 274°



well preserved mollusc shells, both of gastropods and bivalves.

These were of several species, kindly identified in the first instance by Mr. Charles Steel, who referred to Boycott,(1918). Using these identifications, a further study was made in order to recognise these species, in this case with reference to Macan, (1960). They are listed below;-

Gastropods

Lymnaea peregra
Valvata piscinalis
Planorbis crista
P. laevis
P. albus

Bivalves

Probably at least three species of *Pisidia*, possibly including

Pisidium nitidum
P. subtruncatum.

No stratification of the species was observed, their distribution being fairly random throughout the deposit.

At the top of the gyttja a transition occurred, gradual in places but sometimes quite marked. This was from the gyttja to a fen peat. This was mainly a bryophyte peat but with some sedge remains. Some of the mosses were identifiable with the aid of a key, (Watson,1966), and the following were recognized:-

Scorpidium scorpioides
Acrocladium giganteum
and one probably *Drepanocladus*, possibly *exannulatum*.

Phragmites remains were found regularly throughout this layer. Towards the top of this fen peat in places, sedges became dominant in the peat. Some wood was also found here, some of which was identifiable as *Betula*.

Above this a transition to raised bog occurred. This peat was variously composed of well humified *Sphagnum*, *Calluna* and *Eriophorum* remains but in places bands of mainly unhumified *Sphagnum* remains occurred.

The exception to this general pattern is seen at stake 2. This boring was taken through the 'lagg' at the side of the raised bog and consisted of a thin band of sandy clay resting on underlying till and above which lay about a half a metre of highly humified fen peat. More details are included in the diagram of the stratigraphy in figure 4.

b) Pollen analysis.

The results of the pollen analysis are summarized in the three diagrams in figures 5 and 6. In these diagrams everything was calculated as a percentage of the total tree pollen. Further information was gained by producing a tree-shrub-herb ratio. This was done for each level by expressing each of the three pollen types as a percentage of the total number of grains for all the three types. It was done in an attempt to give some idea of the relative proportions of these three types of vegetation and also to see how they changed throughout the vegetational history.

When studying the pollen diagrams it will be noticed that those from Snipe Bog and Deceptive Bog had very few levels counted on them. This is tied up with the fact that as the study progressed it was considered necessary to find another area of peat to work on, as mentioned earlier. This was because when pollen analysis was started on the peat from Snipe Bog, the pollen was found to be in a very poor state of preservation and some extremely difficult to identify. This was considered to be possibly due to the nature of the peat which, being a fen peat, was not acid and therefore possibly allowed some decomposition of the pollen. Also most levels contained some siliceous matter whicn may have contributed to erosion of the pollen, both physically, in situ, and by necessitating the use of hydrofluoric acid.

Although with enough work it was possible to identify most of the pollen, it was very time consuming. Therefore only four levels were counted from Snipe Bog to start with. It was feared, due to its similarity, that the pollen from Deceptive Bog would also be difficult to count. Therefore the next lot of counting was done from the peat of Ingmoor Moss. As will be seen from the diagram this produced a good pollen diagram stretching almost from the late-Glacial period to the present day. This was fortunate and it was therefore used as the main diagram for the area. Four levels were later analysed from a core from Deceptive Bog. The intention was to use that from Ingmoor Moss as a kind of yardstick and to try and fit the outline diagrams from the other two bogs into this to get some idea of the period they covered.

To start with an attempt was made to zone the levels on the diagram from Ingmoor Moss based on the zonation created by Godwin, (1940). The very base of the core analysed showed a pollen spectrum like that of Zone III of late-Glacial deposits. Some difficulty was experienced in placing the boundary of Zones III and IV however, for a number of reasons. Firstly, the bottom two layers showed the presence of considerable quantities of pollen of typical late-Glacial plants such as Artemisia and Thalictrum, together with many other open-habitat plants such as members of the Caryophyllaceae, Compositae and also Rumex, Filipendula, grasses and sedges. Less typically however Salix is quite low and Betula and Pinus quite high so that tree pollen forms a higher percentage now (about 30%), of the total pollen than it does at times during the mid-post-Glacial. This, together with the fact than no Juniperus pollen was recognised, and therefore no marked rise in Zone IV of the post-Glacial was observed, and the fact that no marked rise in Betula occurred made it difficult to place the boundary. It was in fact placed between the 265 cm. and 255 cm. levels. It was here that the percentages of Artemisia and in particular Thalictrum dropped quite markedly, and Betula and total tree pollen showed a slight rise. This was considered to be about the best possible position and further weight was given to this from the change in stratigraphy. It was at about this level that the blue-grey clay, taken to represent the lake clays laid down in Zone III of the late-Glacial changed to the calcareous gyttja, a more organic material deposited in Zone IV.

Zone IV, the pre-Boreal period is typified by a decrease in the quantity of herb pollen while that of Betula and Pinus increases. We see the spread of a pre-Boreal birch-pine forest dominated by birch. The zone ends and passes onto Zone V of the Boreal period when Corylus first appears and quickly increases in amount. Betula remains fairly high throughout the zone but falls away at the top when a large increase in Pinus occurs.

The boundary between Zones V and VI is placed where the thermophilous trees Quercus and Ulmus first play a significant part in the tree pollen spectrum. A possible subdivision of the zone into three parts, as recognised by Godwin is given. The main criteria for this are not outstandingly clear but there are certain features that show up. Firstly there is an area where Ulmus exceeds Quercus and where Corylus has its maximum corresponding to Zone VIa. Then Quercus exceeds Ulmus corresponding with Zone VIb before Alnus first appears denoting Zone VIc.

The boundary between Zone VIc of the late-Boreal and Zone VIIa, the Atlantic period is drawn where the pollen frequency of Alnus suddenly rises and from where it remains high. This correlates well with the appearance of Tilia pollen in the diagram, which did not really reach the north of England until the opening of the Atlantic. Other tree pollen figures were fairly typical for the zone.

Some difficulty was experienced in placing the boundary between Zone VIIa and the zones above it. The upper limit Zone VIIa was placed at the position of the decline in Ulmus pollen. This was inspite of the presence of the pollen of open habitat species such as Plantago and Rumex below the level of the elm decline. Above this level a marked change in the diagram occurs to a more modern pollen spectrum with low tree and shrub proportions and high herb pollen levels. Thus over a vertical distance of about 10 cm. we have passed from the Atlantic period into a modern type of vegetation with no evidence of any sub-Boreal vegetation of Zone VIIb. The possible reasons for this will be put forward during the discussion.

Having gained an idea of the vegetational history of the area from this diagram a comparison between this and the skeleton diagrams from Snipe Bog and Deceptive Bog can be made. The first thing that is apparent is how recent the deposit at Snipe Bog is. Although four levels were prepared, the bottom one from the blue-grey clay was virtually devoid of pollen and no count could be obtained. The next level up that was counted was in the lower peaty clay not far above the base of the organic deposits. This contained a high count of alder pollen, which dated the deposit as recent, unlikely to have been deposited before the Atlantic period. This same level also contained a high count of Plantago lanceolata pollen making it even more recent. Furthermore the tree-shrub-herb ratio forms a picture very similar to that at the top of Ingmoor Moss again making the deposit very modern. It looks therefore as though the deposit started forming at least no earlier than the opening of Zone VIIb.

Deceptive Bog on the other hand shows evidence of having formed since very early in the post-Glacial period. The lowest level counted shows a forest of mainly Betula and Pinus with a little Quercus and some Corylus already present. However, values for Salix, Empetrum, Rumex and members of the Caryophyllaceae family are quite high and also other open-habitat plant pollen is present including that of Thalictrum. The picture best painted is probably one of spreading birch-pine-hazel woodland but with sufficient open spaces for late-Glacial plants to continue. The position of this level is therefore placed at about the Zone IV - V boundary.

The level above this sees the development of a very closed vegetation cover dominated by birch, pine, elm and hazel with again a little oak. This places the level in about Zone VI, probably VIa due to the high values of Corylus and the fact that Ulmus exceeds Quercus in pollen frequency. It is noticeable that the herb frequency is extremely low at this point. The level above sees a marked increase in herb pollen with a decrease in tree pollen and a marked fall in shrub pollen. Values of Betula are high while Pinus is absent. Ulmus is low against quite high values of Quercus. Alnus is now present but Corylus has fallen and this zone is placed in early Zone VIIa.

The top level is seen to be recent as at Snipe Bog. The spectrum of tree pollen does not reflect that seen at Snipe Bog but this may be because very few tree grains were being counted in the totals giving statistics that were not ideal. However, both sites show the low levels of tree and shrub pollen, as also shown at Ingmoor Moss, and they both agree on the dominance of sedges, grasses and Calluna in the upper levels together with other herbaceous pollen types.

IV Discussion.

The area around Sunbiggin Tarn has many areas of peat deposits. Of those studied, the oldest, giving the most complete vegetational history of the area is Ingmoor Moss. The stratigraphy shows that this is a raised bog which has developed on the site of an old lake through a normal hydrosere succession. The layers, as given in the results were a calcareous gyttja-detritus mud containing shells, overlying a blue-grey clay, which in turn overlaid another layer of calcareous gyttja. Pollen analysis showed the upper calcareous gyttja to be of about Zone IV age, according to Godwin's zonation. Analysis from the top of the clay also showed a spectrum from Zone III. Although no borings were possible below the bottom gyttja it was assumed that a lower layer of clay would also have bee found. The reasons for this assumption are that the layer of clay from Zone III represents the lake clays laid down in the second cold period of the late-Glacial period. The upper gyttja and detritus mud, having a Zone IV spectrum, represents the period of rising temperatures in the early-post-Glacial period when deposits of more organic nature were laid down. It was therefore taken that the lower gyttja would represent deposits of Zone II age laid down during the warmer Allerӧd interstadial, and that a lower layer of lake clay would have been laid down beneath this in Zone I of the late-Glacial, when the climate would have been colder, as in Zone III.

All these layers were laid down under open water. Evidence for this comes from the presence of macrofossils in the upper gyttja. Firstly, a seed of the White Water-lily, Nymphaea alba, was found in this layer, a plant that needs open water, but not of too great a depth. Also, this upper layer contained numerous shells of fresh-water molluscs. Although several species were present, little could be gained from them as to the precise conditions at the time the layer was deposited. This was attempted by comparing them with their present day distributions and habitat requirements, (Boycott, 1936, and Ellis, 1926). All species present were ones that today live in a wide variety of habitats ranging from small bodies of water to large lakes and rivers. Regarding the types of water, most species were ones that will tolerate both hard and soft water, none being resticted in any way by the type of water. Present-day distribution of these species provides little more information. All species range throughout Europe and most throughout Asia. A few are also present in North America and North Africa. Therefore none is today restricted enough in its range to give some idea of the type of climatic regime at the time that the deposit was laid down, other than what is already known about the early-post-Glacial climate.

However, it is almost certain that the water of the area was hard. The gyttja when tested with dilute hydrochloric acid was highly effervescent, as expected, and even the blue-grey clay effervesced considerably when tested. The problem however was solved in the peat immediately overlying the gyttja. This peat was typically a fen peat and the bottom of it was found to contain oospores of Chara. The presence of this, an algae characteristic of hard water, and present day knowledge of the area confirms it as an area of drainage of hard water.

The change in stratigraphy from the gyttja to the fen peat marked the change from limnic to telmatic deposits although the transition was probably not sudden. This is thought so because the Chara oospores were found just above the bottom of the fen peat and thus there must have been some standing water as this peat formed. Above the transition a peat characteristic of eutrophic conditions has formed. The majority of the peat is composed of well preserved mosses, but large pieces of Phragmites were regularly found among the bryophytes, denoting a deposit formed with the water table fluctuating at around the surface. Remains of sedges were also frequently found in this peat. A quick study of the ecology of those mosses identifiable, (Watson, 1966), shows them to be species of boggy and marshy areas and one, Scorpidium scorpioides, is said to be regarded by some authorities as a calciphile, confirming again the nature of the ground water of the area.

The period of formation of this peat covers from the last part of Zone IV through Zone V and into part of Zone VI. Betula, which was quite high in Zone III reached its peak in Zone IV and remained high in Zone V until falling at about the boundary of Zones V and VI as the thermophilous trees spread. Despite falling, it still remained at quite high levels composing approximately 50% of the total tree pollen at times, in agreement with other sites in the upland areas of Britain. Pinus, however, behaves quite irregularly. It reaches a peak in Zone V, remaining high in Zone VIa where it reaches another peak. This is in contrast with its usual peak in Zone VIc in the north of England, (Pennington, 1969). Why this should be is difficult to say. It does, however, behave more normally in later pollen zones.

Quercus and Ulmus both behave normally in the samples from this peat as do most other pollen types. Cyperaceae pollen though, and to some extent that of the Graminae reach quite high percentages in this peat. This is considered to be due to the local effect of the fen itself as the peat contained considerable sedge remains and also some of Phragmites. Thus quite a high proportion of herb pollen is seen in the tree-shrub-herb ratio, at a time when the forest would have been dominant, and one would have expected a very low proportion of herbaceous pollen in the regional pollen rain.

At the top of the fen peat there is evidence that it changed from a telmatic peat to a peat forming under more terrestrial conditions. This is marked by a change in structure from a mainly bryophyte peat with some sedge remains, to a sedge peat containing pieces of wood, some of which was identifiable as birch. This sedge layer is most marked on the western side of the transect. In other places it is just seen as an increase in the amount of sedge remains in the bryophyte peat, with wood being found at the top of this.

Above the fen peat transition to an acid raised bog occurred. According to Pennington, (1969), the opening of the Atlantic period, Zone VIIa, was the time when raised bog formation began in Britain with the advent of oceanic conditions. If, however, the suggested zonation for this diagram is correct, this raised bog started to grow at about the start of Zone VIb. Certainly the placing of the VIc-VIIa boundary appears correct, mainly because of the behaviour of the Alnus curve. This is also supported by the presence of Tilia, which reached the north of England at the opening of Zone VIIa and had its widest extension then, and also the Pinus curve, which falls at the start of Zone VIIa, in agreement with the general scarcity of this tree in the Atlantic period forests of England. It is almost certain therefore that this raised bog started to grow before the opening of Zone VIIa at about the opening of Zone VIb as suggested. In fact, from Pennington, (1970), it appears to be a characteristic of the north-west of England that in Zone VIb of the Boreal period, there was a wet spell. In giving evidence to support this, Pennington uses a pollen diagram from one site in the south-west of the Lake District, Brant Rake Moss. This diagram shows a great deal of similarity in some respects to that of Ingmoor Moss. In Zone VIb a sudden rise in the percentage of Sphagnum spores accompanies a change from a wood peat overlying a sedge peat to a Sphagnum-Eriophorum peat, well below the Boreal-Atlantic transition. After this high peak, the percentage of Sphagnum spores falls while at the same time that of Calluna pollen rises, presumably during a drier spell towards the end of the Boreal period. Thus the transition to acid bog at Ingmoor Moss is correlated with sites in the Lake District, where, unlike other sites in the country, a wet spell in Zone VIb of the Boreal period enabled raised bog to form. Zone VIc is represented only by a very narrow layer of peat and is marked by the first record of Alnus pollen in the diagram.

The transition to Zone VIIa, the Atlantic period is marked by a rapid rise in Alnus pollen to a maintained level. The acid peat continued to grow being composed mainly of Sphagnum, Calluna and in places Eriophorum remains. The pollen spectrum of this period remained fairly typical with the greatest extension of deciduous trees and a period of decline of Pinus. There are however one or two points of interest. One is the presence of ash (Fraxinus) pollen, albeit in small amounts, a tree that does not normally make its first appearance until the opening of Zone VIIb. This was when man began to destroy the forest and Fraxinus, being a pioneer tree could colonize open spaces. One possible explanation may be that as it is a tree that likes calcareous soil, it may possibly have found a favourable habitat on the limestone outcrops in the area, and as a result been able to colonize the area earlier than it would normally have done. A second, and perhaps more likely explanation may come from a study of the curves for grasses, Plantago and some other herbs which are seen to rise. Normally the appearance of the Ribwort Plantain (Plantago lanceolata) is associated with the Elm Decline and the transition from Zone VIIa to Zone VIIb, the sub-Boreal. Clearly it is present here during VIIa together with increased grass pollen and pollen of other pastoral herbs. Similar occurrences were found by Walker, (1966), in North and West Cumberland. Here a reduction in Ulmus pollen with a small increase in grasses and P. lanceolata firstly occurred. This was followed by a marked decline in tree pollen at which stage the pollen of grasses, P. lanceolata and Rumex was high enough to suggest clearings of significant size in the forests. Similar horizons also appear in analyses from Barfield Tarn, (Pennington, 1970). Also, at all her West Cumberland sites, and at many around Morecambe Bay the first fall in Ulmus pollen was followed by a second steeper fall in this tree, the latter being accompanied by evidence for significant forest clearance.

From this it seems that there was a period of minor forest clearance in the North-West before the Atlantic - sub-Boreal transition, and this is tentatively suggested as the most likely reason why Fraxinus was present during the Atlantic period. Further support is given to this suggestion by the fact that cereal pollen, although very little, was found at the top of the peat formed during the Atlantic period, more evidence of clearance and Man's activity.

This also confirms the affinity of this site with the North-West and the Lake District, rather than with the rest of England, in particular the North. At Moorhouse, for instance, on the closely adjacent North Pennines, (Johnson and Dunham, 1963), several sites were studied and at none was P.lanceolata or Rumex consistently present before the start of the sub-Boreal period, and often it was not until well after. The same was true to some extent for the increase in grass pollen. Turner et al, (In Press), working in Upper Teesdale also found the first spread of grassland, indicated by Plantago frequency, to be not until well after the start of the sub-Boreal period.

The upper boundary of the Atlantic period is placed where the sudden decline in the pollen frequency of Ulmus occurs on the diagram. However, some difficulty is encountered here in deciding what happened to the bog from here upwards. The next level has a pollen spectrum of a very recent make up. This level at 35 cm. depth lies just above the base of some very fresh Sphagnum peat. This is taken to represent the advent of the wet sub-Atlantic period when such bog surfaces responded to the sudden increase in oceanicity with very rapid growth of almost exclusively Sphagnum. Therefore, a change has occurred from the Atlantic at 45 cm. depth to the sub-Atlantic at 35 cm. depth with the sub-Boreal period being represented in the peat lying somewhere between. This is not unusual because with the dry conditions during the sub-Boreal, peat grew very slowly, and in some cases erosion of the peat may have occurred. Despite this, the Zone is tentatively included in the diagram.

Because of this period of slow growth, or no growth at all, a marked change occurs in the diagram between these two levels. This is shown well by the tree-shrub-herb ratio, which shows a sudden rise in the percentage of herb pollen. This is due mainly to Calluna, and sedges and grasses. The first of these is confined exclusively to the raised bog surface at Ingmoor Moss. Sedges and grasses, however, have a wider local distribution. Both occur on the areas of fen around the bog, and sedges occur both on the raised bog, mainly as Eriophorum, and areas outside the limits of Ingmoor Moss, in the wetter areas of the surrounding fields. It is on these fields of pasture though that the grasses, shown by the high percentage in the top four levels of the diagram, really dominate. From this it is taken that the area has been under the same type of landuse throughout the period covered by these four levels. In fact this makes sense since the period of forest clearance, leading to an increase in pasture, would have occurred mainly during the sub-Boreal period which is not represented in any of the levels counted. Thus when a fresh Sphagnum peat started to grow at the onset of the sub-Atlantic period, the pasture in the area was already well established and is recorded in the palynological investigation. Besides the high levels of grass pollen, pollen percentages of other pastoral plants, such as Plantago lanceolata and Rumex were also high.

In correlating the pollen diagrams from the other two sites with that from Ingmoor Moss, we have seen that that from Snipe Bog has a recent pollen spectrum. A study of the tree-shrub-herb ratio shows the whole of Snipe Bog to be similar to the top four layers of Ingmoor Moss. This may be due to the very high levels of sedge pollen, making the proportion of tree pollen small. It is difficult therefore to say whether this peat started forming in the sub-Boreal or sub-Atlantic. It is unlikely that it started before the sub-Boreal though as the percentage of P. lanceolata pollen is high. Although the levels of herbaceous pollen are very high at both in these levels the make up of this varies at each. At Ingmoor Moss for instance, Calluna reaches much higher levels than it does at Snipe Bog. Here Calluna is found in the immediate area only on the bog surface, yet at Snipe Bog the bog is surrounded by large areas of Calluna moor, much more extensive than the area of Calluna at Ingmoor Moss. The situation is different for Cyperaceae pollen. At Snipe Bog, where the bog surface is dominated by sedges, very high levels of Cyperaceae pollen are found. At Ingmoor Moss, although some sedges occur on the bog the majority are found in the fen surrounding the bog and in the wetter areas of the surrounding fields, and smaller percentages of this pollen occur. This demonstrates how the vegetation of an area of peat influences the pollen diagram obtained from it and for which reason care must be taken in trying to determine the regional vegetation at the time the peat was forming.

Before leaving the discussion of the pollen diagrams two points are of interest from Ingmoor Moss. One is the occurrence of a very high level of pollen of Rumex acetosa at one point in the top of Zone VIa. This is not accompanied by an increase in other herb pollen so it seems unlikely that a clearance occurred and an explanation is very difficult to find. The second point is the presence of pollen of Centaurea cyanus at two levels during the Atlantic period. This is a weed of cornfields which would mean that a clearance would have had to have occurred. In fact there is evidence for a minor clearance in the Atlantic but the levels where this happens are above those where the Centaurea occurs. Either the presence of this species represents the very start of this clearance, or it was just chance that these two grains were counted.

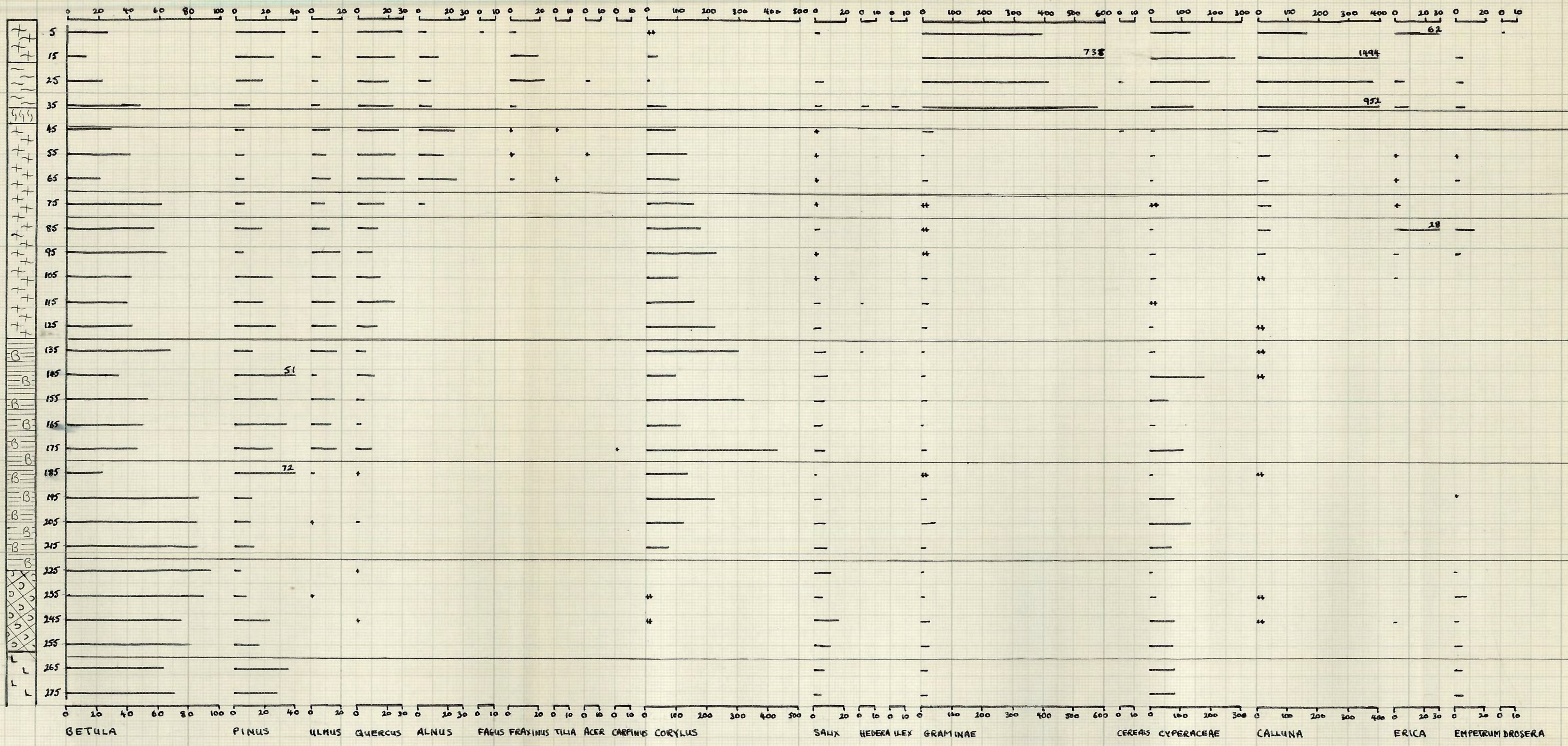
As yet nothing has been mentioned of the problem of the former extent of Sunbiggin Tarn, but now that the history of Ingmoor Moss has been discussed, and it becomes possible to try and fit in the other diagrams, it is pertinent to do so. Snipe Bog is the higher area above the Tarn of the two studied. Therefore, if the Tarn ever reached this level it should have receded from here first and the peat at this point would be older than peat forming lower. At this time no pollen analysis had been done from Deceptive Bog. The presence of the blue-grey clay in the north-west corner of Snipe Bog meant that open water must once have been present in this area, but whether it was just a local, separate body, or part of a larger system was difficult to say. However the problem was solved when analysis from Deceptive Bog was carried out. This showed the peat to have started forming in early post-Glacial times and therefore there could have been no large body of open water present here at the time. It is therefore assumed that as the peat at Snipe Bog started forming very recently the area was covered by a discrete, small body of water until recently when it was completely infilled and peat began to form.

The above impression is gained from the core taken for pollen analysis which was taken from an area where these lacustrine deposits occurred. It is possible, though, that in other areas of the bog, where no open water occurred, peat may have begun to form earlier. However, as the stratigraphy is consistent right across the bog, and the lowest layers of organic material over the lake clays correspond with the lowest layers above the drift elsewhere, it appears that the whole of the area of peat began to form at much the same time. Therefore those areas that were not covered by open water are presumed to have supported a vegetation which decayed normally. In fact, as the peat formation was fairly consistent over the whole area, it is likely that the area of open water was filled in well before any peat formation began.

We therefore know that if the Tarn was once larger, it was before early-post-Glacial times. However, borings below the peat on transect A at Deceptive Bog show no evidence of open water deposits. There is evidence of water sorting of the underlying till as at Snipe Bog, this probably having occurred at the end of the last Glaciation, when the melting ice produced very wet conditions, but no actual open water deposits were found at the bottom of the borings. However, as mentioned earlier, Holdgate, (1955), in the second paper on the area, described some borings done in the peat to the south of the Tarn, around Cow Dub. At the base of the deposit was a layer of blue-grey clay, hard and stony in parts and subdivided in places by a central band of calcareous material. Above this was a layer of fawn or white calcareous sediment, up to 5 metres thick. This layer contained gastropod shells and fragments of _Chara_ and _Fontinalis_ and was very similar to the sediments covering part of the present tarn bed. Above this was a surface layer of peat up to 3 metres thick, with _Phragmites_ rhizomes in the lower parts and a _Phragmites-Carex_ peat higher up. This stratigraphy is very similar to that seen at the bottom of the Ingmoor Moss deposits. If the assumed lower layer of blue-grey clay is present in these then there would be a corresponding layer of clay separated by the calcareous material at both sites. Also the upper calcareous material contains mollusc shells at each, and _Chara_ remains are evident at both sites. The only difference is that the upper calcareous layer was much deeper around Sunbiggin Tarn which would imply a much longer period of open water before the peat began to form. In fact, as the _Phragmites_ rhizomes found in the lower peat near the Tarn were 3 metres below the present level of the Tarn, Holdgate thinks that the Tarn level must be rising. This would have allowed a long period of deposition of open water sediments until such time as the water became shallow enough for a fen peat to start forming.

Figure 5.

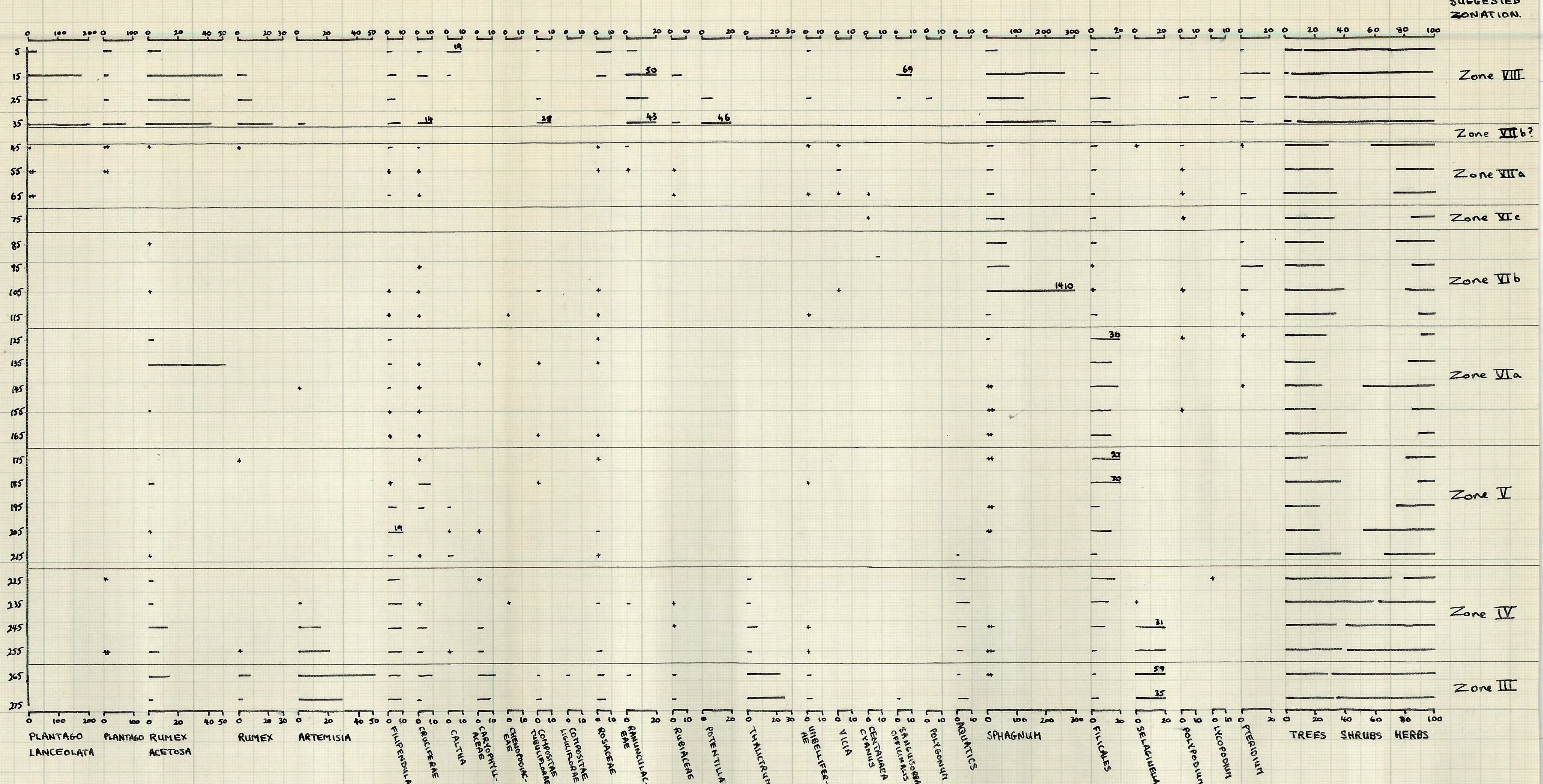
Ingmoor Moss : Pollen Diagram



Tree, shrub and herb pollen ; figures given as percentages of the total tree pollen. + = < 1% ++ = < 5%

Figure 5 - Contd.

Ingmoor Moss: Pollen Diagram including suggested zonation of the diagram



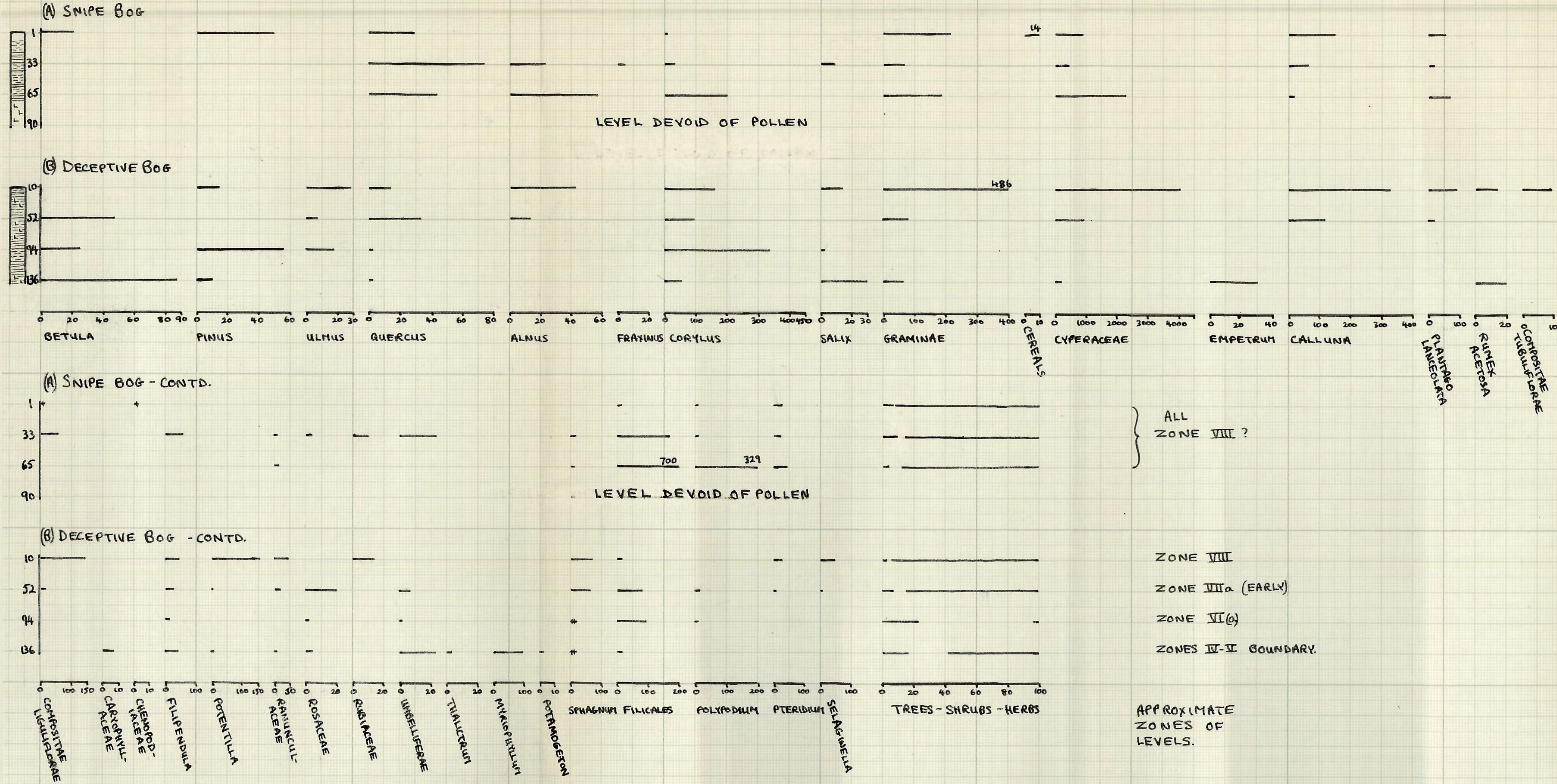
Herb and Aquatic Pollen and Spores; figures as percentages of the total tree pollen.

Tree-shrub-herb ratios, proportions as a percentage of total of the three.

+ = < 1% ++ = < 5%

FIGURE 6.

SNIPE BOG AND DECEPTIVE BOG - POLLEN DIAGRAMS



TREE, SHRUB, HERB AND AQUATIC POLLEN PLUS SPORES. FIGURES AS PERCENTAGES OF TOTAL TREE POLLEN.

As no deposits like the above were found on the transect at Deceptive Bog, it seems likely that the Tarn did not ever extend much further. Even though the level of the Tarn is now above that of Deceptive Bog, and one would have thought it likely for the whole area to be water-covered, the fact that the deposits around Cow Dub have grown upwards for a considerable height may mean that the water level was once below the level of Deceptive Bog. It therefore appears that Sunbiggin Tarn may once have covered a different area in that it may have included the area of Cow Dub before peat began forming to separate the two. It does not mean though that it covered a larger area and indeed it may have been smaller before the time that the level rose and it was ponded back over new areas.

The second point of the study, to determine the effect of the Carboniferous limestone on the vegetational history of the area, shows its influence to be mainly on the types of vegetation rather than just on individual species. This is brought about by the drainage of enriched water of high pH throughout the area. This has manifested itself in a number of ways shown well at Ingmoor Moss. This was once an area of open water, probably similar to what Sunbiggin Tarn is today, and at that time calcareous deposits were laid down. The blue-grey clay proved to be calcareous but more especially so was the calcareous gyttja. This contained numerous shells of molluscs, as mentioned, which must have benefited from the calcareous water, and remains of Chara, an alga characteristic of hard waters. When the open water gave way to fen, the ground water produced a vegetation characteristic of eutrophic conditions, with mosses and sedges. A similar story is seen in the peat around Sunbiggin Tarn and Cow Dub. Areas of such rich fen are common today on Tarn Moor. Only in areas where blanket peat has formed on glacial drift or where raised bog has formed like at Ingmoor Moss is the vegetation not influenced by the ground water.

However, having said that the influence of this ground water is mainly on the type of vegetation rather than on individual species, it has nevertheless had some effect in this last respect. For instance, in comparing this diagram with ones from non-calcareous areas, one sees a greater diversity in herbaceous plants and also a greater percentage in some of these. For example at Moorhouse, (Johnson and Dunham, 1963), although limestone occurs in the area, it is with sandstone and shale, and these are largely overlain by boulder clay. Thus the limestone would not be able to directly affect the vegetation so much. At the sites studied there, the percentages of some of the herbs, such as Plantago and Rumex are lower than at Ingmoor Moss, and also the overall variety of herbs is not so great. The greater variety and larger proportions of some herbs near Sunbiggin Tarn may therefore to some extent be due to the ground water although the greater variety may be also due to the wide variety of habitats in the area.

Having seen the fairly large proportion and the variety of herbs that existed in the area throughout the post-Glacial period one wonders also whether the area might have been a refuge for late-Glacial plants during the forest maximum as in certain areas of Upper Teesdale.

In summing up therefore, the vegetational history of the area, as shown from the palynological investigation has characteristics that relate it more to the North-West of England and the Lake District than to the rest of Northern England. The rich ground water, derived from the Carboniferous limestone of the area has supported a rich vegetation during the history of the area, which is maintained today wherever this groundwater flows at or near the surface. It is unlikely that Sunbiggin Tarn ever covered a larger area than it does today, though its position and outline has probably changed somewhat.

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