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THE INVESTIGATION OF A LOWLAND PEAT BOG IN COUNTY DURHAM

-oOo-

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A Dissertation Submitted for a Master of Science Degree in Ecology

7 MAY 1974
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September 1967

INTRODUCTION: The Background to, and Aims of the Investigation.

The investigation is centred upon Cranberry Bog (grid reference 2354, Ordinance Survey $2\frac{1}{2}$ inch sheet NZ 25), which is situated in the Western part of County Durham, about 8 miles to the south of Newcastle.

The Geology 1 inch map, sheet 105 SW shows a solid rock base of Carboniferous Coal Measures overlain by glacial drift. The Durham Geological Survey Memoir (Francis & Smith) gives the following sequence of sediment deposition for this area -

Upper Stoney Clays 0-50 feet
Middle Sands, Gravels and Clays 0-260 feet
Lower Boulder Clay 0-120 feet
- - - - - - - - - - -
Carboniferous Coal Measures

The Lower Boulder Clay is a stiff dark grey or grey-brown clay, which was deposited by a major ice sheet moving south or south-east from the Southern Uplands of Scotland and the English Lake District. A large part of the Middle Sands, Gravels and Clays were formed during the decay of the Lower Boulder Clay ice by sub-aerial outwash of the ice. Streams cut channels into the Boulder Clay which became filled with cross-bedded coarse gravels, followed by level bedded silty deposits as the amount of turbulence, water flow and supply of sediment was reduced. There is a pronounced lateral variation and transition from one deposit to another. The Middle Sands around Cranberry Bog are thought to have formed terrace deposits of the buried valley of the River Team. The Upper Stoney Clays are generally thin, light brown, sandy gleyed clays with bleached and weathered pebbles.

It is generally thought that this area experienced only one glaciation, but it has been suggested by some, that the Upper Stoney Clays may represent a return to cold conditions, and therefore indicate the presence of a second glaciation. Others explain the presence of the Upper Stoney Clays by saying that they were deposited in a local readvance of the ice in the same glaciation that caused the deposition of Lower Boulder/

cont'd.

Boulder Clay and Middle Sands, Gravels and Clays.

Deposits of the Post-Glacial period are represented by lacustrine alluvium along stream valleys and by peat deposits in poorly drained areas.

Map 3 expresses this varied geology. The complex pattern can be explained by the pronounced lateral variation in thickness of the glacial deposits and the highly dissected nature of the topography. A combination of glacial and fluvial erosion has given rise to the deep valleys, some of which have become partially filled with recent alluvium. Boulder Clay is dominant, covered in some places with sand and gravels, especially along the valley sides of the River Team. Where no glacial sediments have been deposited, or where they have been eroded away, Carboniferous Coal Measures are exposed.

The deep, narrow valleys are, for the most part, forested, with enclosed meadows and arable fields on the more gently sloping land above the valleys. Roads, where possible, avoid the valleys and apart from the towns of Stanley and Chester-le-Street, the settlement pattern is mainly one of small villages scattered amidst the enclosed farm land. (See maps 2 and 4)

In a small depression, in the Middle Sands and Gravels, Cranberry Bog has developed. A 100 ft. bore taken, just to the west of the Bog, by the Cementation Company Ltd., in 1949, reveals the following successions : -

Soil and Ashes	1 ft.
Sand	29 ft.
Sand and Boulders	70 ft.

Within the Bog, there is an average of 7-8 ft. of peat, overlying at least 14 ft. of blue clay with pebbles, and becoming sandy towards the top.

Although it lies within the 300 ft. contour on the map, the western edge of the Bog has been levelled to 00 292 by the Cementation Company. It is surrounded by higher land, except in the south, where there/

cont'd.

there is a break in the surrounding hills, and a ditch drains the Bog to Beamish Burn Valley. There is no sign of any surface drainage over the Bog's small catchment area.

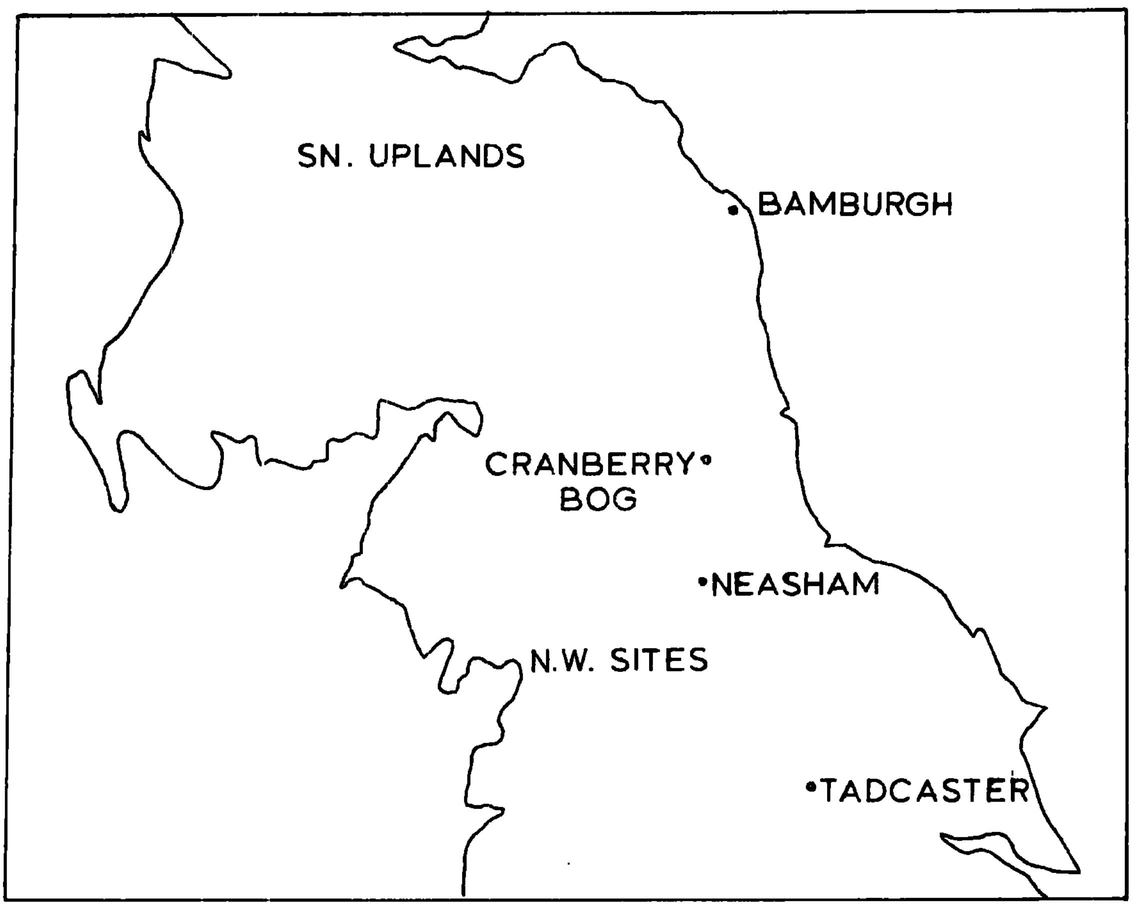
Cranberry Bog itself is very small (Map 5) extending at a maximum to 220 yards, North-South, and 176 yards East-West. Fields surrounding it, illustrate the mixed nature of this region's agriculture. There are 2 pastoral fields, occupied by cows and sheep, 2 fields sown with barley and 1 with potatoes. These sands and gravels are especially well suited to arable cultivation, because of the light porous soils they produce, and the ease with which they can be be enriched with organic matter from Cranberry Bog peat. The peat has long been dug for local agricultural purposes, and 30 years ago, it was marketed commercially. The present owner, Mr. Anderson, has been cutting the peat for horticultural use, for the last 2 years. Due to these peat usages, a large part of the Bog has been removed, and the remainder is riddled with drainage channels to dry out the peat, for future use.

The present vegetation is a reflection of man's intervention. The dried out peat surface is covered with birch trees and a dense ground layer of bracken. The reason why no detailed survey has been carried out here, is due to the almost impenetrable nature of the summer growth of the bracken. Where the outer drainage ditch has been blocked, patches of reed marsh have developed, while over the rest of the area where the peat has been removed, is a covering of grasses, various weeds, bracken and the occasional birch tree. Towards the outer limits of the Bog, the peat becomes very shallow, and contains much sand and many stones. Here, the vegetation changes to mixed woodland with birch, elm, sycamore, oak, hawthorn and ash all represented. The bracken undergrowth becomes less dense, and many grasses are allowed to grow.

Dr. Turner discovered the site, and gave it to me to investigate for the purpose of this dissertation. It was easily accessible by road, and perfect for study as the whole profile of the peat was exposed in/

cont'd.

MAP 1. LOCATION OF SITES



MAP 2. THE LOCATION OF CRANBERRY BOG

(based on O.S. 1 inch sheet 78)

KEY

WOODLAND

--- ROADS

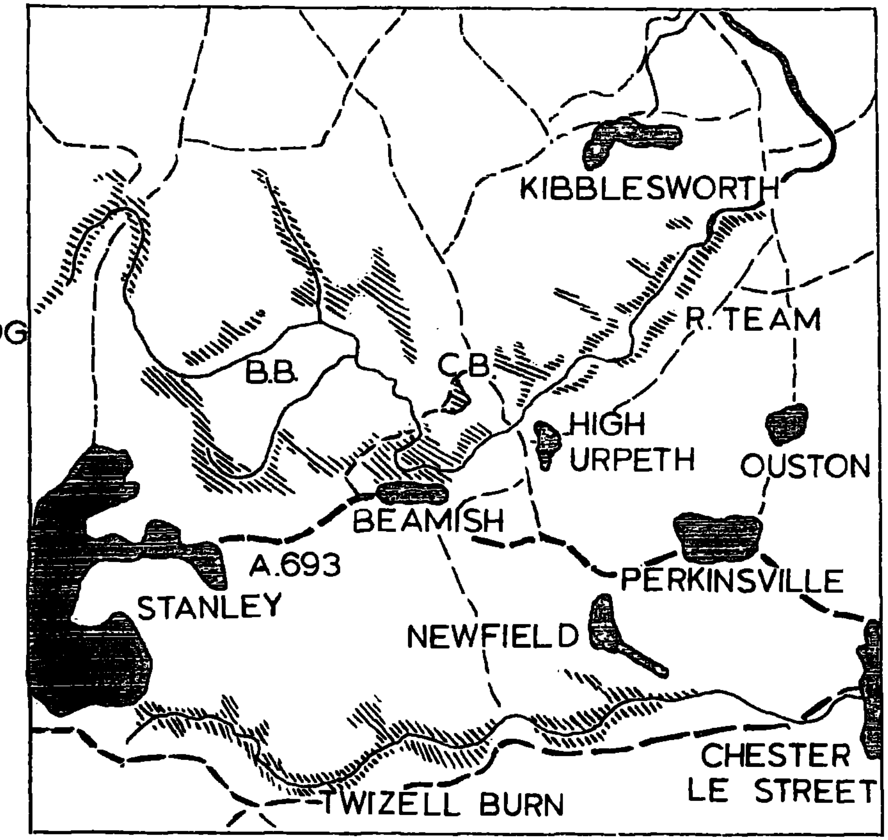
BB BEAMISH BURN

CB CRANBERRY BOG

SCALE

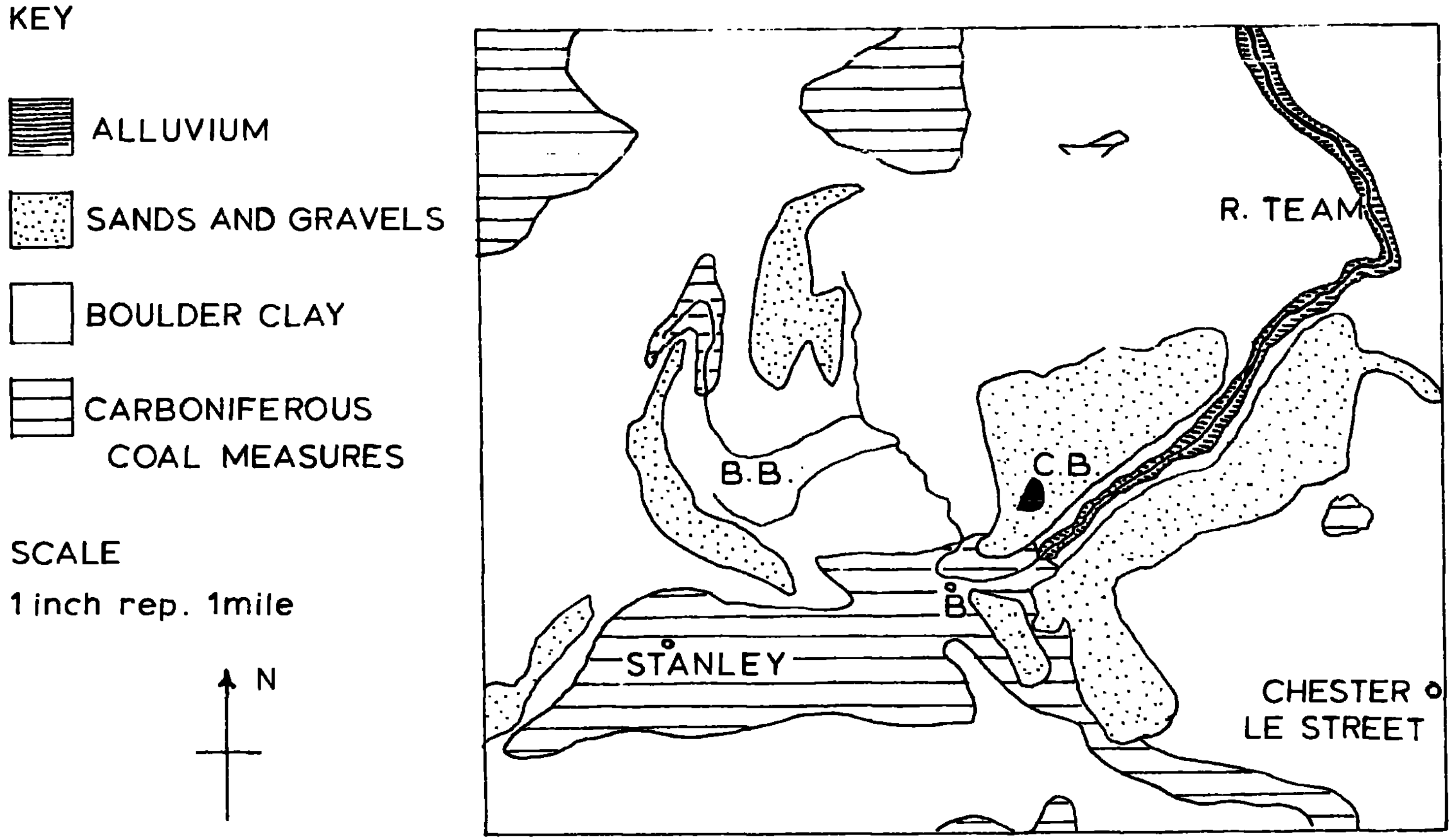
1 inch rep. 1 mile

N



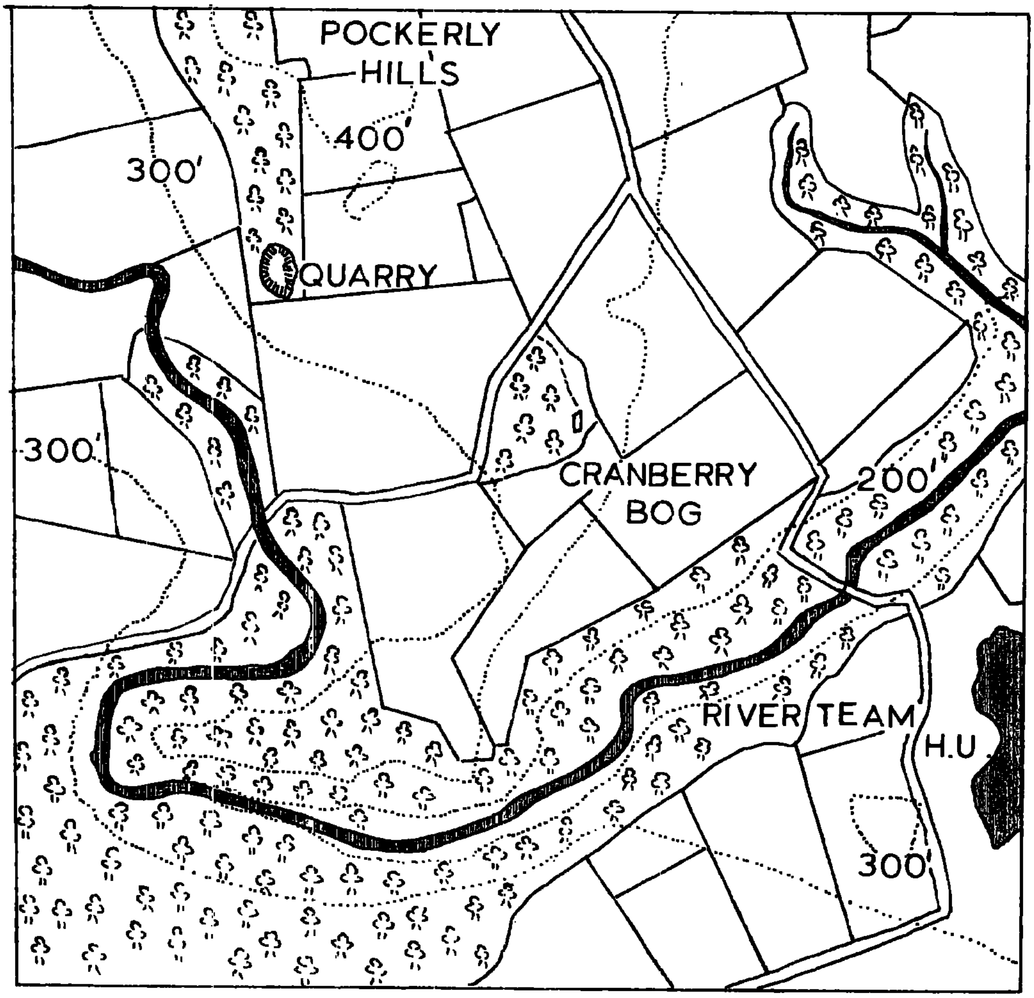
MAP 3. THE GEOLOGY AROUND CRANBERRY BOG

(based on OS. 1 inch sheet 105 SW)



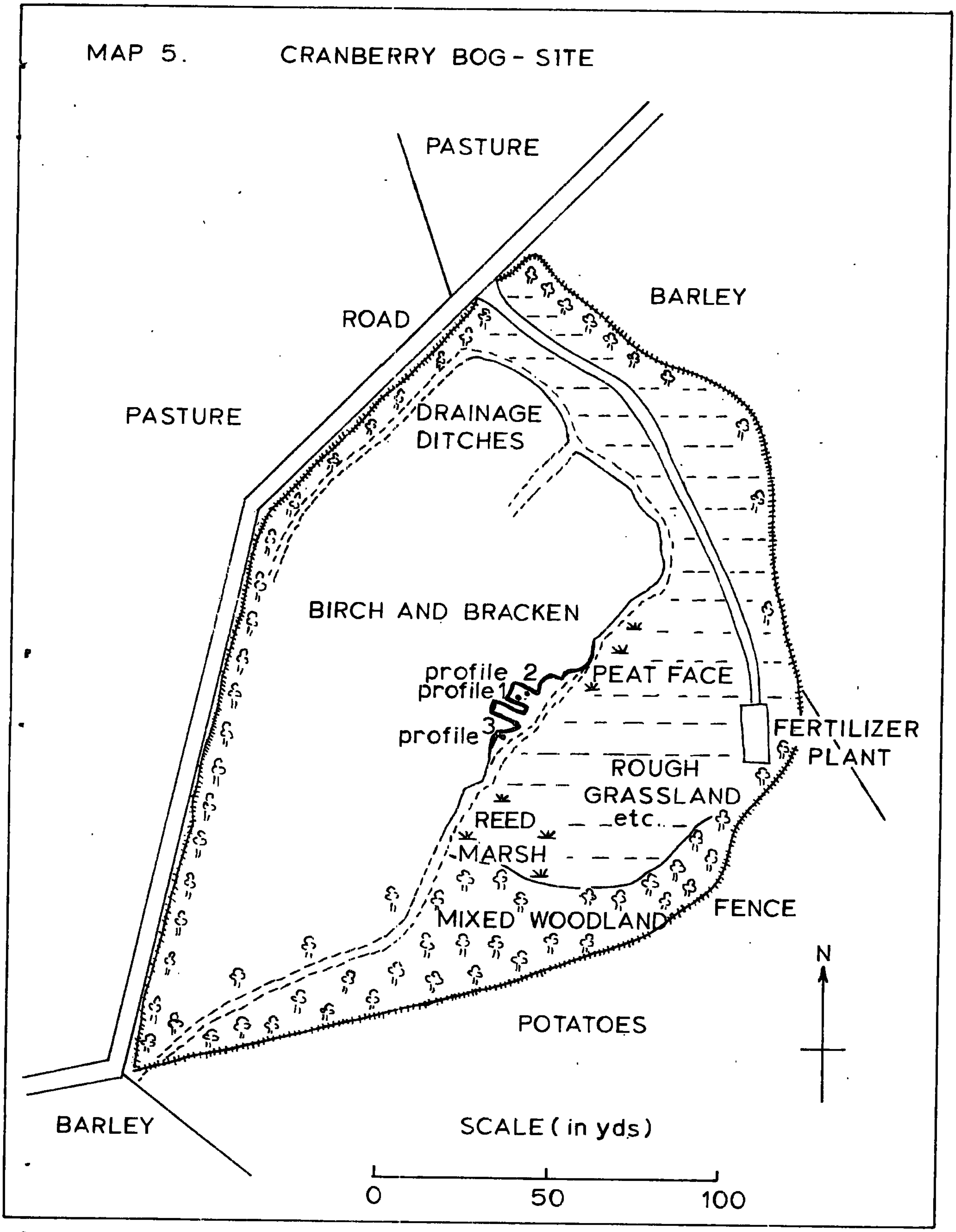
MAP 4. PRESENT LAND USE AROUND CRANBERRY BOG

(based on O.S. 6 inch Sheet 45/25/SW)



SCALE : 6 inches rep. 1 mile

N


MAP 5.
CRANBERRY BOG - SITE
PASTURE
ROAD
BARLEY
PASTURE
DRAINAGE
DITCHES
BIRCH AND BRACKEN
profile 2
profile 1
profile 3
PEAT FACE
FERTILIZER
PLANT
ROUGH
GRASSLAND
etc.
REED
MARSH
MIXED WOODLAND
FENCE
N
POTATOES
BARLEY
SCALE (in yds)
0
50
100

in a newly cut face. The aims of the investigation were to find out the age and origin of the peat, and to study the vegetational history of the area by means of pollen analysis, macro-plant analysis and the analysis of the Bog's stratigraphy. It was originally thought that the peat was of recent age until, through pollen analysis, it was found to have been building up since the end of the Glacial Period, and late-glacial pollen was found in the mineral deposits below the peat. Therefore, the formation of the basic pollen diagram became the main object of study with the subsidiary problems of explaining an apparent break, or number of breaks, in deposition, beneath the recurrence surface of the peat.

FIELD and LABORATORY METHODS

(1) Field Work

For the initial investigation, part of the peat face was selected near the centre of Cranberry Bog, where the sequence of deposition was presumably most complete, cleaned up with a spade, and examined. The stratigraphy was determined, and each horizon measured and examined for composition, structure, texture, colour and degreee of humification. This profile was then compared with other parts of the peat face, and borings through the peat (taken with a Hiller Peat Sampler) and was found to be typical of the central part of the peat mass.

A monolith, about 9 inches by 6 inches in cross section, was then cut from the face, which extended from 0-264 cm. into the mineral deposits below the peat. This was taken back to the laboratory in several sections, to be used for pollen sample preparations, and more detailed plant and stratisgraphical analysis.

In order to obtain samples from deeper than 264 cm. a second profile was examined. A pit was dug into the mineral sediments below the peat, some 5 ft. from where the first monolith had been taken. A monolith was again taken, from 214-338 cm. and sampled in the laboratory.

cont'd.

These 2 profiles were correlated accurately where they overlapped, by stratigraphy and pollen analysis.

A third profile was later examined, and samples for pollen analysis were taken here, at every 4 cm. in the field. This was to provide a check against part of profile 1 where the pollen diagram was unclear.

(2) Laboratory Work

In the laboratory, samples for pollen analysis from the monolith of profile 1, were taken at cm. intervals, put into glass tubes and marked. The advantage of sampling in the laboratory, rather than in the field, is that greater care could be exercised in procuring pure uncontaminated samples. The remaining peat was then cut up into blocks of 5 cm. depth, labelled, and preserved in polythene bags, to keep the peat suitably moist, for further study.

The Preparation of Peat Samples for Pollen Analysis

"The object of preparing the samples is to concentrate any spores and pollen grains present, and render them as visible as possible by (1) deflocculation. (2) removal of extraneous matter and (3) embedding in a suitable medium'. (Faegri and Iverson, 1964).

Each sample was broken down by boiling in a solution of 10% sodium hydroxide ~~boiling~~ in a boiling tube, then filtered through a sieve into a 40 cc. centrifuge tube to remove large plant fragments. These remains were preserved in a labelled glass tube, for future identification. Cellulose was then removed from the filtrate containing the pollen by acetolysis. The stages in this process are :-

(1) washing free of NaOH by adding distilled water.

(2) washing free of water by adding glacial acetic acid.

(3) adding a mixture of 100 cc's of acetic anhydride and 1 cc. of concentrated H_2SO_4, and heating in a boiling water bath for one minute.

(4) adding 2 drops of glacial acetic acid, then distilled water: after each stage the sample was centrifuged in a 15 cc. centrifuge tube.

Each sample was then mounted on slides, in a mixture of glycerine jelly and safranin stain and labelled ready for counting.

Below/ cont'd.

Below 250 cm. samples contained much siliceous matter which was removed by treatment with hydrofluoric acid. This was done before removing cellulose by acetolysis. Each sample was put into a crucible and concentrated hydrogen fluoride added. This was boiled for 4 minutes, then poured into 10% HCl and centrifuged. A white residue formed, which was removed by heating in a water bath. Because of the dangerous nature of HF, the fume cupboard had to be kept on to remove fumes, while rubber gloves and goggles had to be worn for protection against any explosion, or spillage of the solution.

Samples from profiles 2 and 3 were prepared by the same treatments.

The Preparation of Plant Macro-remains for Identification

Each of the glass tubes containing plant remains produced in the preparations of samples for pollen analysis was examined, and such remains as leaves, roots, seeds and fruits identified. The peat blocks preserved in polythene bags were examined more closely than in the field for general composition, texture and structure, then broken down in a solution of 5% NaOH, sieved, and the plant remains identified in a similar way to those remains in glass tubes.

The Identification of Pollen Grains and Spores

Initially, Dr. Turner taught me how to identify pollen grains. Subsequently, grains found for the first time were run down in the key given by Faegri and Iverson (1964), compared with drawings in Erdtman (1943) and finally checked with the type slide collection.

The Identification of Macro-remains.

The commonest recognisable plant remains were Sphagnum leaves, which were run down in the key to British Sphagna (Proctor 1955,) and then compared with type material. The major difficulty, which was paralleled in all other fossil material was classifying down to species level. In the case of the Sphagna it was sometimes only possible/

cont'd.

possible to get them to section level. Other mosses were run down in the key given in Watson (1955) and compared with type material. In the case of seeds and fruits no key was used, but the drawings in Brouwer and Stahlin (1955) and Beijerinck (1947). All identifications were then checked against type material in the Herbarium.

THE RESULTS OF POLLEN AND STRATIGRAPHICAL ANALYSES

The description of the bog stratigraphy is taken from a combination of the investigations of profiles 1 and 2.

0-12 cm: Highly humified peat, with occasional leaves of Sphagnum species; Sph. recurvum agg. and Sph. acutifolia agg. Penetrated by Betula roots and Pteridium rhizomes, and containing dead remains of Betula and Pteridium which give the peat a secondary fibrous nature.

12-40 cm: Dark brown, moderately humified Sphagnum peat. Some Calluna twigs but mainly Sphagnum species; Sph. cuspidatum, Sph. recurvum agg., Sph. palustre and Sph. acutifolia agg. Betula seeds at 25 cm.

40-69 cm: Light brown, weakly humified fibrous Sphagnum peat: Sph. palustre, Sph. cuspidatum, and Sph. recurvum agg. dominant. Also Carex cf. limosa seeds, Menyanthes seeds between 55 and 68 cm. and Betula twigs and wood at the base.

69-98 cm: Dark, brown moderately humified Sphagnum peat; Sph. palustre and Sph. recurvum agg. dominant, with seeds of Carex cf. limosa and Juncus, and remains of Calluna present. The peat is sandy with layers of sand concentrated between 78 and 88 cm. Well rounded sandstone pebbles up to 6 inches across are found at intervals, all at the same horizon, resting on the sand layers. Towards the top of this sediment, there are charcoaled Calluna fragments, suggesting burning of the peat surface vegetation.

98-180 cm: Black, very spongy, moderately humified peat, composed of alternating layers of Bryophytes (Sph. cuspidatum, Sph. recurvum agg, Sph. acutifolia agg, and Aulocomnium palustre) Calluna vulgaris and Eriphorum Vaginatum

180-229 cm: Compact and stratified Bryophyte peat. Moderately humified but moss leaves are in a state of good preservation. Leaves of Sph. cuspidatum, Sph. recurvum agg, Sph. palustre, Drepanocladus fluitans and Aulocomnium palustre dominate the deposit.

cont'd.

229-259 cm: Very compact, well stratified, highly humified swamp peat. Plant remains dominated by the leaves and pyrenes of Potamogeton, leaves of Phragmites, and the remains of Carex cf rostrata. Leaves of Drepanocladus fluitans, Acrocladium cuspidatum, Campylium stellatum and Sphagnum subsecunda agg. are poorly preserved. The occasional seed of Menyanthes was found. The peat becomes sandy towards the base.

259-75 cm: Unconsolidated grey detritus sand, with lenses of pure sand and many coal fragments. Becoming clayey towards 275 cm. Very few plant remains - only Carex cf rostrata fruits, seeds of Empetrum Nigrum and a leaf of Anagallis tennella found at 270 cm.

275-91 cm: Compressed brown-grey clay with a few coal fragments and sandy bands. Few plant remains but achenes of Ranunculus, Batrachian sp. identified.

291 cm: Very abrupt break; very thin layer of yellowish sand.

291-308 cm: Sandy, bluish-grey lake clay; with blue shale fragments. Little organic matter.

308-334 cm: Fine brown detritus with silty texture and sand lenses. Many plant remains. Seeds of Potamogeton and Carex cf rostrata dominant. Also found was a Batrachian achene.

up to 334 cm: Blue sandy lake clay with hardly any organic remains, but many angular fragments of coal, stone and quartz. It grades to blue clay with shale fragments and stones after about 350 cm. This clay has been bored to a depth of 14 ft. without a significant statigraphical change being noted. An explanation of this development sequence will be dealt with in the discussion.

The results obtained from the analyses of the pollen samples have been constructed into pollen diagrams 1 to 8. Diagram 1 shows the relative frequencies of the tress, shrubs and herbs, each expressed as a percentage of total dry-land pollen. In the Post-glacial diagrams (2-5), the relative frequency of the different pollen types, is expressed as a percentage of total tree pollen, while in the Late-glacial diagrams (6-8), each pollen type is expressed as a

cont'd.

percentage of total dry land pollen.

The pollen sum has been 150 tree pollen in the Post-glacial spectra, and 200 dry-land plant pollen in the Late-glacial spectra. There is one exception to this pattern, namely, the top 12 cm. of the profile where over-representation by Betula, Pteridium and the Filicales, growing on the dried bog surface, has had to be corrected for. Faegri and Iverson's formula was used to compensate for this over-representation. (Faegri and Iverson, 1964)

$$pi = a\,p\,\frac{100 - r'}{S - a\,r}$$

pi = the 'corrected' percentage to be calculated

a.p = the number of pollen grains of the species in the count.

r' = the 'fixed' percentage of the over-represented species

a r = the number of grains of the species

S = the total of all pollen grains included in the sum

It was assumed that the non-local Betula percentage had not changed from its reasonably constant values in the 32 cm. below this level. The values were 51.3%, 51.9%, 50.0%, 51.3%, 53.6%, so 52% was used as the fixed percentage of Betula (r') in the counts at 2, 8 and 12 cm. Originally Betula had accounted for up to 98% of the tree pollen. Pteridium and the Filicules were given a 'fixed' percentage at each level, relative to the 52% of Betula.

After each count, the slide was examined for additional pollen grains, which are represented on the diagrams by crosses. Pollen percentages are represented by horizontal lines. These lines have not been connected from one spectrum to the next, because the curves produced may be a false simplification of the actual state of affairs, as the peat between adjacent spectra has not been sampled, and could conceivably contain irregularities.

The diagram has been zoned primarily according to ~~the~~ Godwin's scheme (Godwin, 1956). Pollen zones 11 to V111 are represented. This zonation has been supported in some cases by the bog stratigraphy, but the

cont'd.

the local hydrological succession has not necessarily shown a seral change in accordance with pollen zone indicators. The 1-11, 11-111,111-1V and V11-V111 pollen zone and stratigraphical boundaries show good correlation.

The horizon separating the Late- and Post-glacial periods, is at 259 cms. and is defined by a large drop in herb pollen. It also separates mineral sediments below, from peat, above.

The Late-glacial period is unforested, with zone 1V showing a transition between open vegetation and full birch forest development. The Corylus phase is extremely prominent, extending through zones V and V1 with its peak in zone V1a. The Climatic Optimum is poorly represented, with zone V11 concentrated into a few cms. Herb values rise in V11 b and increase greatly above the zone V11-V11 boundary.

Zone 1 (up to 334 cm.) Represented by the higher, more sandy part of the blue lake clay. A sample prepared from 338 cm. did not contain enough pollen grains to make a full count. From 3 slide preparations, 38 grains were counted; 1 Betula, 10 Pinus, 1 Salix, 4 Gramineae, 2 Cyperaceae, 1 Compositae(Bellis type), 12 Helianthemum and 7 Myriophyllum. It could be that this small amount of pollen was worked down from the zone 11 deposit, were it not for the high Pinus percentage. Pinus grains can be carried a great distance, and it is likely that their high representation is due to the fact that very few plants were growing around Cranberry Bog. Alternatively, it could be that Pinus is one of the few plants, whose pollen is preserved in this deposit.

Zone 11 (334-308 cm.) A brown silty deposit with much organic matter. Tree pollen values are low, varying from 10% to 22%. The shrubs of Juniperus and Salix are consistent through the zone, Salix being low and Juniperus high. The combined tree/shrub percentage is between 22 and 32. Of the land N.A.P., Gramineae, Cyperaceae, Empetrum, Filipendula, Helianthemum and Rubiaceae are high, Filipendula rising to a peak of 6% near the end of the zone. Myriophyllum alternatum dominates the aquatic pollen with 53% at the beginning of the zone, but drops to 3.8% at the end. The Pteridophyte spores are poorly represented. The Plantago grain has/

cont'd.

been identified as P. maritima.

Zone 111 (308-259 cm.) The stratigraphy is varied, but each sediment contains little organic material. A bluish-grey lake clay (308-291 cm.) similar to the zone 1 deposit is succeeded by a distinct thin layer of yellow sand. It must be mentioned that this break sees the end of an unidentifiable 'pollen-grain' which resembles Juniperus, and when counted reaches 42% just below the break. If this were Juniperus, it would provide evidence enough to question the present position of the zone 11-111 boundary. The sand layer is followed by a brownish-grey clayey detritus with sandy bands and lenses (291-275 cm.) and then an unconsolidated grey detritus sand (275-259 cm.). Pollen is preserved in all these sediments. Tree pollen values range from 8-14% and therefore show little change from zone 11. Pinus, is higher in zone 111, and may be responsible for the A.P. values appearing similar, due to over-representation under the colder conditions (see zone 1 description). The shrub and herb ratio changes define the 11-111 boundary more clearly, with a reduction in shrub values and an increase in herb values. Salix rises to nearly 10% while representation by Juniperus is vastly reduced. Gramineae frequencies remain consistently high, but Cyperaceae values, after an initial fall at the beginning of zone 11, then become higher. There is a general rise in most other N.A.P, curves, except in the cases of Empetrum, Filipendula and Helianthemum where falls are observed. The pollen from aquatic plants remains low through most of zone 11, but rises again in the sand deposit.

(NB Rubus chamaemorus pollen was seen but not shown on the diagram, while the Plantago grains present are P. media and P. lanceolata. Betula nana has been recorded in zones 11 and 11, but not counted, and derived Carboniferous spores were prominent in every count.)

Zone 1V (237-259 cm.) Compact and well stratified swamp peat. As stated previously, the Late/Post-glacial boundary is defined on a sharp recession in herb pollen. At this boundary, there is also a sharp increase in shrub values, and then at 248 cm. there is a second decrease in herbs and a sharp increase in tree pollen. Juniperus increases/

cont'd.

increases from 1 to 15% over the boundary, while Salix, after a decline towards the end of zone lll, increases again. At the rise in tree pollen, Betula apparently takes over from Juniperus, with occasional grains of Quercus, Ulmus and Corylus pollen coming into the counts. This change is paralleled by a drop in Gramineae, Cyperaceae and Empetrum, with the extinction from the diagram of the majority of the still sruviving Late-glacial herbs. Salix, unlike Juniperus, remains consistently high throughout the zone. Another significant point is that the main decline of many of the Late-glacial herb pollen curves - especially Taraxacum, Ranunculaceae, Rumex, and Thalictrum - occurs in zone lll, at about 268 cm. Here, also, the initial rises of Filipendula and Empetrum are evidenced. The increase of Myriophyllum towards the end of zone lll is halted at the Late-/Post-glacial boundary and Potamogeton takes over dominance with values of up to 51%. There are noticeable peaks of the Filicales (Dryopteris mainly) and Equisetum, within the zone.

NB. Percentages given in the description of this zone, are still expressed in terms of total dry land pollen.

Zone V (204-237 cm.) Swamp peat followed by Bryophyte peat. Following Godwin, the boundary between zones lV and V is set where the Corylus pollen curve shows the beginning of its sudden and sustained rise to remarkably high values. It reaches 250% (cf total tree pollen) by the end of the zone. Pinus starts expanding rather later and reaches a maximum of 12.5% within the zone. Ulmus and Quercus are present, but in small amounts. Salix and the Cyperaceae remain prominent, but Juniperus, Filipendula and the Gramineae have virtually disappeared. The change from swamp to Bryophyte peat is reflected in the fall of the Myriophyllum, Potamogeton, Dryopteris and Equisetum curves, and the rise of Sphagnum spores.

Zone Vl (204-93 cm.) Bryophyte peat followed by Sphagnum-Eriophorum-Calluna peat. The zone is normally divided into a, b and c sub-zones. Diagram 1 shows that in Vla the shrub phase(comprising mainly of Corylus) is at its maximum, but remains prominent throughout the zone,/

cont'd.

while the herb percentages are at a minimum. Besides the rise in Corylus to over 500% of total tree pollen, the zone V-V1 boundary is defined on the rise in Ulmus and Quercus, with Ulmus dominant over Quercus in V1a. Salix values are reduced, and the first presence of Hedera is noted, half way through V1a. The change from Bryophyte peat to Sphagnum-Eriophorum-Calluna peat at 180 cm. is reflected in reductions in Sphagnum and Cyperaceae, and in increase in the Ericaceae (Ericales and Calluna). Both Ulmus and Quercus increase in V16, but now Quercus becomes dominant over Ulmus. Pinus rises to give its highest Post-glacial values, while Betula, though reduced to 33% at the end of V16, still maintains the highest tree pollen values. Alnus and Tilia join the mixed-oak forest trees of Ulmus and Quercus, in V1c - though they are present only in small numbers. Pinus is reduced, Betula rises, and the Ulmus and Quercus curves are little changed. Corylus shows much lower values, dropping from 211% to 44% within the sub-zone.

Zone V11 (93-69 cm.) Moderately humified, Sphagnum peat. Zone V11 normally covers a long period of time, and therefore is represented by a great thickness of sediment deposition, but it is here concentrated into 24 cm. It is subdivided into V11a and b, but only the latter, apparently is present in Diagram 2. Diagram 3 was prepared from samples taken from profile 3 to try and clarify difficulties created because of the condensed nature of the deposit, and here one prepared sample did reveal true V11a characteristics. The V1/V11a boundary is put where Alnus rises sharply from 2 to 15.5% and where Pinus starts to decline. The boundary between zone V11a and V11b is defined by a fall in Ulmus, and in Diagram 2 the rise in Alnus, and fall in Ulmus, occur in same sample. Pinus is further reduced at the V11a/b boundary, but rises again within V11b. Betula pollen remains the highest tree pollen, with values of about 50%; Quercus remains fairly constant, while Tilia is represented in every count. Fraxinus makes its first appearance in V11b. Herb values/

cont'd.

values rise continuously through the zone, mainly due to the rises of Gramineae and Cyperaceae, but many other plants of open habitats reappear. Especially indicative of human intervention is the rise of Plantago lanceolata and the appearance of the occasional cereal grain.

Zone Vlll (69-0 cm.) Regeneration cycle of Sphagnum peat. The opening of the zone is marked by a pronounced recurrence surface and many pollen indicators of a change to a more oceanic type of climate, and a great increase in human interference. Tilia almost disappears; Pinus and Ulmus greatly decrease, Alnus and Corylus undergo a temporary increase, while the increase seen in Quercus is of a more permanent nature. Betula shows a temporary decrease; Fraxinus establishes itself, while occasional grains of Fagus are found. The top 12 cm. have been greatly disturbed by drying out and long incorporation of more recent pollen, but here Ulmus and Pinus increase again, Corylus falls, and pollen, of the introduced tree Acer, is found. Above the Vll/Vlll boundary, herb values reach a maximum, then fall, but rise again towards the top of the zone.

DISCUSSION: The Development of Cranberry Bog and the Interpretation of Local Vegetational Changes which occur through the Late- and Post-Glacial Periods.

Cranberry Bog has formed in a hollow in the Middle Sands and Gravels, laid down in the Pleistocene. There is much controversy as to just where these deposits fit into the Glacial Succession (Francis and Smith) - whether they were connected with the Gipping or Weichselian Glaciation. A detailed examination of the stoney-clay deposits within the basin may have clarified the situation by exposing deposits of interglacial or interstadial age, but due to the lack of time and adequate boring equipment, this was not done. The hollow within the sands and gravels could have arisen as a result of uneven deposition of glacial material, or have been created by a remnant of stagnant ice, leaving such a depression on melting.

The origin of the clays within the basin poses an interesting problem. One idea is that the deposit was built up by sediment washed into an existing lake by stream action, but it seems unlikely that fourteen feet of lake clay could have been formed by drainage water from such a small catchment area, especially as practically ~~all~~ the whole of the catchment geology is composed of rock particles above clay size. A better suggestion seems to be that if stagnant ice was left behind, the stoney clay could have been deposited from the melting ice. It is possible that the top, very sandy part of the clay is largely composed of solifluction material, formed under the periglacial conditions existing in Zone 1 of the Late-glacial. A hydrological succession, involving mineral and peat deposits,

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developed above the clay.

The successional development of bogs was first explained by Weber in his "Terrestrialization hypothesis". According to him, the starting point for the development of a peat bog is a reservoir of water. Mineral deposits formed at the bottom of the water cause a shallowing of the reservoir. Bog vegetation then colonises, forming a layer of peat, and transforming the previously free water-surface into peat "land." This first stage of terrestrialization is brought about by aquatic reed associations. In subsequent stages, the bog surface is invaded by a vegetation of less exacting requirements as to ground water level. Reed association are replaced by sedge associations and as the surface rises higher and higher above the water-table, proper conditions are created for the invasion of a flora of a more and more terrestrial type. Ultimately, the bog surface is invaded by forest.

Weber thought that the transformation stages of a bog took place without any essential changes of external factors. Kulczynski (1949) greatly modified this theory by explaining that, in the formation of peat-bog types, external factors are of great importance. The factors are of a hydrologic nature, with the most important role belonging to the movements of bog waters. Ombrophilous or raized bogs develop where there is no water flow through them. There is an outflow but no inflow, and their whole water supply comes directly from rainfall. Rheophilous bogs are those developed under the influence of mobile ground water. There is a constant supply of water flowing through them. Transition bogs are

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intermediate between the two and a change from rheophilous to ombrophilous normally involves a transitionary phase.

Weber's Hypothesis, and the modifications made by Kulczynski provide a good basis for explaining the hydroseral development of Cranberry Bog.

Evidence that a lake existed in Zone 1 is provided by a pollen sample at 233 cm., where grains of Myriophyllum alternatum are present. Apart from this, no other plant remains are preserved.

Solifluction deposits are thought to mask the infilling of the lake in Zone 1 but in Zone II, the climatic amelioration made for greater productivity and variety of plants inhabiting the lake. Myriophyllum alternatum dominates the aquatic pollen, while many remains of Potamogeton are found. Remains of Carex cf. Rostrata, Ranunculus (Batrachian type) and Typha are also present. From pollen evidence, it is probable that a closed vegetation had developed on land, stabalising the substratum, and consequently the inorganic percentage added to the lake sediment was much reduced.

Zone III saw a return to more open vegetation, fewer organic remains, and a variable sedimentation. The gleyed, blue, sandy clay shows a return to Zone I type deposition, and this is followed by a uniform layer of thin sand which could represent an unconformity and period of no deposition.

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A brown grey sandy clay, then a coarse solifluction sand succeed this break. The sand grades into the brown clay, and it could have originally been a uniform sediment which, due to the cold conditions, underwent podsolization. Clays, and ions of iron and aluminium would have been leached to thebase of the deposit, leaving the grey loose sand. There is an absence of aquatic plant remains through much of the Zone, but towards the top, Myriophyllum, Carex c.f. Rostrata, Typha and Batrachian remains are again found.

Zone IV sees the beginning of the Post-glacial period and a great increase in the amount of organic matter produced. Potamogeton is dominant at first with Myriophyllum pollen percentages very much reduced. Phragmites, Carex, Menyanthes and occasional moss remains show that the lake rapidly becomes sedimented up in this Zone. The presence of such species as Acrocladium cuspidatum, Campylium stellatum, and species of the Sphagnum subsecunda group suggest that at this stage, the peat formed was transitional in character.

The reason why a transitional bog has developed is, as already mentioned, due to local hydrological conditions. Water can enter a lake basin as rainfall, by run-off and seepage from the immediate catchment, or from an inflow stream, derived from outside the immediate catchment (Bellamy 1966). The latter may be very rich in dissolved salts, and ensures a water flow through the lake to wash away any acidic wastes produced by metabolism of plants in the lake. It is likely that an alkaline rheophilous peat will form. In our case, due to the isolation of the spar supporting Cranberry Bog, there

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is no evidence to suggest that an inflow stream from outside the basin could have been present. Therefore, the only dissolved nutrients present, and the only flow through the basin could have been provided by run off and seepage from the local catchment. As the catchment rock is not basic in origin, few lake nutrients would have been derived from it. Consequently, there was no Rheophilous stage in the bog development, and it was transitional at the start.

At [illegible] cm., transitional swamp peat gives way to ombrophilous Bryophyte peat. As peat accumulated, it impeded the flow of water through the basin, and, in consequence, the level of the lake rose. With continued peat growth, the water table rose above the influence of the flowing ground water, until the character of the peat was determined only by its own water table, which would itself be dependent only on the precipitation-evaporation ratio, under the particular climatic regime. The acid wastes produced by the metabolism of the living mire would accumulate, and the peat would become acid in character. The Bryophyte peat is dominated by moss remains which all have a low mineral requirement, and grow on wet, peaty surfaces.

The presence of <u>Sphagnum palustre</u>, which occurs as a dominant regularly through the ombrophilous succession, is unusual. It is not seen as a dominant in any of the raised bogs outlined by Kulczynski, and tends to like different conditions, being normally found shaded by trees. Either its ecology has changed through time, or Cranberry Bog has been surrounded by trees for at least 8,000 years. A high <u>Betula</u> pollen percentage seen

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throughout the post-glacial diagram, suggests that it was always present near to the bog, and could perhaps have been able to shade the small area of the bog effectively. Bartley (1966) has also found Sphagnum palustre at Longlee Moor, Northumberland, as a co-dominant with Sphagnum cuspidatum, preserved under similar conditions. The Bryophyte peat was formed under fairly consistently waterlogged conditions, but gave way to Sphagnum-Eriophorum-Calluna peat at 180 cm. This exhibits hummock and hollow type, peat growth. In the wet hollows, Sphagnum species grow and their remains build up hummocks above the water table. Sphagnum is replaced by Eriophorum vaginatum, and finally Calluna vulgaris, as conditions become less moist. Calluna remains form very little peat, and it tends to have the opposite effect of breaking down the structure of the peat it is growing on. The water-table rises with the hummock type peat growth, and a peat structure, comprising of alternating layers of Sphagnum, Eriophorum and Calluna, is formed.

Near the Zone VI/VII boundary, there is a change to moderately humified Sphagnum peat, with many Calluna fragments, and wood and twig remains of Betula at the top. This peat layer is only 30 cm. thick and represents the very top part of Zone VI and the whole of Zone VII. Growth must have been very slow, or erosion must have taken place at intervals. Evidence of sand in the peat, with clear sand horizons, concentrated between 78-88 cm., could represent the remnants of the deposit being intermittently eroded. The sand grains could have been blown onto the peat from surrounding bare ground. Pollen evidence shows that human activity was marked in the area, and deforestation could have created temporary bare

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patches of ground which were eroded before plants could recolonise them.

The phenomina of slow peat growth, erosion surfaces, _Calluna_ remains and remains of _Betula_ trees point to drying out of the bog; the natural end result of a domed ombrophilous mire. The bog here reached its maximum elevation, maximum drainage, and maximum marginal gradient down to the lagg surrounding the dome under the particular climatic regime; but charcoaled _Calluna_ fragments and stones resting on the sand layers are evidence of human interference which could also have had and effect on the hydrology of the bog.

At 69 cm. a "recurrence surface" represents a climatic change to more Atlantic conditions, which altered the drainage relations of the bog and allowed regeneration of the peat. A light, weakly humified _Sphagnum_ peat formed. Weber called this surface the grenzhorizont, corresponding to the Zone VII/VIII boundary. It was originally thought to be synchronous throughout North West Europe but carbon dating have proved that it may have formed at various periods due to local conditions, with 500 B.C. being the most frequent. In some places, a number of recurrence surfaces are seen in the same profile. It is hoped that this horizon will be radio-carbon dated in the near future.

The peat above this surface is dominated by the remains of _Sphagnum palustre_, _Sphagnum cuspidatum_ and _Sphagnum recurvum_. _Menyanthes_ seeds and pollen and pollen of _Hydrocotyle_ just above the grenz show that the mire surface was flooded before regeneration of the peat commenced. The

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preserved remains of Betula show that trees established on the the dried bog surface were overcome by flooding and fresh Sphagnum growth.

The Sphagnum peat becomes moderately humified at 40 cm. with similar Sphagnum species present, and highly humified from 12 cm. to the surface with hardly any identifiable remains of the original peat forming community preserved. Again the dome has come into equilibrium with existing conditions. The top 12 cm. show great incorporation of recent pollen from surface vegetation, and have taken on a secondary fibrous nature due to the presence of many living and recently dead roots, leaves and twigs. Betula has colonised the dried bog surface with a change over the 12 cm. from Filicales to Pteridium dominated undergrowth. It must be stressed that this regeneration cycle may not be a natural reflection of growth under a particular climate, as the climate could have been constantly changing. Human in tervention must also have had a great effect on the succession. It is known that the peat has been dug for local agricultural purposes over a long period of time, and it is likely that draining, burning and grazing have been practised on and around Cranberry Bog for many centuries.

This hydrological succession has been seen to be complicated and to contain problematical features, but can be tentatively classified within the system outlined by Kulczynski (1948) as a continental raised bog. The major factor determining its classification is its watershed site, away from the influence of stream-water movement.

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The pollen diagrams provide the material for the next part of the discussion which is an attempt to interprete the vegetational history of the area. Any striking similarities, differences or problems encountered in comparison with other diagrams will be discussed. The Longlee Moor site, investigated by Bartley (1966) is of special interest. It lies to the north of Cranberry Bog, in Northumberland, at a similar altitude and showing a similar successional development. Godwin (1956) is used to provide a basis for camparison with the general pattern of vegetational development over the British Isles.

Diagrams 1 and 6 show that this area was unforested during the Late-glacial period. Birch trees were present but not as closed woodland. The Pine pollen was probably derived from long distance transport, and not indicative of the presence of Pine trees in the area. Very little pollen or plant material is present in the Zone I sediments, and therefore this period must have been one of open vegetation, allowing considerable erosion of mineral soils. Lake clay and solifluction material were replaced by an organic silt in Zone II. This illustrates a closer cover of vegetation dominated by Juniper shrub, which shows high pollen values throughout the zone. Juniper shrub preceeds birch woodland which cannot have been very far away. Although pollen grains are preserved in the Zone III lake clay, there are many evidences of a return to colder conditions; including

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the fact that the lake clay is similar to the Zone I deposit, the absolute number of pollen grains found is less than in the Zone II deposit, Juniper almost disappears, there is a greater representation by the herb species and aquatic pollen is not found. Two other deposits, sandy clay detritus and organic sand, complete the Zone III sediments. Bartley describes a similar stratigraphy for Longlee Moor, but puts the two latter deposits into Zone IV. There, probably due to the more northerly latitude, no pollen is preserved in the lake clay which he makes the whole of his Zone III. In comparing the two diagrams, there is evidence to suggest that his Zone III boundary could be raised to include at least the detritus. This is a point which he brings out in his discussion. On the other hand, with Longlee Moor being further north, or the lake being deeper than at Cranberry Bog, the stratigraphical succession could have been delayed.

The division between the Late- and Post-glacial periods is marked in the diagram by a sharp recession in herb values and in the deposit by a change from sand to swamp peat. These changes are greater and more pronounced than those which accompanied the Zone II-III transition, illustrating a greater and more rapid change in temprature. Juniper quickly re-establishes itself, and then makes way for birch woodland half-way through the Zone. Many Late-glacial herbs persist into Zone IV but are eliminated by the time of arrival of the Birch forest.

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The Filipendula curve rises through Zone II, drops in Zone III, but rises again sharply at theIII/IV boundary and continu es through Zone IV. It is said by Iverson (1954) to indicate a rise in temperature in Late-glacial times, and its close correspondence with the juniper curves adds extra evidence to the positions where boundaries have been located.

The transitional nature of Zone IV is reflected in Diagram 1. At the opening of the zone, herbs reach their maximum extension and by the end of the zone, birch forest has reached its maximum development.

The 'transitional' nature of the locati on of Cranberry Bog with regard to the whole of the Late-glacial period, as well as Zone IV can be illustrated by a comparison to sites which have been investigated, to the north and to the south. To the north, at Longlee Moor, the tree and shrub values, throughout Zones I to IV are lower than at Cranberry Bog, but at Bradford Kaims (Bartley, 1966), situated near Longlee Moor, but at only 150 feet O.D., tree and shrub values exceed the thirty percent. reached in Zone II at Cranberry Bog. But at both these sites, described by Bartley, no pollen is preserved in Zone III. Diagrams published by Donner (1957) from the Southern Uplands of Scotland, show only open vegetation in Zone II with not even park tundra present. Closed birch forest was only established at the very end of Zone IV, with a Filipendula maximum in Zone V.

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To the south at Neasham, 150 feet O.D. (Blackburn 1952) Zone III pollen is preserved as at Cranberry Bog but there, tree and shrub values reach to over 95 percent. of total dry land pollen, in Zone II. Further south, at Tadcaster in Yorkshire (Bartley 1962), pollen is present in Zone I in countable numbers. The juniper maximum appears near the end of Zone I and is followed in Zone II by the spreading of open birch woods. There was no second juniper maximum and therefore, even in Zone III, there must have been open birch woods which became closed woods at the start of Zone IV. This is in contrast to Cranberry Bog, where there was no woodland development at all until the middle of Zone IV.

The opening of Zone V saw a great increase in _Corylus_ which reaches 700 percent. of total tree pollen in VIa. This great increase is not paralleled in _Pinus_ which expands after _Corylus_ and reaches a small peak in Zone V. The Pine curve is interesting through Zones VI and VII. Oldfield (1965) has pointed out that the spread of Pine took place at different stages in the woodland re-colonisation of the British Isles. In southern and eastern England, it spread over pioneer Early Post-glacial birch woodland, while in the north west, Pine spread within an area of established deciduous forest. At Cranberry Bog, pine shows a peak at the beginning of Zone VI before _Ulmus_, _Quercus_ and _Corylus_ reach their highest values

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and in this respect corresponds with the southern and eastern English diagrams, but it reaches its maximum extension after the peaks in Ulmus and Corylus and consecutive with the maximum extension of Quercus at the end of VIb. It rises here at the expense of Betula, Ulmus and Corylus and in these respects corresponds with the north west. During Zone VII, Pinus is still well represented and this must be due to local conditions as it is not reflected in any other part of the British Isles. Betula pollen always represents at least 30 percent. of total tree pollen through the Post-glacial period, and this is probably also due to local over-representation.

Zone VII represents the most confusing part of the diagram, and the reasons why Diagram 3 had to be prepared have been explained. Alnus is very low through Zone VII reaching no more than 20 percent., but values of 40 percent. are recorded at the baze of Zone VIII. This great increase corresponds with human deforestation and the maximum extension c of herb pollen. It is probable that the higher hill slopes were cleared for agricultural purposes and the valleys left forested; a pattern that still exists today. The hills would have been less densley forested and more accessible than the steep valley slopes. Birch and pine on the hills would have suffered the most, leaving the alder-oak covered valleys to provide a greater percentage of total tree pollen-ation.

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Diagram evidence shows that there is a temporary decline in Betula, with a more permanent decline in Pinus.

These, and most other changes in tree pollen curves at this point, are at present regarded as due principally to human interference but the well evidenced climatic changes accompanying this boundary must also have had a great effect.

The onset of human interference and deforestation was at the beginning of Zone VII, but it is not until half-way through the Zone, possibly at the start of the Bronze Age, that the Gramineae and Plantago lanceolata curves show a great increase. Many Late-glacial plants of open habitats re-appear. The opening of Zone VIII and the Iron Age sees a great increase in interference and it would be interesting to be able to date this phase. Four hundred B.C. is the accepted date for Southern England with four hundred A.D. most often found in the North West. As the grenzhorizont is normally dated to four hundred B.C. it seems likely that this is the date for Iron Age activity around Cranberry Bog.

Activity was then reduced; all herb values fall, but increase again towards the top of the profile. This increase is not as great as expected, which most likely shows that a large part of the top of Zone VIII is missing or condensed into such a small thickness of peat that mixing by roots, and

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and recent pollen incorporation has confused the trend.

Despite the fact that parts of the pollen sequence are confused, the major value of the diagram as a whole lies in its completeness and, therefore, usefulness as a basic reference of vegetational development in this part of the British Isles.

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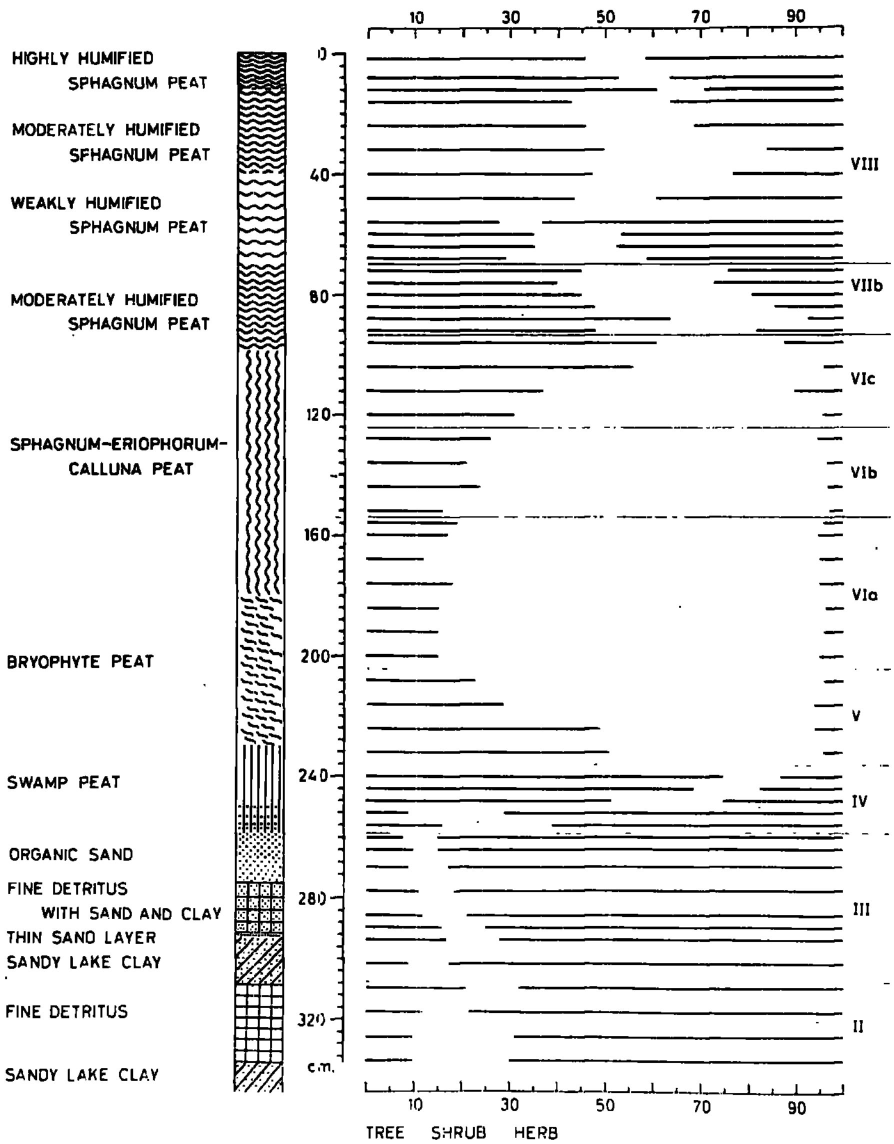
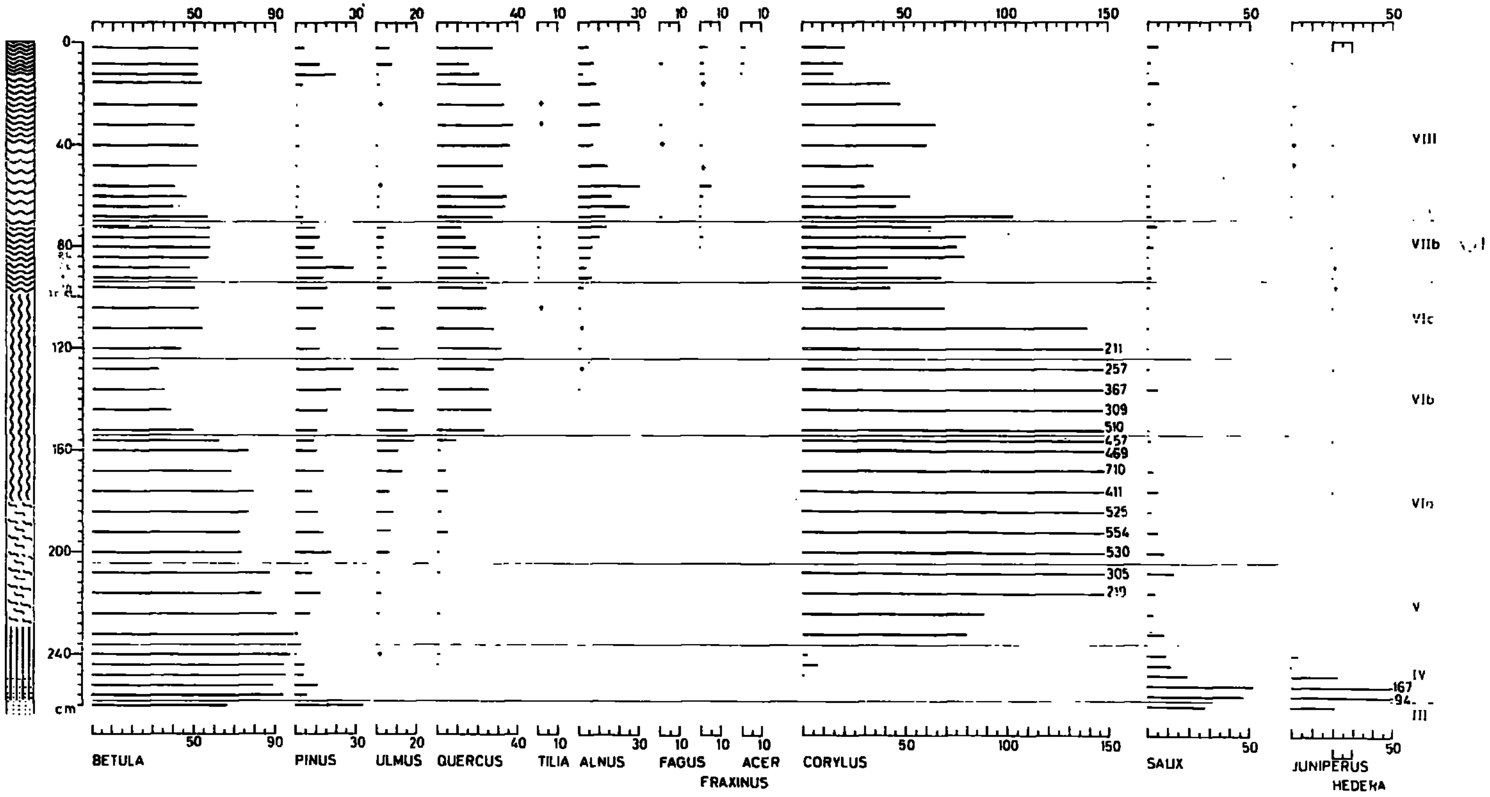
POLLEN DIAGRAM 1. CRANBERRY BOG (1967)

THE TREE-SHRUB-HERB RATIO

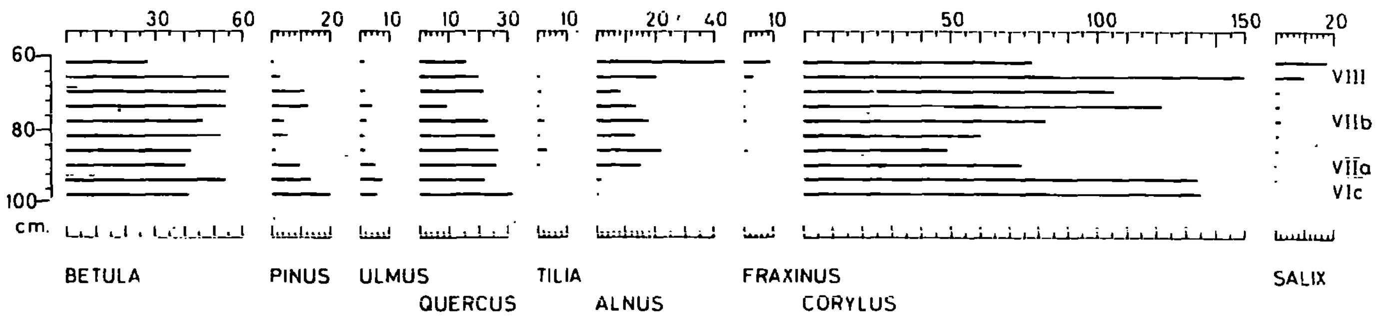


POLLEN DIAGRAM 2. POST-GLACIAL TREE AND SHRUB VALUES (as percentages of total tree pollen) CRANBERRY BOG (1967)

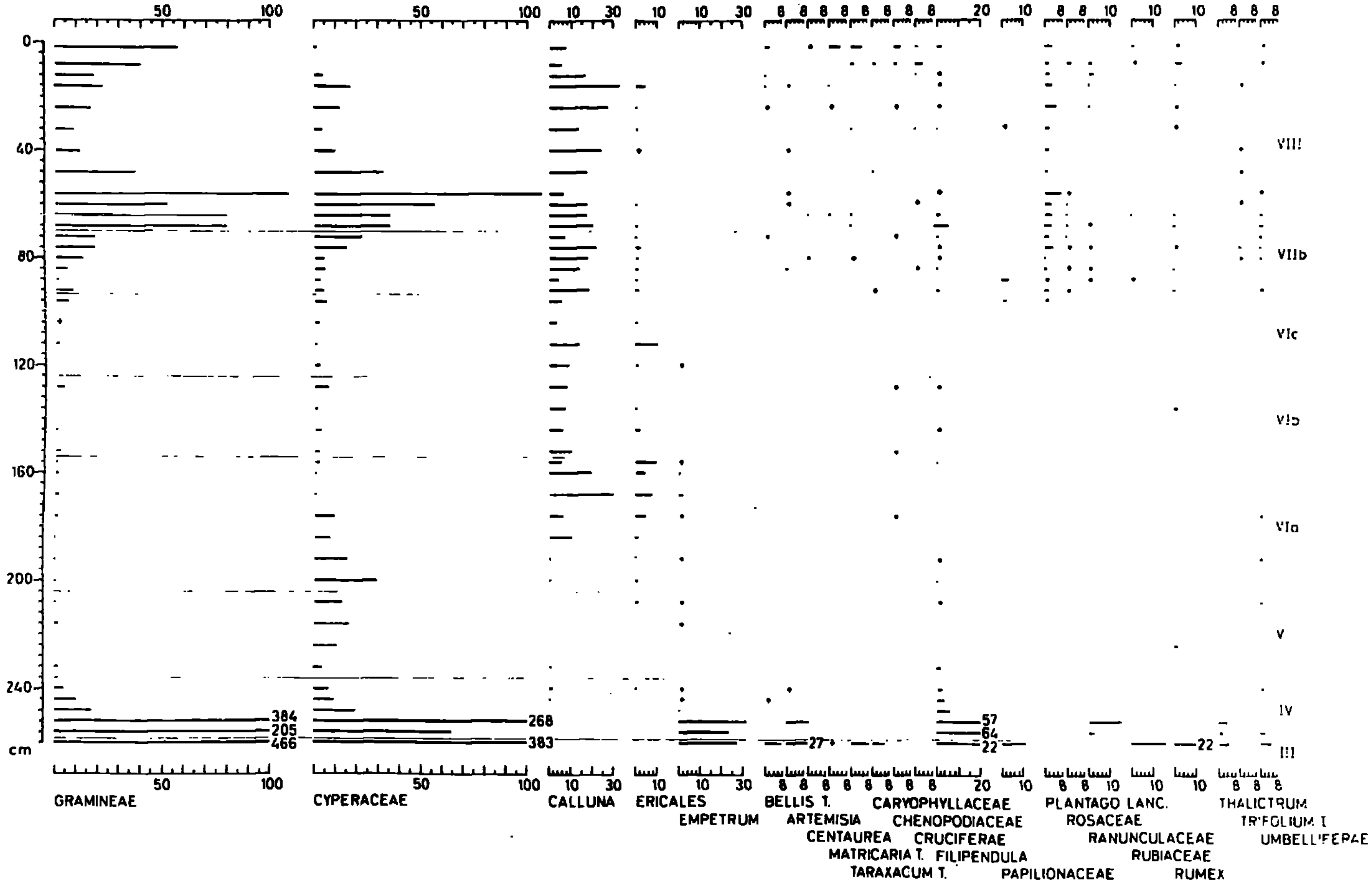


POLLEN DIAGRAM 3. CRANBERRY BOG (1967)

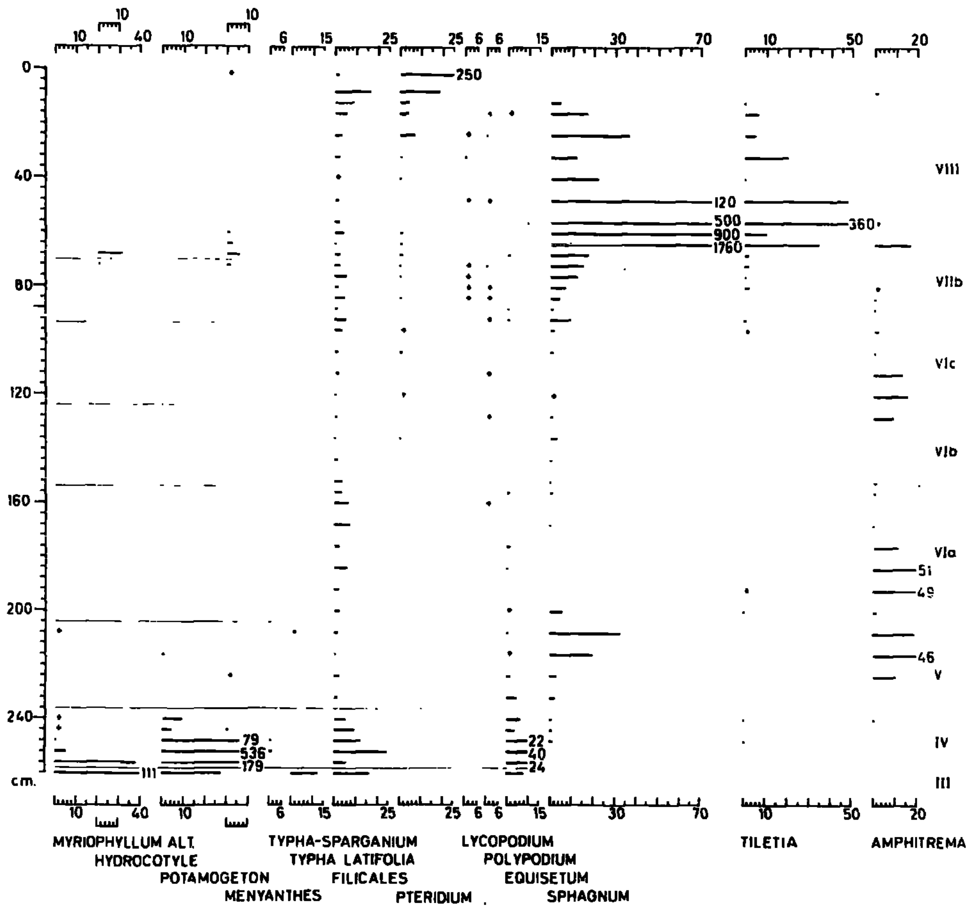
POST-GLACIAL TREE AND SHRUB VALUES (as percentages of total tree pollen)



POLLEN DIAGRAM 4. POST-GLACIAL HERB VALUES (as percentages of total tree pollen) CRANBERRY BOG (1967)

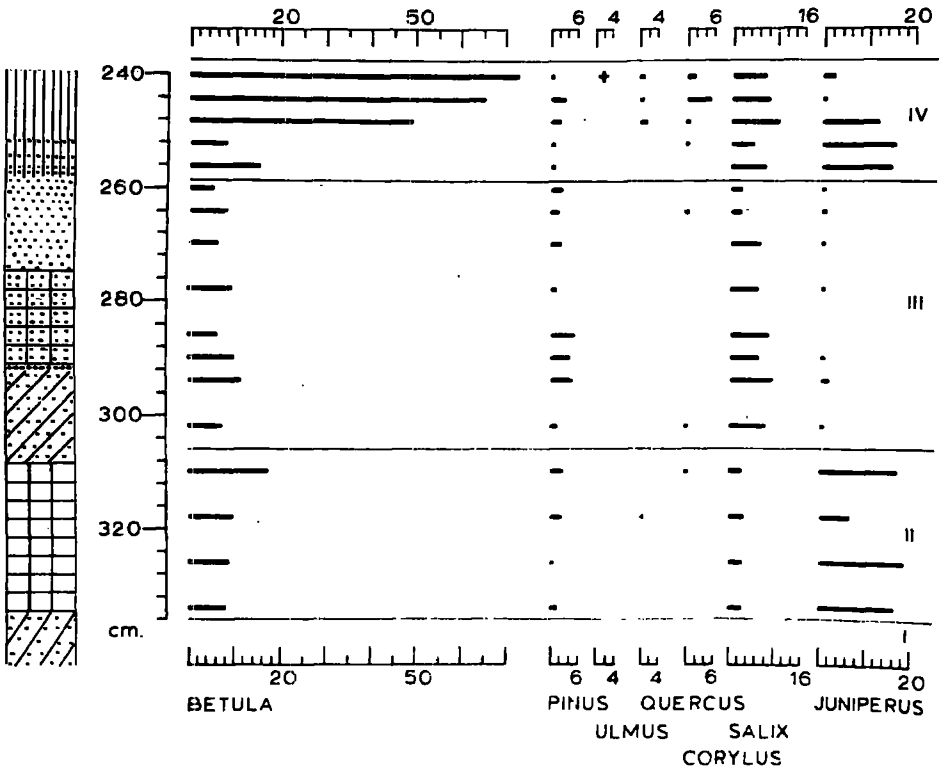


POLLEN DIAGRAM 5. POST-GLACIAL AQUATIC & SPORE VALUES (as percentages of total tree pollen) CRANBERRY MOSS (1967)



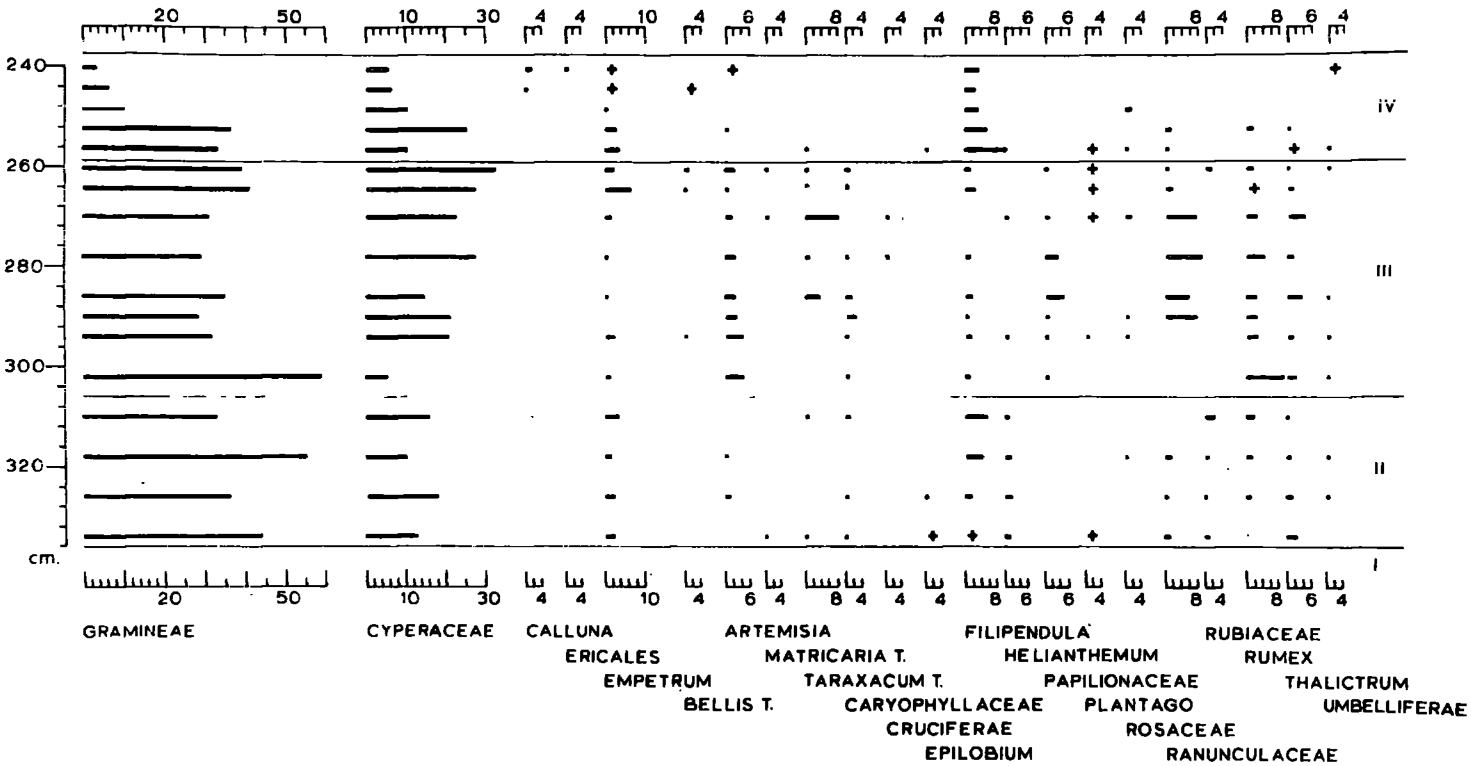
POLLEN DIAGRAM 6. CRANBERRY BOG (1967)

LATE-GLACIAL TREE AND SHRUB VALUES
(as percentages of total dry-land pollen)



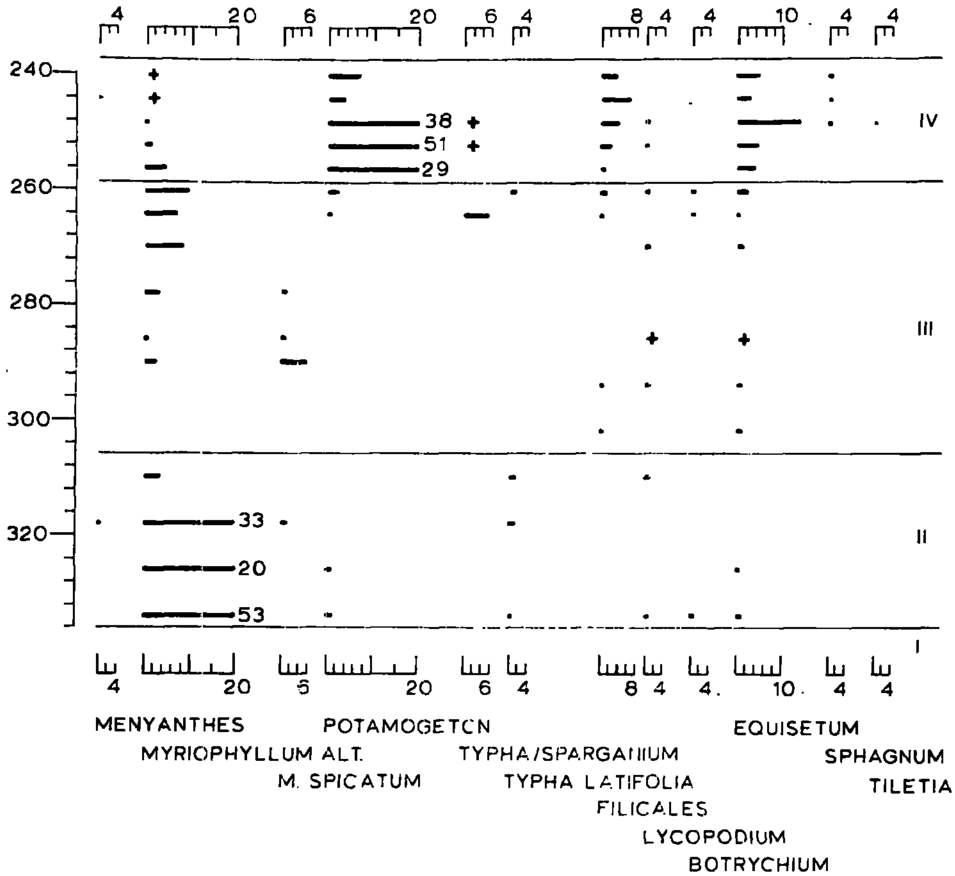
POLLEN DIAGRAM 7. CRANBERRY BOG (1967)

LATE-GLACIAL HERB VALUES (as percentages of total dry-land pollen)



POLLEN DIAGRAM 8. CRANBERRY BOG (1967)

LATE-GLACIAL AQUATIC AND SPORE VALUES
(as percentages of total dry-land pollen)



ACKNOWLEDGEMENTS

My thanks are due to Dr. J. Turner for her constant help and supervision; to Mr. Anderson for permission to carry out field work; To Mr. E.H. Francis for showing me an unpublished map and memoir of the local geology; and to Dr. D.J. Bellamy for help in the interpretation of the bog succession.

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