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THE LATE-WEICHSELIAN FLORA OF THE ISLE OF MAN

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[Plates 1 and 2]

CONTENTS

The last glacial deposits of the Ballaugh–Kirkmichael area in the north-east of the Isle of Man have been investigated by analysis of pollen and macroscopic fossils and by radiocarbon dating. Assemblages totalling over 160 taxa of vascular plants and mosses have been recorded from strata referred to Late-Weichselian zones I, II and III. Among the most noteworthy species are 46 not now living on the island; these include *Dianthus deltoides*, *Juncus balticus*, *Lychnis viscaria*, *Ranunculus hyperboreus*, *Sibbaldia procumbens*, *Meesia tristicha*, *Helodium blandowii* and *Polytrichum norvegicum*.

The vegetation comprised a great diversity of communities of open, largely calcareous grassland, snow beds, mires both base-rich and base-poor, flushes, freshwater, inundated flats and calcareous dunes. Saline conditions are indicated by *Glaux maritima* and *Triglochin maritima*. Trees were represented only by *Betula* and the taller shrubs by *Juniperus* and *Salix*.

Introduction

The botany of the Quaternary deposits described in this paper was first considered by Lamplugh (1903) who listed species from both Ballaugh and Kirkmichael. From the former he recovered nothing undiscovered in the present study except *Sanguisorba officinalis* L. and from the latter nothing but *Carex alpina* Sw., *Carex glauca* Scop., *Acrocladium cuspidatum* (Hedw.) Lindb.

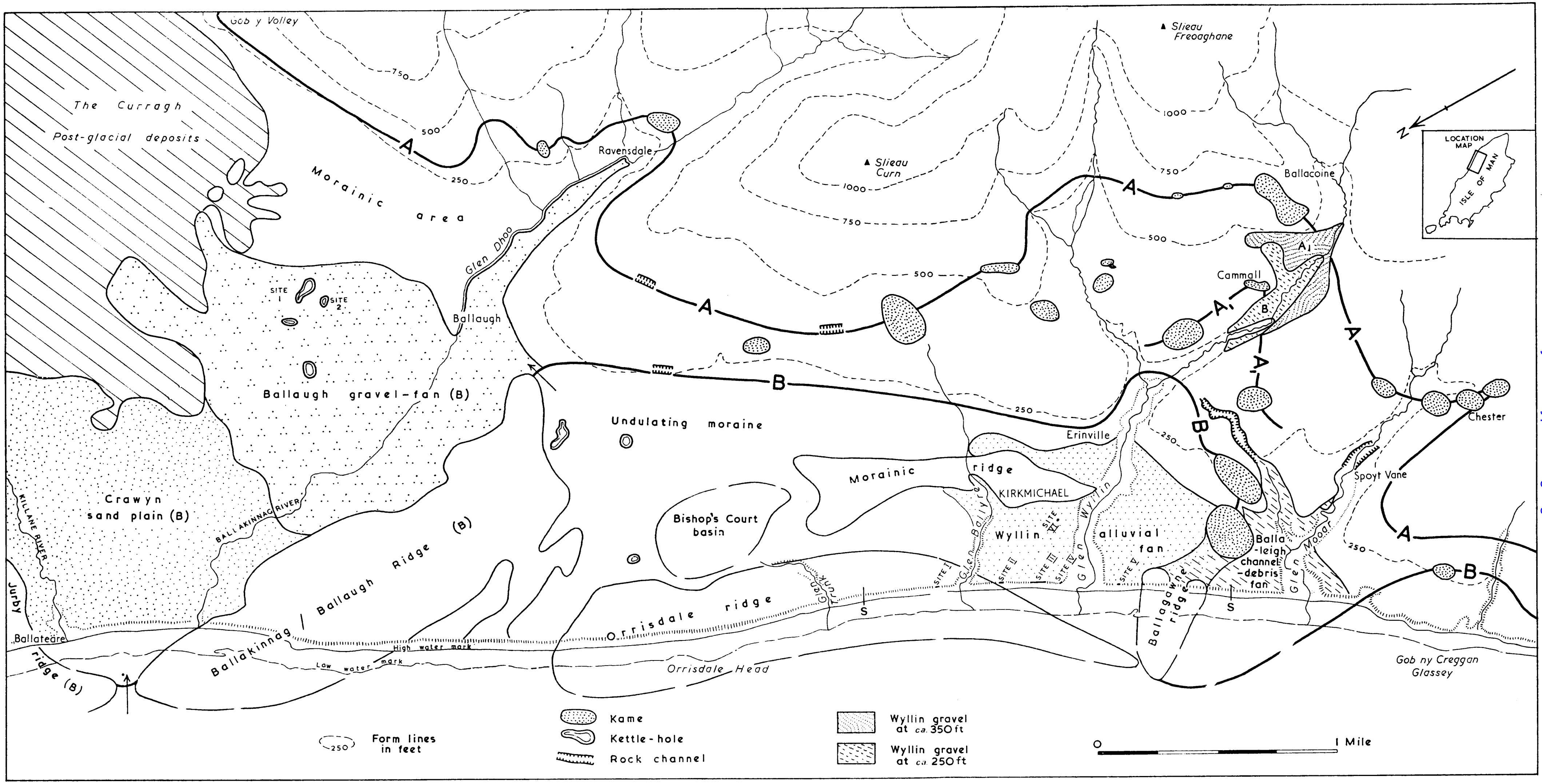


Figure 1. Quaternary deposits of the Ballaugh and Kirkmichael districts, Isle of Man. Line A indicates limit of advance of the last glaciation. Line B (incorporating the Ballakinnag/Ballaugh and the Ballagawne morainic ridges) indicates the ice limit at the time of the Bride Moraine Re-advance. The Kirkmichael and the Orrisdale morainic ridges indicate later retreat stages. The strokes marked S indicate the limits of the section shown in figure 2.

and *Grimmia* sp.; the two carices are interesting discoveries in need of revision. We have not re-examined Lamplugh's species and they are not considered in the following account.

The present investigation began in 1950 when the late Dr D. Wirtz sent fossiliferous material from the Kirkmichael cliffs to G. F. Mitchell, who subsequently collected extensively from both Ballaugh and Kirkmichael, at the latter on several occasions. The results from Ballaugh published in 1958 have been revised and included in this paper. The work on stratigraphy and pollen analysis is that of G. F. Mitchell, macroscopic fossils of flowering plants that of Camilla A. Dickson and mosses that of J. H. Dickson.

We are indebted for help with pollen determinations to Miss R. Andrew and H. J. B. Birks and with macroscopic fossils to Madame U. Körber-Grohne and Mrs G. Wilson. Photography is the work of Mr F. T. N. Elborn and Mr B. V. D. Goddard.

2. Geological and palynological background

2.1. *General stratigraphy*

Ice of the Weichselian (last) glaciation in its passage down the basin of the Irish Sea rose up on the north-west flanks of the Isle of Man to a height of about 198 m (650 ft); the higher ground emerged as a nunatak (figure 1). As the ice melted (its dissolution being perhaps interrupted by minor re-advances) it left behind a complex series of deposits—till, gravel and sand, shaped into push-moraines, morainic ridges with kettleholes, kames, gravel-fans and sand-plains (Mitchell 1965). At Ballaugh there is a gravel-fan pitted by small hollows (Mitchell 1958), while morainic ground predominates at Kirkmichael. The village of Kirkmichael lies on one north-south morainic ridge, and a second, the Orrisdale ridge, lies a little to the west, where the modern waves have cut high cliffs into it (figure 2). The lower part of the ridges and the valley between them were partly buried early in Flandrian (Post-glacial) time by a mass of alluvium which emerged from Glen Wyllin to the east and built up a gently-sloping alluvial fan. This fan has also been deeply cut into by the modern waves. The Kirkmichael Late-Weichselian deposits lie in morainic depressions, and are exposed in the cliff sections. At one site, site 1 (figure 7), the deposits are covered only by a thin layer of soliflucted sand. The other sites are buried by the alluvial fan, in the extreme case to a depth of 14 m.

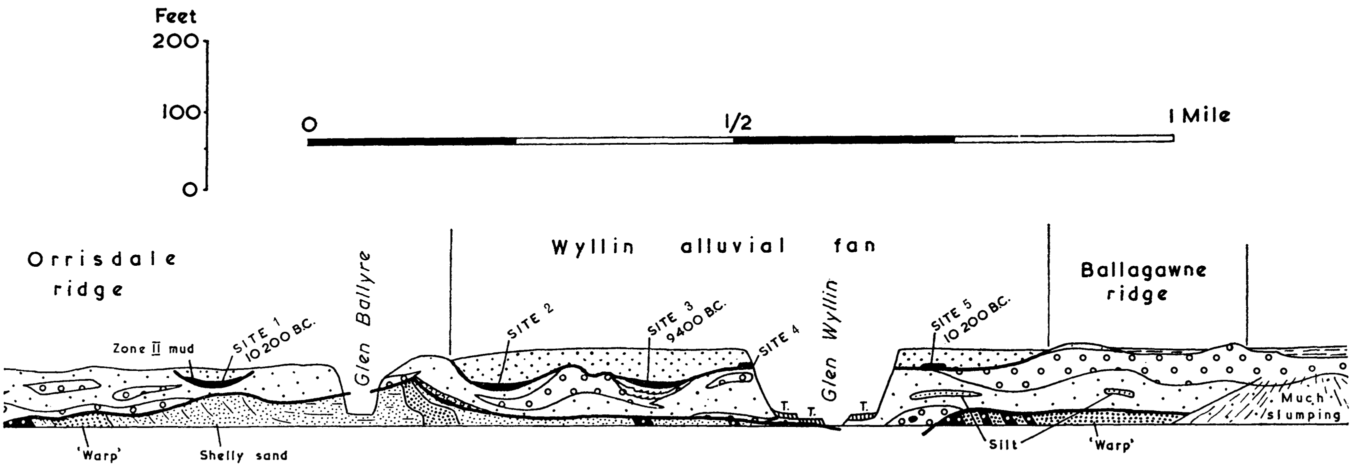


Figure 2. Weichselian and Flandrian alluvial deposits exposed in the cliff-section near Kirkmichael, Isle of Man.

2.2. *Dating*

Through the kindness of Professor Godwin, F.R.S. of Cambridge, and of the late Professor de Vries, of Groningen, five radiocarbon datings were obtained from various layers. The dates range from 10200 B.C. to 8300 B.C., thus making it clear that the deposits belong to the Late-Weichselian period between the Middle-Weichselian and the Flandrian period.

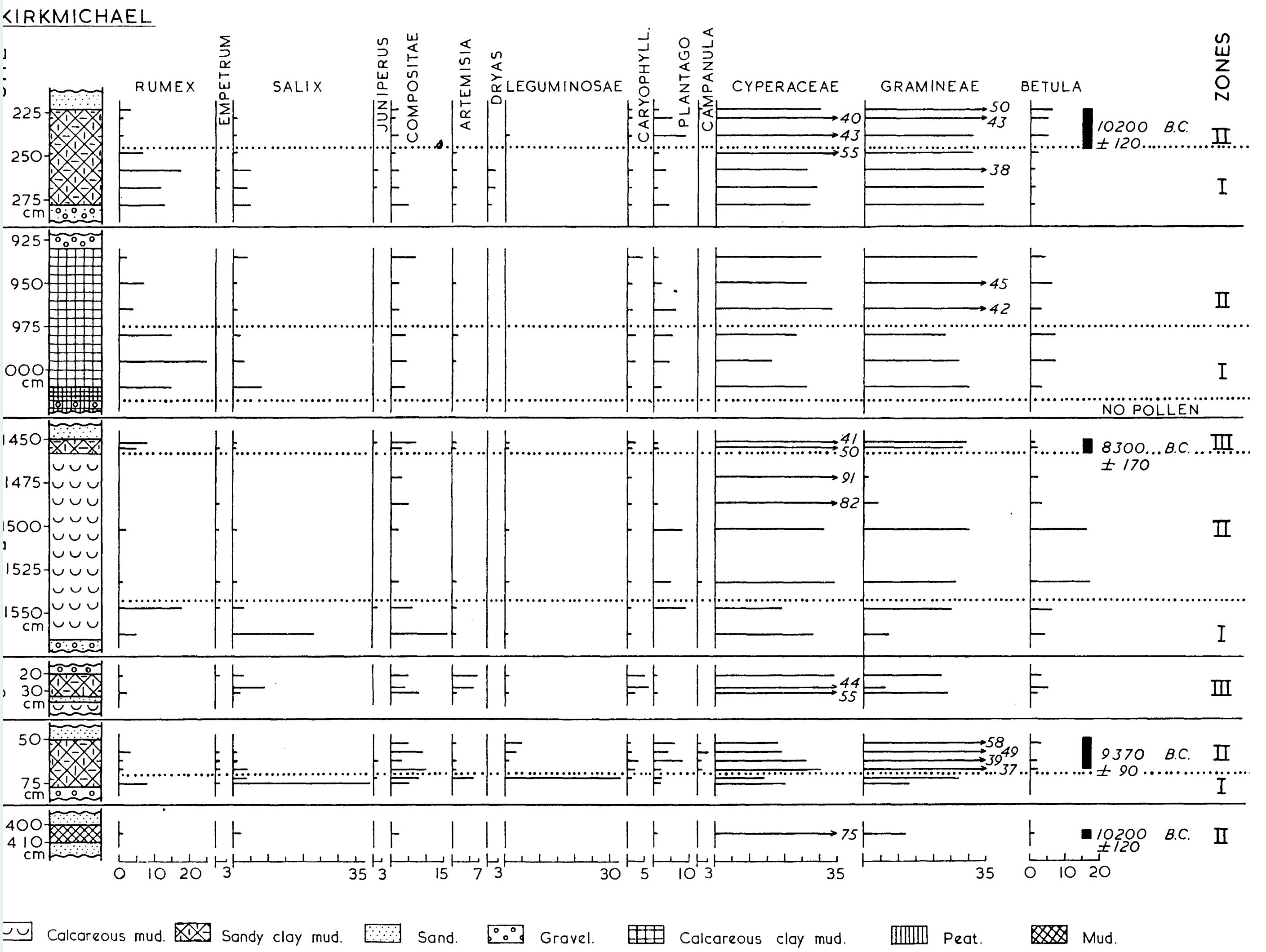


FIGURE 4. Pollen diagrams from Kirkmichael sites 1, 2, 3 and 5. The results are expressed as percentages of 300 non-aquatic pollen grains, see p. 37

Pollen-counts were also made, but the results are not as clear as might be wished for dating purposes, partly because the sampling-interval was often too great, and partly because several samples showed recognizable fragments of anthers, still crowded with pollen. Anther fragments of Caryophyllaceae, Cyperaceae, Gramineae and *Salix* were noted.

The pollen diagrams (figure 4 and 5) have been divided into zones, the boundaries of which are placed where pollen values change (presumably in response to vegetational changes) rather than where sediment types change (see Smith 1961; Watts 1963). It is not easy to discern a uniform pattern of regional change in the vegetation in the British Isles in the Late-Weichselian period, as the controlling factors do not seem to have been the number of plants already immigrated or the temperature, but local variations of soil, drainage and exposure. But Watts (1963) has laid a foundation in this respect, and an attempt has been made to use the criteria he established.

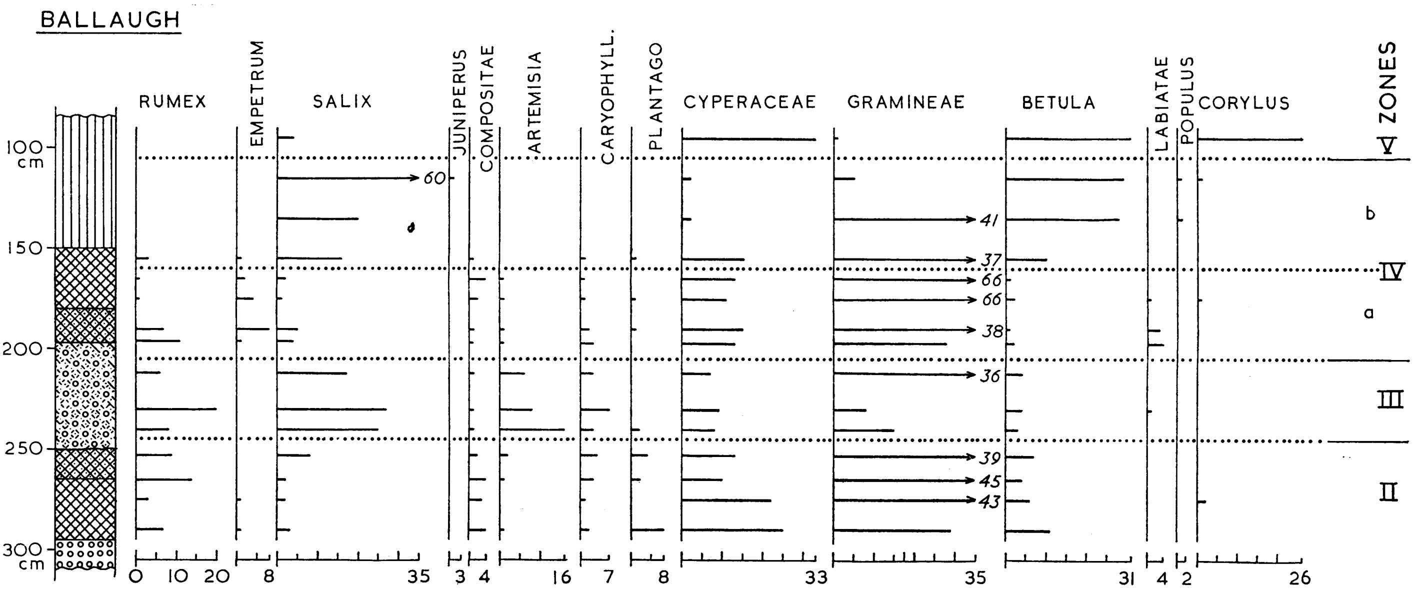


FIGURE 5. Pollen diagram from Ballaugh. Redrawn from Mitchell (1958). Results expressed as figure 4.

The end of the Middle-Weichselian and the opening of Zone I of the Late-Weichselian period is arbitrarily placed at the point where the pollen content of the sample has increased to such a degree that 300 grains (excluding pollen of water plants) can be counted without the expenditure of too exorbitant an amount of time. In Zone I *Artemisia*, *Empetrum*, *Rumex* and *Salix* produced substantial amounts of pollen, though they flourished differently at different sites. At a certain level their pollen is to a large extent replaced by that of Gramineae and *Betula*, and here the end of Zone I and the opening of Zone II, the Allerød stage, is drawn. In certain localities (see Birks 1965, fig. 7), if the samples have been taken sufficiently closely together, the boundary may be emphasized by a fleeting increase in the amount of *Juniperus* pollen; this feature is not seen in the diagrams in this paper. The amount of *Betula* pollen in Zone II varies greatly from site to site, presumably reflecting variation in shelter or some such factor. Where *Betula* values are relatively low, *Plantago* values may be relatively high. As Zone II progresses, pollen of other herbaceous plants tends to increase.

The end of Zone II and the opening of Zone III is drawn where grass pollen is reduced in quantity, and *Artemisia*, *Rumex* and *Salix* increase again, with Cyperaceae also making an important contribution to the pollen rain. Zone III ends with the reversal of this development; Gramineae (and *Empetrum*) increase, while *Artemisia* contracts sharply. The opening of Zone IV shows rapid and striking changes in pollen frequencies (see Watts 1963; Birks 1965); grass pollen gives way to juniper pollen, and this in turn gives way to massive quantities of birch pollen. The peak in *Juniperus* can perhaps be used to separate an early IV*a* with high quantities of Gramineae from a later IV*b* with high quantities of *Betula*. This distinction between IV*a* and IV*b* is made in the Ballaugh diagram (figure 5), though here *Juniperus* was not recorded in quantity.

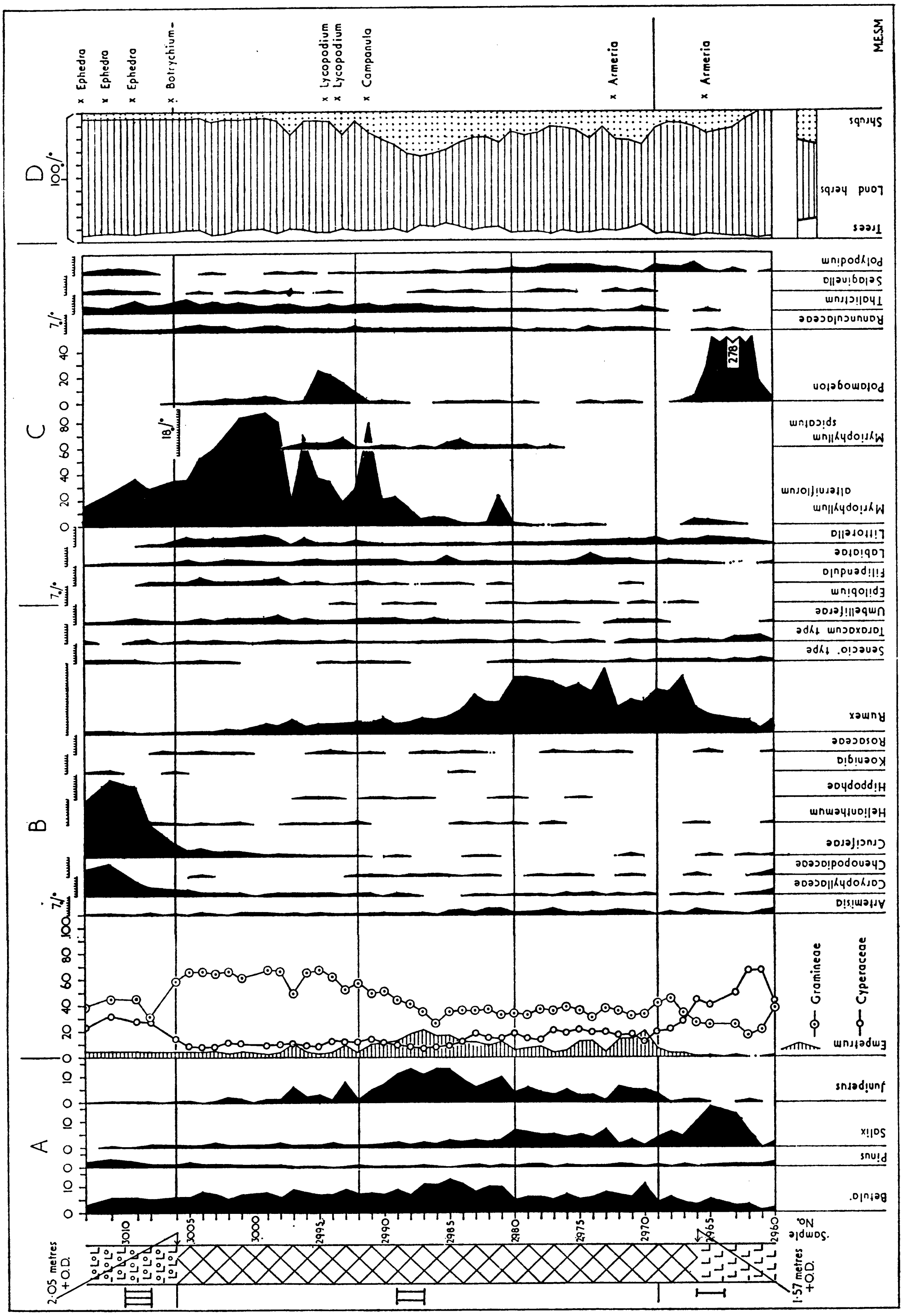


FIGURE 6. Pollen diagram from the lower part of the monolith from point 3, Roddans Port (Morrison & Stephens 1965). The sampling interval was 1 cm. The results are expressed as percentages of the total pollen, excluding pollen of aquatics and spores of pteridophytes.

In this paper the diagram from Kirkmichael Site 2 (figure 4) shows the end of the Middle-Weichselian, Zone I and the lower part of Zone II. The diagram from Ballaugh Site 2 (figure 5) shows the upper part of Zone II, Zone III, Zone IV (subdivided into IV *a* and IV *b*) and the opening of Zone V.

The pollen diagrams show the stratigraphy in a left-hand column. They then show percentage values (based on counts of 300 non-aquatic pollen) of a limited number of pollen types, chosen for their significance or interest. Other pollen types (except *Pinus*) are shown in the general fossil lists. All the values are presented on the same horizontal scale and are indicated by a line of appropriate length; where a value exceeds 35% the line is truncated and the percentage value inserted in figures. Because only certain types are shown the segments of the horizontal line do not total 100%.

In the diagrams from Kirkmichael, which show Zones I to III only, pollen types of interest in Zone I (*Rumex*, *Empetrum*, *Salix*, *Juniperus*, Compositae, *Artemisia*, *Dryas* and Leguminosae) are on the left of the diagram; pollen types of interest in Zone II (*Betula*, Gramineae) are on the right. Cyperaceae (common at all levels), *Campanula* and *Plantago* (largely restricted to Zone II) and Caryophyllaceae (more common in Zones II and III) are shown centrally. Radiocarbon datings and the zonation are shown in right-hand columns.

In the re-drawn diagram from Ballaugh, which shows Zones II to V, the same basic order is followed for ease of comparison. But curves for *Dryas* and Leguminosae (only common in Zone I) are omitted, and curves for Labiatae, *Populus* and *Corylus* (of importance in Zones IV and V) are inserted on the right.

In this paper zone boundaries are drawn where pollen values change. An interesting comparison can be made with the diagram from Point 3 at Roddans Port, Co. Down (Morrison & Stephens 1965), which lies to the west, across 60 km (37.5 miles) of sea, in Ireland. In the relevant diagram (reproduced here as figure 6) the 'zone boundaries have been drawn using stratigraphical evidence, though the Zone I/II boundary has been moved upwards slightly so that it coincides with the greatest indication of pollen changes in the region of the diagram' (their p. 232).

Figure 6 shows a clear stratigraphic change from clay to mud at Sample 2966, but the pollen change used by the authors to end Zone I does not come till some 3 cm higher, where *Betula*, *Empetrum* and *Juniperus* start to rise. But *Salix* and Cyperaceae had high values in the clay (possibly being over-represented if solifluction from a snow patch was carrying anthers as well as other debris into the basin), and the apparent rises in *Betula*, *Empetrum* and *Juniperus* may only reflect the decline in the other two. If the criteria used in this paper are applied to the Roddans Port paper, then Zone I must be extended upwards still another 11 cm to Sample 2980. Here *Rumex* and *Salix* abruptly begin to decline, while *Betula* and *Juniperus* increase. A little higher Gramineae begin their rise to typical Zone II values, and *Artemisia*, *Rumex* and *Salix* sink still farther.

Morrison & Stephens recognize that the continuance of high values for *Rumex* above their Zone I/II border 'suggests the continuance of conditions not very different from those of Zone I' (p. 235). If the criteria of this paper are accepted, then the Roddans Port radiocarbon datings of Sample R 2980 and 2981 would suggest a date around 10150 B.C. for the Zone I/II border there. At Kirkmichael material of early Zone II date had a radiocarbon date of about 10200 B.C.

At the top of the Roddans Port diagram the deposit regains a content of clay, sand and gravel at Sample 3006 indicating renewed solifluction due to a return of cold. A typical Zone III pollen picture does not develop, though the break up of the vegetation cover is indicated by an increase in Caryophyllaceae and Cruciferae, and a reduction in Gramineae. Above the solifluction layer the Roddans Port picture is continued in their figure 6. Here the authors introduce a 'Zone III–IV transitional period' (p. 236) 'between the end of solifluction at Sample 2944 and the expansion of *Betula* woodland at Sample 2951'; at this time a sand-free mud was being deposited. If the principles used in this paper are applied, the end of Zone III must be placed between Samples 2953 and 2950, near the top of the mud. Here a marked rise in Gramineae accompanied by a fall in *Rumex* marks the transition from Zone III to Zone IV *a*. A little higher, in Sample 2954, a massive rise in *Betula* and *Salix*, accompanied by a slighter showing of *Juniperus* marks the transition to Zone IV *b*. This part of the Roddans Port diagram very closely resembles that from Ballaugh. On this basis radiocarbon would give at Roddans Port a date of *ca.* 8150 B.C. for the Zone III/IV border, and *ca.* 8200 B.C. for the IV *a*/IV *b* boundary. At Kirkmichael Zone III was given an age of 8300 B.C.

Another diagram the zonation of which might be altered considerably if sediment changes are ignored is that from Tadcaster, Yorkshire (Bartley 1962, fig. 3). Here there is no sign of Zone I vegetation in the lower part of the diagram where *Betula* and Gramineae are already important, and the fluctuation of *Betula*, Gramineae and *Juniperus* to which the author draws attention might represent local oscillations between birchwood and grassland in Zone II, rather than climatic oscillations in Zone I. On the other hand, Zone III is most clearly seen, as clay is present in the sediment and the pollen picture is typical—low values for *Betula* and Gramineae, high values for Cyperaceae, and increases in *Artemisia* and *Rumex*.

3. The sites

3.1. *Kirkmichael*

(*a*) *On the Orrisdale Morainic Ridge.*

Site 1: 110 m north of the mouth of Glen Ballyre. See figure 3 (*b*), plate 7.

In 1965 Mrs E. M. Megaw discovered a Late-glacial deposit exposed in the cliff face about 110 m north of the mouth of Glen Ballyre; the deposit was in a former hollow on the Orrisdale Ridge. The basin (figure 7), which was about 30 m across, was in the top of the Orrisdale morainic ridge. The basin was lined with a sandy clay, thickest at the centre (*ca.* 0.15 m), and thinning towards the edges. Above this was a layer of detritus mud about 12 m in width, and *ca.* 0.5 m thick in the centre of the basin. At the base the mud was sandy and contained leaves of *Dryas octopetala*; at the top it was laminated and sand-free. On the south the mud was divided into separate lumps, perhaps due to shrinkage consequent on pressure and drainage. A sample of the laminated mud had a ^{14}C age of *ca.* 10200 ± 120 B.C. (GRO 1616). The mud was buried by *ca.* 1 m of stratified sand with seams of fine gravel and of clay. In places the upper part of the sand appeared to be feebly cryoturbated. This sand was probably Zone III in age, deposited by solifluction; on the north side the underlying mud showed signs of having been rucked up into the base of the sand. There was then a layer of sand rich in brown organic material, and then 1.15 m of sand, interrupted at a depth of *ca.* 0.8 m by what might have been an old soil line. This upper sand may have been moved by agricultural activities in sub-recent times. The former basin could still be traced as a hollow in the ground surface, and within its perimeter there was a rich growth of *Equisetum*. Samples were taken for examination for macro- and micro-fossils, and the profile where the samples were taken was as follows:

Profile 1

metres		
0–0.80	brown sand with scattered stones	Flandrian deposits?
at 0.80	darker band, suggesting an old soil-line	
0.80–1.15	brown sand with occasional stones up to 15 cm long	Late-Weichselian deposits
1.15–1.20	dark brown sand, rich in organic material	
1.20–1.40	stratified sand with small stones with their long axes lying horizontally	
1.40–1.43	layer of small rounded pebbles	
1.43–1.93	stratified sand with occasional layers of tiny pebbles and some layers rich in clay	
1.93–1.96	layer of small rounded pebbles	
1.96–2.23	sand with scattered small stones, not so regularly arranged	
2.23–2.33	firm dark brown laminated sand-free detritus mud, with mosses, beetle debris and seeds	
2.33–2.46	as before, with numerous horizontal stems and seeds; ^{14}C age 10200 ± 120 B.C. (GRO 1616)	
2.46–2.64	as before, but with scattered coarse sand grains; sand becoming more prominent below, and some fine gravel present; stems and seeds	
2.64–2.77	as before, but very sandy and with small stones; leaves of *Dryas octopetala*, seeds	
2.77–2.90	fine gravel, with content of sand and clay	
2.90–2.97	blue-grey sandy clay with small stones; rich in precipitated iron at base	
at 2.97	glacial sands and gravels	Weichselian deposits

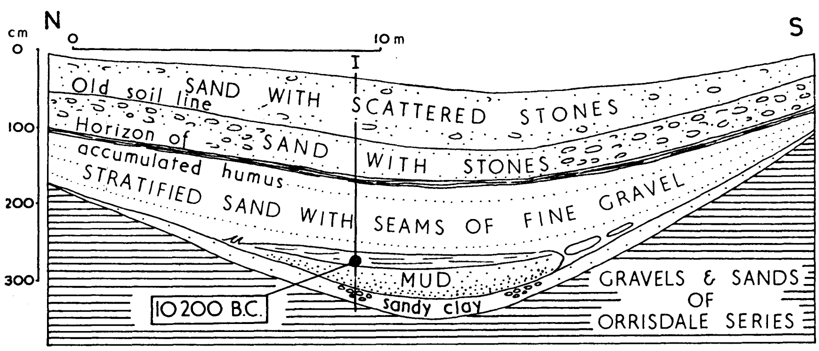


Figure 7. Sketch-section of Site 1.

Pollen samples were counted at 0.1 m intervals between 2.23 and 2.80 m, and the counts are shown diagrammatically in figure 4. Below 2.50 m *Dryas*, *Rumex* and *Salix* are prominent, and this part of the diagram is assigned to Zone I. Many leaves of *Dryas* were noted in the mud at this level. Above 2.50 m *Dryas* disappears, *Rumex* and *Salix* are reduced, and *Betula*, Gramineae and *Plantago* (*maritima/media* type) increase. But *Betula* values remain extremely low, and there cannot have been substantial stands of *Betula* in the vicinity. Zone II is probably not shown in full, having been truncated by the overlying sand.

The mud of Zone I age below 2.50 m had a considerable content of sand, but the Zone II was sand-free. This may indicate that in Zone II the local plant cover was relatively complete.

(*b*) *Below the Kirkmichael alluvial fan*

Site 2: 300 *m south of Glen Ballyre*

Here the cliff was about 26 m high, and a layer of calcareous clay-mud, about 1 m thick and 65 m long, was seen about 10 m below the top of the cliff. The clay-mud rested on glacial deposits of the Orrisdale series. The measured profile was as follows.

Profile 2

metres		
0–1.20	silty sand with lenses of gravel	upper alluvial gravels
1.20–4.90	bedded slaty gravel with seams of sand	
4.90–5.30	clayey sand	
5.30–7.60	bedded slaty gravel	
7.60–8.20	clayey sand with gravel	lower alluvial gravels
8.20–8.80	fine gravel	
8.80–8.90	silt with mud and clay	
8.90–9.30	fine gravel	
9.30–9.45	dark grey calcareous clay-mud with *Chara* (this bed was disturbed and tongues of clay-mud protruded up into the overlying gravel)	Late-Weichselian deposits
9.45–10.10	grey calcareous clay-mud with *Chara*, streaked with lighter coloured horizontal bands	
10.10–10.15	very dark grey calcareous clay-mud with moss and ostracods	
10.15–10.30	dark grey clay-mud with scattered pebbles	
10.30–10.50	grey clay with bands of sand and clay-mud	
10.50–11.70	bedded slaty gravel	Weichselian deposits
at 11.70	glacial sand and gravel	

The disturbance between the gravel and the clay-mud at 9.30 m could be a simple displacement due to the pressure of the thick overlying gravels on the consolidated muds, or due to a reduction in volume in the muds caused by dehydration when the water-table in the deposits fell either when the permafrost melted or as the marine cliff advanced inland.

Pollen samples were counted at 0.15 m intervals between 9.30 m and 10.50 m, and the counts are shown diagrammatically in figure 4, 2. Below 10.20 m pollen was not present in countable quantity, and only occasional grains of *Betula*, *Pinus*, *Salix herbacea*, *Artemisia*, *Calluna*, Cyperaceae, Gramineae, *Rumex* and *Lycopodium* cf. *selago* were noted. The basal clay-mud with pebbles (10.20 to 10.30 m) and the underlying deposits are regarded as pre-Zone I in age. Between 9.75 m and 10.20 m *Rumex* and *Salix* are prominent and a fairly wide range of herbs are represented by small numbers of pollen; this part of the diagram is assigned to Zone I. Above 9.75 m *Rumex* falls markedly and Gramineae rise, and here Zone II begins, though again *Betula* remains at a very low level. Zone II is probably not shown in full, having been truncated by the upper sands.

The mud deposit here has throughout its depth a considerable content of clay. This suggests that even in Zone II the plant cover was not continuous, and bare clay could be readily washed down.

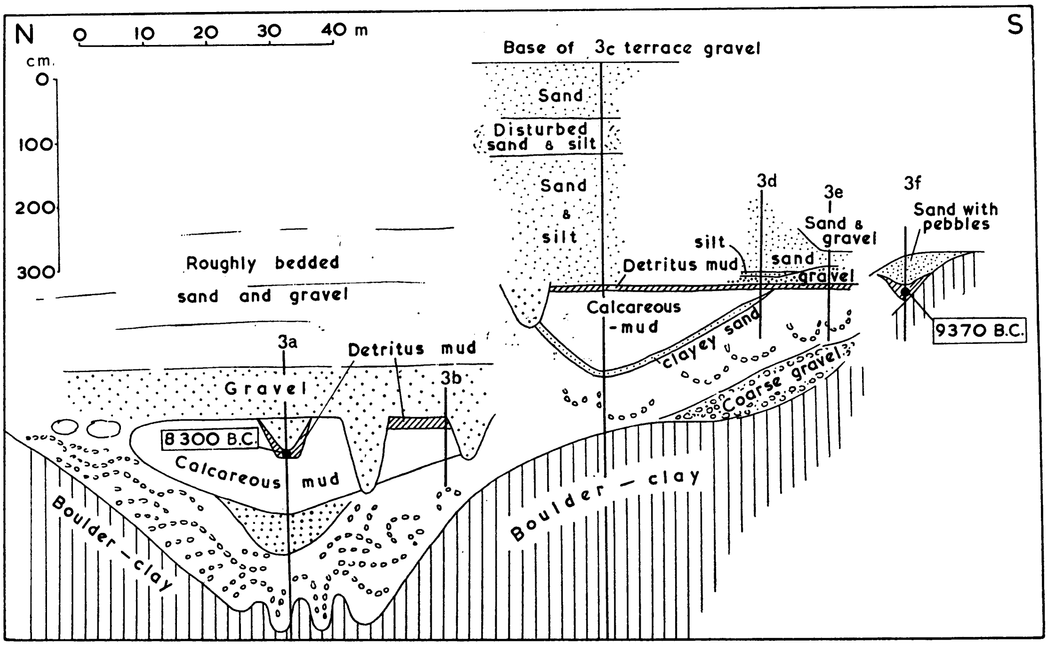


FIGURE 8. Sketch-section of Site 3.

Site 3: 150 m north of Glen Wyllin.

Some 150 m north of the north wall of the mouth of Glen Wyllin a ruined groyne or breakwater runs seaward. Extensive deposits of calcareous mud and detritus mud are intermittently exposed in the cliff from about 100 m north of the groyne to about 50 m south of it. These deposits are below many metres of alluvial gravels, and rest on glacial deposits. A composite sketch section of the deposits is given in figure 8, where they are united into Site 3. There are two main exposures of calcareous mud at slightly different levels, separated by a stretch of gravel. Two Late-Weichselian ponds may be represented, or there may have been one large pond with a floor which either varied considerably in level or was later displaced.

The more northerly exposure was at a relatively lower level. At its northern limit the calcareous mud was broken up into discrete masses, probably due to pressure or to dehydration. To the south it was cut out by a gravel-filled channel. Another, more shallow channel was cut into the calcareous mud, and Profile 3*a* was measured here. A sandy detritus mud rich in moss remains lay in the shallow channel, and this was given a ^{14}C age of 8300 ± 170 B.C. (Q673), placing its age late in Zone III. The channel above the mud was filled with sand and fine gravel, and the whole deposit was deeply buried by bedded gravel and sand. As at Site 2, disturbance was evident in the calcareous mud at some places. Minor faults interrupted its bedding, and it was tilted into the cliff at a relatively steep angle. See figure 3(*c*), plate 1.

Profile 3a

metres		
0–0.60	disturbed soil	upper alluvial gravels
0.60–0.70	well-stratified gravel, most stones lying horizontally	
0.70–1.10	much altered sandy mud, almost free from stones	
1.10–1.30	well stratified gravel	
1.30–1.60	brown to grey-brown sandy clay with few stones	
1.60–2.60	well-stratified coarse gravel	
2.60–2.80	sand with some content of clay	
2.80–3.10	blue-grey sandy clay with scattered small stones	
3.10–3.40	stratified sand with some layers rich in clay	
3.40–3.65	blue-grey sandy clay	
3.65–5.75	well-stratified coarse gravel	
5.75–14.00	roughly bedded layers of sand and gravel	lower alluvial gravels
14.00–14.50	brown sand with small stones filling centre part of channel cut in calcareous mud	Late-Weichselian deposits
14.50–14.58	thin alternating seams of sandy clay, and sandy detritus mud, rich in moss remains. The organic material had a ^{14}C age of *ca.* 8300 ± 170 B.C. (Q673), i.e. late Zone III. This material floored the channel, and also covered, though more thinly, the sloping walls of the channel which was about 2 m wide	
14.58–15.65	sandy calcareous mud, yellow-white in colour with seams brown in colour through it; the material was faulted and tilted	
15.65–15.67	green sandy mud with less calcium carbonate	
15.67–16.90	rounded gravel, not obviously disturbed	glacial deposits
16.90–17.05	sand	
17.05–17.95	frost-heaved gravel, with many fragments of slate	
17.95–18.85	frost-heaved boulder clay of Orrisdale series, with gravel as above in hollows	
18.85–20.10	boulder clay of Orrisdale series	
20.10–36.00	sands, gravels and boulder clay of Orrisdale series	
36.00–41.00	Ballateare boulder clay	
at 41.00	modern beach	

Before the freshwater muds accumulated, a layer of slaty gravel was deposited (as at Site 2) on a layer of boulder clay. Cryoturbation followed, with the result that the surface of the boulder clay was drawn into peaks and hollows, the hollows becoming filled with slaty gravel. At Site 3 in general the deposits immediately below the calcareous mud showed disturbance by frost action, which presumably took place between the withdrawal of the final ice and the opening of Zone II at 10200 B.C.

Pollen samples were counted at 0.15 m intervals between 14.50 m and 15.70 m, and the counts are shown diagrammatically in figure 4, 3*a*. Below 15.40 m *Rumex* and *Salix* are prominent, and below this level the deposit must belong to Zone I. Above this level *Betula* and Gramineae rise, and all the upper part of the calcareous mud probably belongs to Zone II, even though the top sample, due to the presence of anther fragments of Cyperaceae, shows 90 % of this type of pollen. At this site *Betula* values rise to 15 % of all non-aquatic pollen, and there may have been some development of birch copses in the immediate vicinity of the site. Though the calcareous mud had some content of sand, its white colour showed that it was essentially clay-free, and the surrounding plant cover must have been virtually complete at the time of its deposition.

The overlying sandy detritus mud was in a channel cut into the calcareous mud and rested unconformably on it. In addition to high values for Cyperaceae (due to the presence of anther fragments) it also had some content of *Rumex* and low values for *Betula*. It must be later than Zone II, but the relatively low values for Gramineae suggest that it cannot be as young as the opening of Sub-zone IV*a*. Radiocarbon gave an age of 8300 ± 170 B.C. (Q673), and it may be placed in a late stage of Zone III.

A second profile, 3*b* was measured, about 25 m south of Profile 3*a*. The record began at the base of the lower alluvial gravel.

Profile 3*b*

metres		
	base of roughly bedded sand and gravel	lower alluvial gravels
0–0.12	clayey sand with scattered small pebbles	Late-Weichselian deposits
0.12–0.20	sandy gravel; this was the margin of a channel fill to the south; the channel truncated the chalk mud	
0.20–0.26	dark brown sandy detritus mud with vegetable debris	
0.26–0.30	muddy laminae rich in moss remains, separated by laminae rich in sand, leaf of *Salix herbacea*	
0.30–0.33	dark brown laminated detritus mud, rich in plant debris, also sand and tiny pebbles	
0.33–0.36	brown sand	
0.36–0.85	marbled brown and white sandy calcareous mud with scattered small stones	
0.85–1.10	sand with seams of calcareous mud, perhaps worked into it by frost action	
1.10–1.20	clay with stones	Weichselian deposits
1.20– +	contorted sand with included laminae of clay	

While at Profile 3*a* the detritus mud with vegetable debris was in a channel, cut in the calcareous mud, here the debris was lying on the calcareous mud and was at first sight conformable with it. But an intermittent sand rested on the calcareous mud, and the overlying laminated material, layers rich in sand alternating with layers rich in vegetable debris, suggested that the sand and vegetable debris had been washed down on to an exposed surface of calcareous mud. Thick deposits of sand and gravel then buried the Late-Weichselian muds.

Pollen samples were counted at 0.05 m intervals between 0.20 m and 0.33 m, and the counts are shown diagrammatically in figure 4. *Artemisia* and *Salix* are relatively common in the two top samples, and Cyperaceae are abundant in all three. The sandy detritus mud can be assigned to Zone III; a layer of sand separates it from the underlying calcareous mud which was presumably, as at Site 3*a*, deposited in Zone II. Pollen of *Salix herbacea* type was present in all three samples and leaves of this plant were washed from the mud. The top sample contained part of a caryophyllaceous anther.

Further profiles were measured in the southern exposure of calcareous mud, which was at a rather higher level.

Profile 3*c*. *The record began at the base of the upper alluvial gravel*

metres	base of upper alluvial gravel	upper alluvial gravels
0–1.00	brown sand	lower alluvial gravels
1.00–1.60	brown sand with bands of silt much disturbed by cryoturbation or by load-casting	
1.60–3.60	brown sand and silt	
3.60–3.63	brown sandy detritus mud	Late-Weichselian deposits
3.63–5.13	sandy calcareous mud, banded brown and white, with some contortion in the banding, becoming sandier below	
5.13–5.23	grey-green calcareous silt	
at 5.23	surface of disturbed gravel	Weichselian deposits

The disturbance noted between 1.00 m and 1.60 m might have been due to cryoturbation, but was more probably due to load-casting.

Profile 3*d* (1963)

metres		
0–0.33	brown sand	lower alluvial gravels
0.33–0.44	orange sand	
0.44–0.50	grey silt with small stones	
0.50–0.67	fine slaty gravel, with some rounded fragments	
0.67–0.70	sandy detritus mud	Late-Weichselian deposits
0.70–0.87	sandy calcareous mud, banded yellow-brown and grey in colour	
0.87–0.97	clayey sand becoming richer in clay below	
at 0.97	gravel	Weichselian deposits

At the southern end of this exposure of chalk mud, it was clear that here at least the sandy detritus mud was unconformable on the calcareous mud, because in 1963 the detritus mud was exposed for a distance of almost 20 m, resting on calcareous mud to the north, and on gravel to the south. Profile 3*d* was measured near to the edge of the mud. The profile began in the lower alluvial gravels.

In a southerly direction the calcareous mud thinned out against the rising surface of the glacial gravel. Profile 3*e*, again beginning in the lower alluvial gravels, was measured beyond the edge of the calcareous mud as shown in figure 8.

Profile 3*e* (1963)

0–0.50	sand and gravel	lower alluvial gravels
0.50–0.70	fine bedded sand	
0.70–1.00	well washed fine gravel	
1.00–1.15	laminated sandy detritus mud; this was irregular in thickness, and gave the impression of having been eroded away in part	Late-Weichselian deposits
1.15–1.45	well-washed fine gravel	Weichselian deposits
1.45–1.95	less well-washed gravel with some clay; some rough bedding apparently disturbed by frost action	
1.95–2.45	coarser gravel	
at 2.45	pink sandy boulder clay	

The band of sandy detritus mud that was seen here in 1963 may well have been lying on the inner side of a former channel approximately parallel to the modern shore.

In 1956 there was seen in this vicinity a section at right angles to the modern shore through a channel filled with detritus mud. The channel was cut, partly in boulder clay and partly in rough gravel. Here the profile, 3*f* (1956), began at the base of the lower alluvial gravels.

Profile 3*f* (1956)

metres	base of roughly bedded sand and gravel	lower alluvial gravels
0–0.50	brown sand with small pebbles filling channel about 4 m in width	Late-Weichselian deposits
0.50–0.66	coarse wet detritus mud, with beetle debris and scattered sand grains. ^{14}C age 9370 ± 90 B.C. (GRO 1639, 1645)	
0.66–0.74	fine detritus mud with layers of coarse sand	
0.74–0.77	sandy detritus mud with small stones	
at 0.77	coarse gravel abutting against boulder clay	Weichselian deposits

Pollen samples were counted at 0.05 m intervals between 0.50 m and 0.77 m, and the counts are shown diagrammatically in figure 4, 3*f*. The counts are of limited value because the mud contained anther fragments of Cyperaceae, Gramineae and *Salix*, but below 0.7 m *Artemisia*, *Rumex* and *Salix* are higher in value than they are above that level, and this part of the diagram is assigned to Zone I. Above 0.7 m there is more *Plantago* and a limited amount of *Betula*. A Zone II age for this level is confirmed by the radiocarbon date of 9370 ± 90 B.C. Mr H. J. B. Birks kindly examined the *Betula* pollen, and was of the opinion that some of it was of *B. nana* type. No macroscopic remains of *B. nana* were found at Kirkmichael.

The sequence of events at Site 3 may perhaps be summarized as follows. As the last glaciation drew to an end, morainic sands, gravels and boulder clays were deposited with an undulating irregular surface. Where slaty debris had been washed from the hills out on to the ice, this was deposited as a discontinuous upper sheet. After the ice was gone, severe frosts persisted and the slaty gravel and the underlying boulder clay were deeply cryoturbated at Profile 3*a*. The milder conditions of the Allerød period—Zone II—then developed, and surface-melting allowed an open-water pond or ponds to form in some of the hollows on the morainic surface. Mud rich in calcium carbonate was deposited, and as the mud had only a small content of sand, the surrounding slopes were probably largely covered by vegetation. The ponds then drained, possibly due to a lowering in the local water table as permafrost melting descended to lower and lower levels. If a dead-ice lump lay below the calcareous mud, when the ice melted the mud would have been lowered, and the faulting and tilting may have developed at this stage. Streams began to cut channels into and through the mud, and plant debris was washed down into the basin. At Profile 3*a* the plant debris lies in a channel in the calcareous mud (and has a ^{14}C age of 8300 ± 170 B.C.), but elsewhere the debris lies scattered on the mud. In the region of Profiles 3*d*, 3*e* and 3*f* the debris transgresses from the underlying gravel out on to the calcareous mud, and it would seem that it must be unconformable on the calcareous mud.

At the end of Late-Weichselian time any remaining permafrost melted and stream erosion became active. The river draining Glen Wyllin carried large quantities of sand and gravel down from the fluvio-glacial deposits in the upper reaches of the Glen and deposited them in the basin lying inland of the Orrisdale morainic ridge and its now vanished extension to the south. The river-transported debris would first fill the isolated basins with roughly sorted material—the lower alluvial gravels. As the basins filled and the rising surface of the deposit began to level out, braided streams would start to swing across the surface of the growing alluvial fan, depositing well-graded gravel in one place, and finer materials in temporarily abandoned channels in other places. Thus we have, as at Profile 3*a*, beds of well-stratified gravel alternating with beds of sand, sandy clay and sandy mud building up the upper alluvial gravels. No fossils could be identified in these finer layers. The alluvial gravels rest on Late-Weichselian deposits, and the alluvial fan is probably early Flandrian in age, and may have been built up in a relatively short space of time.

Site 4. On the north rim of Glen Wyllin.

In March 1950 the late Dr Daniel Wirtz forwarded a sample from a seam of fine detritus mud. It came from a level high in the cliff on the northern edge of Glen Wyllin. Its pollen content showed that the mud was probably of Late-Weichselian age. The site was visited with Mr A. M. Cubbon of the Manx Museum in 1954; by then the seam of mud had slumped laterally towards the glen, but it was quite possible to determine its original position and collect samples. The section would then have been as shown in Profile 4.

A pollen count from the base of the detritus mud was dominated by Gramineae, with smaller amounts of Cyperaceae, *Betula*, Compositae and *Plantago*. It can be assigned to Zone II.

Profile 4

metres		
0–3.05	horizontally bedded slaty gravel with seams of sand and silt	upper alluvial gravels
3.05–4.90	roughly stratified sand and gravel	lower alluvial gravels
4.90–4.93	brown fine-grained detritus mud	Late-Weichselian deposits
4.93–5.10	sandy mud	
5.10–6.00	sandy gravel, becoming coarser below	Weichselian deposits
at 6.00	sands, gravels and boulder clay	

Site 5. About 200 m south of Glen Wyllin.

About 200 m south of the sloping south rim of Glen Wyllin the following section was measured at the top of the cliff.

Profile 5

metres		
0–2.90	well-stratified gravel with seams of silt	upper alluvial gravels
2.90–4.00	less well-stratified gravel, sand and silt	lower alluvial gravels
4.00–4.03	blue-grey fine silt	Late-Weichselian deposits
4.03–4.08	brown fine-grained detritus mud almost free from sand. ^{14}C age 10200 ± 120 B.C. (GRO 1631)	
4.08–4.09	thin laminae of mud and silt	
4.09–5.70	roughly stratified sand and gravel	Weichselian deposits
at 5.70	red boulder clay	

The pollen count from the mud (see figure 4) was dominated by Cyperaceae, with some Gramineae and traces of *Rumex* and *Salix*. This spectrum is in accordance with the ^{14}C dating of the detritus mud to 10200 ± 120 B.C. (GRO 1631).

Site 6. Near Kirkmichael Railway Station.

This site (as recorded by Lamplugh, p. 374) is 50 m south-east of Kirkmichael Railway Station at about 120 ft. (37 m) O.D. The section was

metres		
0–4.50	slaty gravel	alluvial gravels
	seam of peaty material containing *i.a. Salix herbacea* and *Lepidurus arcticus*	Late-Weichselian deposits
below peaty material	slaty gravel	Weichselian deposits

It seems almost certain that the organic materials at this site of Lamplugh's must correspond in position and age with the detritus muds at Sites 4 and 5.

3.2. *Ballaugh*

In the Ballaugh area there is an extensive fan of slaty gravel, which was probably deposited when a re-advance of the Irish Sea ice was thrusting up the material that now forms the Bride Moraine at the north end of the island and building up the morainic ridge at Kirkmichael. In a limited area north-east of Ballaugh the surface of the fan is pitted by kettle-holes containing Late-Weichselian deposits. The dead-ice masses, the melting of which gave rise to the hollows, may have been either in the older moraine that underlies the gravel or carried along by the same torrents of water that built up the fan. It is not easy to suggest why the hollows are restricted to one area. Their position, on the lower slopes of an alluvial fan, is one where open-system pingoes might have developed, given suitable permafrost conditions, but there are no raised rims round the hollows, such as might be expected if they represented the degraded remains of pingoes.

Site 1 near Ballaugh in figure 1 is the kettle-hole that contained remains of *Cervus giganteus* as described by Lamplugh (1903, p. 377); site 2 has been described by Erdtman (1925) and Mitchell (1958). It will only be briefly referred to here to introduce further fossil identifications. See figure 3(*a*), plate 1, facing p. 60.

Site 2.

Here the remarkably level surface of the gravel-fan, at an altitude of about 20 m, is pitted by a kettle-hole about 50 m in diameter. The measured boring, where samples were taken, was as follows:

metres		
0–1.00	brown amorphous peat	Flandrian deposits
1.00–1.50	wet brown peat with wood and leaf debris	
1.50–1.80	brown mud, becoming grey-brown in colour below	
1.80–1.97	grey-green sandy mud with tiny pebbles; leaf of *Salix herbacea* and fruit-stone of *Empetrum*	
1.97–2.30	alternating layers of sandy clay-mud, coarse sand and small pebbles (disturbed by drill)	Late-Weichselian deposits
2.30–2.65	as before, but with greater content of mud	
2.65–2.95	brown mud with some sand, becoming grey-white in colour below	
below 2.95	stones	Weichselian deposits

Pollen samples were counted at 15 cm intervals between 0.95 m and 3.00 m, and the counts are shown diagrammatically in figure 5. At the base of the diagram *Betula* is present in some quantity and Gramineae are rising strongly while *Artemisia*, *Rumex*, and *Salix* show low values; here we are clearly in Zone II. This suggests that the melting of the dead-ice mass that created the hollow and permitted the accumulation of sediment did not take place until after the beginning of Zone II. Above 2.65 m Gramineae fall back in quantity and *Artemisia* reappears; these changes suggest a break-up of the plant cover as deteriorating climate began to make its influence felt. Zone III opens at 2.45 m, where *Artemisia*, *Rumex* and *Salix* rise sharply, and Gramineae and *Betula* are reduced. Zone III ends at 2.05 m, where *Artemisia* and *Salix* are cut back, and Gramineae begin their expansion to their IV*a* maximum; *Empetrum* expands at the same time. Gramineae then give way in IV*b* to *Betula* and *Salix*, the pollen of which presumably derives from bushes and trees, whereas much of the earlier *Salix* pollen came from *S. herbacea*. Zone IV comes to an end at 1.05 m, because above this level the appearance of *Corylus* pollen marks the opening of Zone V.

4. The flora

4.1. *General*

The Manx flora within the period *ca.* 10200 to 8300 years B.C. included at least 114 taxa of flowering plants, one gymnosperm, nine pteridophytes and 35 mosses (table 1). These figures, limited by the accidents of fossilization and extraction and by the scope of the investigation, must represent a fraction, probably a small fraction, of the total flora, which in reality may have included several hundred species. It seems likely that the Late-Weichselian vascular flora consisted of at least as many species as does the present counterpart of about 700 species (Allen 1957, 1962, 1965).

The assemblages of the Ballaugh–Kirkmichael area constitute one of the richest Late-Weichselian floras yet studied in the British Isles; of published sites only the deposits of Nazeing in the Lea Valley (Allison, Godwin & Warren 1952), which similarly include the glacial-post-glacial contact, but possibly not Zones I and II, have yielded an equally diverse flora.

Eight taxa of angiosperms are new to the British Quaternary: *Arenaria serpyllifolia* ssp. *macrocarpa*, *Dianthus deltoides*, *Epilobium alsinifolium*, *Juncus balticus*, *Lychnis viscaria*, *Poa* cf. *pratensis*, and *Poa* cf. *trivialis*. In addition to several species seldom recovered from Late-Weichselian deposits, a further 18 species are unknown in other British Late-Weichselian assemblages.

Achillea cf. *millefolium*	*J. squarrosus*
Callitriche obtusangula	*Lychnis alpina*
Cardamine pratensis	*Potentilla crantzii* or *P. tabernaemontani*
Carex cf. *curta*	*Ranunculus hyperboreus*
C. cf. *diandra*	*Sagina* cf. *maritima* or *procumbens*
Eriophorum vaginatum	*Sibbaldia procumbens*
Festuca ovina or *F. rubra*	*Scleranthus* cf. *annuus*
Hypericum elodes	*Triglochin maritima*
Juncus bufonius	*Viola reichenbachiana* or *V. riviniana*
J. conglomeratus or *J. effusus*	

The above lists alone, representing an addition of 25 species and one subspecies to the Late-Weichselian flowering plant flora, exhibit the diversity, both phytogeographical and ecological, now well-established as characteristic of the British last glacial flora. A detailed list of taxa is given in table 1.

The bryophyte list is the largest of properly authenticated Late-Weichselian age ever recorded in the British Isles. Many noteworthy species are represented; perhaps most striking is the presence of nine rich-fen species, highly characteristic of Late-Weichselian and early Post-glacial deposits, here represented to a number unparalleled from British deposits; they are as follows.

Acrocladium giganteum	*Drepanocladus revolvens*
A. trifarium	*Helodium blandowii*
Camptothecium nitens	*Meesia tristicha*
Campylium stellatum	*Scorpidium scorpioides*
Cinclidium stygium	

TABLE 1

+ = presence (of pollen or spores), a = achene, bs = bud scale, cl = calyx, cp = capsule, cr = caryopsis, fr = fruit, ft = fruitstone, l = leaf, mc = male cone scale, msp = microspores, mgsp = megaspores, n = nutlet, os = oospore, p = pollen, s = seed, si = spindle, sp = spore, st = leafy stem, u = utricle, v = valve.

The depths (in cm) from which the macroscopic samples were taken are as follows:

Ballaugh. 150–180 Zone IV *b*; 180–197 Zone IV *a*; 197–212, 207–237, 227–250 all Zone III; 230–265 transgresses Zones II and III hence Zone II–III for this sample; 255–275, 260–275, 260–295 all Zone II.

Ballyre. Megaw 12 Top, 233–246 both Zone II; Megaw 11 Base, Megaw 13 Blue Clay, 246–262 all Zone I.

Wyllin 2. 970–980 transgresses Zones I and II; 1010–1020 Zone I; 1020–1030 pre-Zone I.

Wyllin 3 *a*. 1450–1458 Zone III; 1550–1560, 1562–1570 Zone I.

Wyllin 3 *b*. 22-32 Zone III.

Wyllin 3 *f*. 50–76 transgresses Zones I and II.

Wyllin 4. 495–505 Zone II.

Wyllin 5. 400–410 Zone II.

								Kirkmichael													
										Wyllin											
sites ...		Ballaugh					Ballyre		2				3 *a*			3 *b*	3 *f*				
site number ...							1													4	5
zone ...		IV *b*	IV *a*	III	II-III	II	II	I	II	I-II	I	Pre-I	III	II	I	III	II	I-II	I	II	II
Angiosperms																					
Achillea cf. *millefolium* L.	a	.	.	.	.	.	.	.	.	.	.	.	8	.	.	.	.	.	.	.	.
Alchemilla type	p	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.
Arabis cf. *hirsuta* (L.) Scop. or *stricta* Huds.	s	.	.	.	.	.	.	.	.	.	.	.	.	.	4	.	.	.	.	.	.
Arenaria serpyllifolia ssp. *macrocarpa* (Lloyd) Perring & Sell	s	.	.	.	.	.	.	5	.	.	.	.	.	.	8	.	.	.	.	.	.
Armeria maritima (Mill.) Willd.	p	.	+	.	.	+	.	.	+	.	.	.	+	.	+	+	+	.	+	+	+
Armeria maritima (Mill.) Willd.	cl	.	.	.	.	.	.	1	1	.	.	.	2	.	2	.	.	.	.	.	.
Artemisia sp. or spp.	p	.	+	+	.	+	.	+	+	.	+	+	+	+	+	+	+	.	+	.	.
Betula sp. or spp.	p	+	+	+	.	+	+	+	+	.	+	+	+	+	+	+	+	.	.	.	+
B. nana L.	p	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	+	.	.	.	.
B. pubescens Ehrh.	fr	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Betula tree species	fr,mc	1	.	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Callitriche obtusangula Le Gall	fr	.	.	.	.	.	.	3	.	.	.	.	1	.	.	.	.	.	.	.	.
Caltha palustris L.	p	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.
Campanula sp.	p	.	.	.	.	.	+	.	.	.	.	.	.	+	.	.	+	.	.	.	.
C. cf. *rotundifolia* L.	s	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	1	.	.	.
Cardamine pratensis L.	s	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.
Carex sp. or spp.	n	1	1	4	2	6	54	1	.	6	.	.	84	.	12	94	.	63	.	.	31
C. sect. *Carex*	n,u	.	.	.	.	.	14	.	.	.	.	.	.	.	.	.	.	.	.	.	.
C. cf. *curta* Gooden.	n,u	.	.	.	.	.	17	.	.	.	.	.	.	.	.	.	.	.	.	.	.
C. cf. *diandra* Schrank	n,u	.	.	.	.	.	.	.	.	.	1	.	.	.	.	5	.	.	.	.	.

TABLE 1 (*cont.*)

							Kirkmichael														
									Wyllin												
sites ...		Ballaugh					Ballyre														
site number ...							1		2				3*a*			3*b*	3*f*			4	5
zone ...		IV*b*	IV*a*	III	II-III	II	II	I	II	I-II	I	Pre-I	III	II	I	III	II	I-II	I	II	II
Angiosperms																					
C. rostrata Stokes	n,u	.	.	.	.	.	110	44	.	.	.	.	8	.	.	6	.	.	.	.	.
Caryophyllaceae	p	+	+	+	.	+	+	+	+	.	+	.	+	+	+	+	+	.	+	.	.
Caryophyllaceae	cp	.	.	.	.	.	.	2	.	.	.	.	.	.	4	.	.	.	.	.	.
Cerastium type	p	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.
C. arvense L.	s	.	.	.	.	.	.	.	.	.	.	.	.	.	13	.	.	.	.	.	.
C. holosteoides Fr.	s	.	.	.	.	.	.	.	.	.	.	.	5	.	.	2	.	.	.	.	.
Chenopodiaceae	p	+	+	.	.	.	.	.	+	.	.	.	+	+	+	+	+	.	.	+	.
Chenopodium sect. *Pseudoblitum*	s	6	63	111	8	9	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Compositae	p	+	+	+	.	+	+	+	+	.	+	.	+	+	+	+	+	.	+	.	+
Crassulaceae	p	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.
Cruciferae	p	.	+	+	.	+	.	.	.	.	.	.	+	+	+	.	+	.	.	.	.
Cyperaceae	p	+	+	+	.	+	+	+	+	.	+	+	+	+	+	+	+	.	+	.	+
Dianthus deltoides L.	s	.	.	.	.	.	.	1	.	.	.	.	.	.	1	.	.	.	.	.	.
Draba sp. or spp.	s	.	.	.	.	.	.	1	.	1	1	.	1	.	22	.	.	.	.	.	.
D. incana L.	v	.	.	.	.	.	.	.	.	.	.	.	.	.	9	.	.	.	.	.	.
Dryas octopetala L.	p	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.
Dryas octopetala L.	l,fr	.	.	.	.	.	.	+	.	.	.	.	.	.	+	.	.	.	.	.	.
Eleocharis multicaulis (Sm.) Sm.	n	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
E. palustris (L.) Roem. & Schult.	n	7	1	2	2	6	.	47	.	1	.	.	.	.	.	.	.	.	.	.	.
Empetrum nigrum agg.	p	+	+	.	.	+	.	+	.	.	.	.	+	+	+	+	+	.	+	.	+
Empetrum nigrum agg.	ft	30	40	30	6	7	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.
Epilobium sp. or spp.	p	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.
E. alsinifolium Vill.	s	.	.	.	.	.	.	.	.	.	.	.	.	.	12	.	.	.	.	.	.
Ericaceae	p	.	.	.	.	.	+	+	+	.	+	+	.	.	.	+	+	.	.	.	.
Eriophorum vaginatum L.	si	.	.	.	.	.	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Festuca ovina L. or *F. rubra* L.	cr	1	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	.
Filipendula type	p	+	+	+	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Gentianaceae	p	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.
Glaux maritima L.	s	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.
Gramineae	p	+	+	+	.	+	+	+	+	.	+	+	+	+	+	+	+	.	+	.	+
Helianthemum sp	p	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	.	.	.	.
Hippophaë rhamnoides L.	p	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.

TABLE 1 (*cont.*)

sites …		Ballaugh					Kirkmichael: Ballyre		Kirkmichael: Wyllin												
site number …							1		2				3*a*			3*b*	3*f*			4	5
zone …		IV*b*	IV*a*	III	II-III	II	II	I	II	I-II	I	Pre-I	III	II	I	III	II	I-II	I	II	II
Angiosperms																					
Hippuris vulgaris L.	fr	1	.	.	.	.	.	.	.	40	2	.	3	.	2	2	.	.	.	.	.
Hypericum elodes L.	s	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Jasione montana L.	p	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	+	.	.	.	.
Juncus sp. or spp.	s	.	.	1	.	1	.	1	.	.	.	.	.	.	4	.	.	.	1	.	.
J. balticus Willd.	s	.	.	.	.	.	1	.	.	.	.	.	2	.	.	.	.	.	.	.	.
J. cf. *balticus* Willd.	s	.	.	1	.	1	.	1	.	.	.	.	4	.	.	.	.	.	.	.	.
J. bufonius L.	s	1	.	8	.	1	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.
J. bulbosus L.	s	.	.	2	5	6	1	8	.	.	.	.	.	.	.	.	.	.	.	.	.
J. bulbosus type	s	1	8	10	5	10	5	10	.	.	.	.	30	.	.	20	.	1	.	3	1
J. conglomeratus L. or *effusus* L.	s	.	.	.	1	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.
J. squarrosus L.	s	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.
Koenigia islandica L.	p	.	.	+	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.
Labiatae	p	.	+	.	.	.	+	.	.	.	.	.	.	+	.	.	+	.	.	.	.
Leguminosae	p	.	.	.	.	.	+	+	.	.	.	.	+	+	+	+	+	.	+	.	.
Leontodon cf. *hispidus* L.	fr	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.
Linum catharticum L.	s	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	.	.	.
Lychnis alpina L.	s	.	.	.	.	.	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.
L. flos-cuculi L.	s	.	.	.	.	.	.	.	.	.	.	.	53	.	.	3	.	.	.	.	.
L. viscaria L.	s	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.
Littorella uniflora (L.) Aschers	p	.	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Littorella uniflora (L.) Aschers	fr	.	.	.	2	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Luzula sp. or spp.	s	.	.	.	1	.	27	2	.	.	.	.	9	.	2	.	.	.	.	.	5
Lycopus europaeus L.	n	.	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Mentha aquatica L.	n	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Menyanthes trifoliata L.	p	.	1	+	.	.	.	.	+	.	.	.	+	.	.	.	.	.	.	.	.
Menyanthes trifoliata L.	s	.	.	.	1	.	.	.	.	.	.	.	36	.	.	35	.	.	.	.	.
Montia fontana L. ssp. *fontana* L.	s	.	1	.	.	.	.	.	.	.	.	.	13	.	.	.	.	.	.	.	.
Myriophyllum alterniflorum DC.	p	+	+	+	.	+	.	.	+	.	+	.	+	.	.	+	.	.	.	.	.
M. alterniflorum DC.	n	9	1	3	2	13	.	9	.	1	.	.	.	.	.	.	.	.	.	.	.
M. spicatum L.	p	.	.	.	.	+	.	.	+	.	+	.	.	.	+	.	.	.	.	.	.
M. spicatum L.	n	.	.	.	.	.	.	.	.	1	4	.	.	.	.	.	.	.	.	.	.
M. spicatum or *verticillatum*	n	.	.	.	5	2	.	1	.	.	1	.	.	.	.	.	.	.	.	.	.

TABLE 1 (*cont.*)

		Ballaugh					Kirkmichael															
									Wyllin											
sites ...							Ballyre													
site number ...							1		2				3*a*			3*b*	3*f*			4	5
zone ...		IV*b*	IV*a*	III	II–III	II	II	I	II	I–II	I	Pre-I	III	II	I	III	II	I–II	I	II	II
Angiosperms																					
M. verticillatum L.	p	.	.	.	.	.	.	.	.	.	.	.	+	.	+	.	.	.	.	.	.
Oxyria digyna (L.) Hill or *Rumex crispus* L.	p	.	.	+	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.
Parnassia palustris L.	s	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.
Pedicularis palustris L.	s	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.
Plantago sp. or spp.	p	+	+	+	.	+	+	+	+	.	+	.	+	+	.	+	+	.	+	.	+
Plantago sp. or spp.	cp	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.
P. major L.	p	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.
P. maritima L.	p	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.
Poa cf. *pratensis* L.	cr	.	.	.	.	.	.	.	.	.	.	.	.	.	13	.	.	.	.	.	.
P. cf. *trivialis* L.	cr	.	.	.	.	.	.	.	.	.	.	.	.	.	7	.	.	.	.	.	.
P. cf. *pratensis* or *trivialis*	cr	.	.	.	.	.	.	.	.	.	.	.	.	.	8	.	.	.	.	.	.
Polygonum sp.	n	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
P. bistorta L. or *viviparum* L.	p	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Potamogeton sp. or spp.	ft	1	5	.	1	2	.	.	.	2	.	.	2	.	2	.	.	.	.	.	.
P. acutifolius Link or *P. trichoides* Cham. & Schlect.	ft	3	5	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
P. alpinus Balb.	ft	.	.	.	.	.	.	19	.	.	.	.	.	.	.	.	.	.	.	.	.
P. berchtoldii Fieb.	ft	7	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.
P. crispus L.	ft	2	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
P. filiformis Pers.	ft	.	.	1	.	.	.	.	.	1	2	.	6	.	6	1	.	.	.	.	.
P. natans L.	ft	.	.	.	.	.	.	13	.	.	1	.	.	.	.	.	.	.	.	.	.
P. obtusifolius (Mert.) Kock	ft	.	.	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
P. pectinatus L.	ft	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.
P. praelongus Wulf.	ft	.	.	3	.	13	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Potentilla type	p	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.
Potentilla spp.	a	.	1	2	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
P. anserina L.	a	2	1	1	1	2	.	.	.	.	.	.	1	.	5	.	.	.	.	.	.
P. crantzii (Crantz) G. Beck ex Fritsch or *P. tabernaemontani* Aschers	.	.	.	.	.	.	.	2	.	.	.	.	.	.	6	3	.	.	.	.	.
P. palustris (L.) Scop.	p	.	.	+	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	+

TABLE 1 (*cont.*)

sites …		Ballaugh					Kirkmichael: Ballyre		Kirkmichael: Wyllin												
site number …							1		2				3*a*			3*b*	3*f*			4	5
zone …		IV*b*	IV*a*	III	II-III	II	II	I	II	I-II	I	Pre-I	III	II	I	III	II	I-II	I	II	II
Angiosperms																					
P. palustris (L.) Scop.	a	.	.	.	.	.	50	120	.	.	.	.	2	.	.	.	.	.	.	.	5
Ranunculus sp.	a	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
R. acris L.	a	.	.	1	.	.	.	.	.	.	.	.	6	.	.	.	.	.	.	.	.
R. subgenus *Batrachium* (DC) A. Gray	a	7	2	7	22	59	.	3	.	5	1	.	6	.	4	5	.	.	.	.	.
R. flammula L.	a	.	4	.	1	2	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.
R. hyperboreus Rottb.	a	.	.	1	2	.	.	.	.	.	.	.	27	.	.	13	.	.	.	.	.
R. repens L.	a	1	1	3	.	1	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.
R. sect. *Ranunculus*	a	.	1	.	.	.	.	.	.	.	.	.	6	.	1	.	.	.	.	.	.
Rorippa islandica (Oeder) Borbas	s	.	9	22	6	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Rubiaceae	p	.	.	.	.	.	+	+	+	.	+	.	+	+	+	.	+	.	.	+	+
Rumex acetosa L.	p	+	+	+	.	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.
R. acetosella L.	p	+	+	.	.	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.
R. acetosella L.	n	.	.	8	4	10	.	31	.	.	.	.	26	.	20	4	.	2	.	1	.
Sagina cf. *maritima* Don. or *procumbens* L.	s	4	6	165	1	10	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.
Salix sp. or spp.	p	+	+	+	.	+	+	+	+	.	+	.	+	+	+	+	+	.	+	.	+
Salix sp. or spp.	bs	8	1	24	15	11	2	4	.	.	1	.	5	.	.	10	.	1	.	1	4
S. herbacea L.	p	.	.	+	.	+	+	+	+	.	+	+	.	.	+	+	+	.	+	.	+
S. herbacea L.	l	.	.	1	2	1	.	.	.	1	.	.	1	.	.	10	.	.	.	.	.
Saxifraga cf. *hirculus* L.	p	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.
S. hirculus L.	s	.	.	1	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.
S. cf. *hypnoides* agg.	s	.	.	.	.	.	1	1	.	.	.	.	.	.	.	1	.	.	.	.	.
S. cf. *nivalis* L.	p	.	.	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.
S. cf. *oppositifolia* L.	p	.	.	+	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.
S. cf. *stellaris* L.	p	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.
Scirpus cf. *americanus* Pers.	n	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
S. lacustris L.	n	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Scleranthus cf. *annuus* L. s.l.	fr	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.
Sedum sp.	p	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	+	.	.
Sibbaldia procumbens L.	a	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Silene maritima With. or *vulgaris* (Moench.) Garcke	s	.	.	.	.	.	.	.	.	.	.	.	2	.	.	3	.	.	.	.	.

TABLE 1 (*cont.*)

sites ...		Ballaugh					Kirkmichael														
							Ballyre		Wyllin												
site number ...							1		2				3*a*			3*b*	3*f*			4	5
zone ...		IV*b*	IV*a*	III	II-III	II	II	I	II	I-II	I	Pre-I	III	II	I	III	II	I-II	I	II	II
Angiosperms																					
Sparganium sp. or spp.	p	+	+	.	.	+	.	+	+	.	.	.	.	+	+	+	.	.	+	.	.
S. angustifolium Michx.	ft	.	.	.	.	.	.	48	.	.	.	.	.	.	.	.	.	.	.	.	.
Stellaria cf. *crassifolia* Ehrh.	s	.	.	.	.	.	.	.	.	1	1	.	2	.	.	5	.	.	.	.	.
Succisa pratensis Moench	p	.	.	+	.	+	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.
Taraxacum sp. or spp.	fr	.	.	.	.	.	.	.	.	.	1	.	.	.	2	.	.	.	.	.	.
Thalictrum sp. or spp.	p	.	.	.	.	.	+	+	+	.	+	.	+	+	.	+	+	.	.	+	+
T. minus L.	a	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4
Triglochin maritima L.	fr	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.
Typha sp.	s	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.
Umbelliferae	p	+	+	+	.	.	+	.	+	.	.	.	.	.	.	.	+	.	+	.	.
Urtica sp.	p	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Valeriana officinalis L.	p	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	.	.
Viola sp. or spp.	s	.	1	.	.	.	.	.	.	.	.	.	4	.	.	.	.	4	.	.	.
V. cf. *canina* L.	s	.	.	.	.	.	1	.	.	.	.	.	16	.	.	7	.	2	.	.	1
V. palustris L.	s	.	.	.	1	.	41	.	.	.	.	.	33	.	.	2	.	12	.	.	.
V. reichenbachiana Bor. or *V. riviniana* Rchb.	s	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	5	.	.	.
Gymnosperm																					
Juniperus communis L.	p	.	.	.	.	.	.	+	.	.	.	.	+	.	+	.	+	.	+	.	.
Pteridophytes																					
Botrychium sp.	sp	.	+	+	.	+	.	+	.	.	.	.	+	+	+	+	+	.	+	.	.
Dryopteris sp.	sp	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Equisetum sp.	sp	.	.	+	.	.	.	+	.	.	.	.	.	.	.	+	+	.	.	.	.
Lycopodium sp.	sp	.	.	.	.	+	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.
L. annotinum L.	sp	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.
L. clavatum L.	sp	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.
L. selago L.	sp	.	.	.	.	.	.	.	+	.	.	+	.	.	.	.	.	.	.	.	.
Ophioglossum sp.	sp	.	.	.	.	+	.	.	.	.	.	.	+	.	.	.	+	.	.	.	.
Polypodium vulgare L.	sp	+	.	+	.	+	.	.	+	.	+	.	.	.	+	+	+	.	+	.	.
Selaginella selaginoides (L.) Link	msp	.	.	.	.	.	.	.	.	.	.	.	+	.	+	+	+	.	.	.	.
Selaginella selaginoides (L.) Link	mgsp	.	.	1	1	1	1	.	.	1	.	.	2	.	1	1	.	.	.	.	.

TABLE 1 (*cont.*)

							Kirkmichael													
									Wyllin											
sites ...		Ballaugh					Ballyre													
site number ...							1		2				3*a*			3*b*	3*f*			4	5
zone ...		IV*b*	IV*a*	III	II-III	II	II	I	II	II-I	I	Pre-I	III	II	I	III	II	I-II	I	II	II
Mosses																					
Acrocladium cordifolium (Hedw.) Rich. & Wall.	st	.	.	.	.	.	.	.	.	.	.	.	8	.	.	.	.	.	.	.	.
A. giganteum (Shimp.) Rich. & Wall.	st	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.
A. trifarium (Web. & Mohr.) Rich. & Wall.	st	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.
Antitrichia curtipendula (Hedw.) Bridel	st	.	.	.	.	.	4	.	.	.	.	.	1	.	12	.	.	.	.	.	.
Aulacomnium palustre (Hedw.) Schwaegr.	st	.	.	.	.	.	.	.	.	.	.	.	4	.	.	.	.	.	.	.	.
Bryum sp.	st	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	.	.	.
Camptothecium lutescens (Hedw.) B., S. & G. or *sericeum* (Hedw.) Kindb.	st	.	.	.	.	.	.	.	.	.	.	.	.	.	7	.	.	.	.	.	.
C. nitens (Hedw.) Schimp.	l	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.
Campylium stellatum (Hedw.) J. Lange & C. Jens.	st	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.
Ceratodon purpureus (Hedw.) Brid.	st	.	.	.	.	.	.	.	.	.	.	.	3	.	3	.	.	.	.	.	.
Cinclidium stygium Sw.	l	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.
Climacium dendroides (Hedw.) Web. & Mohr.	st	1	.	.	.	.	.	.	.	.	.	.	7	.	.	.	.	.	.	.	.
Cratoneuron commutatum (Hedw.) Roth.	st	.	.	.	.	.	.	.	.	.	.	.	8	.	.	.	.	.	.	.	.
C. filicinum (Hedw.) Spruce	st	.	.	.	.	.	.	.	.	.	.	.	5	.	.	.	.	.	.	.	.
Dicranum scoparium Hedw.	st, l	.	.	.	.	.	4	.	.	.	.	.	.	.	7	.	.	.	.	.	.
Ditrichum flexicaule (Schwaegr.) Hampe	st	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	.
Drepanocladus aduncus (Hedw.) Warnst.	st	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.
D. revolvens (Turn.) Warnst.	st	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.
Fontinalis antipyretica Hedw.	st	.	.	.	.	.	.	.	.	mass		.	.	.	.	.	.	.	.	.	.

Table 1 (cont.)

							Kirkmichael														
									Wyllin												
sites ...		Ballaugh					Ballyre														
site number ...							1		2				3a			3b	3f			4	5
zone ...		IVb	IVa	III	II-III	II	II	I	II	I-II	I	Pre-I	III	II	I	III	II	I-II	I	II	II
Mosses																					
Helodium blandowii (Web. & Mohr.) Warnst.	st	.	.	.	.	.	.	.	.	.	.	.	4	.	.	.	.	.	.	.	.
Hylocomium splendens (Hedw.) B., S. & G.	st	.	.	.	.	.	.	2	.	.	.	.	1	.	.	.	.	.	.	.	.
Hypnum cupressiforme Hedw.	st,l	.	.	.	.	.	.	1	.	.	.	.	.	.	3	.	.	.	.	.	.
Meesia tristicha B. & S.	st	.	.	.	.	.	.	.	.	.	.	.	7	.	.	.	.	.	.	.	.
Mnium rugicum Laur.	st	.	.	.	.	.	.	.	.	.	.	.	6	.	.	.	.	.	.	.	.
Philonotis sp.	st	.	.	.	.	.	.	.	.	.	.	.	4	.	.	.	.	.	.	.	.
Pohlia wahlenbergii (Web. & Mohr.) Andr.	st	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.
Polytrichum alpinum Hedw.	st,l	.	.	.	.	.	1	.	.	.	.	.	1	.	1	.	.	.	.	.	.
P. aurantiacum Sw.	st	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.
P. juniperinum Hedw.	l	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.
P. norvegicum Hedw.	st	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Rhacomitrium sp.	st	.	.	.	.	.	.	7	.	.	.	.	3	.	2	.	.	.	.	.	.
Rhytidiadelphus squarrosus (Hedw.) Warnst.	st	.	.	.	.	.	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.
Scorpidium scorpioides (Hedw.) Limpr.	st	.	.	.	.	.	.	.	.	.	.	.	3	.	2	.	.	.	.	.	.
Sphagnum sg *Litophloea*	l	.	.	.	.	.	.	.	.	.	.	.	7	.	.	.	.	.	.	.	.
Tortula ruralis (Hedw.) Crome	st	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	.	.	.	.
Capsule													1								
Algae																					
Chareae	os	+	+	+	+	+	+	+	.	+	+	.	+	.	+	+	.	.	.	.	.
Nitella	os	+	+	+	+	+	+	+	.	.	.	.	+	.	+	+	.	.	.	.	.

Particular interest attaches to *Acrocladium trifarium*, *Camptothecium nitens*, *Cinclidium stygium*, *Helodium blandowii* and *Meesia tristicha*, all of which have relict ranges in the British Isles.

There appear to be no other records of *Polytrichum aurantiacum* from the British Quaternary. This is also true of *Tortula ruralis*, though there are four records of the closely related *T. norvegica*.

4.2. *Notes on the identifications*

Descriptions are provided of the macroscopic subfossils of almost all the species seldom or never recorded before. Taxa which are described by Clapham, Tutin & Warburg (1962) or by Godwin (1956) or by references therein are not discussed here.

Achillea cf. ***millefolium***

Eight elliptical dark brown fruits measuring 1.5–1.85 × 0.6–0.75 mm are referred to *Achillea*. The narrow translucent wing of the pericarp has disappeared in every case. However, the long, narrow cells of the body were distinctive and common to both *A. millefolium* and *A. ptarmica* (figure 9 (*a*), plate 2). Fruit size separates the two species (Clapham *et al.* 1962); the subfossils compare best with the larger fruits (*ca.* 2.0 mm long) of *A. millefolium*.

Arabis cf. ***hirsuta*** or ***stricta***

Three well-preserved seeds and one badly preserved one are referred to *Arabis*. They measure 1.3–1.4 × 0.8–1.0 mm and have a translucent wing broadest at the apices (figure 9 (*b*), plate 2). The two British species which have seeds of a similar size, shape and cell pattern are *A. hirsuta* and *A. stricta*.

The identification is tentative because we have little familiarity with Northern European species within the *hirsuta* group, which have seeds similar in size and wing type.

Mitchell (1953) has recorded both species from Late-Weichselian deposits in Ireland.

Arenaria serpyllifolia ssp. ***macrocarpa***

Capsules (exceeding 3 × 2 mm) and seeds (exceeding 0.6 × 0.4 mm) of ssp. *macrocarpa* can be distinguished from ssp. *serpyllifolia* and *leptoclados* (Reichenb.) Nymen by size (Perring & Sell 1967).

The subfossils consist of 13 seeds, some well-preserved, and incomplete capsules, one containing three seeds. The capsules measure 3.5 × *ca.* 2.5 mm and the seeds are 0.65–0.8 mm in diameter.

Re-examination may show that previously discovered subfossils of this species, particularly those from maritime situations (e.g. Minnis Bay, Conolly 1941), are referable to ssp. *macrocarpa*, a little-known taxon scattered round the British coasts (Perring 1968).

Cardamine pratensis

Two flattened, black seeds rounded in shape and measuring 1.9 × 1.25 mm are referred to this species. In order to reveal the cell pattern of the seed figured (figure 9 (*c*), plate 2), bleaching with dilute sodium hypochlorite was carried out, a process which detached the fragile tip of the radicle. The hilar area remains very dark after bleaching. Overlying the pattern of clearly visible rounded cells (0.02–0.04 mm in diameter) is a layer of faintly seen, larger, thin-walled polygonal cells up to 0.06 mm in diameter.

After treatment with hot, dilute sodium hydroxide and removal of the embryos reference seeds of *Cardamine* exhibit similar cell layers. The layer of rounded cells seems the more resistant in both treated and the subfossil seeds. The subfossils agree in all respects with *C. pratensis*, a species most easily separated from the other British species by size. Reference seeds of *C. pratensis* measure 1.5–2.0 × 1.1–1.3 mm and those of the other species 0.9–1.6 × 0.7–1.0 mm. Moreover, the hilar area is more extensive in *C. pratensis* than in the others.

Seeds of *C. pratensis* were tentatively recorded by Duigan (1956).

Dianthus deltoides

Two black seeds are referred to *Dianthus* for the following reasons: (*a*) strongly compressed shape, (*b*) subacute apex and rounded base, (*c*) low radially elongated tubercules radiating from the central hilum, (*d*) strongly sinuous margins of the tuberculate cells.

They measure 1.5 × 0.8 and 1.7 × 1.0 mm; reference seeds of *D. deltoides* measure 1.1–1.7 × 0.75–1.05 mm.

The seed patterns are very similar throughout the genus. However, all but two of the British species have seeds exceeding 2 mm long. The exceptions are *D. armeria* L. and *D. deltoides*.

Cells on the hilum side of the testa measure 0.05–0.15 × 0.02–0.04 mm in *D. deltoides* and 0.06–0.08 × 0.06 mm in *D. armeria*. In the latter they manifest themselves as broader, shorter ridges than in *D. deltoides*. Where the cells are clearly seen in the subfossils they measure 0.06–0.125 × 0.025–0.06 mm and support fine clearly radiating tuberculate ridges, exactly similar to those of *D. deltoides*.

Epilobium alsinifolium

Twelve seeds, some with pappus remains (figure 9(*f*), plate 2), show the ventral groove characteristic of *Epilobium*. They range from 1.5 to 2.2 mm long and 0.55 to 0.9 mm broad.

With high-power microscopy the outermost layer was seen to consist of thin-walled polygonal cells with raised margins but lacking the tubercles shown by most species of the genus. Moreover, most species have seeds less than 1.0 mm long.

E. palustre has large enough seeds (1.8–2.2 mm long) but is tuberculate. Though the cell pattern matches that of the sub-fossils, the seeds of *E. anagallidifolium* are too small (1.0 × 0.45 mm). Only *E. alsinifolium* has seeds correct in both size (1.7 × 0.5 mm) and pattern.

Eriophorum vaginatum

Four sclerenchymatous spindles characteristic of this species were recovered from Zone II of Ballyre. Fine illustrations of these resistant structures are given by Puffe & Gross-Brauckmann (1963) and Benda & Schneekloth (1965).

Gramineae

Grass caryopses are often recovered from Quaternary deposits but seldom identified (e.g. Hubbard's determinations in Duigan 1956). The publication by Körber-Grohne (1964) of her monograph on subfossil Gramineae and *Juncus* has greatly facilitated the task. Her plates and key to subfossil and reference caryopses were used for the following determinations, which we were fortunate in having confirmed by Körber-Grohne herself.

All the subfossils fall in the size ranges given by Körber-Grohne, except one caryopsis referred to *Poa* cf. *pratensis* which is a little larger than the given measurement. We are unable to exclude the possibility that some of the subfossil *Poa* spp. may be referable to such species as *P. glauca* Vahl., *P. flexuosa* Sm. and *P. alpina* L., which are not considered by Körber-Grohne, but they are not *P. annua* L. or *P. palustris* L., both of which are described in the monograph.

Festuca cf. *ovina* or *rubra*. Four fruits (2.55–3.2 × 1.2 mm) are referable to *Festuca*. The oblong, diagonal mottled cells but not the transverse walls can be seen in figure 9(*d*) and (*e*), plate 2. The cells radiate from the end of the long narrow hilum, which is about 2 mm long.

Poa cf. *pratensis*. Thirteen fruits (1.9–2.4 × 0.8–1.5 mm) were identified by the conspicuous circular hilum and weak deposition in the indistinct pericarp cells, which are arranged in longitudinal rows (figure 9 (*g*), plate 2).

Poa cf. *trivialis*. Seven fruits (1.65–2.2 × 0.6–0.9 mm) can be distinguished from *P. pratensis* by the hilum, which is oval, and by the stronger, brown deposition in the cells of the pericarp (figure 9 (*h*), plate 2).

Hypericum elodes

One cylindrical, oblong seed (0.85 × 0.45 mm) is placed in *Hypericum elodes*. At each end there is a blunt mamilla. A layer of thick-walled, polygonal cells (0.55 mm wide) arranged in longitudinal rows makes up the outermost layer.

On removal of the testa from reference seeds an identical pattern is revealed. The size, cell pattern and wall thickness of the seed distinguish this species from all other British members of the genus. Watts (1959) has stressed the distinctiveness of the seeds of *H. elodes*.

Juncus

The monograph by Körber-Grohne (1964) deals more effectively with the identification of *Juncus* seeds than any previous work. Well-preserved seeds may be easy to identify but it must be pointed out that, as Körber-Grohne states, corrosion often destroys the cells of the testa and exposes the rectangular or weakly hexagonal cells of the endosperm.

J. bufonius and *J. conglomeratus* or *effusus*. The subfossils of these species match reference material and Körbner-Grohne's descriptions.

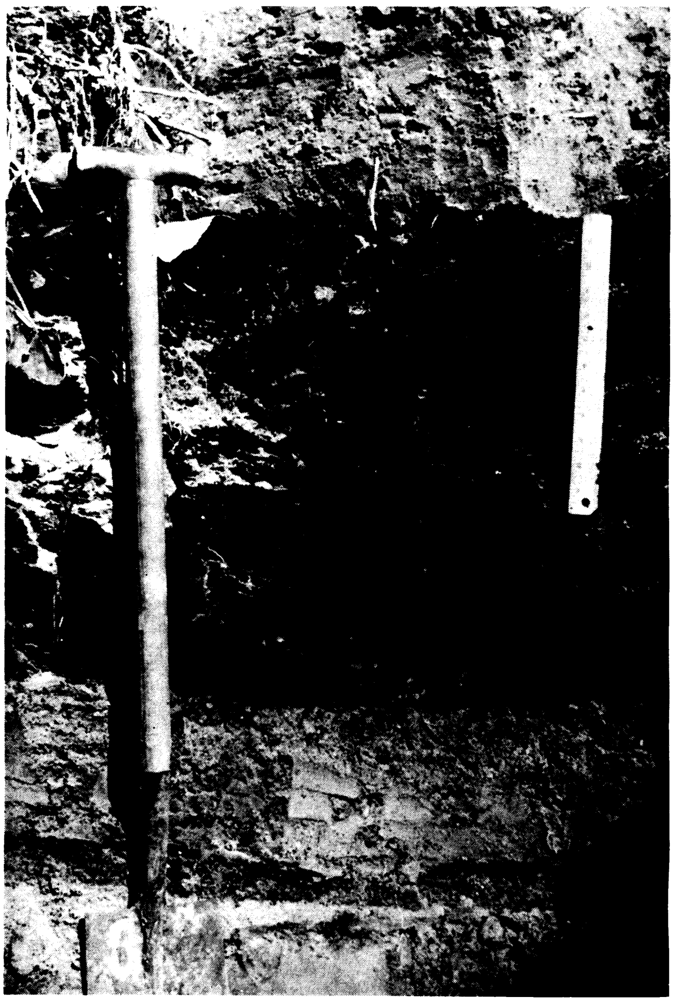
J. bulbosus. Small-seeded, British *Juncus* spp. which undergo corrosion are *J. acutiflorus* Hoffm., *J. articulatus* L., *J. bulbosus*, *J. mutabilis* Lam. and *J. subnodulosus* Schrank. They range from 340 to 620 μm long and 200 to 370 μm wide. Subfossil seeds within this size range, lacking testas but showing the characteristic endosperm cells, are here recorded as *J. bulbosus* type. In most cases seeds with testas and firmly identifiable as *J. bulbosus* have been recovered from the same samples.

Juncus balticus and *J. squarrosus*. Three seeds, light brown with a black boss, are referred to *J. balticus*. Damaged and flattened they measure 0.8 × 0.65 mm (figure 9 (*i*), plate 2). The testas are transparent with narrow, faint 'cobwebby' cells transversely elongated and in irregular longitudinal rows.

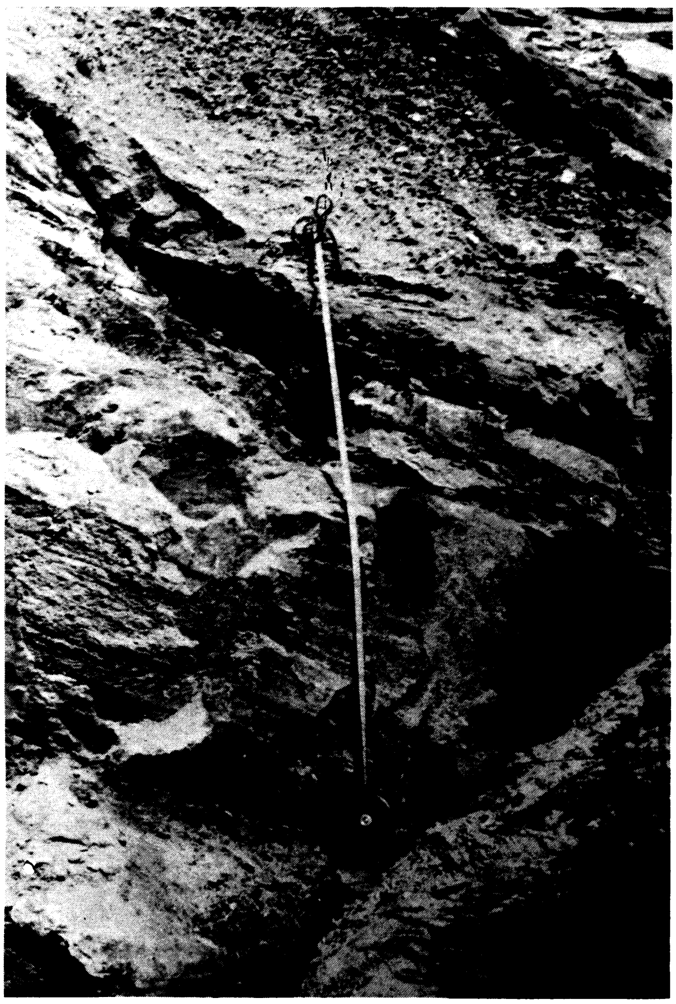
Of the British species four have seeds of similar size and shape. They can be eliminated by testa characters. *J. acutus* L. has approximately square cells in longitudinal rows. *J. gerardi* Lois. has narrow, transversely elongated cells but thickened longitudinal walls. *J. maritimus* has narrower cells with rather thick longitudinal walls. *J. squarrosus* has approximately square cells which are incrassate and pitted.

Only *J. balticus* has cells with obscure walls, difficult to discern even in reference material. This is the first British Quaternary record of *J. balticus*; Baker (1965) found seeds of this species

(*a*)



(*b*)



(*c*)

FIGURE 3. (*a*) The kettle hole at Ballaugh Site 2 is in the middle to the right. (*b*) Kirkmichael Site 1: detritus mud with mineral deposits above and below. (*c*) Kirkmichael Site 3*a*: lower peat and mud, gravel above and below.

FIGURE 9. For description see facing page.

throughout almost the entire depth of sediment in a Late-glacial site in Minnesota, an area where *J. balticus* is common in deposits of this age (Watts 1967).

Seeds of a similar size but lacking the diagnostic testa and consisting only of the endosperm outer coat are recorded as *J.* cf. *balticus*. The qualified determination is necessary because the four species discussed above have somewhat similar endosperm; their larger size separates them from the species considered under *J. bulbosus*.

A single seed with very thick testa is referred to *J. squarrosus*.

Lychnis

The three reniform seeds (0.55–0.6 × 0.55 mm) referred to *L. alpina* bear low obtuse tubercles on rounded polygonal cells arranged concentrically. They match exactly Greenland material treated with NaOH but less well Norwegian material the tubercles of which are radially elongated.

A single reniform seed (0.55 × 0.45 mm) is readily distinguished from those of *L. alpina* by the acuteness of the tubercules, which are borne on radially and concentrically orientated cells. It is referred to *L. viscaria*.

The collapsed state and opaque blackness of the *Lychnis* seeds prevents easy illustration.

Polytrichum aurantiacum

The solitary well-preserved shoot has the broad elamellose margin, the lamellae and the short sheath cells characteristic of this species.

Potentilla crantzii or *tabernaemontani*

Eleven achenes were recovered from the Kirkmichael deposits. See West, Lambert & Sparks (1964) for a figure and description of the achenes of these taxa.

Ranunculus hyperboreus

The distinctive achenes of *R. hyperboreus* will be described and illustrated in an account of the macroscopic subfossils from Wretton, Norfolk.

Sagina cf. *maritima* or *procumbens*

About 180 translucent, reniform seeds measuring 0.35–0.5 × 0.3 mm and almost white to light brown in colour resemble unripe reference seeds of *Sagina*, which are a darker brown when mature. The semicircular hilum is well marked.

The testa cells are very slightly raised, radially elongated on the face and rounded on the back. The sinuous cell margins are indistinct.

Scirpus cf. *americanus*

A single fruit was found from Ballaugh zone IV*b*. See Lambert, Pearson & Sparks (1963, p. 23) for a discussion of the fruits of this species.

Description of plate 2

Figure 9. (*a*) Fruit of *Achillea* cf. *millefolium*, × 47. (*b*) Seed of *Arabis* cf. *hirsuta* or *stricta*, × 60. (*c*) Seed of *Cardamine pratensis*, × 45. (*d*) Cell pattern on caryopsis of *Festuca ovina* or *rubra*, × 250. (*e*) Caryopsis of *Festuca ovina* or *rubra*, × 40. (*f*) Seed of *Epilobium alsinifolium*, × 33. (*g*) Caryopsis of *Poa* cf. *pratensis*, × 42. (*h*) Caryopsis of *Poa* cf. *trivialis*, × 60. (*i*) Seed of *Juncus balticus*, × 100.

Scleranthus annuus L. s.l.

The single fruit is in no better state than that tentatively identified and described by West *et al.* (1964) from Ilford, Essex. Calyces were 'common' in the Upton Warren deposit (Coope, Shotton & Strachan 1961).

Sibbaldia procumbens

The single semicircular subfossil achene has a flattened ventral margin and a prominent point of attachment. Its dimensions of 1.5 × 1.1 mm match those of reference achenes which have a glossy outermost layer represented in the subfossil only by a small remnant adherent to an inner layer of small, rounded cells.

Sibbaldia is distinguished from *Potentilla* and *Fragaria* by the achene shape. The apex of *Sibbaldia* is central and obtuse while that of *Fragaria* is more pointed and that of *Potentilla* is inclined towards the ventral side.

Stellaria cf. ***crassifolia***

Nine black seeds of a *Stellaria* with low concentric ridges formed by elongate tubercles were identified as the taxon. The two complete seeds measure 1.25 × 1.2 mm and 1.15 × 1.0 mm. Of the British species they most resemble *S. graminea* L. in size, and arrangement and shape of the tubercles, but differ in the height of the tubercles. In *S. graminea* the tubercle height is about 0.05 mm, that of *S. crassifolia* about 0.025 mm.

While the arrangement, shape and height of the tubercles fit *S. crassifolia*, the identification of the subfossils must remain tentative, because reference seeds measure only 0.9–1.0 × 0.8 mm. A similar size discrepancy previously forced Mitchell (1953) to qualify in the same way the determination of a Zone III seed from Dromsallagh, Co. Limerick.

Tortula ruralis

All the specimens have the hair points eroded away. However, the robustness, lack of a central strand, obtuse leaf apices and margins recurved far up the leaf point to this species.

Viola reichenbachiana or ***riviniana***

Six pointed ovoid seeds of a *Viola* must on size and shape belong to *V. reichenbachiana* or *V. riviniana*. They measure 1.8–2.2 × 1.1–1.3 mm, reference seeds of *V. reichenbachiana* 2–2.4 × 1.3–1.5 and those of *V. riviniana* 1.7–2.0 × 1.1–1.4 mm.

Thick-walled polygonal cells of the testa are faintly visible on some parts of the subfossils.

4.3. *Communities*

4.31. *Woody plants*

Though at both Ballaugh and Kirkmichael occasional *Pinus* pollen occurs in all zones, it is assumed that no pine grew on the island. The long-range transport of pine pollen is a well-known phenomenon; much greater percentages than the 1% or 2% found could easily be attributed to distant sources. Surface samples from Spitzbergen (Środoń 1960) have revealed values from 34% pine in sparse high-altitude vegetation down to minute values in lowland areas where the moss tundra shares many species with the Manx Late-Weichselian flora. Such species as *Koenigia*, *Ranunculus hyperboreus*, *Cardamine pratensis* and *Saxifraga hirculus* are given in Środoń's lists. Surface samples from Arctic Quebec reveal an exactly comparable situation (Bartley 1967).

Though Środoń obtained values of several per cent tree birch pollen in moss tundra, *Betula* cannot be dismissed in the same way as *Pinus*, however low the values are (up to 16%). Meagre they may be, but fruits and cone scales of tree birches from Ballaugh are conclusive; moreover the pollen values, if only low representation of *B. nana* is assumed, are such as are usually accepted as indicating local presence.

We may assume that at Ballaugh, if not Kirkmichael, tree birches grew, albeit in small stands in favourable localities. The pollen curves show an expansion in Zone II, contraction in Zone III, succeeded by massive expansion late in Zone IV.

Pollen of *Corylus* and *Ulmus* from Kirkmichael certainly belongs to the long-distance component, but not necessarily that of *Hippophaë*, which may have grown locally. Many recently made records of *Hippophaë* pollen help to substantiate the species as widespread in Late-Weichselian Britain; however, the pollen values are tiny, far removed from the large, conclusive values of Late-Lowestoftian deposits (West 1956; Watts 1964).

The tiny values of *Juniperus* pollen can safely be taken as indicating local growth; they merely reflect under-recording of marginally recognizable pollen or sparse sampling. No zonal pattern of the kind shown in many Late-Weichselian diagrams is apparent.

4.32. *Grassland*

Many species allow us to envisage, throughout the period under investigation, extensive, open rocky grassland, some of which was calcareous.

As an example of the Zone I flora, Wyllin 3*a* yielded the three grasses *Festuca ovina* or *rubra*, *Poa* cf. *pratensis* and *P.* cf. *trivialis* in addition to the taxa listed below:

Arabis hirsuta or *stricta*
Artemisia
Cerastium arvense
Dianthus deltoides
Draba
Dryas octapetala
Leontodon cf. *hispidus*
Potentilla crantzii or *tabernaemontani*
Rubiaceae
Salix herbacea
Taraxacum
Botrychium
Selaginella selaginoides
Antitrichia curtipendula
Camptothecium lutescens or *sericeum*
Ceratodon purpureus
Dicranum scoparium
Ditrichum flexicaule
Hylocomium splendens
Rhacomitrium
Rhytidiadelphus squarrosus
Tortula ruralis

Zone II of Ballyre gave

Campanula
Gramineae
Labiatae
Leguminosae
Luzula
Rumex acetosa
R. acetosella
Salix herbacea
Saxifraga cf. *hypnoides*
S. cf. *nivalis*
Viola cf. *canina*
Lycopodium annotinum
Selaginella selaginoides
Thalictrum
Umbelliferae
Antitrichia curtipendula
Dicranum scoparium
Polytrichum alpinum

Zone III of Wyllin 3*a* gave

Achillea cf. *millefolium*
Artemisia
Campanula cf. *rotundifolia*
Cerastium holosteoides
Compositae
Draba
Empetrum nigrum
Gramineae
Leguminosae
Linum catharticum
Luzula
Lychnis viscaria
Plantago major
Potentilla anserina
Ranunculus acris
R. repens
Rubiaceae
Rumex acetosella
Salix herbacea
Viola cf. *canina*
Botrychium
Ophioglossum
Antitrichia curtipendula
Ceratodon purpureus
Hypnum cupressiforme
Hylocomium splendens
Polytrichum alpinum
P. aurantiacum
P. juniperinum
Rhacomitrium

Typical of the marked representation of calcicoles in these lists are *Arabis hirsuta* or *stricta*, *Linum catharticum*, *Dianthus deltoides*, *Saxifraga* cf. *nivalis*, *Dryas octopetala* and *Ditrichium flexicaule*.

The abundance of calcareous substrata in Late-Weichselian times contrasts with the present situation on the island, where base-rich soils are now almost absent (Allen 1968).

That the soils were not uniformly calcareous is, however, shown by such species as *Rumex acetosella*, *Ceratodon purpureus*, *Salix herbacea*, *Polytrichum aurantiacum*, *Scleranthus annuus*, *P. juniperinum*, and *P. norvegicum*.

There is little more than a suggestion of tall herb communities in the vegetation; no single layer yielded convincing evidence. However, such taxa as *Filipendula*, *Valeriana officinalis*, *Rumex acetosa*, Umbelliferae, *Succisa pratensis*, and *Urtica* point to the presence of such communities.

4.33. *Snow-bed vegetation*

The only certain indication of snow-bed vegetation is the single stem of *Polytrichum norvegicum*, obligately chionophilous, from Ballaugh 230–265 (Zone II–III) a layer which also yielded the less markedly chionophilous *Salix herbacea* and *Sibbaldia procumbens*.

Extreme late snow-bed vegetation on acid soil has been recognized at Loch Droma, Wester Ross (Zone I; Kirk & Godwin 1963) and also at Stannon, Cornwall (Late-Weichselian; J. H. Dickson, unpub.), where *P. norvegicum* was well represented with *P. alpinum* and *Salix herbacea*. Apart from *Polytrichum norvegicum*, *Salix herbacea*, *Saxifraga* cf. *stellaris*, *Lycopodium selago* and *Polytrichium alpinum* can occur in such vegetation. Of these species only *Salix herbacea* is well represented in the Ballaugh–Kirkmichael deposits.

Sibbaldia procumbens, however, points to less extreme snow-bed conditions on better soil.

4.34. *Mires and flushes*

Over half of the mosses are species of mires; the majority point to well-developed rich fen communities.

Acrocladium cordifolium
A. giganteum
A. trifarium
Cratoneuron commutatum
C. filicinum
Drepanocladus aduncus

Aulacomnium palustre	*D. revolvens*
Camptothecium nitens	*Helodium blandowii*
Campylium stellatum	*Meesia tristicha*
Cinclidium stygium	*Scorpidium scorpioides*
	Sphagnum sg. *Litophloea*

They could well have been associated with such angiosperms, mostly helophytes, as

Carex rostrata	*Mentha* cf. *aquatica*
Eleocharis spp.	*Menyanthes trifoliata*
Filipendula ulmaria	*Pedicularis palustris*
Hippuris vulgaris	*Potentilla palustris*
Lychnis flos-cuculi	*Ranunculus flammula*
Lycopus europaeus	*Saxifraga hirculus*

The species listed above, especially *Carex*, *Lychnis flos-cuculi*, *Menyanthes* and also *Viola palustris*, are particularly well represented in layer 1450–58 cm of Wyllin 3*a* (see §3.4 under *Saxifraga hirculus* for a further discussion of this stratum).

Such species are well-known from Late-Weichselian deposits. By contrast, the following are unusual.

Carex cf. *curta* (Ballyre Zone II), *C.* cf. *diandra* (Wyllin 2, Zone I, and 3*b*, Zone III), *Eriophorum vaginatum* (Ballyre Zone II), *Hypericum elodes* (Ballaugh Zone III), *Juncus squarrosus* (Wyllin 3*b* Zone III), *Sphagnum* sg. *Litophloea* (Wyllin 3*a* Zone III).

They point to the development of oligotrophic mire vegetation during all three zones and at five sites; though it is more than plausible to assume the presence of such communities on base-poor rock in Late-Weichselian times the fossil record has given little corroboration; all five angiosperms are recorded here for the first time as Late-Weichselian species in the British Isles.

Particularly worthy of comment is *Eriophorum vaginatum*, an ombrotrophic species abundantly represented in Flandrian acid peats. Glacial occurrences of this species are very sparse in the rest of Europe also (Jessen & Milthers 1928). There is a Flandrian record (Godwin 1956, p. 97) of *Hypericum elodes*, which grows in 'bogs and wet places beside ponds and streams on acid soils' (Clapham *et al.* 1962, p. 205). There is evidence that *Juncus squarrosus* is base-indifferent but it is a shade-intolerant species restricted by competition to acidic soils, usually podsols with mor humus and peaty gleys (Welch 1966).

Sphagnum, both as spores and macroscopic fossils, is very sparse but nevertheless widely encountered in Late-Weichselian deposits; perhaps the species represented here is merely one of the more base-tolerant species. The weight of the argument rests on the angiosperms, four of which are species of bog and poor fen. Other species which could have grown in such communities include *Betula nana*, *Empetrum nigrum*, *Aulacomnium palustre*, *Dicranum scoparium* and *Hylocomium splendens*.

Various species from level 1450–58 cm of Wyllin 3*a* suggest the presence of spring and streamside vegetation. Several bryophytes, notably *Cratoneuron* spp. and *Philonotis* sp. as well as *Montia fontana* ssp. *fontana*, often grow in such places.

4.35. *Water plants*

As is typical of rich Late-Weichselian assemblages, numerous aquatic species are represented. They occur in almost all levels.

Callitriche obtusangula
Littorella uniflora
Myriophyllum alterniflorum
M. spicatum
M. verticillatum
Potamogeton acutifolius or *P. trichoides*
P. alpinus
P. berchtoldii
P. crispus
P. filiformis
P. natans
P. obtusifolius
P. pectinatus
P. praelongus
Ranunculus sbg. *Batrachium*

The species in the list point to eutrophic conditions; none is restricted to oligotrophic water though *Littorella* is usually regarded as such (e.g. Clapham *et al.* 1962). However, in the Burren, Co. Clare (Ivimey-Cook & Proctor 1966), and at Colgach Lough, Co. Sligo, *Littorella* flourishes on calcareous marl.

4.36. *Inundated flats*

Mitchell (1958) discussed the presence of temporarily inundated gravelly, sandy or clayey flats at Ballaugh which could have supported such taxa as *Chenopodium* sect. *Pseudoblitum*, *Rorippa islandica*, *Sagina*, *Potentilla anserina* and *Rumex acetosella*. Perhaps to these may now be added *Juncus* species including *J. bulbosus*, *Koenigia islandica* and *Ranunculus hyperboreus*.

Such vegetation may well have been widespread in Late-Weichselian times. It has been envisaged at both Mapastown, Co. Louth (Mitchell 1953) and Moss Lake, Liverpool (Godwin 1959).

4.37. *Saline plants*

Such species as *Armeria maritima*, *Plantago maritima* and *Silene maritima* have long been familiar as Weichselian species (Godwin 1956). Their alpine populations in rupestral habitats in the British mountains made them readily acceptable as components of last glacial vegetation so characteristically rich in heliophiles of open, often rocky situations. However, recent discoveries suggest that their presence may indeed on occasion point to saline rather than merely open conditions. There are now well-established histories of strict halophytes unknown as alpine species. *Glaux maritima* and *Triglochin maritima* are the best substantiated; macroscopic subfossils are unmistakable (figures in Florschütz 1958 and Coope *et al.* 1961). Both have been recorded from Kirkmichael and Upton Warren and the latter is a Middle-Weichselian species in Holland (Florschütz 1958).

	Ballaugh and Kirkmichael	Upton Warren	Sidgwick Av.
Armeria maritima	many levels	+	+
Blysmus rufus		+	–
Glaux maritima	Ballyre Zone I	+	–
Plantago maritima	Wyllin 3*a* Zone III	+	?
Silene maritima	Wyllin 3*a* Zone III and 3*b* Zone III	–	+
Suaeda maritima		–	+
Triglochin maritima	Wyllin 3*a* Zone III	+	–
Zannichellia palustris		+	+

The source of the saline conditions must remain uncertain. Sea-level was substantially below its modern level in Late-Weichselian time, and the contemporary sea-shore may have been at some distance from Kirkmichael. The glacial material when first deposited may have had a content of sodium silicates derived from the crushing of basic igneous rocks. Before the silicates were leached by chemical weathering, the soil may have had a sufficient content of sodium to make possible the growth of plants with halophyte affinities.

That *Armeria*, *Plantago* and *Silene* are indicators of saline conditions in the Kirkmichael Late-Weichselian is supported by the occurrence of all three with *Triglochin* in Wyllin 3*a* Zone III and *Armeria* with *Glaux* in Ballyre Zone I.

4.38. *Dune plants*

The number of species which can occur in present-day sand-dune vegetation is very large; few taxa are restricted to such a habitat. We may mention the following as examples of species which may have grown in fixed dune or slack situations.

Arabis cf. *hirsuta* or *stricta*
Arenaria serpyllifolia ssp. *macrocarpa*
Cardamine pratensis
Cerastium spp.
Dryas octopetala
Hippophaë rhamnoides
Jasione montana
Juncus balticus
Parnassia palustris
Sagina maritima or *procumbens*
Selaginella selaginoides
Succisa pratensis
Thalictrum minus
Polytrichum juniperinum
Tortula ruralis

None is restricted throughout the European range to dunes though *Arenaria serpyllifolia* ssp. *macrocarpa* is so confined (Perring & Sell 1967) apart from maritime shingle (Petch & Swann 1968); in Britain both *J. balticus* and *Hippophaë* are virtually restricted to dunes. *Dryas* may seem an unexpected species in the list. However, on the Sutherlandshire coast at Bettyhill *Dryas* is a very successful sand-binder over many acres.

The calcareous conditions indicated by our plant list contrast with those of the present sand-dune system which is poorly developed, lacking in slacks, species poor, and acid (Hartley & Wheldon 1914; Moore 1931).

If these indications of calcareous dunes are correct, suitable edaphic conditions existed for the 'Lusitanian' orchid *Neotinea intacta* (Link) Reich. f., which was recently discovered on the Ayres, a stretch of fixed dunes at the north end of the island; the assumption by Allen (1968) that the species must be an immigrant post 4000 B.C. need not hold, unless one considers the Late-Weichselian climate as prohibitive.

4.4. *Survival, immigration and extinction*

Moraines of the last glaciation have not been traced above about 198 m, and it is thus very probable that the higher ground of the island projected above the ice surface as a nunatak available to plants and animals even at the greatest spread of the ice.

Pollen analysis of sediment of pre-Zone I age may be an indication of the species existing in this severe habitat. The following taxa have been recognized: *Artemisia*, *Betula*, Cyperaceae, Ericaceae, Gramineae, *Lycopodium selago*, *Rumex* and *Salix herbacea*.

The great number of glacial records of *Salix herbacea*, as Godwin (1956) pointed out, facilitates acceptance of this species as a perglacial survivor; many records of spores of *Lycopodium selago* made in recent years put the plant in the same category.

Both hardy species are probable Manx Middle-Weichselian plants; the former extends above 80 °N and the latter is one of the species known from the Jensen nunataks in Greenland in company with 25 other species including only one woody species, the diminutive *Cassiope hypnoides* (Iversen 1953). In the absence of firm generic or specific records, little can be said of the bulk of taxa in the list. The possibility of long-distance transport, perhaps especially of *Betula*, cannot be excluded; indeed this phenomenon conceivably could account for the entire assemblage.

If the assemblage is a reflexion of local plant growth, it seems reasonable to envisage for the island a meagre Middle-Weichselian flora, much smaller than that of the Late-Weichselian; more than 30 taxa have been found as pollen and spores in Zone I alone. The list of eight taxa stands in great contrast to the diverse Middle-Weichselian floras of such localities as Upton Warren (Coope *et al.* 1961), the Lea Valley (Warren 1912) and Barnwell Station (Chandler 1921).

The present isolation of the Isle of Man adds to the biogeographical interest, just as the isolation from Europe does for the British Isles as a whole and Ireland in particular, and one naturally enquires when and to what extent has the Irish Sea formed a barrier to dispersal? The sea may be a severe barrier now as it has been for the great part of the Flandrian. However, the extreme richness of the Late-Weichselian flora points to ease of dispersal and establishment, not just in the context of the island itself, where abundant open habitats existed as throughout the British Isles, but in there being land where now there is sea. If glacial sea-level dropped by 300 ft. (91.4 m) or more and remained at that level in Late-Weichselian times, terrestrial connexions existed between the island and the surrounding mainlands. The possible morainic ridges discussed by Mitchell (1963) can be envisaged as massive topographic features providing a range of habitats which perhaps persisted until early Flandrian times. However, this is not to deny the possibility of long-range transport, the success of which may have been greater when open habitats enhanced the chances of establishment much more than the closed forests of the Flandrian.

If the above view of the Middle-Weichselian flora is accepted, plant immigration and establishment became easy only in Zone I as the climate moderated. It is clear that by the end of Zone I, if not earlier, a rich flora existed on the island. Some 82 ecologically varied taxa of vascular plants are known from Zone I.

With complete plausibility one may postulate a constant immigration in the succeeding periods. However, it may well be that the bulk of the Late-Weichselian flora had arrived by late Zone I. The large proportion of species common to all three zones shows that equivalent, ecologically varied habitats existed in all three zones (table 2). Of the 35 taxa recovered from all three zones, 14 are aquatics or marsh plants, 21 are terrestrial, the bulk of the latter being heliophiles.

Even with highly detailed pollen data or a macroscopic fossil diagram, it may be very difficult to pin-point the time of immigration of a particular species. It may be that the *flora* changed little in the Late-Weichselian, despite the numbers of species recovered from samples referred to one zone only. The changes of *vegetation* shown in the pollen diagrams may mean that the abundance of a particular species altered substantially in the periods investigated and accordingly chances of fossilization were altered.

TABLE 2. TAXA OCCURRING IN ALL LATE-WEICHSELIAN ZONES OF THE BALLAUGH-KIRKMICHAEL DEPOSITS

Armeria maritima	*Potamogeton filiformis*
Artemisia	*P. pectinatus*
Botrychium	*Potentilla anserina*
Carex rostrata	*P. palustris*
Eleocharis palustris	*Ranunculus* sg. *Batrachium*
Empetrum nigrum agg.	Rubiaceae
Equisetum	*Rumex acetosa*
Ericaceae	*R. acetosella*
Helianthemum	*Salix herbacea*
Hippuris vulgaris	*Saxifraga hypnoides* agg.
Juncus balticus	*Selaginella selaginoides*
J. bufonius	*Succisa pratensis*
J. bulbosus	Umbelliferae
Juniperus communis	*Antitrichia curtipendula*
Leguminosae	*Rhacomitrium*
Luzula	*Chara*
Myriophyllum alterniflorum	*Nitella*
Polypodium vulgare	

For the purposes of this table bulk samples of Zone I–II and II–III are not considered. Pollen taxa such as 'Compositae' are not included because specific records have been made on macroscopic remains.

The 26 species listed below have markedly southern ranges in Sweden at present (as shown by Hultén's atlas) or else do not occur there at all (marked*).

Arenaria serpyllifolia ssp. *macrocarpa*	*Ophioglossum*
*Callitriche obtusangula**	*Potamogeton acutifolius* or *trichoides*
Dianthus deltoides	*P. crispus*
Eleocharis multicaulis	*Scirpus lacustris*
*Hypericum elodes**	*S.* cf. *americanus**
Jasione montana	*Saxifraga* cf. *hypnoides**
Juncus conglomeratus or *effusus*	*Succisa pratensis*
J. squarrosus	*Thalictrum minus*
Leontodon cf. *hispidus*	*Viola* cf. *canina*
Littorella uniflora	*V. reichenbachiana* or *riviniana*
Lycopus europaeus	*Antitrichia curtipendula*
Mentha aquatica	*Camptothecium lutescens* or *sericeum*

Hypericum elodes is particularly worthy of comment as is *Callitriche obtusangula*. The former is strongly southern and western in the British Isles, the latter does not reach Scotland. Similarly the present European ranges of such taxa as *Dianthus deltoides*, *Eleocharis multicaulis*, *Juncus squarrosus*, *Lychnis viscaria* and *Scirpus* cf. *americanus* make the Late-Weichselian occurrences noteworthy. The presence of such a large total flora and especially the considerable, diverse representation of 'southern' species lead to the speculation that the bulk of the present flora had arrived on the island by the end of the Late-Weichselian period.

Of the 163 taxa in the subfossil assemblages 46 (28 %) are no longer to be found as native plants in the Isle of Man (table 3). There are many familiar Late-Weichselian species among them. Such taxa as *Betula nana*, *Dryas octopetala*, *Helianthemum*, *Koenigia islandica*, *Oxyria digyna*, *Potamogeton filiformis* and *Sparganium angustifolium* need no special comment here. However, there are many species which demand discussion because of their particular ecology or chorology or because they are additions to the Late-Weichselian flora.

TABLE 3. TAXA NOW ABSENT FROM MAN

Vascular plants

* *Arabis* cf. *hirsuta* or *stricta*	* *Polygonum viviparum*
Betula nana	*Potentilla crantzii* or *tabernaemontani*
* *Carex* cf. *diandra*	*Potamogeton acutifolius* or *trichoides*
Dianthus deltoides	*P. filiformis*
Draba (genus)	*P. praelongus*
Dryas octopetala	*P. obtusifolius*
Epilobium alsinifolium	*Ranunculus hyperboreus*
Helianthemum (genus)	*Saxifraga hirculus*
Hippophaë rhamnoides	*S. hypnoides* agg.
Juncus balticus	* *S.* cf. *nivalis*
Koenigia islandica	* *S.* cf. *oppositifolia*
* *Leontodon* cf. *hispidus*	* *S.* cf. *stellaris*
Lychnis alpina	* *Scirpus* cf. *americanus*
L. viscaria	*Sibbaldia procumbens*
* *Lycopodium* cf. *annotinum*	*Sparganium angustifolium*
Montia fontana ssp. *fontana*	* *Stellaria* cf. *crassifolia*
* *Oxyria digyna*	*Thalictrum minus*
Parnassia palustris	*Typha* (genus)

Mosses

Acrocladium giganteum	*Cinclidium stygium*
A. trifarium	*Helodium blandowii*
Antitrichia curtipendula	*Meesia tristicha*
Drepanocladus aduncus	*Mnium rugicum*
Camptothecium nitens	*Polytrichum norvegicum*

Taxa now rare on Man

Alchemilla (genus)	*Potamogeton alpinus*
* *Carex* cf. *curta*	*Rorippa islandica*
Juniperus communis	*Salix herbacea*
	Polytrichum alpinum

* Tentative determination.

Acrocladium trifarium

This is the first properly authenticated British Late-Weichselian record of *A. trifarium*, a species at present restricted to the Scottish Highlands apart from a few Irish stations in the Burren. Combined with the previously discovered subfossils it indicates a more widespread range in the Late-Weichselian, Pre-Boreal and Boreal.

Antitrichia curtipendula

This species of rocks and tree trunks has a very detailed Quaternary history (Dickson 1967, 1968). It is well known from Late-Weichselian sites but only those in Britain and there only in the west. Apart from the Isle of Man it has been extracted, sometimes in abundance, from deposits in Cornwall, North Wales and the Lake District. Its present range in Britain is extensive but patchy. Rocky woodlands of the west are the most favoured habitat. In Scandinavia the species shows a similar western and also a southern tendency (Nyholm 1960).

Carex* cf. *diandra

A decreasing lowland species, *C. diandra*, is very widespread but local in the British Isles, where it grows in wet, peaty meadows, alder-sallow carr and more acid wet grassland (Jermy & Tutin 1968).

The sole previous British subfossil is of Zone VIII age (Godwin 1956).

Dianthus deltoides

In Britain this species has a scattered, mainly eastern range and is absent from Ireland. Kirkmichael lies at the western limit of the present distribution. Clapham *et al.* (1962, p. 230) describe the species as 'A local lowland plant of dry grassy fields and banks and hilly pastures...' In Scandinavia, where the species is mainly south-eastern, the habitats are similar (Hultén 1950); it ascends to about 1000 m.

Epilobium alsinifolium

This species occurs widely in the Scottish Highlands and also in the Southern Uplands, northern England and Caernarvonshire. There is a single Irish locality, a limestone cliff in Glenade, Co. Leitrim. The characteristic habitat of this and the related *E. anagallidifolium* is the bryophyte flush, commonplace in the highland zone.

Few if any of the other species extracted from the same zone (Wyllin 3*a*, Zone I–II) are likely to have been associates of *E. alsinifolium*.

Helodium blandowii

This species became extinct in the British Isles as a result of the anthropogenic destruction of its mire habitats. It was restricted to three localities (in Yorkshire and Cheshire). Numerous subfossils, particularly of Late-Weichselian and early Flandrian age, proved occurrence as far north as Aberdeenshire and as far west as the Isle of Man (Dickson 1965).

Juncus balticus

Apart from three localities in Lancashire, *J. balticus* is exclusively Scottish and there mostly northern. It is almost restricted to duneslacks. In Scandinavia too it is largely maritime. Hultén (1950, p. 111) describes the habitats as seashores and calcareous fens.

Lychnis alpina

Both previously published subfossils from England are Middle-Weichselian in age. The Angel Road deposit of the Lea Valley Arctic Bed (Warren 1912) yielded the first record and Upton Warren, Worcestershire (Coope *et al.* 1961) the second.

In the Arctic, where *L. alpina* is common, no special edaphic restriction has been noted; Polunin (1959, p. 182) states that it 'prefers open areas of dampish sand or gravel but also grows in a variety of more vegetated habitats...'. However, Rune (1953) has classified the species as serpenticolous in Sweden, where it occurs preferentially on ultrabasic rock, rich in heavy metals. In Britain it is exclusive to heavy-metal soils. Analyses by Ratcliffe (1960) of the soil from the station on the cliffs at Hobcarton Crags in the Lake District revealed richness in manganese. In Clova the species grows on serpentine.

The three Weichselian discoveries confirm a widespread range very different from the rare, disjunct occurrence in the highland zone at present (figure 10).

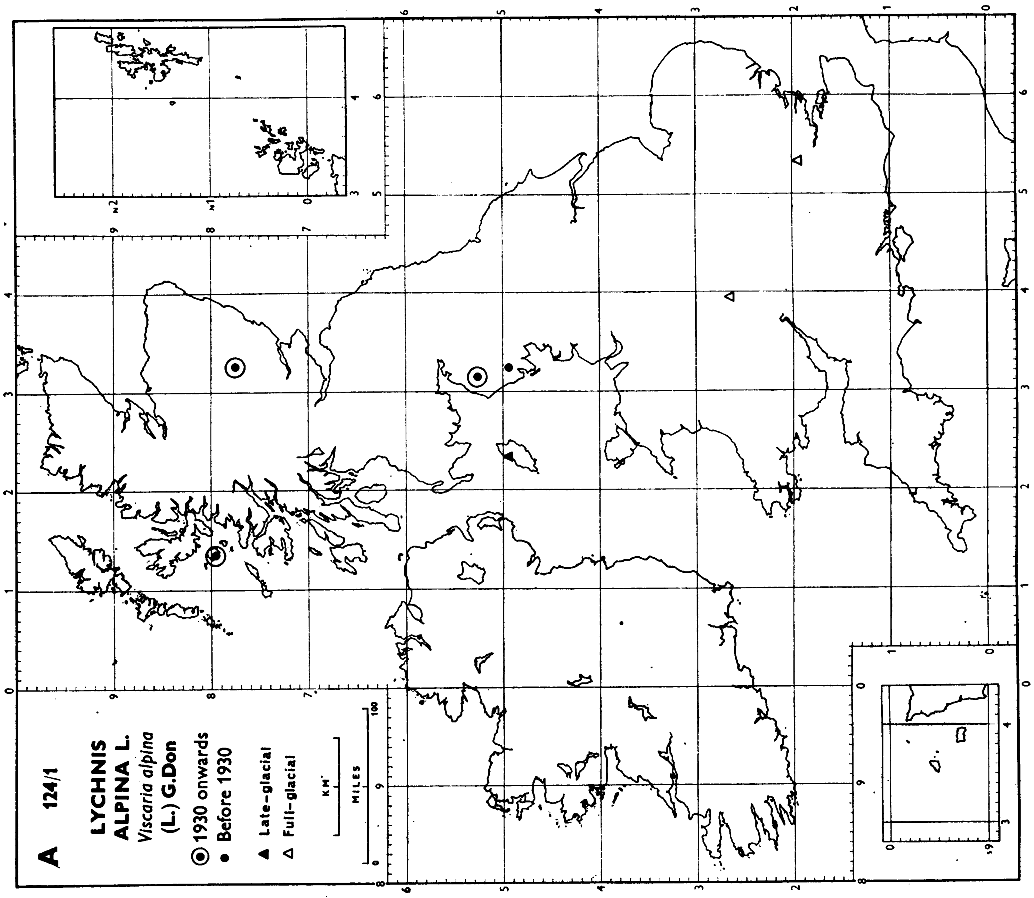


FIGURE 10. Map of *Lychnis alpina*.

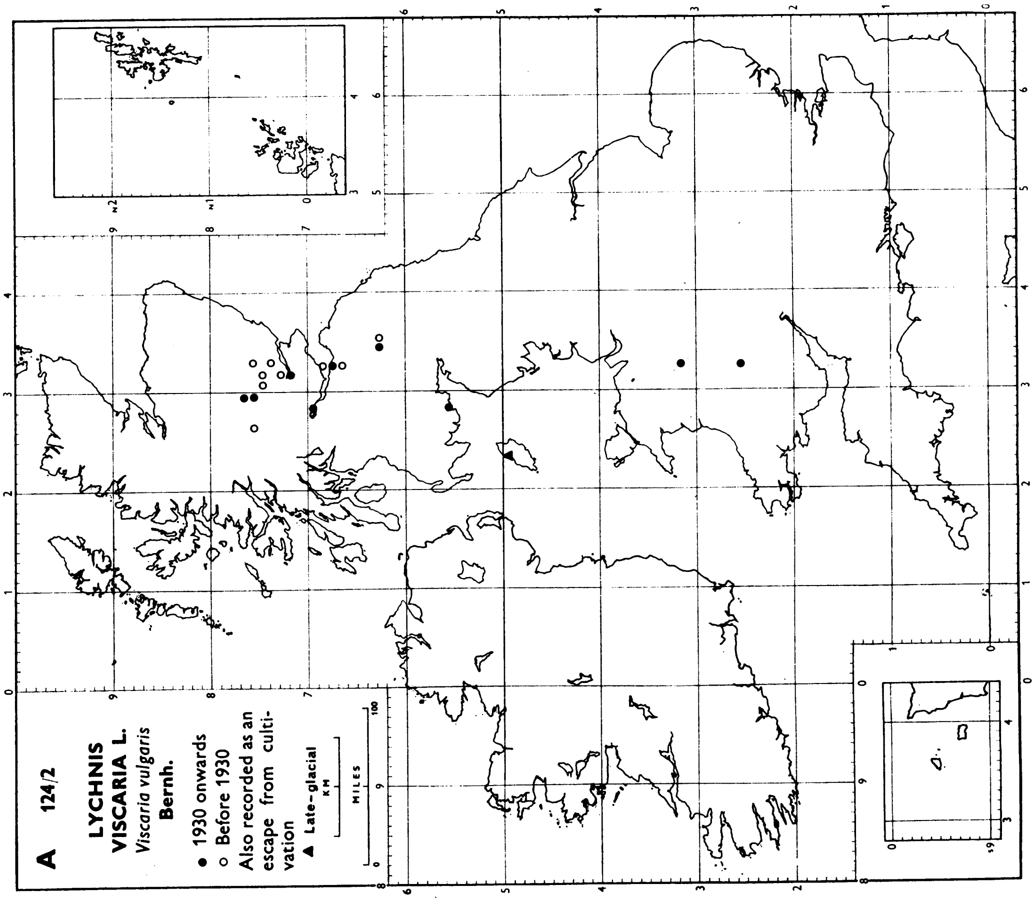


FIGURE 11. Map of *L. viscaria*.

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Lychnis viscaria

This species has an almost exclusively eastern Scottish range in the British Isles (figure 11). Its British habitats (dry rocks on stony slopes) are similar to those in Scandinavia where the species is southern (Hultén 1950).

Meesia tristicha

At present in the British Isles this species has a single locality in Co. Mayo, where the entire population consists of five large clumps (King & Scannell 1960). The habitat is discussed under *Saxifraga hirculus* below. The detailed late Quaternary history makes it clear that in Late-Weichselian and early Flandrian times the range was widespread and continuous (Dickson 1965). In Scandinavia, where the species is commonest in the north, it inhabits rich fens (Mårtensson 1956).

Parnassia palustris

A calcicolous species, *P. palustris* is local and mainly northern in the British Isles where it inhabits marshes, wet moors and dune slacks (Clapham *et al.* 1962). Polunin (1959, p. 248) gives the Arctic habitats as 'damp sand or waterside mud of calcareous origin'.

There is a Middle-Weichselian record from Upton Warren (Coope *et al.* 1961).

Polytrichum norvegicum

In Britain this species is now restricted to the Scottish Highlands, where it grows exclusively on acid substrata in areas of very late snow-lie. Its lower limit is about 3000 ft. (915 m). The Ballaugh subfossil and those from the Late-Weichselian site at Stannon, Cornwall (Dickson 1965), indicate a southern range very different from the present one.

Ranunculus hyperboreus

This species is now well established as a Weichselian species in areas far to the south of its present exclusively northern range in Europe.

Of the five glacial records one is Polish (tentative determination; Ralska-Jasiewiczowa 1966), one is Danish (Mathiesen 1925) and three are British (Wretton, Norfolk, unpublished; the Lea Valley Arctic Bed, Reid 1949; Ballaugh, Zones III and II–III, and Kirkmichael 3*a* and 3*b*, Zone III). See Tralau (1963) for a map of past and present European range.

Böcher, Holmen & Jakobsen (1968, p. 44) describe the Greenland habitats as follows: 'On moist clay and occasionally enriched soils, or in small pools. Also in moss-rich habitats around springs.' In Scandinavia the species occurs in the mountains, where it favours pools fouled by livestock at the summer grazings (Lid 1963).

Saxifraga hirculus

S. hirculus is a rare, decreasing species with a disjunct range in the British Isles (figure 12). The four Late-Weichselian localities—Colney Heath, Herts. (Godwin 1964); Ballaugh, Zone III; Ballyre, Zones I and II; and Wyllin 3*a*, Zone III—point to a wider, more continuous range than at present.

Polunin (1959, p. 260) describes the Arctic habitats as chiefly 'swampy areas and mossy tracts in marshes or drier patches of open clayey soil'. The British habitats are given by Clapham *et al.* (1962) as 'wet grassy ground on moors... ascending to over 2000 feet'. At two Scottish localities recently found by D. Welch (Anchindoir, Aberdeenshire and Cabrach, Banffshire, unpublished) *S. hirculus* grows in sedge-grass communities dominated mainly by *Carex rostrata*, *Holcus lanatus* and *Agrostis* spp. In Co. Antrim at Collin Top on the Garron Plateau the habitat has been briefly described by Kertland (1956), who found the species, luxuriant over some 20 square yards in a 'soak', associated with *Montia fontana*, *Juncus articulatus* and *Ranunculus flammula*. More detail is available of the site at Bellacorick Bog, Co. Mayo (King & Scannell 1960). Here the species is widely scattered in a large flush supporting rich fen vegetation including patches of *Cladium mariscus*. Amongst its associates are the following.

Carex rostrata	*Aulacomnium palustre*
Empetrum nigrum	*Camptothecium nitens*
Lychnis flos-cuculi	*Campylium stellatum*
Potentilla palustris	*Drepanocladus revolvens*
Ranunculus flammula	*Hylocomium splendens*
Acrocladium giganteum	*Meesia tristicha*

All these were recovered from the same layer, 1450–58 cm (Zone III), of Wyllin 3*a* as one of the *S. hirculus* seeds. Another parallel can be drawn with *S. hirculus* communities described by Albertson and Larsson (1960) from the mire at Sjöangen, southern Sweden. Here the species grows in a rich fen, where its associates include *Stellaria crassifolia* var. *paludosa*, *Helodium blandowii*, *Meesia tristicha* and the more commonplace *Cardamine pratensis*, *Linum catharticum*, *Menyanthes trifoliata*, *Potentilla palustris*, *Carex rostrata*, *Aulacomnium palustre*, *Acrocladium giganteum*, *Campylium stellatum* and *Drepanocladus revolvens*. Again all these species were extracted from layer 1450–1458 cm of Wyllin 3*a*.

Sibbaldia procumbens

S. procumbens has a widespread, continuous range in the Scottish Highlands and a solitary outlier in the Pennines (figure 13). Though it occurs in a variety of alpine communities, it avoids the poorest soils and is 'particularly abundant in areas where snow persists late in the summer, such areas supporting a rich flora of bryophytes, with some angiosperms, such as *Salix herbacea* and *Gnaphalium supinum* which can survive long periods of snow cover' (Coker 1966, p. 875).

The Weichselian subfossils from Ballaugh Zone II–III and particularly the Lea Valley Arctic Bed indicate occurrence in southern areas far from the present distribution.

Stellaria cf. *crassifolia*

In northern Europe this species is widespread but local (Hultén 1950); it extends southwards to Germany but not to the British Isles. In the Arctic the habitats include 'damp grassy areas about sea shores or around habitations' (Polunin 1959, p. 188). Hultén's description (p. 172) is 'wet places, seashores'. As described by Albertson & Larsson (1960) the species inhabits rich fens.

Of the species discussed in this section there is little difficulty in accommodating species such as *Dianthus deltoides*, *Juncus balticus*, *Lychnis viscaria* and *Sibbaldia procumbens* in the kind of theory advocated by Godwin (1956) to explain the extinction over much of lowland Britain of species such as *Dryas octopetala*, *Draba incana* and *Saxifraga* spp. The change from the predominantly

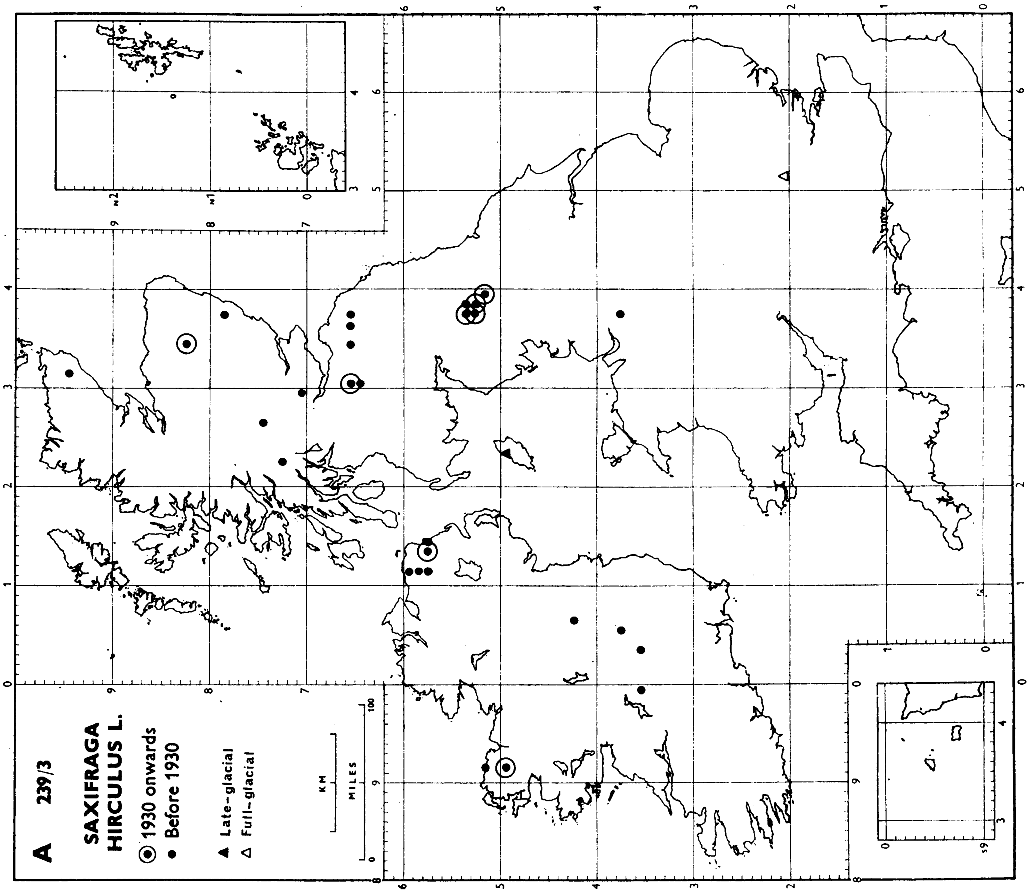

FIGURE 12. Map of *Saxifraga hirculus*.

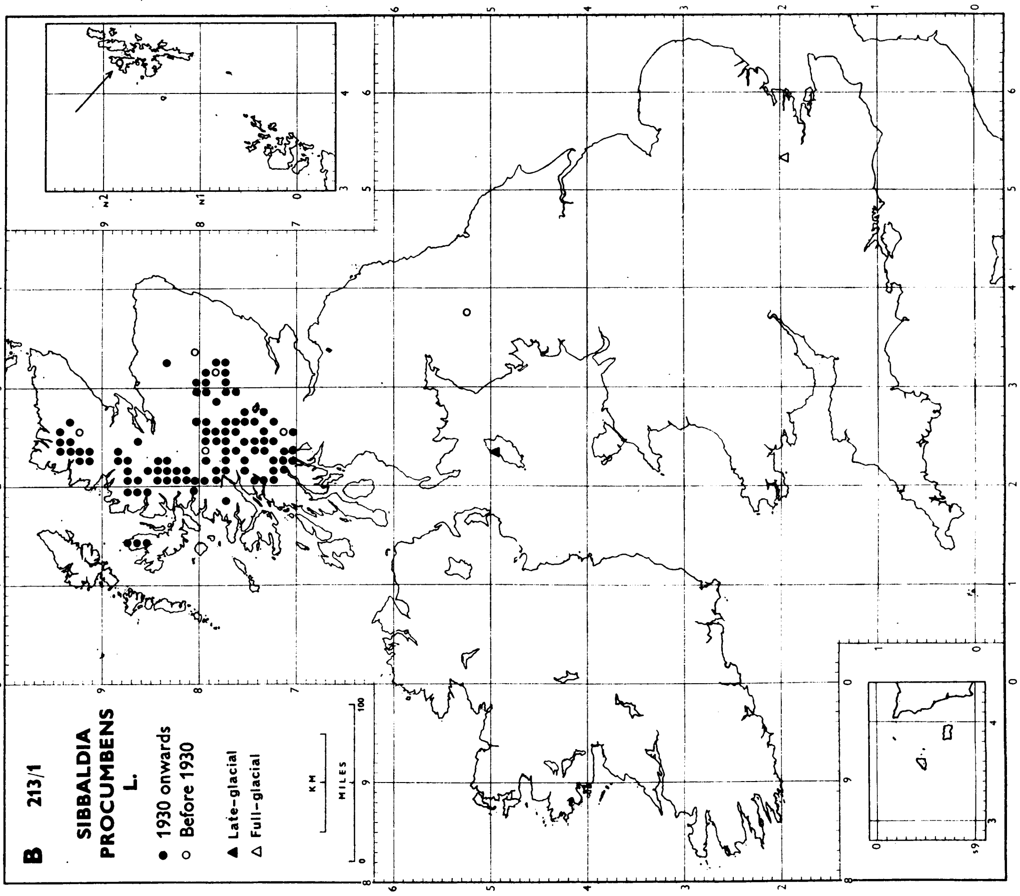

FIGURE 13. Map of *Sibbaldia procumbens*.

tree-less vegetation to closed forests taking place at the Zone III–Flandrian transition had a drastic effect on heliophiles.

In a few cases, however, some extra comment is needed.

The ecology and chorology of *Antitrichia* is enigmatic. Why this species should have become extinct in the Isle of Man or, for that matter, in many areas of the British Isles is not clear (Dickson 1965). Certainly its ecology is such that it would not have been reduced by forest development. The reverse might well have been the case.

The demise of *Polytrichum norvegicum* might have been brought about solely by climatic change resulting in less prolonged snow lie or, perhaps more likely, competition was decisive in this case also. However, competition from herbs, and not trees, would have been the agent.

Another tempting speculation concerns *Lychnis alpina*. One may imagine that during last glacial times this species was edaphically less restricted than at present and that though Flandrian climatic/vegetational changes resulted in wholesale extinction over large areas, the special edaphic preference allowed populations to survive in a few areas where heavy metal soils and permanently open ground coincide.

5. The fauna

5.1. *Vertebrates*

Though bones of *Cervus giganteus* (Irish giant deer) were not found during the investigations described here, large numbers of such bones were found in kettle-holes at Ballaugh (and elsewhere in the island) in the nineteenth century, and the records of the British Association Research Committee (Lamplugh 1903) make it clear that the bones, as in Ireland, were in mud of Zone II age (Mitchell & Parkes 1949). Why at this time the giant deer was rare in Britain, but common in the Isle of Man and in Ireland, remains a mystery. The reindeer, *Rangifer tarandus*, often associated with the giant deer in Ireland at this time, is not recorded from the Isle of Man. The modern vertebrate fauna of the island is, like that of Ireland, very limited by comparison with that of Britain (Allen & Cowin 1954).

5.2. *Invertebrates*

The notostracod *Lepidurus* (*Apus*) *glacialis*, Kroeyer, presumably a synonym of *Lepidurus arcticus* Pallas, has nineteenth-century subfossil records both from Ballaugh and Kirkmichael. It was rediscovered in quantity at the transition from Zone II to Zone III at Ballaugh, where its habitat must have been very similar to that of today. It is often very abundant in ponds and around shallow lake-margins between 65° and 80° N around the world. It has also been recorded from a number of other Late-glacial sites in the British Isles (Morrison 1959).

Large coleopteran assemblages are being investigated by Dr G. R. Coope.

6. Conclusions

We first picture the Isle of Man towards the end of the last glaciation partly buried by ice to a height of 198 m (650 ft.), with Snaefell and its upper slopes projecting as a nunatak, on which *Salix herbacea* and *Lycopodium selago* and a few other species may have maintained a precarious foothold.

The bulk of the ice then melted, though permafrost and dead ice masses may have persisted at depth. Sea-level was still low, and not only the lower slopes of the island but also a considerable area of what is now sea-floor, covered with glacial deposits of different facies, became available for plant colonization in Zone I. Many of the glacial deposits were initially calcareous, though some on the island slopes were rich in slaty debris.

Zone I must have seen a steady amelioration of climate, and before it ended not later than 10000 B.C. some 82 ecologically varied taxa had entered the island, among which *Artemisia*, *Rumex* and *Salix* were common. The bulk of the Late-Weichselian flora may have entered the island by the end of this zone.

Even if broad land bridges did not exist in Zone II (10000 to 8800 B.C.) there must have been little impediment to dispersal to and from Britain on the one side and Ireland on the other.

Fossil ice continued to melt, and consequent subsidence produced new ponds and kettle-holes.

Chemical weathering will have become more important as temperature rose and calcium was leached from the soil and re-precipitated by algae in ponds to form a mud rich in calcium carbonate. Where slate fragments were common, leaching will have intensified the acid nature of the soil.

The high values for grass pollen, the numerous fossils of heliophiles, and the varying, but usually low values for *Betula* pollen, suggest that grassland studded with flowering herbs, and with scattered birch copses in sheltered places, was the dominan habitat. This is supported by the numerous records for *Cervus giganteus*, which in Ireland at this time was most common on the calcareous lowlands, where Late-Weichselian values for grass pollen were high and the richest grazings are found today.

As the colder condition of Zone III (8800 to 8300 B.C.) developed snow-patches lasted longer, and *Apus glacialis* flourished in shallow ponds. *Polytrichum norvegicum*, virtually restricted to snow-beds, has its only record at this horizon.

In Zone III cold rendered less continuous the plant cover of Zone II, and solifluction made the soils on slopes unstable. *Artemisia*, *Rumex* and *Salix* regained some of their earlier importance, and grasses became less numerous.

The evidence, gained primarily from the macroscopic fossils, points to an extremely rich Late-Weichselian flora of diverse geographical elements. The vegetation was highly varied. A mosaic of grassland, mires both eutrophic and oligotrophic, flushes, inundated flats, ponds, dunes and areas with halophytes can be envisaged.

As the cold of Zone III disappeared and the temperate conditions of the Flandrian developed, the grasses were quick to respond, and their pollen again reaches very high values in Sub-zone IV*a*. Tree willows and birches then spread rapidly, obliterating many of the Late-Weichselian herbs, as they initiated the Flandrian woodlands in Sub-zone IV*b*. *Corylus* then appears to open Zone V. These early Flandrian developments in the Isle of Man entirely parallel those in Britain and in Ireland, and suggest that even as late as the opening of the Boreal, migration into the island (and into Ireland) was still relatively unimpeded by the continuing rise in sea-level.

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(a)

(b)

(c)

FIGURE 3. (a) The kettle hole at Ballaugh Site 2 is in the middle to the right. (b) Kirkmichael Site 1: detritus mud with mineral deposits above and below. (c) Kirkmichael Site 3 a: lower peat and mud, gravel above and below.

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FIGURE 9. For description see facing page.