X.

THE BOGS AT BALLYBETAGH, NEAR DUBLIN, WITH REMARKS ON LATE-GLACIAL CONDITIONS IN IRELAND.

By KNUD JESSEN and A. FARRINGTON.

[Communicated by R. Lloyd Praeger.]

[Read 28 June, 1937. Published 27 May, 1938.]

Note.—The introductory part (pp. 205–216) is by A. Farrington, the remainder (pp. 216–256) by Knud Jessen.

Introduction.

The Ballybetagh bogs have long been famous as sites which have yielded remains of the Irish Elk (*Cervus giganteus*) in remarkable quantity. The investigations described in the following pages were made with the object of examining the deposits in the bogs, both by the collection of the macroscopic plant remains and by pollen-analysis, in order to discover the conditions under which the Elk flourished, and to try to throw some light on the climatic changes of late- and post-glacial times in this area.

The investigations were carried out under the auspices of the Committee for Quaternary Research in Ireland.

The work in the north-western bog, where the most complete study was made, was under the direction of Professor Knud Jessen, of the Royal University of Copenhagen, assisted by H. Jonassen. Professor Jessen, with Mr. Jonassen, undertook this investigation as a part of the general survey of Irish peat bogs upon which he was engaged at the invitation of the Committee for Quaternary Research in Ireland. For this purpose Professor Jessen had also a subvention from the Danish Rask-Örsted Foundation. F. T. Riley was in charge of the actual work of excavation in the other bogs, being assisted by Thomas Maher, who also made the preliminary surveys. G. F. Mitchell participated in the work, and later assisted A. Farrington, who, as Secretary of the Committee, was responsible for the general organization, in making the final survey of the excavations.

Extensive excavations were necessary in the south-eastern and eastern bogs where the ground was much disturbed, and it was obligatory to expose a considerable area before any correlation with previous work or with the complete section in the north-western bog could be attempted. The Committee owes its grateful thanks for grants in aid of the research to

the Government of Saorstát Éireann, the Royal Irish Academy, University College, Dublin, Trinity College, Dublin, the Royal Dublin Society, the Royal Society of Antiquaries of Ireland, and the Belfast Natural History and Philosophical Society. The cost of labour for the work was defrayed by a special grant under the Government Minor Relief Schemes for Unemployment.

Special thanks are due to Mr. Thomas Roe, Ballybetagh House, who granted permission to excavate on his land and facilitated the work in many ways.

Topography.

The deposits to be described in this paper lie about 7 miles S.S.E. of Dublin in a hollow between two of the foothills at the northern end of the long ridge of the Leinster Chain. The mountain range ends in two summits now known as Fairy Castle (1763 ft.) and Three Rock Mountain (1479 ft.). The latter mountain slopes steeply northwards to the lower ground fringing the southern side of Dublin Bay. Fairy Castle, which lies south of Three Rock, is flanked by lower hills extending to the east with gradually diminishing height. It is in a depression between two of these, Ballyedmonduff (1103 ft.) and Ballybetagh (840 ft.), that the marshes bearing the latter name lie.

South of Fairy Castle a deep consequent valley (Glencullen) has been excavated by the Cookstown River. This is a straight valley, the lower reaches of which contain accumulations of glacial drift. The natural drainage from the north-western and south-eastern bogs, now diverted northward through a drainage trench, originally fell directly into this river through a gully cut partly in the old rock wall of the valley, and partly in the drift. The drainage of the eastern bog goes eastward to the Scalp, a fine glacial "dry valley" which cuts across the ridge immediately east of Ballybetagh.

The marshy area in which bones have been found may be divided into three parts:—the north-western bog, the south-eastern bog, and the eastern bog. The north-western bog lies at the bottom of a short, steep-sided and immature valley (without a stream) which separates Ballybetagh Hill from Ballyedmonduff. This valley is about 300 metres long and 40 metres wide at the bottom, and the steep sides are about 30 metres high on the western side and about 20 metres high on the eastern side. It has been classed as a glacial drainage channel, and the very rough aspect of the slopes lends weight to this view; but the existence of undisturbed boulder-clay at the bottom indicates the unlikeliness of its excavation having been effected as a retreat phenomenon of the last glaciation to invade the district.

Partially separated from the north-western bog by a low ridge of drift, the south-eastern bog lies at the opening of the above valley, where the

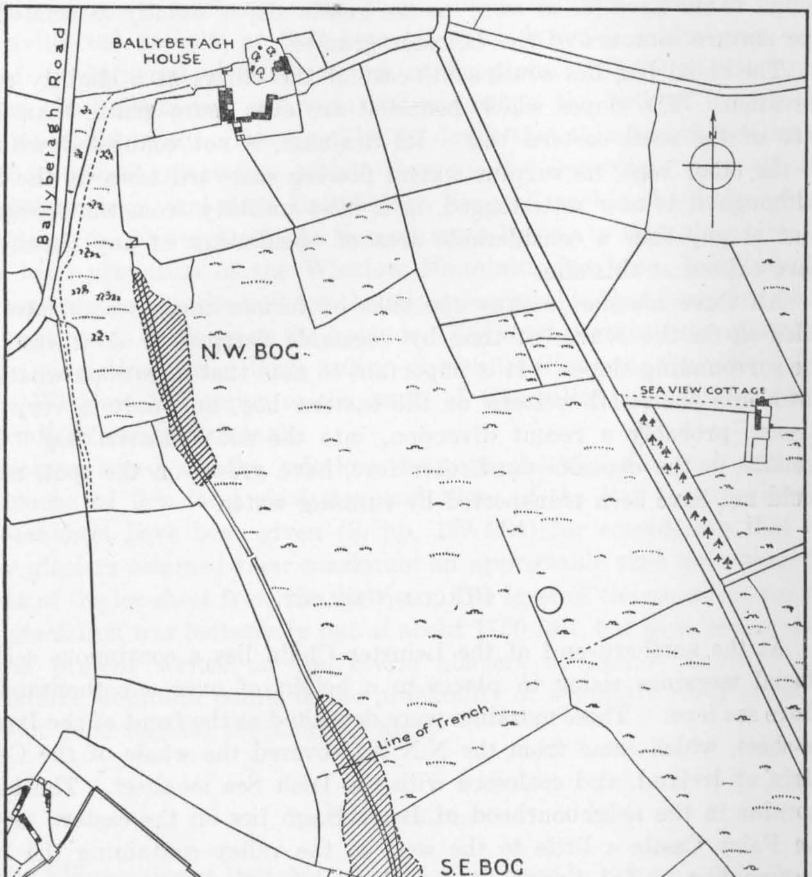


FIG. 1.

Based on the Ordnance Survey by permission of the Minister for Finance of Ireland.

rough banks have fallen away to the gentle slopes usually associated with the mature contours of the Leinster granite.

The third bog lies south-south-east of the others at a slightly greater elevation. The slopes which bound it are even more gentle than in the case of the south-eastern bog. Its drainage is not connected with that of the other bogs, its surplus waters flowing eastward towards the Scalp. Although it is now waterlogged, it is most unlikely from the topography that at any time a considerable area of open water of any depth could have existed at this site.

All three marshes occupy the sites of former tarns which have been filled up in the course of time by vegetable detritus or downwash from the surrounding slopes. It is important to note that no stream whatsoever flows into the north-western or the eastern bog, and only a very small stream, probably a recent diversion, into the south-eastern bog. Plant remains in the deposits must, therefore, have grown on the spot, as they could not have been transported by running water.

Glacial Geology.

At the northern end of the Leinster Chain lies a continuous series of glacial moraines rising in places to a height of over one thousand feet above sea level. These moraines were deposited at the front of the Ivernian ice-sheet, which came from the N.N.W., covered the whole of the Central Plain of Ireland, and coalesced with the Irish Sea ice-sheet. The highest moraine in the neighbourhood of Ballybetagh lies on the eastern slope of the Fairy Castle a little to the west of the valley containing the north-western bog. The limit is reasonably well defined along the mountain slopes by a series of gravel mounds and thick deposits of sandy clay bearing plentiful limestone boulders and is almost coincident with the one thousand foot contour. The moraines are the outermost of the Newer Drift described by Charlesworth (1) and considered by him (2) to be contemporaneous with the York Moraine of England.

Outside this line of moraine an older drift, also extraneous to the area, is found. This is preserved, for example, on the sides of Glencullen farther up the valley than the great piles of fresh drift which are the continuation of the moraines mentioned in the last paragraph. That this old deposit is of glacial origin is shown by the far-travelled stones, some still bearing distinguishable marks of striae. Andesite of the same type as that of Lambay occurs with slate, quartzite, chert, and sandstone of Carboniferous type. Here and there pebbles of limestone may be found, so leached that they may be crushed into mud in the hand. The drift is weathered right down to the underlying rock surface into a yellowish-brown sandy clay. In the bottom of the valley the recent stream deposits lie on a hard rubble composed of the denuded remnants of the old drift mixed with angular granite detritus.

This contrasts markedly with the boulder-clay that has been found underlying the deposits at Ballybetagh. This latter is a blue-grey clay, full of unweathered, striated pebbles of limestone. Although the upper portion has been moved and rewashed somewhat, the bulk of it seems to be quite undisturbed. There can be no doubt that this deposit belongs to the most recent glaciation which covered the immediate area of the Ballybetagh bogs, and since Ballybetagh lies well within the limits of the moraine of the Newer Drift the deposit must belong to that glaciation.

A local glaciation of the Wicklow Mountains has been described (3). This was confined to the valleys, though it is probable that large firn fields were continuous in places on the uplands. The most northerly manifestation of this glaciation was a large valley glacier in Glencree, the next valley of the Wicklow Mountains to the south of Glencullen, and distant about three miles from Ballybetagh.

Reasons based on the relations between the deposits and drainage phenomena of this local glaciation and those of the last Ivernian—Irish Sea—ice-sheet have been given (3, pp. 199–204) for considering that the valley glaciers attained their maximum an appreciable time later than the retreat of the ice-sheet from the district. The level of the snow-line for the local glaciation was tentatively put at about 1750 feet, but more recent work by the present writer on the corrie glaciers of Mount Leinster and Blackstairs Mountain points to the probability of a slightly lower snowline at about 1650 feet for the Leinster area.

HISTORICAL.

The Elk remains at Ballybetagh were discovered in the year 1847 during the construction of a deep trench which was to bring water from springs at the southern end of the south-eastern bog to supply various commercial enterprises located at the foot of the hills to the northward. During the excavation of this trench, which was in places 21 feet in depth, the skulls and antlers of some thirty deer were found, together with many of the other bones. At the same time, the skulls and horns of Reindeer were discovered. This discovery was the subject of a short note by Professor Oldham (4).

Nearly thirty years afterwards, further excavations, with the object of determining the conditions under which the remains of the deer were embedded in the deposits, were undertaken by R. J. Moss (5). This paper is accompanied by a plan, but this, unfortunately, is on so small a scale and contains so little detail that it is now impossible to determine on the ground the position of the excavations made. A short discussion, by George Porte (6), of the results of this excavation, puts forward opinions on the significance of the discoveries.

The extraordinary wealth of remains unearthed attracted the attention of W. Williams, of the firm of Williams & Son, naturalists, Dublin, and he, over a period of several years, excavated in the area. He published a paper (7) which was accompanied by a diagrammatic sketch of a cross-section of the bog, but contained no plans. It is now impossible to find out exactly where Williams made his excavations. The most recent general report on the subject to appear is a short paper by Stokes (8). This contains no plans, but has a summarised description of his finds and of the stratification of the material met with.

All the writers were concerned chiefly with the discovery of the bones, and gave no critical attention to the deposits in which these bones were discovered, or to those overlying or underlying the bone-bearing beds with the exception of Williams who discussed the material comprising the beds, and evolved a theory of climatic changes. His findings were altogether based on the physical condition of the strata, and he made no attempt to identify any remains other than those of the large vertebrates. His work has frequently been quoted, notably by C. E. P. Brooks (9) and C. B. Whelan (10).

G. Erdtman (11) visited the area in 1924 and took samples for pollen analysis. In 1927, A. W. Stelfox (12) recorded his discovery of the occurrence of *Salix herbacea* in beds associated with those in which Elk bones were found.

Summary of Previous Work.

Most of the previous excavations appear to have been made in the south-eastern bog. So far as it is possible to locate the positions of the trenches made by Moss (5), only one was in the north-western bog, and none in the eastern bog. Williams (7) also confined himself chiefly to the south-western bog, but excavated also in the north-western bog in which he discovered some remains as may be inferred from his remark "The megaceros remains have been found mostly in the smaller lake" (*i.e.*, the south-eastern). Stokes (8) dug four pits in the north-western bog, but, in contrast, worked for seven weeks in the south-eastern bog and for three weeks in the eastern bog. Only one rib of Elk was taken from the north-western bog, as against twenty-eight skulls, nineteen antlers, three complete skeletons and many other bones from the other two bogs.

It has already been mentioned that the lack of adequate plans makes it exceedingly difficult to locate exactly the positions in which the excavations made by Moss, Williams and Stokes were sunk. However, the position of the original drainage trench is still clearly to be seen. The note by Oldham (4) is especially important for he saw the trench freshly open, and his account presumably gives a generalisation of a very large section. He says "The first Elk was discovered about eight feet from the surface being about four feet of bog, and two of a kind of vegetable compost containing leaves, grass, and mud, or fine granite sand, with mica. The entire number (thirty) found within a space of a hundred yards in length, by four yards wide, were, without exception, found embedded under the turf in the vegetable compost; the two being divided by a thin bed of fine sand. Under the vegetable compost, was a blue puttylike marl, about nine inches deep, forming a bed over a blue marl of a more solid character."

From the internal evidence in the publications of the other excavators it appears that all the "typical sections" were built up from the information obtained by excavation in the south-eastern bog. Describing the deposits from the top downwards, Moss (5, p. 548) first went through peat, under which lay a stratum of sand resting upon a brown clay at the bottom of which was a bed of granite boulders. The spaces between these boulders were occupied by a fine bluish-grey clay, and it was in the brown clay that the animal remains were found. A second excavation by Moss (5, p. 549) gave the following section:—peat, a trace of sand, a grey clay with vegetable layers, brown clay and blue clay, not bottomed. Williams, in his diagrammatic section, gives peat, grey clay, brown clay, yellowish-grey clay, and a fine tenacious clay without stones, with boulder clay at the bottom. Stokes accepts this section with qualification, "stating that the strata were usually arranged as described by the late Mr. Williams," but he does not give any different sections. Williams gives the additional information that in the north-western bog the grey clay bed was replaced by one of gravel. Also that there were seams of clay and quartz sand in the brown clay.

The first section revealed by Moss's work is that found in a trench which was sunk near the edge of the bog, whereas the second section was more in the centre. It is clear that, allowing for this difference, the strata correspond exactly; the thick bed of sand in the first being a shore facies of two strata in the second section, namely the traces of sand and the grey clay with vegetable layers. Below this, his sections are the same, varying only in the thickness of the deposit. Williams does not say whether he dug near the centre or at the edge of the bog, and makes only a most general reference to the thicknesses of the beds through which he passed. However, although his descriptions are vague, his section agrees fairly well with that of Moss; Williams having sub-divided Moss's brown clay into two beds, viz., brown clay and yellowish-grey clay. The 'fine sticky clay' of Williams is obviously the 'blue clay' of Moss's sections. In the first section quoted from Moss, this clay was thin, and lay in the clefts between granite boulders, whereas in his second and more central section, it was very thick.

All four investigators are agreed that the animal remains did not occur higher than the brown clay. Williams records *Megaceros* remains from the brown clay only, but mentions (7, p. 12) a Reindeer antler from the grey clay overlying it. Stokes states clearly that the remains are found in all the layers below the grey clay, adding that they are most plentiful in the yellowish-grey clay. There is a difference of opinion here.

The discovery of Elk remains in the eastern bog is due to Stokes, and, so far as can be ascertained, his excavations were the only ones previously made in this area. The section which he gives is peat, underlain by a brownish clay which, in turn, lies upon a fine tenacious clay. He equates the brownish clay to the similar clay in the south-eastern bog, and considers the fine tenacious clay to be the same as the sticky clay at the bottom of the Williams section. If this be so then the grey clay which comes between the peat and the brown clay, as well as the yellowish-grey clay which lies immediately below the brown clay in the south-eastern bog, is absent from the eastern bog. Stokes comments on this, but does not offer any explanation.

Comparison of Former Work with the Present Excavations.

It was clear from the foregoing remarks that new excavations for stratigraphical purposes would be best undertaken in the north-western

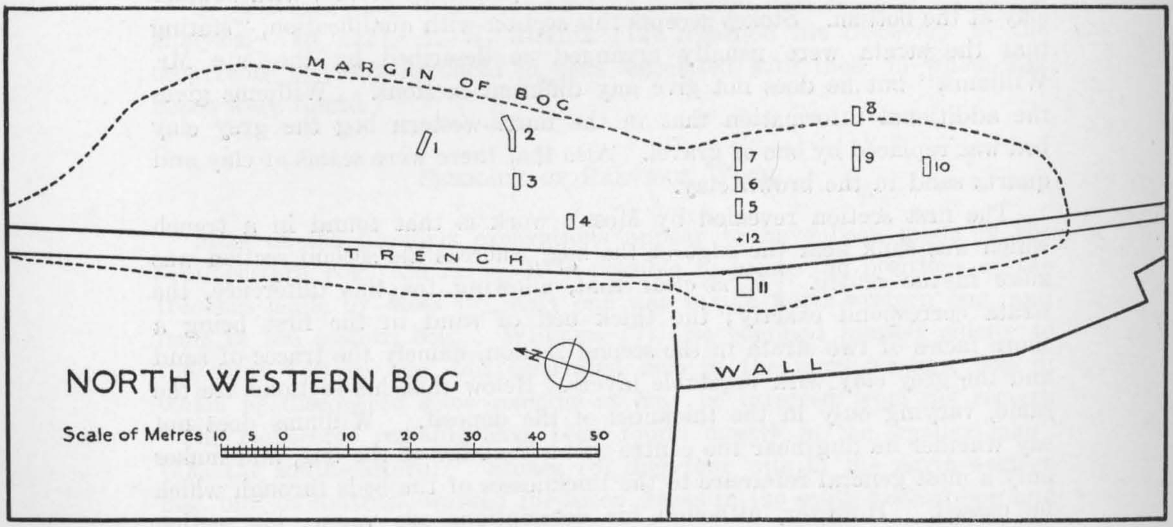


Fig. 2.—Showing positions of excavations.

bog, as there was much less likelihood of disturbance there than in the other areas. Accordingly, pits were sunk there, eleven in all, varying in depth from eighteen inches to nine feet. Skulls and antlers of *Cervus giganteus* were discovered at the western side. A complete section, including pit 11 in which skulls and antlers were found, was made across the old lake basin: borings being made where the boulder-clay was not reached in digging. This constituted the most important work, but sinkings were made in the south-eastern bog, and also in the eastern bog to discover the conditions there, and to see whether there was a possibility that the strata in these bogs, where most of the previous discoveries had been made, could be correlated exactly with the carefully measured section of the north-western bog.

In the full section excavated during the investigations described in the present paper, the strata were very much sub-divided in comparison with the descriptions previously given. The details may be taken from Pit 6, which lies about one-third of the distance from the eastern end of the section in which the Elk was found in the north-western bog. The full details of the section are as follows:—

A.	0–30 cm.	Earthy peat
B.	30–70 cm.	Peat with stumps of *Alnus* and *Betula*
C.	70–85 cm.	Brown muddy drift peat with *Salix* leaves
D.	85–120 cm.	Light-brown Chara-mud with plant remains
E.	120–175 cm.	Alternating layers of grey clayey sand and stony clay
F.	175–338 cm.	Light-yellow mud with slight variations in colour without sand
G.		The bore ended in a stony clayey layer through which the drill could not be forced

It seems clear that if this section is to be compared with that of Oldham, Moss, Williams or Stokes, deposits which are here clearly differentiated must be taken together; for example, the first four items must be equated to the peat stratum of Williams and Moss. The next bed is the equivalent of the grey clay of Williams, and the sand and grey clay of Moss. Below this, the deposits agree very closely with Williams. It seems, on the whole, that the detailed section found in the north-western bog corresponds well with the generalizations given by former workers from the south-eastern bog. The bottom clay found in this particular section was not the fine tenacious clay which Williams considered to be a transported boulder-clay, but a stony clay which at the top was mixed with granite debris, and seems to have been derived by washing down of the boulder-clay originally deposited on the sides of the valley. Below this was undoubted and completely undisturbed boulder-clay.

The excavations in the south-eastern bog on this occasion were not very successful, as it was exceedingly difficult, firstly, to find a place which had not been disturbed by previous excavations, and secondly, owing to the amount of water lying on the surface (the drainage of the bog having become stopped up), to sink down to any depth. One pit was sunk well into the bog, from which Mr. Riley recorded the following section:—

Peaty matter	137 cm.
Chara-mud with leaf layers	100 cm.

Below this lay a thin layer of small gravel, 2–4 cm., followed downwards by another yellowish-brown mud. It is not clear where this fits into the scheme, and it is not certain that the ground was undisturbed. At the northern end of this bog, a large trench was sunk to the boulder-clay right across the depression. This proved, beyond a doubt, the existence of an undisturbed bed of boulder-clay of unknown thickness underlying the deposits, but the deposits themselves were not clear. It appears that this bog has been so dug over that there is little chance now of finding a true section, and full use must be made of the very incomplete information already published.

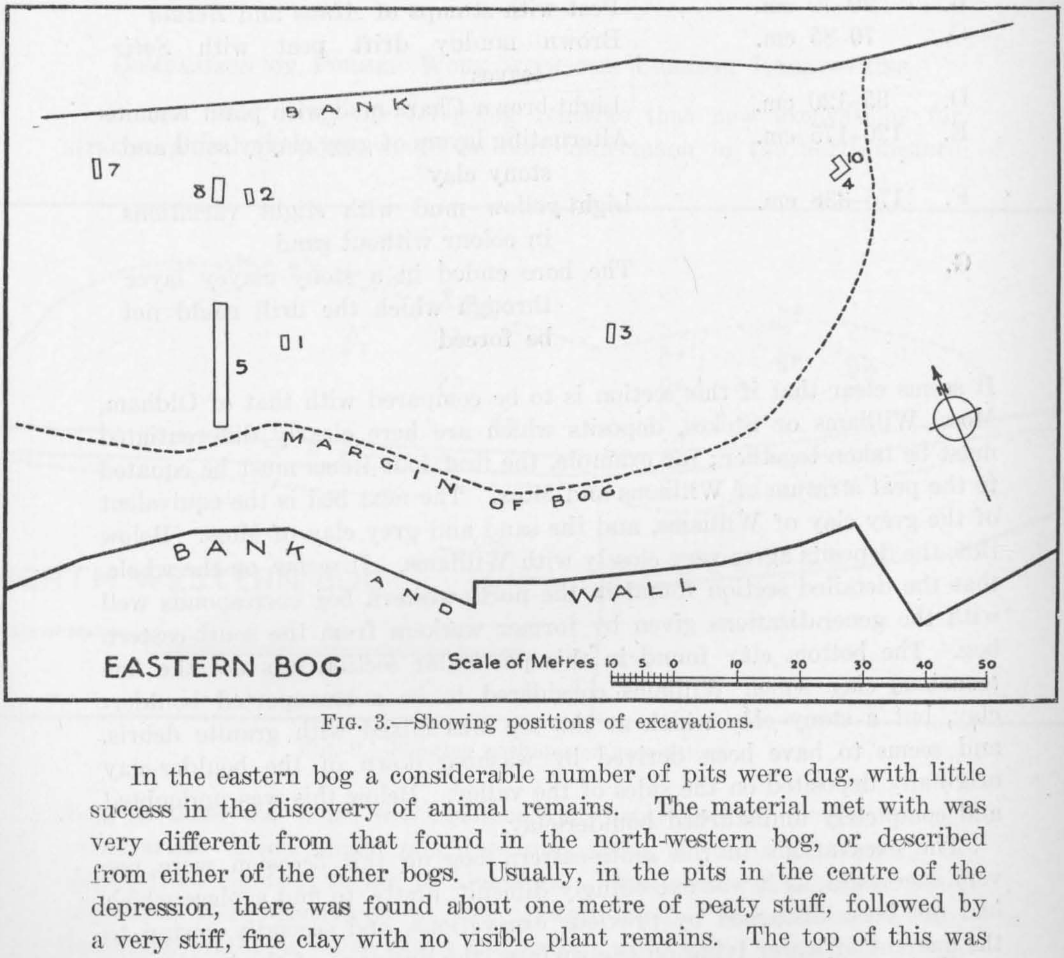


FIG. 3.—Showing positions of excavations.

In the eastern bog a considerable number of pits were dug, with little success in the discovery of animal remains. The material met with was very different from that found in the north-western bog, or described from either of the other bogs. Usually, in the pits in the centre of the depression, there was found about one metre of peaty stuff, followed by a very stiff, fine clay with no visible plant remains. The top of this was sometimes slightly sandy, but, on the whole, except for irregular variations in colour, there was little change throughout the depth excavated.

The Section taken from Pit No. 8 is typical of the sinkings made in the deeper part of this bog:—

0–55 cm. Clayey peat.
55–90 cm. Drift peat with seeds.

90–103 cm.	Mottled black and grey mud without sand, a layer of small stones a little above the bottom.
103–140 cm.	Black mud mixed with a stiff grey clay.
140–260 cm.	A very tough clay, light grey in colour, with occasional small stones.
260–330 + cm.	Coarse sand, full of water. The bottom of this layer was not reached.

Also of interest are the sections taken from Pits 4 and 10 as some details can be given as to the content of plant remains in one of the layers in these. The description of the section at the corner (see the map, fig. 3) between Pit 4 and Pit 10 runs thus:

0–15 cm.	Mouldered peat.
15–17 cm.	Quartzy gravel.
17–25 cm.	Mouldered peat.
25–42 cm.	Gravelly sand.
42–110 cm.	Brown peaty, sandy mud or grey marly mud with many small stones.
110–150 cm.	Stiff stony clay irregularly black and grey; rewashed boulder clay?

Rolled fragments of bone were found underlying but not in the brown peaty mud. The sample (*b*) for washing analysis was taken just above the stony clay beds; compare p. 223.

It is evident that the deposits here are quite different from those found in either of the other bogs and are not without considerable suspicion of having been disturbed.

According to Stokes, in this bog, which he calls Mulligan's Bog, the bones were found directly beneath the brownish mud. Apparently, then, if the position of the bones is to be used for stratigraphical purposes, we must equate the peat and brownish mud of Mulligan's Bog to the whole upper portion of the section from either of the other bogs, the arctic bed so marked in the other areas being absent or at least not recognisable by the unaided eye. This is not altogether surprising, since the slopes surrounding Mulligan's Bog are very much more gentle than those enclosing either of the others, and, as we would expect, the north-western bog, where the sides of the containing valley are steepest, has the thickest deposit of gravelly material.

Stokes records a ''sandy marl'' and a ''sandy clay with shells'' of considerable thickness at the bottom of the section in the north-western bog. A marly bed with shells is also recorded by Mr. Stelfox from the same bog (private communication). This bed was not found during the recent excavations. Presumably it is a facies of the lower Chara mud.

Summing up the foregoing notes, it may be said that the descriptions of the strata given in previous reports agree well with what has been found during the present investigation; and the stratigraphical position of the finds of bones of *Cervus giganteus* recorded by Oldham, Moss, Williams and Stokes is the same as that in which they occur in the definitive section from the north-western bog.

In addition to the bones of *Cervus giganteus,* remains of *Rangifer tarandus* were also recorded. These were found in contact (Oldham). Moss and Stokes also record *Rangifer tarandus,* but do not state at what horizon. Williams notes one antler of *Rangifer* from the grey clay.

Stokes mentions bones of *Cervus elaphus,* but does not record their stratigraphical position.

A. F.

Stratigraphical and Palæontological Investigations of the North-Western Bog at Ballybetagh.

The situation of this bog is described above by A. Farrington. It lies at about 750 feet above sea level, and from the point of view of plant geography is near the upper limit of the farmland. The surrounding hills are occupied by a *Pteris*-association (12). The bog is about 180 metres long, has a maximum width of only 35 metres, and fills up the deeper part of a small basin. The original upper peat beds of the bog have been long ago dug away for fuel, and any remnant of them has been disturbed during excavations in search of the remains of Irish Elk. A deep trench 6 metres broad running along the western side of the bog is now nearly filled up with recent mud and peat.

Stratigraphy and Outlines of Development.

The deposits of the bog were studied in 11 pits and by a number of borings[1] which showed that the basin was filled up with lake deposits more than 5 metres thick covered with a thin layer of peat.

Farrington has given above the details from pit 6, and further detailed evidence of the stratification of the deposits is given here.

Section at pit 1 (*compare fig.* 24).

A. 0–25 cm. Earthy peat.

B. 25–±90 cm. Dark brown forest peat; wood of *Betula*; in the lower part many branches of *Salix*; a piece of wood and a branch of *Pinus sylvestris*[2] were found in the upper part of the section very likely in this layer. Even transition to the next layer.

[1] The boring apparatus used was Hiller's peat borer having a chamber-length of 50 cm.

[2] In the Latin nomenclature of the plants I follow R. Ll. Praeger: *The Botanist in Ireland,* 1934 (14), but the sectional name *Batrachium* of the genus *Ranunculus* is here used as the generic name.

C. ±90–140 cm. Brown crumbling peat-like drifted mud containing many fruits of water plants, wood of *Betula*, many leaves of *Salix* (*Salix cinerea*, *S. aurita*), a nut of *Corylus* at 120 cm. Here was also found a thigh-bone of a young hare (*Lepus* sp.) as kindly determined by Dr. M. Degerböl, Copenhagen.

C_1. 140–170 cm. Grey brown mud full of leaves of *Salix caprea* and *S. aurita*; wood of *Betula*.

D. 170–250 cm. Chara-mud whitish-grey for the most part, turning browner towards the bottom. Numerous oospores of *Characeæ*, fruits of *Betula pubescens* and of water plants.

D_1. 250–265 cm. Greyish green Chara-mud; fruit stones of *Potamogeton* sp. and *Sparganium ramosum*, a leaf of *Salix caprea*. The drill on stone.

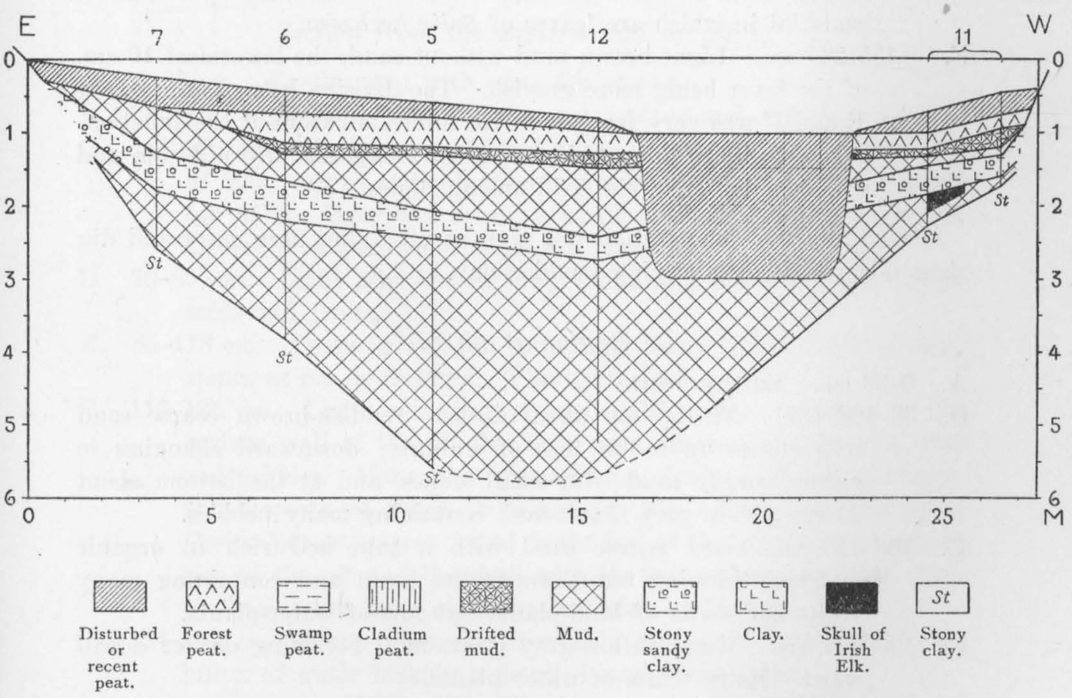


FIG. 4.—Cross-section of the north-western bog at Ballybetagh. With explanation of stratigraphical symbols.

This being the first section we surveyed in the Ballybetagh bog, we stopped boring when the stony "bottom" was reached. There can, however, be no doubt but that this stony bottom was the so-called arctic layer (E) which we recognised later on and that the lower layer of mud (F) lies below it.

Fig. 4 shows a cross-section of the middle part of the bog running through the pits 5, 6, 7, and 11 (see fig. 2), and a boring between pit 5 and pit 11. The deposits lying deeper than about 2 metres must everywhere be studied by means of the drill. The section at pit 6 (see p. 213) gives the details as to the general layer sequence in the basin apart from the border zones.

The section at pit 7 shows the conditions at the eastern border of the bog.

Section at pit 7.

A. 0–42 cm. Dark brown earthy peat.

D. 42–102 cm. Grey coarse sand containing stones mostly the size of a man's fist and in the lower part of the layer reaching the size of a man's head. The bed corresponding to the mud layer.

E. 102–±155 cm. Changing layers of reddish-brown gravel and grey clayey sand containing many stones and thin lenses of organic material in which are leaves of *Salix herbacea.*

F. ±155–235 cm. Light brown mud without sand, the lowermost 10 cm. of the layer being more greyish. The division between the strata E and F was very irregular with interlamination at the junction. Many fruits of *Batrachium* sp., *Myriophyllum alterniflorum* and *Potamogeton* sp. The drill among stones.

Practically the same section was seen at pit 8, but here one could dig right down to the underlying boulder-clay.

Section at pit 8.

A. 0–33 cm. Earthy peat.

D. 33–108 cm. At the top about 25 cm. reddish-brown coarse sand with stones up to the size of walnuts; downward changing to clayey muddy sand with small stones, and at the bottom about 25 cm. yellow-grey Chara-mud containing many pebbles.

E. 108–123 cm. Grey coarse sand with a thin bed rich in organic material thinning out towards the basin and containing many fruits and seeds of land-plants but few of water-plants.

F. 123–157 cm. Light yellow-grey Chara-mud becoming darker downward. Many fruits of water plants.

G. 157–180 cm. Stratified grey clay with small stones lying in layers.

H. 180–200 cm. +. Grey hard, non-stratified clay with striated stones lying irregularly; boulder-clay.

The lowest of these clay beds (H) was certainly undisturbed boulder-clay, and the layer G may be interpreted as boulder-clay moved down from its original position on the sides of the valley. A similar material—rather soft, somewhat bedded stony clay forming the very bottom of the basin—was also found in the southern bog; see p. 215. This moved boulder-clay is probably an effect of arctic solifluction in the period directly following the melting away of the ice-cover (15), (16). In the deposits of the following period when *Betula pubescens* throve at the locality no trace of such an effect has been found, and indeed very little inorganic material made its way down into the basin.

The main difference between the sections taken at a distance from the shore and sections taken near it is a result of the downwash of sand and pebbles which impeded the formation of mud and peat in the shore region. On the western side, however, at least at pit 11, the downwash of inorganic material was weak. A detailed description of the section at this pit is given as it was here, in layer F, that remains of the Irish Elk (*Cervus giganteus*) were found, viz., a stump of an antler at the western side of the pit and an almost complete skull with the two antlers at the eastern side of it. For the section at the eastern wall of the pit see fig. 4.

Section from the western wall of pit 11.

A. 0–30 cm. Earthy peat with some few stones.

B. 30–±45 cm. Dark brown forest peat (*Alnus* and *Betula*).

C. ±45–70 cm. Dark brown drifted mud. Fruits of water-plants, buds of *Salix caprea* at the bottom, a nut of *Corylus* at 50 cm. In the top of the layer was found a small bone determined by Dr. M. Degerböl as a coracoid bone of a male duck (*Anas boscas*).

D. 70–85 cm. Light olive-brown mud containing many pebbles. Many seeds and fruits.

E. 85–113 cm. Coarse grey sand containing many rounded and angular stones as big as walnuts. Plant remains.

F. 113–124 cm. Light olive-brown mud with some pebbles; in the eastern wall of the pit this layer was practically free from sand and pebbles. Many plant remains, *i.e.*, fruits of *Betula pubescens* and stomata of *Pinus* (compare fig. 21). Part of an antler of *Cervus giganteus* was found in the top of the layer at the western side of the pit and the skull with its two antlers was taken from the top of the layer at the eastern side of the pit.

G. 124–140 cm. Stony grey clay, probably reassorted boulder-clay, the influx of water making a detailed study impossible.

From an examination of the foregoing we may state the development of the glacial and late-glacial deposits in the basin as follows:—after the retreat of the ice-sheet and the deposition of the glacial drift on the bottom and the sides of the valley at Ballybetagh it seems that the still prevailing arctic climate caused solifluction and so gave rise to the formation of a layer of moved boulder-clay on the bottom of the valley. Later the valley was filled with a small lake in which the Chara-mud was deposited, except for the border zones, substantially without content of sand. The flora found in this layer (see p. 223) supports the view that the climate was of a northern type, the only macroscopic remains of woody plants found being of *Betula, Juniperus, Salix,* and *Empetrum,* to which may be added *Pinus,* as stomata of this tree were recorded from the mud (see also p. 250). Nearly all the plant species determined from the lower Chara-mud (F) have a widespread northern distribution in Europe, those with the southernmost range being *Myriophyllum verticillatum* and *Potamogeton obtusifolius,* which from south Norway, however, go fairly far north in Sweden. They are referred by G. Samuelsson to his Lappish group (17). *Myriophyllum verticillatum* is known from one locality in Iceland (18).

Of special interest for the history of the development of the deposits in the north-western bog at Ballybetagh is layer E, the sandy, stony, clayey bed separating the two mud layers D and F. As well as in the cross-section this layer was studied at pit 8, as mentioned above, and at pit 2 consisting at the latter point of clayey sand with small stones containing only very little organic matter. From the cross-section the description of layer E has been given from pits 6, 7, and 11. Further details of this layer are given below from pit 5 and from the boring at point 12.

At pit 5.

D. 105–148 cm. Grey Chara-mud; leaves of *Salix.*

E. 148–185 cm. Grey muddy clayey sand with small stones; thin brown beds rich in organic matter, i.e., containing many leaves of *Salix herbacea.*

F. 185–216 cm. +. Light brown mud without sand.

At point 12.

D. 70–160 cm. Brownish-greyish Chara-mud.

E. 160–195 cm. Grey sandy clay with pebbles up to the size of beans.

F. 195–450 cm. +. Olive-brown mud, dark in the upper part, becoming light downward, a little sandy in the uppermost 25 cm., downward practically without sand.

The layers D and F, consisting of mud rich in $CaCO_3$, have been sedimented quite normally in the small lake. As this was without inflow or any noticeable supply of terrigenous material, their rich content of plant remains originated to a great extent from water plants. In comparison with these layers the formation of the sandy, clayey, stony, or gravelly layer E, without, or very poor in, $CaCO_3$ must have been formed in quite another way, the very heterogeneous material of the bed being incompletely sorted. It should also be noted that the thickness of this layer decreases from the shore, especially on the eastern side, toward the central part of the basin, and that the pebbles in it are distinctly smaller in the central part than near the margins. The determinable plant remains in the layer are mostly confined to thin brown beds rich in organic detritus and lying in the sandy-clayey parts of it.

On comparison of the floral lists from the two layers F and E (see p. 223) some essential differences will be seen. Remains of *Betula* and of the taller *Salices* have not been found in E, the remains of water-plants are rare, at most some few fruits of *Batrachium* sp. *Myriophyllum* sp. and *Potamogeton natans.* Most of the species found in E are such as grow on relatively dry land, viz., *Arabis* cfr. *petræa, Arenaria ciliata, Armeria vulgaris, Carex panicea, Empetrum nigrum, Juniperus communis, Ranunculus repens, Rumex Acetosella, Salix herbacea, Saxifraga hypnoides,* and *Viola palustris.* To this group must be added *Oxyria digyna* which also belongs to the *Salix herbacea* flora at Ballybetagh. The material, as well as the plant content, of layer E derives principally from the surroundings of the lake basin and only to an insignificant extent from the lake itself.

The floral list from layer E must be said to possess a more northern character than that from layer F, all the plants having a wide northern range, some of them even reaching far into the arctic region. The species with the most southerly northern limit, viz., the *Eleocharis*-species, *Potamogeton natans, Ranunculus repens,* and *Saxifraga hypnoides* are more or less common in Iceland. But especially the occurrence of *Salix herbacea* and *Oxyria digyna* at Ballybetagh, together with the lack of *Betula pubescens,* when layer E was formed supports the view that the climate at that time was more alpine or arctic than in the nearest preceding time.

There is no support for the view that any portion of the material of layer E was the deposit of a stream flowing into the valley (see p. 208), and the supposition that the material was simply washed out into the lake from the slopes by means of oozing water does not give a satisfactory explanation of the structure of the layer: viz., the lack of real sorting of the material, and the stones carried out to the central part of the lake. I think that the formation of this layer is to be explained as an effect of a kind of solifluction, and for comparison attention should be drawn partly to the explanation given of the sandy, clayey, or gravelly beds covering the inter-glacial bogs in the western part of Jutland and in the north-western Germany which have not been transgressed by the last ice-sheet (19), and partly to the idea advanced by L. von Post (20) that the late-glacial freshwater deposits of sandy clay in the Baltic regions were deposited in basins as a consequence of solifluction-like action on the surrounding slopes. Since the slopes at the north-western Ballybetagh bog are very steep, the result of the solifluction on them would be a vigorous transport of coarse and fine material down into the lake, or the bottom of which the movement of the material would be carried on by the action of the water affected by freezing and thawing as may be seen in shallow lakes, *e.g.,* in southern Greenland.

To account for this solifluction at Ballybetagh, after a long period without any traces of such action, a return of a more arctic or alpine type of climate must be assumed just as is maintained for the last *Dryas*-period in the Baltic region; see the scheme, p. 246. This view, at Ballybetagh as well as in the Baltic region, is supported by the comparison of the floras in the "arctic" layer and in the underlying "subarctic" one. The objection could be advanced that the occurrence of the alpine species, especially *Salix herbacea,* in layer E and the lack of them in layer F may be due principally to the difference in the way in which these beds have been deposited. Against this, however, it should be asserted strongly that the leaves of *Salix herbacea,* which are common in layer E, would have had an equally good opportunity of coming out into the lake from the surrounding steep slopes by the action of the wind while layer F was being deposited if the plant had been growing there to any extent at that time.

At the cessation of the solifluction causing the formation of layer E I propose to put the end of the late-glacial period. The post-glacial period here then started with an amelioration of the climate and a renewal of the deposition of Chara-mud. The *Betula* and the big-leaved *Salices* spread along the shores of the lake and the floral development described later on took place. The lake gradually got filled up by the deposition of drifted mud or shore mud, out over which the swamp forest of *Betula* and *Alnus* colonized, forming the layer which now is the upper peat-layer in the basin.

According to the view here advanced, that the layers E and F are late-glacial (for the evidence of the pollen flora see p. 247), the age of the remains found of the Irish Elk (*Cervus giganteus*) is fixed at the end of the relatively warm period in late-glacial time. The position of the skull with its antlers presented the peculiar fact that all the upward-directed projections just reached to the under side of the solifluction bed, and never protruded up into this layer. As demonstrated later (see p. 252) the vegetation at the site at this time was characterized by open birch growth with plenty of grass. Further studies may throw more light upon the history of the Irish Elk in Ireland supplementing previous experience (for literature see G. Erdtman (11, p. 169)). This author mentions a find of remains of the Irish Elk in one of the bogs at Ballybetagh, in a bed of stony clay lying below a thin muddy layer containing leaves of *Salix herbacea* and being interpreted as an arctic bed. The section given by Erdtman agrees rather imperfectly with my sections from the north-western bog. If this bed of stony clay is to be considered as undisturbed boulder-clay the Elk remains might derive from an inter-glacial individual, or, as is more likely, if the clay bed is moved boulder-clay then the Elk would be contemporaneous with my layer G, and the animal would have lived in Ireland in the first part of the late-glacial time in which in other basins clay without stones was deposited (see Ralaghan, p. 244); a period of the vegetation of which we have as yet very little knowledge.

REMAINS OF PLANTS AND ANIMALS IN the BALLYBETAGH BOGS.

Pollen and fern spores omitted.

(B = buds, Fl = parts of flowers, F = fruits, Fst = fruit stones, L = leaves, S = seeds, Sp = spores, St = stomata, W = wood, cc = very common, c = common, + = frequent, r = rare, rr = very rare.)

Species.	Remains.	Zones[3] and layers of the north-western bog.					Eastern bog.	
		V		IV	III	II	II	?
		B	C	D	E	F	a[4]	b[5]
Arabis cfr. *petræa*	S	...	...	...	+	...	...	...
Arenaria ciliata	S	...	...	...	c	rr	...	...
Armeria vulgaris	Fl	...	...	...	c	...	...	...
Batrachium sp.	F	...	+	+	r	cc	...	+
Betula pubescens	F, L, W	...	+	c	...	+	..	...
Carex aquatilis or *rigida* ...	F	...	...	...	+	+	...	...
„ *panicea*	F	...	...	...	r	...	...	...
„ *inflat*	F	...	...	...	...	...	...	+
„ sp.	F	...	...	...	cc	+	...	cc
Caryophyllaceæ	S	...	...	...	+	+	...	rr
Ceratophyllum demersum ...	L[6]	...	+	+	...	...	...	...
Corylus Avellana	F	...	rr	...	...	...	...	...
Cratægus monogyna	Fst	...	rr	...	...	...	...	...
Eleocharis palustris	F	...	...	...	...	...	...	+
„ *palust.* or *uniglumis*	F	...	...	...	rr	c	...	...
Empetrum nigrum	Fst	...	...	...	rr	rr	...	rr
Hippuris vulgaris	Fst	...	r	...	...	...	...	rr
Juniperus communis	S	...	...	...	r	r	...	...
Littorella uniflora	F	...	...	...	...	r	...	..
Menyanthes trifoliata ...	S	...	...	...	...	...	...	+
Myriophyllum alterniflorum ...	F	...	...	...	...	+	...	c
„ *spicatum* ...	F	...	...	...	...	+	...	
„ *verticillatum* ...	F, L	...	...	+	...	c	...	...

[3] For the division into zones I–VI, see p.250.

[4] Unlocalised sample of sandy mud from the eastern bog, see p. 233.

[5] See p. 215.

[6] Bristles from the leaf-tips.

Species.	Remains.	Zones and layers of the north-western bog.					Eastern bog.	
		V		IV	III	II	II	?
		B	C	D	E	F	a	b
Myriophyllum sp.	F	...	rr	...	r	...	...	...
Oxyria digyna	Fl	...	...	...	...	...	rr	...
Pinus sylvestris	W, St	r	...	r[7]	...	r[7]	...	...
Populus tremula	B, W.	...	rr	r	...	...	...	...
Potamogeton alpinus	Fst	...	...	...	...	...	...	c
,, *filiformis* ...	Fst	...	...	...	...	+ (?)	...	+
,, *natans*	Fst	...	c	c	r	c	...	c
,, *obtusifolius* ...	Fst	...	r	...	...	+	...	...
,, *prælongus* ...	Fst	...	...	rr	...	c	...	cc
,, *pusillus*	Fst	...	...	...	...	rr	...	...
,, sp.	Fst	...	c	+	...	+	...	...
Potentilla palustris	F	...	...	r	...	...	...	...
,, sp.	F	...	...	...	...	...	...	rr
Ranunculus acris	F	...	...	...	...	r	...	...
,, *repens*	F	...	...	...	+	+	...	...
,, sp.	F	...	..	...	...	rr	+	...
Rumex Acetosa	Fl	...	...	...	...	rr	...	...
,, *Acetosella*	F	...	...	...	c	...	...	...
,, cfr. *aquaticus*	Fl	...	...	...	...	...	...	rr
,, *crispus*	Fl	...	...	...	...	rr	...	...
Salix aurita	L	...	c	+	...	rr	...	...
,, *caprea*	L	...	+	+	...	...	...	...
,, *cinerea*	L	...	+	+	...	..	...	...
,, *herbacea*	L	...	...	...	cc	...	cc	...
,, cfr. *phylicifolia* ...	L	...	...	...	...	r	...	...
,, sp.	L, Fl, W	c	c	...	...	...	...	...
Saxifraga hypnoides	L, F ?	...	...	...	+	...	...	...
Scirpus Tabernæmontani ...	F	...	rr	...	...	...	...	...
,, sp.	F	...	rr	...	...	..	...	...
Sparganium minimum ...	Fst	...	...	...	...	rr	...	...
,, *ramosum* ...	Fst	...	rr	rr	...	...	...	...
,, *simplex*	Fst	...	+	...	...	...	...	...

[7] Stomata.

Species.	Remains.	Zones and layers of the north-western bog.					Eastern bog.	
		V		IV	III	II	II	?
		B	C	D	E	F	a	b
Thalictrum alpinum	F	...	...	...	...	rr	...	...
Viola palustris	S	...	...	...	+	r	...	...
Hypnum sp.	L	+	r	+	...	+	...	...
Sphagnum sp.	Sp	...	...	rr	...	...	...	...
Botryococcus Braunii	...	r	c	+	...	+	...	...
Characeæ	Sp	...	...	cc	r	cc	...	...
Pediastrum boryanum	...	+	+	c	...	r	...	...
,, *duplex*	...	+	+	+	...	...	...	...
,, *integrum*	...	...	+	...	...	...	...	...
,, sp.	...	c	c	+	...	...	...	...
Anas boschas	Bone	...	rr	...	...	...	...	...
Cervus giganteus	Bone	...	...	...	...	rr	...	...
Lepus sp.	Bone	...	rr	...	...	...	...	...
Agabus sp.	...	...	...	...	...	...	...	rr
Barynotus schonherri[8]	...	rr	...	...	...	...	...	...
Calathus cisteloides	...	...	...	...	...	rr	...	...
Colymbetes sp. (*fuscus ?*)	...	...	...	...	...	...	...	rr
Dytiscus semisulcatus	...	...	...	rr	...	...	...	...
Geotrupes vernalis	...	...	...	...	...	...	...	rr
Haltica sp.	...	...	...	rr	...	...	...	...
Leptocerus sp.	...	...	...	...	...	...	...	rr
Otiorrhynchus dubius	...	...	...	...	...	rr	...	...
Phryganea sp.	...	...	...	...	...	...	...	rr
Pterosticus vulgaris	...	...	...	rr	...	...	...	...
,, sp.	...	...	...	...	rr	...	...	...
Silpha atrata var.	...	...	...	rr	...	...	...	...
Staphylinus olens	...	...	rr	...	...	...	...	...
Cladocera	Shields	...	...	+	...	+	...	...
Daphnia pulex	Ephipp.	...	...	+	...	...	...	...
Cristatella mucedo	Statobl.	...	...	...	r	r	...	r

[8] For notes on the insect remains and the authors responsible for naming them, see p. 240.

Remarks on the Floral List.

Arabis cfr. *petræa.* Fig. 5. Several seeds belonging to the *Cruciferæ* were recorded from layer E at Pit 5. They were somewhat compressed, oval, having a campylotropous shape. They varied from about 1·4 mm. to 1·7 mm. in length and from about 1·0 mm. to 1·25 mm. in breadth. The chalaza area was rounded or somewhat flattened, the micropyle area more or less projecting. The outermost cell-layer had nearly isodiametric cells, their outer wall curving a little outward. The colour was brown and on the chalaza and micropyle areas blackish-brown. Of northern European and arctic cruciferous seeds they resemble most those of one

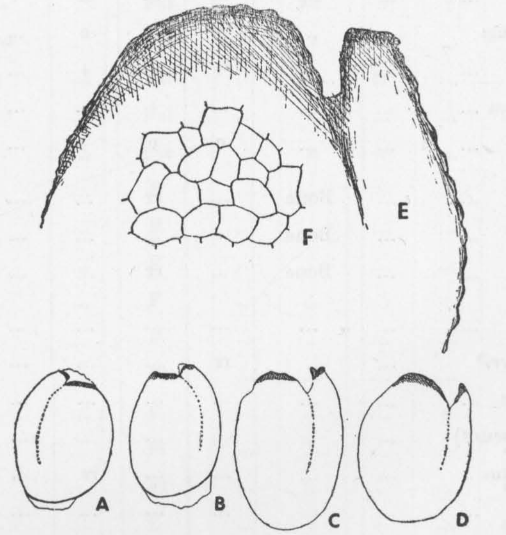


Fig. 5.—Cruciferous seeds. A, a recent seed of *Arabis petræa* from Cairntoul, Aberdeenshire, Scotland; B–F, seeds or parts of seeds from layer E in the north-western bog at Ballybetagh; E, the micropyle and chalaza area; F, cells of the outer cell layer. A–D 12/1; E 45/1; F 150/1.

or other species of *Arabis.* C. A. Weber (21) has described and figured a cruciferous seed from the sub-arctic "Mammoth flora" at Borna in Saxony, referring it to the central European mountain species *Arabis saxatilis* All. However, the seeds from Ballybetagh do not seem to be identical with seeds of this species, their shape and size differing too much, but they come rather near to seeds of *A. petræa* from Scotland which have been kindly provided by the Royal Botanic Garden, Edinburgh, for comparison. This was the case especially with one of the Ballybetagh seeds (see the figure) on which was preserved a remnant of the little "wing" at the micropyle as well as a narrow wing at the opposite end which is often seen on seeds of *Arabis petræa.* The seeds of this species may vary much in size and shape, the biggest I have seen being about 1·5 mm. long and about 1·0 mm. broad.

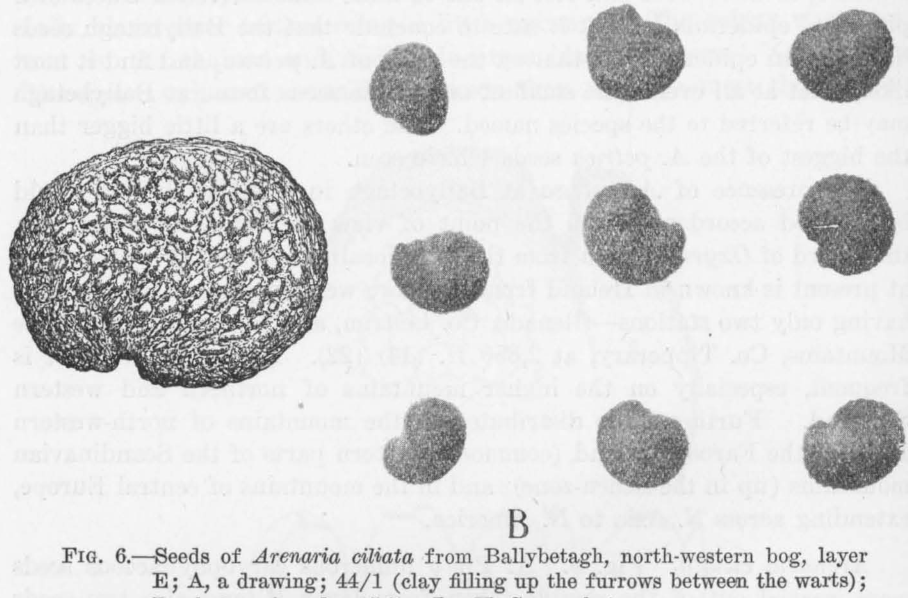
The seeds of *A. petræa* seem to differ essentially from the Ballybetagh seeds, however, in having a thin, rather large-celled epidermis the cells of which are papillary. But as this epidermis is not very resistant, easily sliming away in water, it seems very likely that it would disappear should the seeds be fossilized as are the Ballybetagh seeds. Below the epidermis lies a layer of fairly thick-walled cells the size and shape of which agree quite well with the cells of the outer layer of the Ballybetagh seeds. Further, as there were still left on one of these some shrivelled traces of a papillary epidermis I think it safe to conclude that the Ballybetagh seeds have had an epidermis like that on the seeds of *A. petræa,* and find it most likely that at all events the smallest one of the seeds found at Ballybetagh may be referred to the species named. The others are a little bigger than the biggest of the *A. petræa* seeds I have seen.

The presence of *A. petræa* at Ballybetagh in late-glacial time would be in good accordance from the point of view of plant geography with the record of *Oxyria digyna* from the same locality (see p. 233). *A. petræa* at present is known in Ireland from the more western parts of the country having only two stations—Glenade, Co. Leitrim, at 1330 ft. and the Galtee Mountains, Co. Tipperary, at 2,650 ft. (14) (22). In Great Britain it is frequent, especially on the higher mountains of northern and western Scotland. Further, it is distributed in the mountains of north-western Europe; the Faroes, Iceland (common); western parts of the Scandinavian mountains (up in the lichen-zone); and in the mountains of central Europe, extending across N. Asia to N. America.

Arenaria ciliata. Fig. 6. At Pit 5 numerous caryophyllaceous seeds were washed out of the sample taken from layer E, and also two seeds of exactly the same type were found in the top of layer F. These seeds are distinctly campylotropous, 0·8–0·95 mm. long, about 0·7 mm. broad and 0·5–0·6 mm. thick, an optic section showing their backs to be evenly rounded. The testa is black, crustaceous, each epidermal cell forming a low, often somewhat flattened wart, usually distinctly set with small grits along the margin. The warts, irregularly isodiametric near the central part of the seed's side, are arranged in distinct rows towards the back of the seed, becoming oblong, up to about 0·1 mm. long, toward the micropyle and the chalaza area and on the back. On most of the seeds the furrows between the warts were partly filled with a fine clayey stuff which, however, could be removed by boiling with hydrofluoric acid.

To identify these characteristic seeds I have compared them with seeds of all the northern European and Greenlandic species of *Caryophyllaceæ,* and only in the case of the polymorphic species *Arenaria ciliata* were seeds found which, though varying somewhat as to the structure of the test, were practically identical with the Ballybetagh seeds as to size, shape, colour, consistence and sculpture of the test (compare the figure on Pl. I, Nordhagen (23)).

Among the arctic flora of the Cam Valley at Barnwell, Cambridge, Miss M. E. J. Chandler (24) mentions *Arenaria gothica* Fries, in Europe a western species occurring in south Sweden, England (one station), France, west Switzerland, and nearly allied to *A. ciliata*. The seeds I have seen of this species, originating from Kinnekulle in Sweden, were a little smaller than the fossil seeds in question: 0·7 to 0·85 mm. long, 0·6 to 0·7 mm. broad and about 0·55 mm. thick. They differed also as to sculpture, the



B

FIG. 6.—Seeds of *Arenaria ciliata* from Ballybetagh, north-western bog, layer E; A, a drawing; 44/1 (clay filling up the furrows between the warts); B, photos of seeds; 15/1. Dr. K. Gram phot.

warts with pronounced radial elongation being arranged in distinct concentric rows, therefore the seeds of this species could not be identified with the Ballybetagh seeds. Also *Arenaria biflora* L., recorded at Barnwell by Miss Chandler, must be left out of consideration as the warts on its seeds are too small and the grits much more densely placed than on the fossil seeds.

Arenaria ciliata in Ireland now grows only in the mountains near Ben Bulben, Co. Sligo, at 1200 to 1950 feet (14), represented by the subspecies *hibernica* Ostenf. & Dahl. It is lacking in England, but the subspecies *norvegica* has its southernmost station at a locality in north Scotland (Sutherlandshire). It ranges over the Shetland Islands (one station), Norway, the northern part of west Sweden, northernmost Finland (one station) and Iceland, see the map, fig. 10, Nordhagen (23). The purely arctic subsp. *pseudofrigida* is distributed in north-eastern Greenland, Spitzbergen, the northernmost parts of Norway and Finland, the Kola peninsula, arctic Russia and Novaja Semlja (see Nordhagen's map). The subsp. *polycarpoides* (Rouy & Fouc.) Braun-Blanquet is found on the Pyrenees, and the subsp. *moehringioides* Murr. in the western Alps. The subsp. *tenella* is a more eastern central European form.

The sculpture of the seeds of the subsp. *pseudofrigida* is somewhat less conspicuous than that of the fossil seeds, therefore this arctic form may be left out of consideration. On the other hand it does not seem possible, on the basis of the comparative material at hand, definitely to identify the fossil seeds with one of the other subspecies of *A. ciliata* of which I have seen the seeds, viz., *norvegica, hibernica* and *tenella,* the seeds of which are all much like each other, as to the arrangement of grits around the warts. Even if the fossil seeds seem to be more like those of *norvegica* than those of *hibernica* and *tenella,*[9] it will for the present be necessary to be contented with the statement that one or other form of the polymorphous species *A. ciliata* is represented in the late-glacial deposits at Ballybetagh.

According to Nordhagen (23, p. 31) the subsp. *hibernica,* commonly looked on as a relict in its single station at Ben Bulben, shows distinct relations with the central European form cyclus, *i.e.,* by the distinct

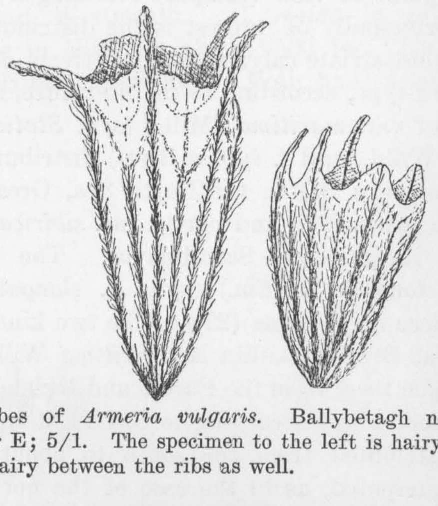


FIG. 7.—Calyx tubes of *Armeria vulgaris.* Ballybetagh north-western bog, bog, layer E; 5/1. The specimen to the left is hairy on ribs only, the other is hairy between the ribs as well.

secondary nerves of the leaves, while it differs in several characters from the subspp. *norvegica* and *pseudofrigida.* As *norvegica* at present has only one station in Great Britain it would not be surprising if it should prove that it is a relict there, and that it, together with *hibernica,* lived in Ireland in late-glacial time.

Armeria vulgaris Willd. (syn. *Statice armeria* L., *Armeria elongata* Koch, *sensu lat.*). Fig. 7. Many of the characteristic campanulate calyx-

---

[9] To Professor R. Nordhagen, who has seen the fossil seeds of *A. ciliata,* I am grateful for valuable details as to the sculpture of seeds of the various subspecies.

tubes of one or other form of this species occurred in the layer E in company with *Salix herbacea.* Most of them were hairy on the ribs only (pilose-striate); but some few of them were hairy between the ten ribs as well as on them. Previously calyx-tubes of an *Armeria* species have been found on the continent and in England in company with arctic plants; thus late-glacial specimens from Denmark are simply called *A. maritima* Willd. by N. Hartz (25), but C. A. Weber (21) referred an *Armeria*-calyx from the "Mammoth flora" at Borna in Saxony to *A. arctica* Wallr., an arctic North American species, principally because it was hairy on the ribs only. C. Reid (26), following this view, mentions the same species from various arctic beds in England and Scotland, *e.g.*, Mundesley on the Norfolk coast, the late-glacial beds in the Lea valley in Cambridge, and at Soughton and Corstorphine, close to Edinburgh. In addition it is recorded by Miss M. E. J. Chandler (24) from the glacial beds at Barnwell, Cambridge. However, I can see no reason for referring the Ballybetagh specimens to *A. arctica,* as the campanulate pilose-striate calyx is common also in the *A. vulgaris* form-cyclus in northern Europe and in Greenland.

A. vulgaris is a very variable species, see Gams (27) and G. Turesson (28), and its various forms are not yet fully studied as far as I know from a systematic point of view (compare Nordhagen; 23, p. 51). What here, however, is principally of interest is the distribution of the entirely hairy and of the pilose-striate calyx-tube respectively of *A. vulgaris.* The first mentioned calyx-type, according to the literature, characterizes partly the common form of var. *maritima* (Mill.) (syn. *Statice maritima* Miller, *Armeria maritima* Willd., and f. *typica* Blytt) distributed especially along the coasts of the western Baltic, the North Sea, Great Britain, and the Norwegian Atlantic coasts (29), and partly var. *sibirica* (Turcz), occurring on the mountains in northern Scandinavia. The pilose-striate calyx characterizes var. *elongata* (Hoffm.) (syn. *A. elongata* Koch) occurring around the Baltic (see map, Gams (27)). The two kinds of calyx-tube are represented in Great Britain, within *A. maritima* Willd. (30). Ostenfeld and Gröntved mention them from the Faroes and Iceland within *A. vulgaris* Willd. In Greenland, where according to C. H. Ostenfeld (31) *A. vulgaris* var. *sibirica* is distributed from the south to about 82° N. lat., both calyx-types are represented, as in the case of the northern Scandinavian mountains.

As far as I can see at present the character of the hairiness of the calyx-tube in *A. vulgaris* is a rather inconstant one and not of much systematic value for the definition, at all events, of some of the varieties of the species. But as there is a very good agreement between the Ballybetagh specimens and the calyx-tubes of the species mentioned I think it safe to see in them remains of some northern form of this species, most likely of var. *sibirica,* and it would seem laboured to go to the American *A. arctica* to find an identical form.

According to the Irish botanists (14) only *A. maritima* Willd. occurs in Ireland, principally confined to the neighbourhood of the coasts, but ascending the mountains to high levels in the western and northern parts of the country, so that it is likely that it comprises at all events various ecotypes. It avoids shade, and it may be supposed that it was expelled from its late-glacial localities in the interior of the country owing to the invasion of the forests at the beginning of the post-glacial period.

Carex aquatilis or *C. rigida.* Fig. 8. Numerous flat *Carex*-nuts from the layers E and F enclosed in their thin, nerveless utriculus are to be referred to the group *heterostachyæ-distigmaticæ,* and in this to one of the two species mentioned. F. Firbas (32) figures some fruits of *Carex aquatilis* from late-glacial and early post-glacial deposits in Niederlausitz in Germany which are very like the fruits from Ballybetagh. Compare also fruits figured by Hellmuth Albert Weber (33, fig. 5, and p. 203), and very similar fruits which I have figured under the name of *Carex* sp. from an inter-glacial bog in Jutland, where they were found in company with *Betula nana* (19, p. 125). I do not think it possible to determine which of the two species in question is represented by the fruits from Ballybetagh. The two species, according to Praeger (14), are not uncommon in Ireland, *C. aquatilis* both in the mountains and on the lowland. It has recently appeared in Co. Dublin, the nearest known localities before being in Meath and Westmeath. *C. rigida* is more confined to the mountains, growing in Wicklow above 2500 feet (22). Watson includes them among his "Highland plants." Both have a wide-spread northern distribution (34).

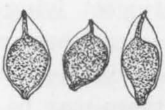


FIG. 8.

FIG. 9.

FIG. 8.—Fruits of *Carex aquatilis* or *rigida.* Ballybetagh, north-western bog, layer E; 4/1.

FIG. 9.—*Carex panicea,* the top of a female spike and two nuts. Ballybetagh, north-western bog, layer E; 4/1.

Carex panicea. Fig. 9. A top of a female spike and some fruits of a *Carex* found in layer E come very close to *Carex panicea,* having a short oblique beak on the somewhat inflated, faintly nerved utriculus and short obtuse or subacute bracts. In some characters, however, the spike resembles rather that of the northern *C. sparsiflora* (Wg.) Steud., viz., in the great distance between the few (here two) top flowers and the nearest following one and in the occurrence of a sterile flower at the very top of the spike. The beak of the utriculus of *C. sparsiflora* is, however, somewhat longer than that of *C. panicea* and has an obliquely cut orifice (34). I think it safest to see in the Ballybetagh spike the lowermost spike from a poor specimen of *C. panicea.*

Caryophyllaceæ. Fig. 10. At Ballybetagh, besides *Arenaria ciliata,* several other seeds of caryophyllaceous type were found, which, however, have not been identified. The three seeds seen in fig. 10 were taken in layer E together with the seeds of *A. ciliata*; two of them have a size very near that of these seeds, the third being 1·3 mm. long and 1·0 mm. broad, all having a brown to light brown colour and a rather thin testa, so that they were flattened and somewhat damaged. The sculpture of their testa exhibits various differences and they may represent at least two species.

FIG. 10.—*Caryophyllaceæ.* Three seeds from Ballybetagh, north-western bog, layer E; 15/1. Dr. K. Gram phot.

Ceratophyllum demersum. The characteristic leaf-bristles of this plant are recorded from the mud layers C and D, making it evident that this rather thermophilous water-plant has lived in Ireland from the beginning of the post-glacial period (Zone IV, see p. 253). According to Praeger (14) at present it is local in its occurrence in Ireland, not being recorded, *e.g.,* from the district between Dublin and Waterford. In Europe the northern border for its more common distribution runs through southern Scandinavia from about Oslo to Uppsala. Farther to the north it is represented at some few scattered localities only, the northernmost lying in northern Norway. Even if records of its fossil fruits in several bogs make it likely that the plant had invaded this northern region during the post-glacial optimum period, and that its present localities there may be looked on as relict stations from that time, such records as that from Ballybetagh and a very similar find of its fruits in mud from zone IV in northern Jutland (35) show that outposts of this plant could colonize in regions the vegetation conditions of which, for the rest, indicate a climate, as regards temperature, like that which now prevails in northern Scandinavia. The explanation of this fact is given by Wesenberg-Lund (36), who shows how thermophilous water-plants may be able locally to spread far outside their ordinary range to lakes, the position, the form of the bottom, the depth, etc., of which condition an extraordinary heating of the water during the summer. As well as a certain temperature in the water, *Ceratophyllum* requires an alkaline condition (37), and the richness in

$CaCO_3$ of the mud layers in question proves that this requirement was also met at Ballybetagh. Compare p. 244.

Eleocharis palustris. Fig. 11. *Eleocharis* fruits, which by the shape of the nut are to be referred to *E. palustris* or *E. uniglumis,* were common in layer F in the north-western bog and in the sample from the eastern bog. Usually the persistent base of the style was gone and the species could not be identified. But in cases where this little conical tubercle still was preserved, being rather narrow at the base, it proved that the fruits in question belonged to *E. palustris.*

Littorella uniflora. Some few of the easily recognizable nuts of this species were washed out of layer F in the north-western bog. They have previously been recorded here and there in the north European quaternary

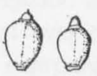


FIG. 11.—Two nuts of *Eleocharis palustris.* Ballybetagh, eastern bog; 4/1.

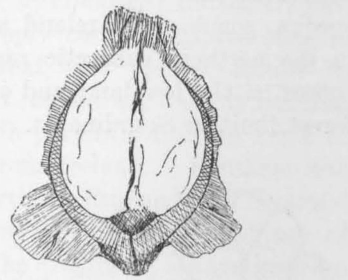


FIG. 12.—A fruit of *Oxyria digyna.* Ballybetagh, eastern bog; 12/1.

deposits, and figured, *e.g.,* in (19). C. Reid (38) found the nuts in central Ireland in "Megaceros-marl" in company with a common water-flora, and at Ballaugh on the Isle of Man. He considers the species to be late-glacial, see p. 247.

Oxyria digyna. Fig. 12. A very nice, though somewhat fragmentary, fruit of this species was washed by G. F. Mitchell out of a sandy mud sample, rich in leaves of *Salix herbacea,* from the eastern bog, and one may be allowed to assume that it is contemporaneous with the layer E in the north-western bog. The wings of the fruit are complete at the basal part only. In the figure the keel is seen running along the median line of the fruit; the cavity of the fruit and in the basal part of this the dark-coloured pointed end of the seed are also shown. The structure of the wings as well as of the epidermis of the fruit agrees very well with recent material. Praeger (14) mentions the present distribution of the plant in Ireland as on the mountains in the western part of the country and in Tipperary. It belongs to the so-called "Highland plants" which may reach the very top of the mountains; even if it also in some places descends to a level somewhat below 1,000 feet. It is frequent in the mountains of Scotland, northern England, and northern Wales and wide-spread in arctic and alpine regions (39), often occurring on the "snow-patches" where it may be very common (40, p. 120). The find of the plant at Ballybetagh proves that in late-glacial time it occurred also on the Wicklow mountains. The find is the first to fill in the gap between the present areas of the species in Ireland and in Great Britain. Previously *Oxyria digyna* has been recorded from late-glacial time in deposits at Corstorphine, near Edinburgh (38) and in southern Sweden (41).

Rumex Acetosa. Fig. 13. In the mud layer F at Pit 11 were found, still connected, the three inner perianth leaves of this species, enclosing a nearly ripe fruit. The marginal part of the perianth leaves was gone, only the central part with its characteristic plexus of veins being left; the undulated walls of the epidermal cells of the perianth leaves were very distinct. Similar remains of this species have previously been found in bogs, *e.g.*, on the Faroes in mud near the bottom of the bog. (42). The species, common in Ireland as in other parts of Europe, is wide-spread in the northern subarctic zone in meadows, in birch woods and willow copses on the low land and in the mountains. It goes far up over the forest limit in Scandinavia.

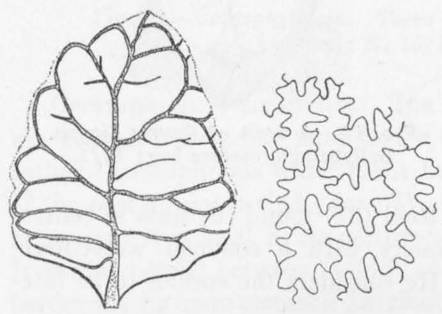


FIG. 13.—*Rumex Acetosa.* To the left the central part of an inner perianth leaf, ca. 18/1; to the right epidermal cells from the former, ca. 160/1. Ballybetagh, north-western bog, layer E.

FIG. 14.—*Rumex* cfr. *aquaticus.* The central part of an inner perianth leaf, 4/1. Ballybetagh, eastern bog.

Rumex Acetosella. The easily recognizable, small, obtusely three-angled nuts of *R. Acetosella* were rather common in layer E. This plant, wide-spread in the low-lands, reaching far into the arctic and high up in the alpine regions, is common in all districts of Ireland from sea level up to the naked tops of the mountains, where it grows with other of the prevailing summit plants such as *Empetrum* and alpines such as *Salix herbacea* and *Carex rigida.* Previously recorded, *e.g.*, at Cromer (24).

Rumex cfr. *aquaticus* L. Fig. 14. Two perianths, each of them enclosing a ripe nut, were washed out of the sandy-mud sample from Pit 10 in the eastern bog. The marginal part of the inner perianth-leaves was gone but enough was left to show that the base had been flat or rounded, not cordate. They have strongly marked reticular veining, the lower secondary veins forming obtuse angles with the primary one. Tubercles are entirely lacking. Only fragments are left of the outer perianth-whorl. One of the elliptic, sharply triangular nuts measured was ca. 3 mm. long and 1·9 mm. thick.

Of central and northern European *Rumex* species without tubercles on their perianth and with big nuts, which may be compared are: belonging to the section *Lapathum*; *R. alpinus* L., *R. aquaticus* L. and *R. domesticus* Hartman, and belonging to the section *Acetosa*: *R. scutatus* L. The last mentioned may immediately be excluded because of the form of the base of the inner perianth, which is highly cordate, and its nervation and also the size of the nuts, these being more than 3 mm. long. The nervation of the perianth of *R. alpinus,* the lower secondary nerves forming acute angles with the primary one, excludes this possibility too. *R. domesticus,* considered as perhaps a hybrid form between *R. aquaticus* and *R. crispus,* has the base of the inner perianth-leaves deeply cordate, approaching to reniform, which makes it very unlikely that this species should be represented by the Ballybetagh specimens. *R. aquaticus,* then, is left and the remains found agree fairly well with the perianth and the fruit of this species. At present it is not known from Ireland. Bentham and Hooker (39) mention a *R. aquaticus* from northern England and Scotland as a luxuriant variety of *R. crispus,* but are surely speaking of *R. domesticus,* compare Hayward (30). On the continent, always growing near fresh water, it is fairly wide-spread without being common. In Scandinavia, too, it is usually rare, reaching northward in Sweden to southern Lapland and in Norway to Finmark at 70° 40′ N. lat.

Rumex crispus. In the mud near the skull of the Irish Elk, in layer F, was found a complete fruiting perianth enclosing its nut. The inner perianth-leaves were broadly cordate, each of them bearing an ovoid tubercle of which one was greater than the two others. It may be referred to *Rumex crispus.* This species, common in Ireland, is wide-spread in northern Europe, occurring there independent of cultivation especially along the shores, but without being halophile; and always avoiding shade. It was very likely expelled from its late-glacial locality at Ballybetagh in early post-glacial time by the overshadowing of the forest. Clement Reid mentions it from the so-called glacial clay at Hoxne in Suffolk (38).

Salix herbacea. Fig. 15. In 1927 A. W. Stelfox (12) in company with G. Erdtman (11) recorded the occurrence of the leaves of this arctic and alpine species in a muddy layer in one of the Ballybetagh bogs (see p. 210). The investigations in 1934 were able to confirm this statement as to two of the bogs at Ballybetagh, in which the leaves of *Salix herbacea* were extremely common. In 1935 leaves of this plant were recorded also from clay beds in a bog at Frenchpark, Co. Roscommon, and in two bogs at Roundstone, Co. Galway. According to the stratigraphy of the north-western bog at Ballybetagh, and of the bogs from the two last-mentioned localities, the *Salix herbacea* beds therein very likely may be looked on as contemporaneous, belonging to the late-glacial zone III (see p. 253). As the plant, in the period in question, was distributed on the low land (Frenchpark), and even descended right down to present sea-level (Roundstone), these finds indicate that the climate in Ireland at that

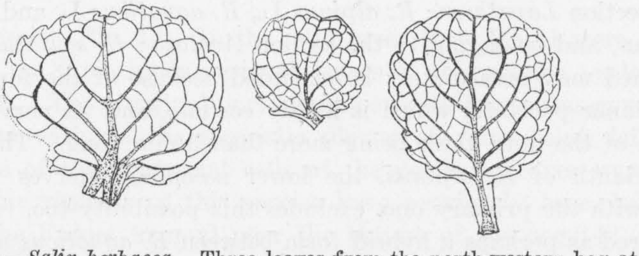


FIG. 15.—*Salix herbacea.* Three leaves from the north-western bog at Ballybetagh, layer E; 4/1.

time had an arctic character. *Salix herbacea* at present is confined in Ireland mostly to the higher mountains, occurring in Wicklow at levels above 2,000 feet (22). It is wide-spread in arctic and alpine regions, where it often occurs in the "snow-patches" as a quite dominant plant (40). On

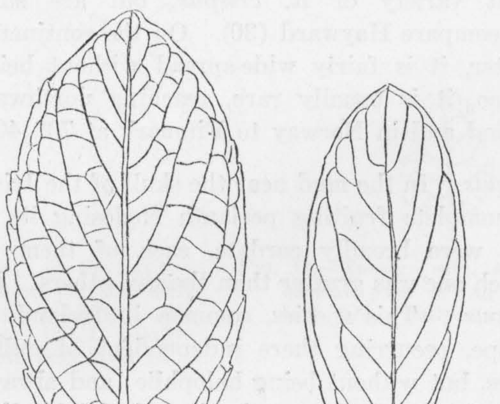


FIG. 16.—*Salix* cfr. *phylicifolia.* Two leaves from the north-western bog at Ballybetagh; the left one from layer C, the right one from layer F; 45/10.

the continent in low-lying ground *Salix herbacea* has been recorded from many localities in arctic and subarctic layers from late-glacial and interglacial times, and in Great Britain it is known, *e.g.*, from the arctic or late-glacial floras from Barnwell and the Lea valley, Cambridge (24).

Salix cfr. *phylicifolia.* Fig. 16. Two entire willow leaves, besides some fragments, may with some uncertainty be referred to *S. phylicifolia.* Most like this species is the leaf from layer F at pit 11, the nerves being rather weak and not very salient on the upper surface, though the apex is rather obtuse. On the other leaf, from layer C at Pit 3, this is the case with the basal part too, but this leaf, however, has rather weak nerves. Of other species which might be compared is *S. repens,* but it seems a deciding factor that the two fossil leaves have flat margins, not recurved as is characteristic for *S. repens,* the nerves of which, too, are strongly marked on the upper surface of the leaf. *S. phylicifolia* leaves are not uncommonly recorded from subarctic late-glacial layers on the continent. Having a wide distribution in northern and subarctic Europe and Asia and on the mountains in central Europe, it is confined in Ireland to the northern and north-western districts, thriving in thickets, on rocky places or near streams, on the mountains and in some places descending to the low land (14).

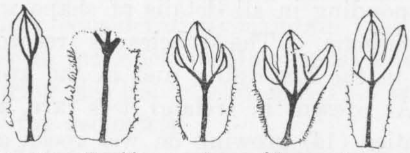


FIG. 17.—*Saxifraga hypnoides.* Leaves from the north-western bog at Ballybetagh; layer E; 4/1.

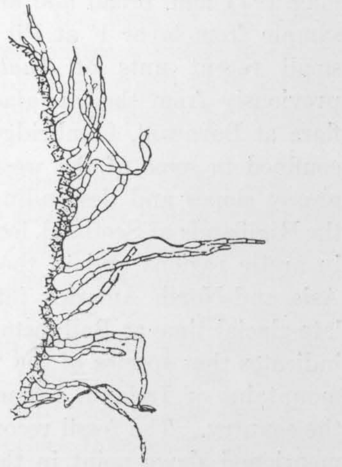


FIG. 18.—*Saxifraga hypnoides.* The lower part of the edge of one of the leaves in fig. 17; 50/1.

FIG. 19.—*Thalictrum alpinum.* A nut seen from the two sides. Ballybetagh, north-western bog, layer F; ca. 9/1.

Saxifraga hypnoides aggr. Figs. 17 and 18. In layer E at Pit 5 several leaves were found which because of their form and nervation and the characteristic hairiness on the margins of their lower parts must be referred to the species mentioned, the same, perhaps, being the case with a little saxifrage fruit which is recorded from the same sample. It will hardly be possible to determine to which of the many *Saxifraga hypnoides* forms occurring in Ireland the Ballybetagh leaves belong (14), as the dividing characteristics do not concern the leaves alone, and so one must be content to note the existence of the species *sensu lat.* in the layer mentioned. This species, in Ireland, lives especially in the western and northern counties, ascending high on the mountains, also on cliffs on Lugnaquilla in Wicklow (14), at a level of about 1,800 feet according to a communication from Mr. A. W. Stelfox. It also occurs in the mountains of Wales, northern England and Scotland (39), on the Faeroes and in Iceland (18) and in a single locality at Söndfjord in south-western Norway (29).

Scirpus Tabernæmontani. From layer C at Pit 1 was recorded a somewhat flattened nut exactly resembling that of the species mentioned. Some of the perianth bristles were preserved. Even if the habitat for this species is principally salt marshes at the sea-shore it may be found in some places in the interior of the country, too, in fresh-water lakes, as in Ireland at the present time at Lough Neagh (14).

Thalictrum alpinum. Fig. 19. A little nut, in dry condition 1·5 mm. long, 0·77 mm. broad and about 0·5 mm. thick, was washed out of a mud sample from layer F at Pit 5, corresponding in all details of shape with small recent nuts of *Thalictrum alpinum.* The species is recorded previously from the late-glacial beds in the Lea valley and in the arctic flora at Barnwell, Cambridge (24). At present in Ireland it is rare, and confined to some of the western counties (14) growing on wet rocks and grassy slopes and descending to about 900 feet (22). It is abundant in the Highlands of Scotland, local in northern England and Wales, widespread in arctic regions and in the mountains of northern and central Europe, Asia and North America (39). The record of *Thalictrum alpinum* from late-glacial time at Ballybetagh in conjunction with that of *Oxyria digyna* indicates that species of the "highland type," now confined to the western mountains of Ireland, formerly had a more continuous distribution over the country. The fossil records of *Salix herbacea* and *Saxifraga hypnoides* mentioned above point in the same direction.

Discussion.

The most interesting records of plants at Ballybetagh are those of *Arabis* cfr. *petræa, Arenaria ciliata, Oxyria digyna,* and *Thalictrum alpinum,* as they are all species which are now absent from eastern Ireland and which are either very rare in the country or have a very limited distribution there on the western or northern mountains. To these should be added *Saxifraga hypnoides,* which in eastern Ireland is known only from Lugnaquilla in the Wicklow Mountains. Together with *Salix herbacea* and *Armeria vulgaris* they characterize the Irish late-glacial flora as far as this is known.

As *Salix herbacea* is found in other late-glacial layers in Ireland, evidently of the same age as the *Salix herbacea* layer at Ballybetagh, and as the first-mentioned species are all more or less common in the mountains of Scotland and England, one may advance the hypothesis that these species were more widely distributed in Ireland in late-glacial time.

In view of their all being northern (subarctic or arctic) and alpine species, and especially as it is known that *Salix herbacea* was distributed right down to present sea-level, one may see in these facts a confirmation of the view that the climate had an arctic character when the strata in question were deposited (compare 43, p. 388).

In the extensive discussions on the history of the Irish flora the view has been advanced that the old elements of the flora have survived the Ice Age, or at least the last glaciation, on ice-free refuges within the country itself (44). R. Nordhagen (23, p. 172) subscribes to this view with reference to the occurrence in Ireland, *e.g.*, of *Arenaria ciliata* and *Arabis petræa*, being inclined to think that the localities of these species, on and near Ben Bulben in Co. Sligo, indicate the position of a glacial refuge.

With this conception one might, justly, on the basis of the records under consideration, maintain that an ice-free refuge could have existed also in the Wicklow Mountains, on which an old flora might have survived during the last glaciation. This is a question which might be discussed by the geologists.

However, one either imagines that the late-glacial flora, within that part of Ireland that was ice-covered during the last glaciation, either immigrated exclusively from outlying areas, gradually following the disappearing ice-cover, or one considers that the flora was also able to spread from ice-free refuges existing within the area invaded by the ice. The results of the present investigation invite the assumption that there was less floristic difference in late-glacial times between the vegetation of the Wicklow Mountains and the mountains of the north and west of the country as regards the representation of arctic-alpine species than exists at present (see 14, § 68), and, further, that this difference first clearly showed itself in the course of post-glacial times.

In discussing the reasons for the establishment of this *Florengefälle* one must consider the effect of the amelioration of climate at the beginning of the post-glacial period. This effect must have been felt all over the country, but it would have acted differently on the arctic-alpine element of the flora in the Wicklow Mountains and that in the mountains of the north and west.

The rise of temperature caused the forest to spread, and this, if nothing else, would force the arctic-alpine plants away from the lowland and from the lower slopes of the mountains of which the forest would take possession. Most of the species mentioned are plants of open land.

The problem of the level of the post-glacial forest-limit (*Baumgrenze*) in the mountains in various parts of the country is, certainly, not yet definitely solved, but, according to the details at hand (45, p. 73; 14,

§§ 28, 49; see also footnote, p. 245, in this paper[10]), it seems clear that, even during the post-glacial climatic optimum, forest-free tops existed on the mountains of all parts of the country, including the Wicklow Mountains. In the latter area, however, the fossil forest-limit apparently lies higher than in the northern and western mountains, where, in addition, it must always have been especially low in localities exposed to the wind. Cliffs are rare in the Wicklow Mountains, and the gently-domed summits have been disposed to be covered, to a great extent, with soligenous peat formations. In contrast with this, the northern and western mountains, so rich in peaks, ridges, cliffs, and steep slopes, offer more suitable localities to the calcicole grass and herb vegetation, in which many of the arctic-alpine species linger. Thus greater and more favourable areas would be at the disposal of the arctic-alpine floral elements in the west and north than in the Wicklow Mountains.

These considerations in connexion with the plant records from Ballybetagh are advanced here because they enable the problem of the causes of the difference in the distribution of the arctic-alpine species in the east and west of Ireland to be viewed from a different point than by reference solely to the possible existence of glacial refuges, it now being scarcely possible, on a purely floristic basis, to refuse to admit that these could also have existed in Wicklow.

Species such as *Arabis petræa, Arenaria ciliata, Oxyria digyna, Thalictrum alpinum* might remain, in their present stations, as relicts of conditions older than the last glaciation, but, as they had a wider distribution in late-glacial times, they must be regarded as relicts from this period, since the cause of the restriction of their distribution is to be sought in the development of post-glacial conditions.

Remarks on the list of Insects.

All the remains of insects washed out of the samples from the Ballybetagh bogs have been determined by Dr. K. L. Henriksen, keeper at the Zoological Museum at Copenhagen, and I wish also here to tender to Dr. Henriksen my best thanks for the very considerable work he has done. The following details as to the European distribution and fossil records of the species mentioned in the list I owe to Dr. Henriksen's paper (46) dealing with the quaternary insect fauna in Denmark and Scania. *Staphylinus olens* alone is not mentioned in this paper. In the following remarks the remains found are referred to in parenthesis after the specific name:—

Agabus sp. (Pronotum and mesosternum.)

Barynotus schonherri (Zetterstet) Germ. (The two elytra.) A north-

[10] On the mountain Tievebulliagh, Co. Antrim, the forest growth ascended to at least 1200 ft.

western European species occurring also on the mountains in southern France; see map, fig. 22, Henriksen (46). In Ireland it seems to be confined to a small area in the north-east. As the remains of the insect at Ballybetagh are recorded from the border between the earthy peat layer A and layer B, it is not quite sure that they have been found in a original situation, but may perhaps be younger than layer B, and so of uncertain age. Once recorded from young peat in Denmark.

Calathus cisteloides Panz. (The two elytra.) Distributed over the greater part of Europe, including Ireland, northwards to the Shetland Islands, Trondheim in Norway, Västmanland in Sweden. Once found in a bronze-age tomb in Denmark. It is a remarkably southern species to be found in a late-glacial bed, even if the flora of this is rather temperate and may be compared with the Alleröd-flora of the Baltic (see p. 246). It lives among moss and below stones, in or outside the forest.

Colymbetes sp. (*fuscus* L.?). (A fragment of an elytrum.)

Dytiscus semisulcatus Müll. = *D. punctulatus* F. (Fragment of a left elytrum.) Previously found fossil in a mud layer from the oak mixed-forest period in Denmark and in a submarine bog at Belle-Ile in France. The find at Ballybetagh is surprisingly old in relation to the present distribution of the animal, which covers western, northern, and central Europe, towards the north reaching southern Norway and Sweden.

Geotrupes vernalis L. (A part of pronotum, remains of legs.) Distributed over the greater part of Europe, including Ireland, the northern limit running through northern Scotland, Norway at Bergen (also at Saltdalen, 67° N. lat.), and Lapland in Sweden. Several records from post-glacial peat in Scania, Denmark, England, and France are known.

Haltica sp. (One well-preserved elytrum; for a determination of the species the presence of the penis is needed.)

Leptocerus sp. (Pupal cases.)

Otiorrhynchus dubius Ström. (The two elytra and parts of sterna.) A boreo-atlantic and alpine species in Europe (Scotland, northern England, Newcastle in Ireland); see map, fig. 4, Henriksen (46); common in Iceland, reaching to 67° N. lat. in West Greenland. Many fossil records in northern Europe from arctic and subarctic beds of glacial, inter-glacial, and late-glacial age, some few post-glacial records, *e.g.*, from moor-log from the Dogger Bank. The find in layer F at Ballybetagh corresponds very well with those from the Alleröd beds in Denmark (see p. 246).

Phryganea sp. (Closing web (*Siebmembran*) of pupal case.)

Pterosticus vulgaris L. (The two elytra.) Northern, western, and central Europe, northwards to southern Norway, Lapland (in Finland to 67° N. lat.), the Kola peninsula, Peshora. The vegetation at Ballybetagh when the layer D was formed may have been rather like the present vegetation in parts of the last-mentioned northern regions.

Pterosticus sp. (The outer end of an elytrum.)

Silpha atrata L. var. (A right elytrum.) Western, northern, and central Europe. Several fossil records, in Scania one from an old part of the post-glacial period.

Staphylinus olens Müll. (Pronotum.) Has a wide distribution in western, northern, and central Europe; in the north through the whole of Great Britain and Ireland, Denmark, and southern Sweden; in the east to East Prussia, Poland, Siebenbürgen, Greece, Asia minor, and the Caucasus. Not previously recorded as fossil.

Comparison with a Bog at Ralaghan, Co. Cavan.

The investigations, especially of the eastern bog at Ballybetagh, seem to show a different development from that which took place in the north-western basin, and in order to get a fuller background to help in understanding the significance of the section from this it is desirable that stratigraphical studies should be extended to other basins. For this reason attention is drawn here to a bog at Ralaghan, Co. Cavan, which I had the opportunity of investigating in 1934 in company with Mr. H. Jonassen and Mr. G. F. Mitchell.

This little bog lies about 6 km. north-east of Bailieborough, near the northern border of a low plateau, which rises to a summit at 982 feet about 500 metres east-south-east of the bog. The level of the bog itself is nearly 700 feet. The bog is now dug away to a great extent. My attention was drawn to this bog by Dr. A. Mahr, Director of the National Museum, Dublin, because during peat-cutting several years ago a "wooden god," which is now preserved in the museum, was found here. The depth in the peat at which the idol had been found being known, Dr. Mahr invited me to try if an investigation of the site could, perhaps, give some hint as to the age of the object. It should be said immediately that I did not succeed in this; the find had been made too long ago. The upper layers of the peat were cut away in that part of the bog where the owner of the bog said the idol had been found. Fig. 20A shows the section through the bog in this part where a narrow wall of earth and peat was left, but even here the position given for the idol of "3½ feet below surface" would give an age reckoned from the pollen diagram near to that of the flint industry which C. Blake Whelan (47) has described from the shore of Lough Neagh at Toome Bridge (48), viz., referring it to a rather early level of zone Vb, which would be hardly credible.

However, the investigation of the bog gave a very interesting view, I am inclined to think, of the complete section of the Irish late-glacial fresh-water deposits. This opinion is strongly supported by investigations made in 1935 in a bog at Carrowreagh, Frenchpark, Co. Roscommon, and in two bogs at Roundstone, Co. Galway, where the same alternating mud and clay layers as at Ralaghan were found. The examination of the material from these localities, however, is not yet finished.

The sections on fig. 20 give an idea of the structure of the bog at Ralaghan. The following description gives details:—

Section A[11] taken about 50 metres west of point 4 in the cross-section B which runs across the eastern end of the bog.

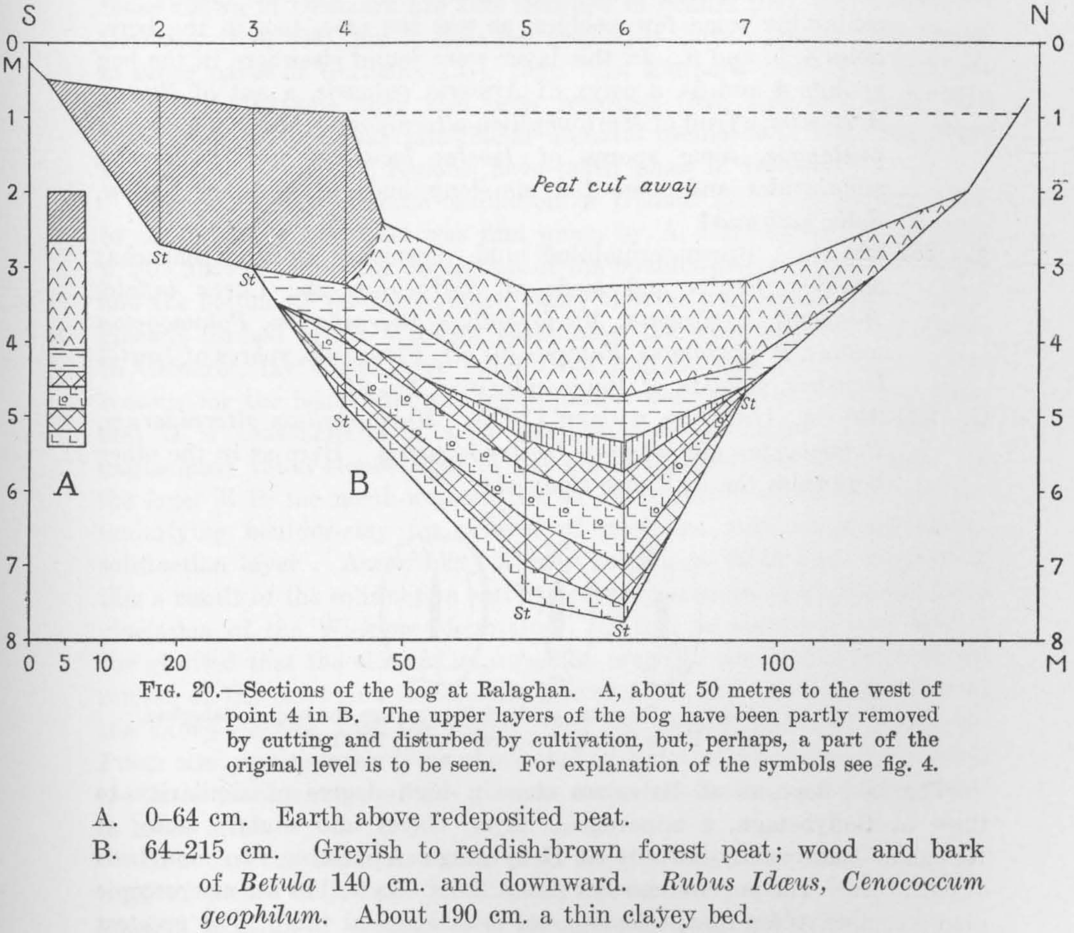


FIG. 20.—Sections of the bog at Ralaghan. A, about 50 metres to the west of point 4 in B. The upper layers of the bog have been partly removed by cutting and disturbed by cultivation, but, perhaps, a part of the original level is to be seen. For explanation of the symbols see fig. 4.

A. 0–64 cm. Earth above redeposited peat.

B. 64–215 cm. Greyish to reddish-brown forest peat; wood and bark of *Betula* 140 cm. and downward. *Rubus Idæus, Cenococcum geophilum.* About 190 cm. a thin clayey bed.

C. 215–240 cm. Brown sedge-peat, rootlets of *Carex,* also a fruit (*Carex* cfr. *inflata*), seeds of *Menyanthes trifoliata* and a nut of *Potentilla palustris.* The bore-holes 5 and 6 run through a bed of *Cladium*-peat with rhizomes of *Cladium Mariscus* and *Phragmites communis* and fruits of *Cladium Mariscus* lying between the sedge-peat and the mud.

[11] From 140 cm. and downward surveyed by boring; the cross-section B is entirely surveyed by boring.

D. 240–258 cm. Olive-brown mud with many fruits of *Potamogeton natans,* much pollen of *Typha latifolia, Myriophyllum alterniflorum* and *Myriophyllum* sp. — *Pediastrum Boryanum* var. *granulatum, P. muticum.* In addition in the same layer at the bore-hole 4 were found: Bud-scales of *Populus tremula,* one fruit of each of *Betula pubescens, Ceratophyllum demersum,* and *Potentilla palustris,* seeds of *Menyanthes trifoliata,* fruits of *Carex inflata.*

E. 258–287 cm. Light greyish-blue, sticky clay without $CaCO_3$ but containing some few pebbles, as was the case, too, in the bore-holes 4, 5, and 6. In this layer were found elsewhere in the bog (points 4 and 5), a calyx of *Armeria vulgaris,* a nut of *Rumex Acetosella,* a fruit of *Myriophyllum alterniflorum,* and *Potamogeton prælongus,* some spores of *Isoetes lacustris* and *Selaginella selaginoides* and some 1–2 mm.-long buds of a dwarf willow, *Salix herbacea?*

F. 287–320 cm. Brown crumbling mud, downward turning somewhat clayey. Fruits and seeds of *Batrachium* sp., *Carex inflata, Menyanthes trifoliata, Myriophyllum alterniflorum, Potamogeton natans, P. prælongus, Ranunculus* cfr. *Flammula,* spores of *Isoetes lacustris,* stomata of *Pinus sylvestris,* fig. 21.

G. 320–340 cm. Grey clay without $CaCO_3$. *Myriophyllum alterniflorum, Potamogeton* cfr. *alpinus, Isoetes lacustris.* Here as in the other bore-holes the drill met stony clay.

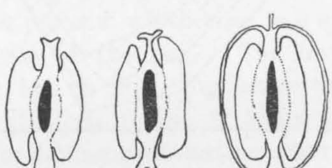


FIG. 21.—*Pinus sylvestris.* Stomata, to the left two from the bog at Ralaghan, layer F; to the right a recent one. 350/1.

The lake-deposits at Ralaghan show a high degree of similarity to those at Ballybetagh, a minerogenic layer, clayey and slightly stony at Ralaghan, more sandy-gravelly at Ballybetagh, separating two mud beds at both sites. The pollen-diagrams (see p. 247 f.), as well as the macroscopic plant-remains, refer these lake-deposits to late-glacial time. The greatest difference is found in the lowest layer, which at Ralaghan was a true lake sediment and at Ballybetagh a bed of reassorted boulder-clay. In the before-mentioned bogs at Frenchpark and Roundstone a development of the late-glacial layers similar to the Ralaghan section was recorded, leaves of *Salix herbacea* being found in the intermediate clay layer. It is likely that this will prove to be the type of the late-glacial fresh-water deposits in Ireland. The special orography, with steep slopes surrounding the lakes as at Ballybetagh, caused a somewhat special development. For the discussion of the formation of the clay layers see p. 221.

THE LATE-GLACIAL DEPOSITS IN IRELAND COMPARED WITH THOSE IN DENMARK.

For the stratigraphy of the Danish late-glacial fresh-water deposits, touched on earlier in this paper, and the changes of the late-glacial climate in Denmark, compare the scheme given below (for the details see (25), (49), (50), (51), (52), (53)). Late-glacial climatic oscillations similar to those known in Denmark are also recorded in Scania (54) and in northern Germany (55), (56), but it does not seem they have hitherto been traced in other parts of Germany (57), (58). In southern Norway late-glacial climatic oscillations have also been recorded (59), and now it is very interesting to find that late-glacial climatic oscillations, very like those known from the Baltic regions, have taken place in Ireland.

The proof of a climatic oscillation in Ireland after the melting away of the Ivernian Ice Sheet was first given by A. Farrington (3), compare p. 209 above. After the deposition of the boulder-clay covering the slopes and the bottom of the Ballybetagh valley this ice withdrew. Later valley-glaciers formed in the Wicklow Mountains, the most northerly of which, in Glencree, lay about three miles from Ballybetagh. Farrington gives reasons for the belief that the precipitation was very heavy at that time, and it is consonant with such circumstances to assume that on the unglaciated valley-slopes close to the glaciers solifluction took place. In the layer E in the north-western bog at Ballybetagh, separated from the underlying boulder-clay by a layer of mud, we have an unmistakable solifluction layer. Accordingly it may be safe to think that we have in this a result of the solifluction activity contemporaneous with the last local glaciation of the Wicklow Mountains. If this be right we may take it for granted that the climate improved so much in the period between the retreat of the ice which formed the Newer Drift and the transgression of the valley-glaciers, that the upper limit for *Betula*, and very likely for *Pinus* also, rose to levels lying above that of Ballybetagh,[12] and that during the later transgression of the glaciers these tree-limits were forced down to lower levels.

How far the *Salix herbacea* beds are contemporaneous in the four bogs in which they have been found up to the present (compare the scheme) is still, of course, open for discussion by geologists. But in so far as this late-glacial section proves the existence of only one amelioration (zone II) and only one deterioration (zone III) of the climate in the period between the formation of the boulder-clay at the bottom of the basins and the deposition of the mud belonging to

[12] The post-glacial limits of these trees in the mountains north-west of Glendalough, near Lough Firrib, may be placed for the birch at about 2100 feet and for the pine at about 2000 feet, according to observations made on an excursion in company with Mr. A. Farrington in 1934.

zone IV., in which the post-glacial forest development starts, it weighs decisively in favour of the contemporaneity of the phases of the late-glacial development at the localities mentioned. Then, if the *Salix herbacea* bed (zone III) at Ralaghan, Frenchpark, and Roundstone, of which at least the two last-mentioned localities lie behind the central Irish moraines (1), should be younger than the zone III at Ballybetagh, one would expect to find the traces of a second climatic deterioration in the zone IV at this locality; but this does not seem to be the case.

In the comparison given below between the late-glacial development in Ireland and in Denmark no assumption is made as regards the contemporaneity of the developments in the two countries. Such a contemporaneity may be a reality, but before anything decisive can be said on this question much more extensive studies of the late-glacial fresh-water deposits, not least in England and Scotland, will be necessary. Thus the scheme must be taken as a purely formal comparison only :—

Zones.		Ballybetagh.	Ralaghan, Frenchpark, Roundstone I & II.	Denmark.[13]
Late-glacial.	IV	Post-glacial mud.	Post-glacial mud.	Post-glacial mud.
	III	Solifluction earth. *Salix herbacea.* *Oxyria digyna.* *Armeria vulgaris.*	Clay (stony). *Salix herbacea.* *Armeria vulgaris.*	Dryas-clay. Arctic flora.
	II	Mud. *Betula pubescens.* *Pinus sylvestris.*	Mud. *Betula pubescens.* *Pinus sylvestris.*	Alleröd-Layer. Mud, mould. *Betula pubescens.* *Pinus sylvestris.*[14]
	I	Solifluction earth.	Clay.	Dryas-clay. Arctic flora.
Last glaciation.		Boulder-clay.	Boulder-clay.	Boulder-clay.

Comparison of the late-glacial development of the fresh-water deposits in Ireland and Denmark.

[13] For the zones of the Danish deposits see (53).
[14] An unpublished find of stomata of this tree by Dr. J. Iversen.

Here attention should be drawn to C. Reid's section from a silted-up hollow in glacial gravel at Ballaugh on the Isle of Man (38, p. 56), as it seems to give evidence of late-glacial climatic changes. The description, somewhat abbreviated, runs thus:—

A. Peat, "recent or Neolithic."
B. Sand without fossils.
C. Sandy silt; *Salix herbacea, Apus glacialis.*
D. Loamy peat; *Littorella uniflora* and other water-plants.
E. Gravel without fossils.
F. Chara mud with *Cervus giganteus, Empetrum nigrum, Littorella uniflora* and other water-plants.

C. Reid classes layer C as late-glacial and tentatively classes D and F with C, but thinks it possible that they may belong to an inter-glacial period. A definite comparison of this interesting section with the Irish late-glacial sections is not possible principally because the stratigraphical value of the layer E is not distinct. This layer may be glacial and F, therefore, inter-glacial; but however this may be, it is tempting to see in layer C, and perhaps B, deposits synchronous with layer E at Ballybetagh and in the loamy peat (D) a layer synchronous with layer F at that locality.

POLLEN DIAGRAMS.

The construction of the pollen diagrams has been made, partly in the ordinary way, using the tree pollen,[15] "TP" as employed by L. von Post (compare, *e.g.*, H. Godwin (60) where the literature is cited,[16]) partly on the lines proposed by Knut Fægri (59), so as to make clear the proportion between the TP and the non-tree-pollen "NTP" (Nichtbaumpollen, NBP), figs. 22, 24, 26, and also between the single groups of NTP and the sum of NTP, figs. 23, 25, 27, which may be of interest, especially in the late-glacial parts of the diagrams. As NTP are reckoned the pollen of *Ericaceæ* and *Empetrum, Gramineæ, Cyperaceæ* and other herbaceous plants apart from water-plants ("WPP"). "Unknown" pollen, reaching often not insignificant frequencies in the late-glacial as well as in the post-glacial beds, has here been omitted. The TP-diagrams are supplemented with the NTP-curve giving the frequency of the sum of the NTP as a percentage of the TP, and in the NTP-diagrams the frequency of each NTP-pollen group is given as a percentage of the sum of the NTP. The frequency of the WPP as well as of the fern spores, "FSp," is reckoned as a percentage of the sum of the NTP.

[15] The pollen analyses have been done mainly by Mr. H. Jonassen and Mr. K. M. Eriksen.

[16] As usual the frequency of *Corylus* is expressed as a percentage of the sum of TP in which it is not included.

When discussing the NTP-curve in the ordinary diagram it must be remembered that the NTP will originate principally from plant-communities situated outside the tree-covered areas around the locality investigated

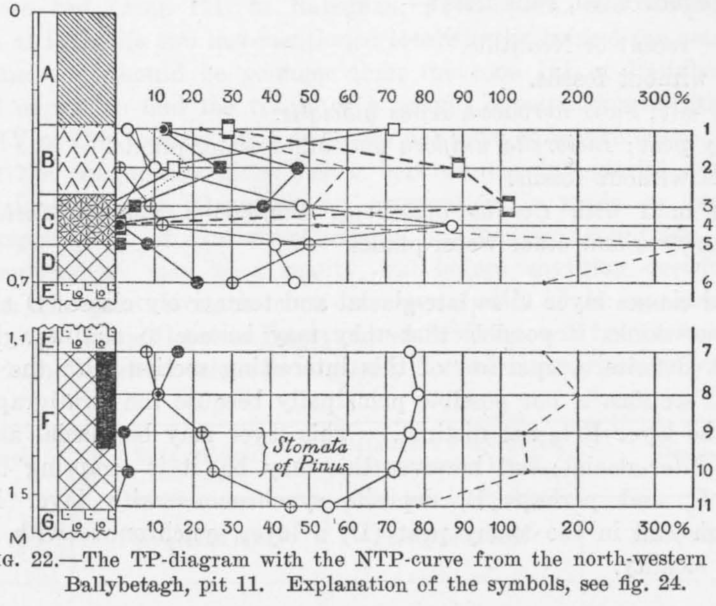


FIG. 22.—The TP-diagram with the NTP-curve from the north-western bog at Ballybetagh, pit 11. Explanation of the symbols, see fig. 24.

(compare Fægri (59, p. 16)), and that only a part of these non-forest-grown areas possessed edaphic conditions suitable for forest-growth, the swamps usually being too moist. The pollen of the swamp plants, however,

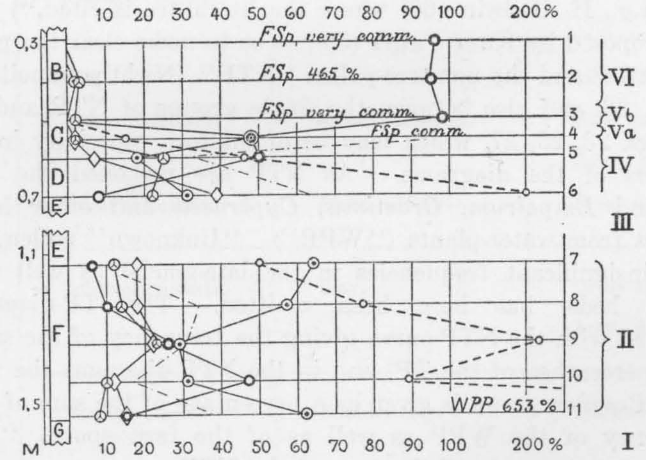


FIG. 23.—The NTP-diagram corresponding to the diagram in fig. 22.

cannot be counted separately (*Gramineæ, Cyperaceæ*). A change in the pollen production of the swamp plants may very easily cause movements in the curve mentioned, even with an unchanged production of TP.

However, when a lake has been surrounded by open dry areas without, or with a scanty, forest-growth, as may have been the case in late-glacial

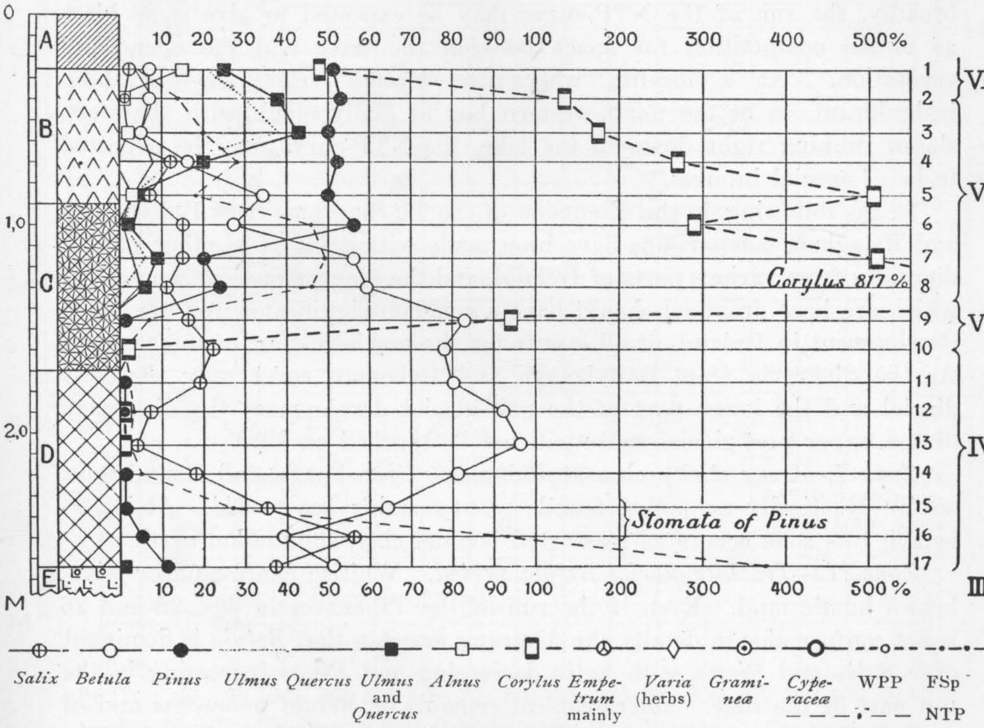


FIG. 24.—The TP-diagram with the NTP-curve from the north-western bog at Ballybetagh, pit 1. Explanation of the pollen symbols.

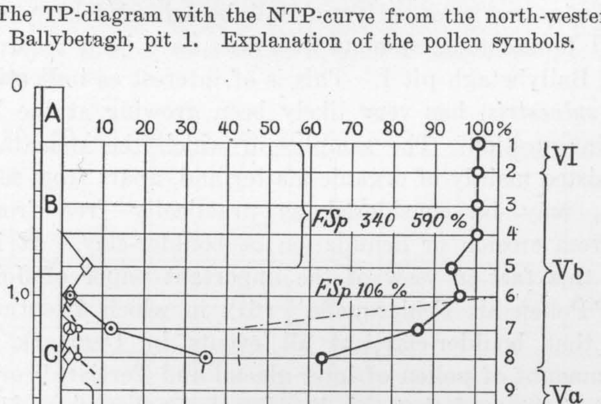


FIG. 25.—The NTP-diagram corresponding to the diagram in fig. 24.

and early post-glacial time, an essential part of the NTP falling in the lake may have come from the vegetation on these open spaces and, speaking broadly, the run of the NTP-curve may be expected to give some hints as to the competition for space between the trees and the open land vegetation. At a locality where the swamp vegetation has been insignificant, as at the north-western bog at Ballybetagh with the steep slopes running right down to the lake, the NTP-curve may be expected to be of special interest.

In the following, in the discussion of the TP-diagrams from Ballybetagh and Ralaghan, comparisons have been made with a series of other pollen-diagrams from various parts of Ireland, and the diagrammatical zones I–VI which are here proposed should have a common significance for the forest development in Ireland, at all events for the northern part of the country. As the diagrams from Ballybetagh and Ralaghan cover only the late-glacial and the lower part of the post-glacial development the discussion of the upper post-glacial zones will not be touched on here.

Zone I.—Grey sticky clay at Ralaghan, Frenchpark and Roundstone, so far practically no pollen found; plant-remains, see p. 244. At Ballybetagh this zone occurs as reassorted boulder-clay, solifluction earth.

Zone II.—The late-glacial Betula period. Whitish chara-mud or olive-brown humic mud. Even if the run of the TP-curves in figs. 22 and 26 is not conformable in details, the diagrams agree in that *Betula* is dominant over *Salix* and *Pinus*, with *Salix* decreasing and *Pinus* increasing in the top part of the zone. Macroscopical remains of *Betula pubescens* and of some *Salix*-species are recorded from Ballybetagh, and here, as well as at Ralaghan and Roundstone, stomata of *Pinus* have been recorded, just as in zone IV at Ballybetagh pit I. This is of interest as indicating that the Pine (*Pinus sylvestris*) has very likely been growing at the localities in the periods in question. The samples in which the stomata have been recorded consisted mainly of organic matter and, apart from sample no. 27 at Ralaghan, may be considered as practically free from material originating from erosion or denudation of boulder-clay. It is necessary to point out this fact in view of the important paper of Johs. Iversen, "Sekundäres Pollen als Fehlerquelle" (61), in which attention is drawn to the fact that boulder-clay, at all events in Denmark, contains a considerable amount of pollen of inter-glacial and Tertiary[17] origin as well as stomata of *Pinus*, and that this boulder-clay pollen flora is also found in lacustrine clay beds, showing there the same proportion between the various secondary pollen species as in the boulder-clay; naturally enough, as such beds consist of clay originating through the action of solifluction in the boulder-clay (see p. 221). In pure autochthonous sediments, however, the occurrence of, e.g., *Pinus* stomata may indicate the existence of *Pinus* contemporaneous with the deposit in question. I have no knowledge of

[17] As regards pollen of Tertiary origin compare especially Rudolph, 1935 (62).

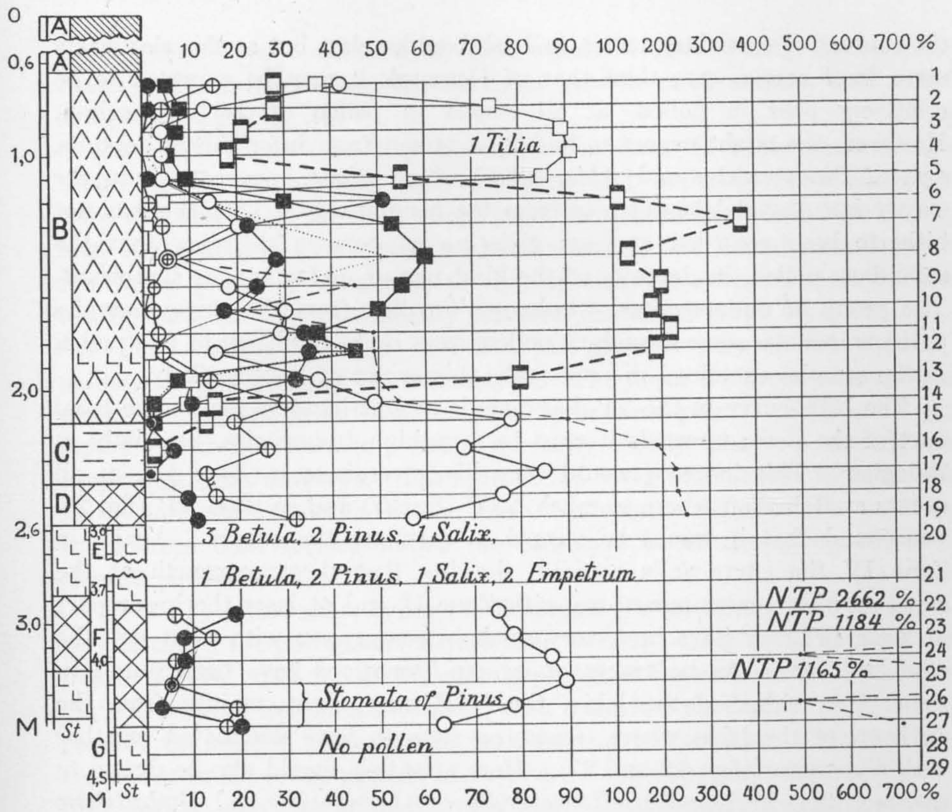


FIG. 26.—The TP-diagram with the NTP-curve from Ralaghan. The upper part of the diagram (layers B, C, D) derives from section A, the lower part (layers E, F, G) from section B, point 6. Explanation of the symbols see fig. 24.

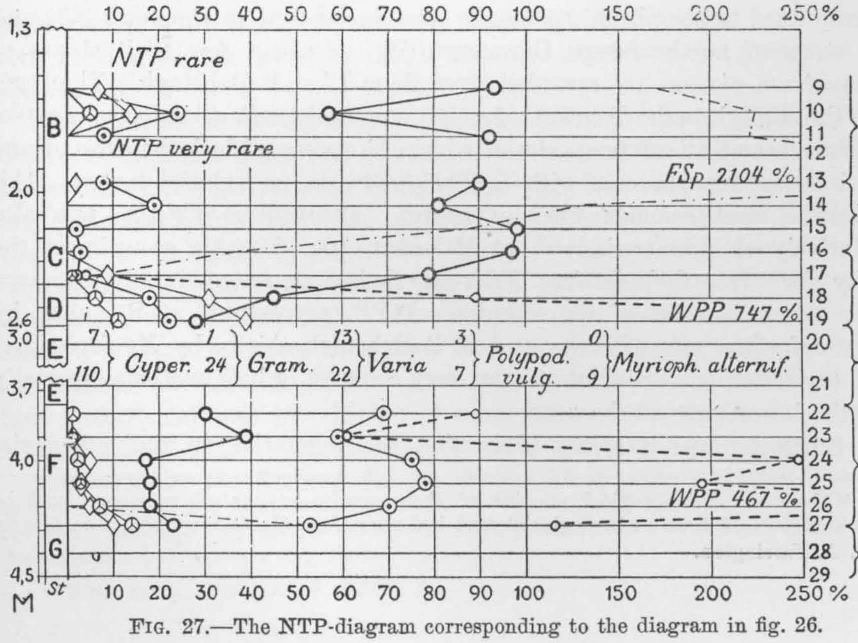


FIG. 27.—The NTP-diagram corresponding to the diagram in fig. 26.

the content of secondary pollen in Irish boulder-clay, but as this clay has a more local origin, *e.g.*, than that of Denmark it may be expected to be relatively poor in pollen, at all events in pollen of Tertiary origin. However, one might expect to find in it pollen from inter-glacial deposits, *e.g.*, of *Picea excelsa* and *Abies alba*[18] which might have come into the clayey late-glacial lake-deposits from the boulder-clay. That this has not hitherto been recorded at least gives no support to the view that the secondary pollen, in deposits of the kind named in Ireland, is significant. The group of undetermined "unknown" pollen from the clayey samples perhaps includes some secondary pollen, even if the condition of this pollen in the samples examined did not make this origin of it very likely.

The NTP-curve in the TP-diagrams is proportionately low in the basal part of the zone; upwards it runs to very high frequencies, especially at Ralaghan. This increase would very likely continue in Zone III, at all events at Ralaghan where so much NTP (fig. 27) and so little TP (fig. 26) was found that it would be absurd to calculate the curve. Again, in Zone IV the curve falls rapidly, showing that the tree-growth at the two localities, contemporaneous with Zone II and at least the lower part of Zone IV, may have been very weak in comparison with what was the case later on. As no traces of swamp-formations have been found in zone II in either of the lakes, the NTP may derive mainly from the environs of the lakes where *Gramineæ* seem to have dominated together with *Cyperaceæ* (figs. 22 and 27). Here attention should also be drawn to the fact that herb pollen, *Caryophyllaceæ, Compositæ* and *Umbelliferæ* may be common in this zone—up to 22 per cent. at Ballybetagh, fig. 23. The relative insignificance of the *Ericaceæ-Empetrum*-curve, here mainly represented by *Empetrum*, makes it likely that Crowberry-heaths have played only a minor rôle in the vegetation-cover of the environs, just as is supposed to have been the case in late-glacial time in Denmark (61) and in parts of north-western Germany (63). Only a few fruit stones of *Empetrum nigrum* are recorded from Zone II at Ballybetagh. The ferns in the Ballybetagh diagram (fig. 23) are *Polypodium vulgare, Lastrea Filix-mas* and a *Lastrea* species of which the spores all lack the exosporium, as is commonly the case with *L. Thelypteris* in post-glacial layers. This was the most common kind of spore. *Polypodium vulgare* was also relatively abundant; indeed, at Ralaghan (fig. 27) this was almost the only fern recorded, *Lastrea Filix-mas* being represented only by some few spores in some of the samples. WPP, represented at Ralaghan by *Myriophyllum alterniflorum* and at Ballybetagh chiefly by *Myriophyllum* sp. (*spicatum* or *verticillatum*) was very common in both sections especially in the lower part of the zone.

Summing up; it seems likely that the vegetation in the late-glacial

[18] Numerous macroscopical remains of these species among others were found by the author in 1935 in an inter-glacial mud bed near Gort, Co. Galway, shown to him by Mr. A. Farrington.

Betula period was composed of open woods of *Betula* with *Salix,* some *Pinus* and *Juniperus* and an extensive growth of *Gramineæ* and other herbaceous plants.

Zone III.—This zone may be called the *Salix herbacea* zone as the leaves and other remains, such as twigs and buds, of *Salix herbacea* were common in it at Ballybetagh and have been recorded from it by help of the drill at Frenchpark and Roundstone. At Ralaghan only some few buds, probably belonging to this species, have been found in the bed in question. At this locality the zone contained much NTP but very little TP (compare figs. 26 and 27), the greatest part of the "varia" pollen recorded being of the *Silene*-type. The floral list from Ballybetagh shows the vegetation as being rich in herbaceous plants, partly with an alpine or arctic character, while the only woody plants recorded are *Empetrum* and *Juniperus.* The zones I–III cover what should be reckoned as the late-glacial portion of the Irish fresh-water deposits (see p. 246), which have been formed under the influence of an arctic or subarctic climate (compare 43, p. 388).

Zone IV.—This zone, being the first post-glacial one in the diagrams, may be called the post-glacial *Betula* zone, corresponding to *the post-glacial Betula period.* The top of the zone is placed at the rational border of the *Corylus*-curve. *Betula* is dominant, with a marked maximum in the upper part of the zone.[19] The curves for *Pinus* and *Salix* have their greatest frequency in the lower portion of it, where *Salix* even may surpass *Betula,* then falling rapidly inwards. *Salix* at Ballybetagh (fig. 24) and at Ralaghan (fig. 26) again rises to a secondary maximum in the top of the zone as it does also in other Irish diagrams. Macroscopical remains of *Betula pubescens* and of several *Salix*-species are recorded from this zone at Ballybetagh, and the recording of several stomata of *Pinus* (fig. 24) embedded in pure mud without sand and clay, in the lower part of the zone at Ballybetagh indicates that *Pinus* also shared in the formation of the vegetation.

The NTP curve for the zone has been mentioned before (p. 252). The diagrams exhibit a difference of remarkable interest for the discussion of the value of this curve. At Ballybetagh (fig. 24) the curve has a very low minimum before the start of the *Corylus*-curve, while at Ralaghan (fig. 26) it is relatively high throughout the zone, and one gets the impression that the *Betula* wood has been handicapped at Ralaghan in comparison with Ballybetagh. However, I do not believe that this is the case, as it may be taken as a fact that topography may have a great significance for the run of this curve, not least in such a period as the first post-glacial one in which the competition between the open-land

[19] In comparing the diagrams, figs. 22, 24, and 26, it must be noticed that the intervals between the samples in the diagram from Ballybetagh (pit 11, fig. 22) are too great, although they are, on an average, only about ·8 cm. apart, the formation of the beds here having been very slow.

vegetation and the forest might have been specially acute. At Ballybetagh the steep slopes running down into the lake hindered an extensive growth of swamp-vegetation so long as the lake was not filled up; and the *Betula* wood covering the slopes, together with *Salices* in the last part of the period, produced nearly all the pollen falling into the lake. It was otherwise at Ralaghan in that the environs of the lake-basin were much flatter, and at an early period permitted the growth of a swamp or fen vegetation, the production of pollen of which, together with other NTP, might exceed the production of TP from the more remote higher levels around the lake.

An attempt to find synchronous levels in zone IV in the two diagrams from Ballybetagh seems to show that the level 4–5 at pit 11 (fig. 22) corresponds with the level 15–16 at pit 1 (fig. 24). Here the curves for *Betula* and NTP cross, the curve for *Salix* and *Empetrum* are falling from their maxima, the curve for *Gramineæ* is rising, that for *Cyperaceæ* inclines to fall a little and the fern curve increases rapidly. The upper few centimetres of the zone in fig. 22, then, should correspond to nearly the upper—80 cm. in fig. 24. This makes it understandable that the absolute minimum of the NTP curve at pit 11 has not been met, and it indicates that it was in the period corresponding to the lower portion of the zone that the expanding *Betula* wood superseded the other vegetation elements, of which, according to the testimony of the diagrams, there existed shrubs of *Salix* and very likely, too, patches of *Empetrum*-heaths.

In the upper part of the zone IV in pit 1 at Ballybetagh too few NTP were found for calculating the diagram (fig. 25). But comparing the lower part of the diagram with the corresponding part of the diagram from Ralaghan (fig. 27) several similarities may be seen; for example, the tendency of the *Cyperaceæ* to dominate, the relatively retired *Gramineæ*-curve, the falling of the curves for *Empetrum* and herb pollen. Of the last-mentioned pollen-group pollen tetrads of *Typha latifola* take a part in the lowest spectrum in all three diagrams, at Ralaghan (fig. 27) reaching up to 27 per cent. of all NTP.—WPP, also here *Myriophyllum* is very common in the mud, *M. alterniflorum* especially in the lower part of the layer.

Zone V represents the period of the so-called boreal *Corylus* maximum[20] (11) and of the first post-glacial high-forests in Ireland in which *Pinus, Ulmus,* and *Quercus* were most prominent. In all likelihood, too, *Fraxinus* now spread in the forests, but macroscopical remains of this tree have not been found in the bogs here in question and its pollen is always very rare. The top border of the zone is placed at the rational limit for *Alnus,* figs. 22, 24, 26. Practically, it may be divided into two sub-zones (*a*) and (*b*). The border between these is placed at the rational border for *Ulmus.* In sub-zone Va *Corylus* is rising, *Betula* tends to fall, though with an attempt

[20] Within this zone may be placed the submerged peat at Milewater Dock, Belfast (64).

at a little outswing at a level where the absolute maximum for the *Betula*-curve may occur in some diagrams. *Pinus* is beginning to rise. The *Salix* curve, falling at Ballybetagh, in other diagrams has a very low frequency; at Ralaghan it shows what seems a local maximum. The sub-zone Vb covers the greatest portion of the *Corylus* maximum, the frequency of which may reach more than 800 per cent. as it does at Ballybetagh, pit 1. In the upper part of the sub-zone the *Corylus*-curve falls inward. The main direction for the *Betula*-curve is inward; *Salix* in most diagrams is without great significance. The *Pinus*-curve, often continuing its outward direction, may reach a rather high maximum, up to about 50 per cent. near the top of the zone or a little above it.

Of special interest for the sub-zone are the curves for *Ulmus* and *Quercus*; the first of these here reaches its absolute maximum, locally running up to about 50 per cent. (fig. 26). That the *Ulmus* maximum in fig. 22 is met first in zone VI may be because the samples there have not been taken closely enough. *Quercus,* for which the rational border most often lies a little higher than *Ulmus,* does not usually reach the frequency of *Ulmus* in the sub-zone in which it mainly has a rising tendency, in some places showing a relative maximum within the *Ulmus* maximum.

Usually only traces of *Alnus* are found, never forming an unbroken curve, and it seldom reaches a frequency of more than about 10 per cent. as at the base of the sub-zone at Ralaghan, fig. 27.

The NTP curve rises somewhat in the lower part of zone V at Ballybetagh (fig. 24), being dominated by *Cyperaceæ,* which may have taken part in the growing-over of the lake; at Ralaghan (fig. 27), through the greater part of the zone, it falls unevenly because a forest vegetation had at this time here replaced the fen- or swamp-vegetation forming layer C.

Zone VI corresponds to the first period in which *Alnus* reaches a dominating position among the forest trees known from zone V. Only the lowest portion of zone VI is represented in the diagrams published here. In two of these (figs. 22 and 26) the *Alnus*-curve rises quickly to very high frequencies, being much over-represented owing to the fact that *Alnus* grew out over the surface of the bogs; for this reason the other curves are forced inwards to an exceptional degree. Independent, however, of this over-representation of the *Alnus* pollen is the falling inward of the *Corylus*-curve to a minimum in the lower part of zone VI which seems to be typical.

The discussion of the upper portion of the diagrams must await the publication of the other diagrams of the material collected during my investigations in Ireland in the years 1934 and 1935.

When comparing the pollen diagrams here published with earlier published pollen diagrams from Ireland (11), (65), it will be seen that a couple of these reach down to zone IV, viz., one from Athlone (11, fig. 32) and one from Claremorris (11, fig. 35), and, further, that in several of them the zone borders IV/V and V/VI will be easily found. In the Newferry diagram from the Bann valley (48) the border V/VI falls at sample 21, and as the top of zone VI may be placed in the upper part of the diatomite (layer C), it is evident that the Bann culture covers the upper portion of zone VI, and this is younger than even the top of the diagrams published here.

K. J.

BIBLIOGRAPHY.

(1) CHARLESWORTH, J. K.—"The glacial Retreat from Central and Southern Ireland." Quarterly Journal of the Geological Society, vol. 84, p. 293.

(2) ——— "A Tentative Reconstruction of the Successive Margins of the Quaternary Ice Sheets in the Region of the North Sea." Proceedings of the Royal Irish Academy, vol. 40, B, p. 67.

(3) FARRINGTON, A.—"The Glaciation of the Wicklow Mountains." Proceedings of the Royal Irish Academy, vol. 42, B, p. 173.

(4) OLDHAM, THOS.—"On a remarkable Group of the remains of Deer found near Kiltiernan." Journal of the Geological Society of Dublin, vol. 3, p. 252.

(5) MOSS, R. J.—"Report on the exploration of Ballybetagh Bog." Proceedings of the Royal Irish Academy, vol. 12, p. 547.

(6) PORTE, GEORGE.—"Remarks on the recent Discovery of remains of the *Cervus megaceros* at Ballybetagh." Proceedings of the Royal Irish Academy, vol. 12, p. 738.

(7) WILLIAMS, W.—"On the occurrence of the great Irish Deer, *Megaceros hibernicus,* in the ancient lacustrine deposits of Ireland, with Remarks on the probable age of these beds." Geological Magazine, August, 1881.

(8) STOKES, HENRY.—"Irish Elk and other animal remains found at Howth and Ballybetagh, Co. Dublin." The Irish Naturalist, vol. 23, p. 113.

(9) BROOKS, C. E. P.—"Correlation of the Quaternary Deposits of the British Isles with those of the Continent of Europe." Report of the Smithsonian Institution, 1917.

(10) WHELAN, C. BLAKE.—"The Palæolithic Question in Ireland." Report of the XVIth International Geological Congress, Washington, 1936, pp. 1209–1217.

(11) ERDTMAN, G.—"Studies in the post-arctic history of the forests of north-western Europe. I. Investigations in the British Isles." Geologiska Föreningens i Stockholm Förhandlingar, 1928.

(12) STELFOX, A. W.—"An arctic peat in Ireland." Nature, vol. 119, 1927, p. 781.

(13) PETHYBRIDGE, G. H., and PRAEGER, R. LL.—"The vegetation of the district lying south of Dublin." Proceedings of the Royal Irish Academy, vol. 25, 1905 (the map).

(14) PRAEGER, R. LL.—"The Botanist in Ireland." Dublin, 1934.

(15) GRIPP, KARL.—"Beiträge zur Geologie von Spitzbergen." Abhandlungen aus dem Gebiete der Naturwissenschaften, vol. 21, Hamburg, 1927.

(16) SÖRENSEN, THORV.—"Bodenformen und Pflanzendecke in Nordostgrönland. Beiträge zur Theorie der polaren Bodenverzetzungen." Meddelelser om Grönland, vol. 93, No. 4, Copenhagen, 1935.

(17) SAMUELSSON, G.—"Die Verbreitung der höheren Wasserpflanzen in Nordeuropa." Acta Phytogeographia Suecica, vol. 6, Uppsala, 1934.

(18) OSTENFELD, C. H., and GRÖNTVED, JOHS.—"The flora of Iceland and the Faeroes." Copenhagen, 1934.

(19) JESSEN, KNUD, and MILTHERS, V.—"Stratigraphical and Paleontological Studies of Interglacial Fresh-water Deposits in Jutland and Northwest Germany." Danmarks geologiske Undersögelse. II. Række, No. 48, Copenhagen, 1928.

(20) VON POST, L.—"Medel och mål i skånsk torfmosseforskning." Sydsvenska geografiska Sälskapets Årsbok. Lund, 1926, p. 106.

(21) WEBER, C. A.—"Die Mammuthflora von Borna." Abhandlungen hrsg. vom Naturwissenschaftlichen Verein zu Bremen, 1914, vol. 23.

(22) MORE, A. G., COLGAN, N., and SCULLY, R. W.—"Cybele Hibernica." Dublin, 1898.

(23) NORDHAGEN, ROLF.—"Om *Arenaria humifusa* Wg. og dens betydning for utforskningen av Skandinavias eldste floraelement." Bergens Museums Årbok, 1935. Naturvidenskapelig rekke. No. 1.

(24) CHANDLER, M. E. J.—"The arctic flora of the Cam Valley." Quarterly Journal of the Geological Society, vol. 77, pt. 1, London, 1921.

(25) HARTZ, N.—"Recherches sur la flore et la faune glaciaire postérieures du Danemark." (Summary of a Danish paper.) Danmarks geologiske Undersögelse. II. Række. No. 11, Copenhagen, 1902.

(26) REID, CLEMENT.—"Armeria arctica Wallr. fossil in Britain." Journal of Botany, 1914.

(27) GAMS, H.—"Plumbaginaceæ," in Hegi, G., "Illustrierte Flora von Mittel-Europa." Vol. 5, pt. 3, 1926.

(28) TURESSON, G.—"The genotypical response of the plant species to the habitat." Hereditas, vol. 3, 1922.

(29) BLYTT, AXEL.—"Haandbog i Norges Flora." Oslo, 1906.

(30) "Hayward's Botanist's Pocket Book." Revised by Druce, G. C. London, 1917.

(31) OSTENFELD, C. H.—"The Flora of Greenland and its Origin." Det

Kgl. Danske Videnskabernes Selskab. Biologiske Meddelelser. VI, 3, Copenhagen, 1926.

(32) Firbas, F., und Grahmann, R.—"Über jungdiluviale und alluviale Torflager in der Grube Marga bei Senftenberg (Niederlausitz)." Abhandl. der mathematisch-physischen Klasse der sächsischen Akademie der Wissenschaften, vol 40, No. 4, Leipzig, 1928.

(33) Weber, Hellmuth Albert.—"Über spät- und postglaziale lacustrine und fluviatile Ablagerungen in der Whyreniederung bei Lobstädt und Borna und die Chronologie der Postglazialzeit Mitteleuropas." Abhandlungen hrsg. vom Naturwissenschaftlichen Verein zu Bremen, 1918, vol. 24.

(34) Ostenfeld, C. H.—"Flora Arctica." Part 1. Copenhagen, 1902.

(35) Jessen, Knud.—"Late-Quaternary Studies from the Isle of Mors in Jutland." (Summary of a Danish paper.) Danmarks geologiske Undersögelse. IV. Række, vol. 2, No. 5, Copenhagen, 1929.

(36) Wesenberg-Lund, C.—"Über einige eigentümliche Temperaturverhältnisse in der Litoralregion der baltischen Seen und deren Bedeutung, nebst einem Anhang über die geographische Verbreitung der zwei Geschlechter von *Stratiotes aloides.*" Internationale Revue der gesammten Hydrobiologie und Hydrographie, Leipzig, 1912, p. 208 f.

(37) Iversen, J.—"Studien über die pH-Verhältnisse dänischer Gewässer und ihren Einfluss auf die Hydrophyten-Vegetation." Botanisk Tidsskrift, vol. 40, Copenhagen, 1929.

(38) Reid, Clement.—"The Origin of the British Flora." London, 1899.

(39) Bentham, G., and Hooker, J. D.—"Handbook of the British Flora." London, 1920.

(40) Resvoll, Thekla R.—"Om planter som passer til kort og kold sommer." Archiv for Mathematik og Naturvidenskab, vol. 25, No. 6, Oslo, 1917.

(41) Andersson, Gunnar.—"Svenska växtvärldens historia." Stockholm, 1896, p. 15.

(42) Jessen, Knud, and Rasmussen, R.—"Section of a bog in the Faeroe Islands." (Summary of a Danish paper.) Danmarks geologiske Undersögelse. IV. Række, vol. 1, No. 13, Copenhagen, 1922.

(43) Charlesworth, J. K.—"Some geological observations on the origin of the Irish fauna and flora." Proceedings of the Royal Irish Academy, vol. 39, Sect. B, No. 16, Dublin, 1930.

(44) Praeger, R. Ll.—"Recent views bearing on the problem of the Irish flora and fauna." Proceedings of the Royal Irish Academy, vol. 41, Sect. B, No. 8.

(45) Wright, W. B.—"The Geology of Killarney and Kenmare." Memoirs of the Geological Survey of Ireland. (Chapter VII, Glaciation.) Dublin, 1927.

(46) Henriksen, K. L.—"Undersögelser over Danmark-Skånes kvartære

Insektfauna.'' Videnskabelige Meddelelser fra den Naturhistoriske Forening i København, vol. 96, Copenhagen, 1933.

(47) WHELAN, C. BLAKE.—''Studies in the significance of the Irish Stone Age; The Campignian Question.'' Proceedings of the Royal Irish Academy, vol. 42, Sect. C, No. 7, Dublin, 1934.

(48) JESSEN, KNUD.—''Palæobotanical Report on the Stone Age Site at Newferry, County Londonderry. Appendix I to Movius, Hallam L. A Neolithic Site on the River Bann.'' Proceedings of the Royal Irish Academy, vol. 43, Sect. C, No. 2, Dublin, 1936.

(49) HARTZ, N.—''Alleröd-Gytje und Alleröd-Mull.'' Meddelelser fra Dansk Geologisk Forening, vol. 4, Copenhagen, 1912.

(50) JESSEN, KNUD.—''Bog-investigations in North-East Sjælland.'' (Summary of a Danish paper.) Danmarks geologiske Undersögelse. II. Række, No. 34, Copenhagen, 1920.

(51) IVERSEN, J.—''Fund af Vildhest (*Equus caballus*) fra Overgangen mellen Sen- og Postglacialtid i Danmark.'' Danmarks geologiske Undersögelse. IV. Række, vol. 2, No. 13, Copenhagen, 1934.

(52) JESSEN, KNUD.—''The Composition of the forests in northern Europe in epipalæolithic time.'' Det. Kgl. Danske Videnskabernes Selskab. Biologiske Meddelelser, XII, 1, Copenhagen, 1935, p. 24, Pl. I and III.

(53) ——— ''Archæological dating in the history of north Jutland's vegetation.'' Acta Archæologica, vol. 5, Fasc. 3, Copenhagen, 1935, figs. 2 and 3.

(54) NILSSON, TAGE.—"Die pollenanalytische Zonengliederung der spät und postglazialen Bildungen Schonens." Geologiska Föreningens i Stockholm Förhandlingar, vol. 57, Stockholm, 1935.

(55) GROSZ, HUGO.—''Der Döhlauer Wald in Ostpreussen.'' Beihefte zum Bot. Centralbl, vol. 53, Dresden, 1935.

(56) BOEHM-HARTMANN, HEDWIG.—''Spät- und postglaziale Süsswasser-Ablagerungen auf Rügen.'' Archiv für Hydrobiologie, vol. 31, 1937.

(57) FIRBAS, F.—''Die Vegetationsentwicklung des mitteleuropäischen Spätglacials.'' Bibliotheca Botanica, Heft 112, Stuttgart, 1935.

(58) SCHÜTRUMPF, RUDOLF.—''Paläobotanisch-pollenanalytische Untersuchungen der paläolithischen Rentierjägerfundstätte von Meiendorf bei Hamburg." Inaugural-Dissertation. Veröffentlichungen des Archäologischen Reichsinstituts, vol. 1, 1936, p. 50. The same author.—'' Pollenanalytische Untersuchungen der Magdalenien- und Lyngby-Kulturschichten der Grabung Stellmoor." Nachrichtenblatt für Deutsche Vorzeit. 2. Jahrgang. Leipzig, 1935, p. 231.

(59) FÆGRI, KNUT.—''Quartärgeologische Untersuchungen im westlichen Norwegen. I. Uber zwei präboreale Klimaschwankungen im südwestlichsten Teil." Bergens Museums Årbok, 1935. Naturvidenskapelig rekke, No. 8, Bergen.

(60) von Post, L.—"Pollenanalyse. Reallexikon der Vorgeschichte." Berlin, 1928. Compare Godwin, H.: "Pollen analysis. An outline of the problems and potentialities of the method." Part I. The New Phytologist, vol. 33, No. 4, 1934.

(61) Iversen, J.—"Sekundäres Pollen als Fehlerquelle. Eine Korrektionsmethode zur Pollenanalyse minerogener Sedimente." Danmarks geologiske Undersögelse. IV. Række, vol. 2, No. 15, Copenhagen, 1936.

(62) Rudolph, K.—"Mikrofloristische Untersuchung tertiärer Ablagerungen im nördlichen Böhmen." Beihefte zum Botanische Centralblatt, vol. 54, Abt. B., Dresden, 1935.

(63) Overbeck, F., und Schmitz, H.—"Zur Geschichte der Moore, Marschen und Wälder Nordwestdeutschlands. I. Das Gebiet von der Niederweser bis zur unteren Ems." Mitteilungen d. Provinzialstelle f. Naturdenkmalpflege, Hannover. Heft 3, Hannover, 1931, p. 161.

(64) Charlesworth, J. K., and Erdtman, G.—"Postglacial section at Milewater dock, Belfast." The Irish Naturalists' Journal, vol. 5, No. 9, p. 234.

(65) Erdtman, G.—"Mitteilungen über einige irische Moore." Svensk Botanisk Tidskrift, vol. 18, Stockholm, 1924.