

## THE HISTORY OF THE VEGETATION IN SW CONNEMARA (IRELAND)

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### SUMMARY

The vegetation history of S.W. Connemara was reconstructed on the basis of the available palynological and palaeobotanical data of the region. In the Pre-Boreal Period birch forests replaced the late-glacial tundra-like vegetation. In the early Boreal Period hazel immigrated and the eutraphent water plant communities reached their optimum. After that thermophilous deciduous forests gradually crowded out the birch woods and reached their optimum in the Atlantic Period. The lakes were increasingly filled with peat, the eutraphent character of the marsh vegetation weakened and ombrogenous bog communities spread across the region. Shortly before the Sub-Boreal Period the first indications of human interference in the forests were detectable. During the Sub-Boreal and Sub-Atlantic Periods the forest area was reduced gradually as a result of human activities and the spreading of the bogs. A more or less complete forest clearance took place in the last thousand years.

### 1. INTRODUCTION

In connection with a detailed investigation of the recent vegetation of SW Connemara, carried out by some postgraduate students of the Department of Geobotany of the Nijmegen University (VAN GROENENDAEL et al. 1979), we have attempted to give an overall view of the history of this vegetation since the end of the last glacial period.

For this purpose we used as a basis the paleobotanical and palynological data, published by JESSEN (1949) for the surroundings of Roundstone, and the results of our own palynologic research. To obtain age determinations we used the datings of some characteristic points in the Irish vegetation development, which became known in the last few years by radiocarbon dating.

### 2. GEOLOGICAL STRUCTURE OF THE REGION

The region, from which the paleobotanical and palynological data originate, is mainly built up by precambrian schists, gneisses and other metamorphic rocks (Dalradian Formation). In the southeastern part of the region (near Roundstone) late cryptozoic gabbro intrusions (Mt. Errisbeg) and lower Devonian granites (Roundstone granite) outcrop (CHARLESWORTH 1963, WHITTON 1974, LEAKE 1970).

During the Pleistocene the region was covered by glaciers more than once; the last glaciation left it a bare landscape with numerous basins, 'roches moutonnées' and drumlins. In the Flandrian Period (in Ireland: Littletonian Period, MITCHELL 1976) many basins were filled by peat and on the less steep rocky hill slopes blanket bogs developed.

### 3. THE SOURCE MATERIAL

In order to get a deeper insight into the late quaternary vegetation history of Ireland, Jessen in the 1940's investigated a large number of peat profiles, dispersed throughout Ireland, which he examined for botanical macro- and microfossils. In Connemara Jessen sampled two profiles, described by him as Roundstone I and Roundstone II.

The sampling location Roundstone I lies on the coast some hundreds of metres north of Letterdyfe House in the narrow granite zone between the coast and the Errisbeg gabbro complex. Sampling location Roundstone II is situated some 5 km north of Roundstone I in the lake area south of the Twelve Bens not far from the Ballinaboy-Cashel road (*fig. 1*). This spot lies in the transitional zone between the gneiss formations and the ultrametamorphic rocks (migmatites).

In the 1940's palynological analysis had not yet reached the refinement usual at present. Jessen's pollen diagrams – although of great value – therefore offer only limited information. Because of this we examined another 5 metre deep profile in the area between Errisbeg and Lough Maumeen (the Dolan area). This area is a rather extensive, flat peat complex, the surface of which is interrupted locally by the tops of drumlins and 'roches moutonnées'. The bedrock here consists of schistose hornblende-plagioclase rocks, the Ballyconneely amphi-

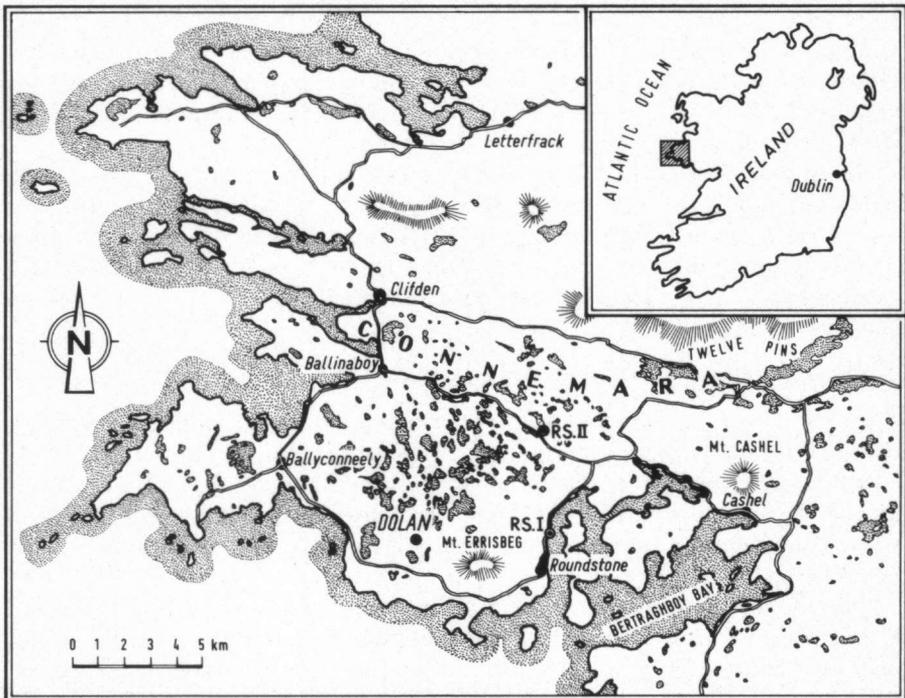


Fig. 1.

bolites (LEAKE 1970). We sampled the peat by means of a Dachnowsky auger; the incoherence of the peat, however, prevented the sampling of a section of 50–100 cm below the surface. We therefore sampled a supplementary profile, about 150 m away in a turf cutting, where a section from 20–120 cm was taken by driving tin boxes into the peat wall. As we found that the palynological pattern at both sides of the hiatus in the main profile was parallel with that in the secondary profile, the hiatus in the main profile could be filled up without any problem (profile Dolan, *fig. 4*).

Profile Roundstone II 5 of Jessen, whose location in the landscape corresponds rather well with that of the Dolan profile, has developed mainly since early Boreal times. In order to complete the picture of the palynological events in the environs of Roundstone, we combined the Roundstone II 5 diagram with parts of the Roundstone I 6 and II 11 diagrams, which give information about events in Pre-Boreal and Late-glacial times. At the same time we recalculated Jessen's data in such a way that the pollen sum includes pollen of all trees and shrubs as well as the pollen of herbs of drier habitats. The remaining palynomorphs (produced by herbs from wetter habitats and by spore plants) are expressed as percentage of the pollen sum. Though this distinction cannot always be sustained for all pollen species (Gramineae, for instance, should ideally be placed partly within, partly out of the pollen sum), the picture of the regional tree/non tree pollen ratio is thus not disturbed too much by the local pollen production of the marsh and bog vegetation. In the first column of the diagram (*fig. 2*) the curves of all pollen species belonging to trees and 'dry herbs' have been brought together; moreover a curve indicating the ratio of tree pollen to non tree pollen is given. In separate columns the curves of individual palynomorph types, partly included in the pollen sum, partly excluded from it, are specified. The Dolan diagram is constructed in the same way (*fig. 3*).

Vertically the diagrams have been divided according to the zones of JESSEN (1949) and MITCHELL (1951, 1956). A division in  $^{14}\text{C}$ -years is added, based on the absolute datings of characteristic points in the Irish vegetation history as these have become known in recent years (SMITH 1970, PILCHER *et al.* 1971, SMITH & PILCHER 1972, 1973, BIRKS *et al.* 1975). As several characteristic changes in the vegetation have proved to be more or less diachronous, the  $^{14}\text{C}$ -chronology is only approximate. Finally the 'Scandinavian' period divisions are added (BLYTT 1876, SERNANDER 1908, ERDTMAN 1928), but they are used here in the geochronological sense only. The merging of this zonation with the  $^{14}\text{C}$  chronology was carried out according to views which are generally accepted on the European continent (*cf.* JELGERSMA 1961, GACHON 1963, BEHRE 1966, REHAGEN 1967, GILOT *et al.* 1969; so far as it concerns the Late-Glacial Period: VAN DER HAMMEN *et al.* 1967, ZAGWIJN & PAEPE 1968).



#### 4. THE DEVELOPMENT OF THE VEGETATION OF SW CONNEMARA

From the combined data the following picture results:

##### 4.1. The Older *Salix herbacea* Period

Zone I according to JESSEN (1949) and MITCHELL (1951, 1956), the last part of the Weichselian (Devensian, Ireland: Midlandian) Pleni-Glacial Period, 13000–12500 <sup>14</sup>C-years before the present (VAN DER HAMMEN et al. 1967, MITCHELL 1976, WATTS 1977).

This period is possibly represented in profile Roundstone II. Jessen found little pollen in the deepest samples of this profile; macroscopic remains of *Salix herbacea*, *Empetrum nigrum* and *Carex* sp., and also remains of the moss *Racomitrium lanuginosum* were recorded, however. Elsewhere in Ireland the presence of *Isoëtes lacustris*, *Myriophyllum alterniflorum* and *Dryas octopetala* has been demonstrated for this period.

The landscape, rich in lakes and pools, was covered by an open tundra vegetation composed of a relatively small number of species. Trees had not yet appeared in this region. The climate had an arctic character.

##### 4.2. The Late-Glacial Birch Period

Zone II of JESSEN (1949) and MITCHELL (1956), Woodgrange Interstadial (MITCHELL 1976), more or less equivalent to the Bølling up to and including the Allerød Interstadial on the continent, 12500–10900 years before the present (compare WATTS 1977 with ZAGWIJN & PAEPE 1968 and other literature mentioned by the latter authors).

Period of climate improvement, represented in the profiles Roundstone I 6 and II 11. According to SMITH (1970) and WATTS (1977) several modern Irish diagrams have proved that this period began with a Juniper maximum. This maximum has been dated at about 12160 years before the present (WATTS 1977), which places this event in the Bølling Interstadial in continental nomenclature. *Juniperus* usually appears shortly before the passage of the tree-line (GAMS 1943, FIRBAS et al. 1948, FIRBAS 1949, ZAGWIJN 1952, BERTSCH 1961). Unfortunately Jessen in his days did not detect the (indistinct) pollen of *Juniperus*. Probably his Connemara pollen diagrams do not reach further back than the time of the Allerød Interstadial. Zone II of these diagrams reflects a non-local 'pollen rain' consisting of more than 85% non-tree pollen (mainly Gramineae and especially *Empetrum nigrum*); towards the top of this zone this percentage has dropped to about 65. In contrast to this decline there is a marked increase of the *Betula* pollen and a temporary expansion of the pollen of *Salix*. There is also a certain increase of *Pinus* pollen, but the percentages are such that they can be explained by long distance transport. The pollen of *Myriophyllum alterniflorum* and the Cyperaceae is numerous, while the spores of *Polypodium vulgare* are represented as well. Finally some pollen of *Epilobium* sp. and *Artemisia* sp. was recorded, and some spores of *Dryopteris* (*Lastrea*) sp. and *Lycopodium selago* were observed.

In zone II of the Roundstone profiles Jessen found the macroscopic remains of *Betula pubescens*, *Juniperus communis*, *Salix* sp., *Empetrum nigrum*, *Rumex acetosella*, *Eleocharis multicaulis*, *Carex* sp., *Viola palustris*, *Menyanthes trifoliata*, *Myriophyllum alterniflorum*, *Nymphaea alba*, *Potamogeton natans*, the lycopod *Selaginella selaginoides* and the mosses *Racomitrium lanuginosum*, *Campithecium nitens*, *Sphagnum imbricatum* and *Hypnum callichroum*. Thus this assemblage includes arctic-alpine as well as oceanic elements.

Elsewhere in Ireland, in sediments of about the same age, remains have been found of the dwarf trees *Betula nana* (in the near-by Burren region, WATTS 1977), *Salix herbacea* and *Salix viminalis*, of the arctic-alpine herbs *Dryas octopetala*, *Oxyria digyna*, *Saxifraga oppositifolia*, *Silene acaulis* and *Thalictrum alpinum*, of the oceanic species *Erica tetralix*, *Cladium mariscus*, *Littorella uniflora*,

*Callitriche stagnalis*, *Isoëtes lacustris*, *Pilularia globulifera* and many others (MITCHELL 1951, SMITH 1970, WATTS 1977). Macroscopic remains of *Pinus* have not been found.

A distinct separation between Bølling and Allerød sediments has not been observed in Ireland, although WATTS (1977) found indications for an erosion phase between his *Juniperus* assemblage zone (ca. 12160 B.P.) and his Gramineae assemblage zone (ca. 11500 B.P.), the latter of which immediately precedes the cold *Artemisia* assemblage zone (zone III). The erosion phase could possibly represent the very short Older *Dryas* Stadial of the continent (12000–11800 B.P.; ZAGWIJN & PAEPE 1968).

The plant remains permit the conclusion that the Woodgrange Interstadial was characterised by a relatively mild oceanic-subarctic climate. The tree birches spread over Connemara (probably preceded by *Juniperus communis*, as in other parts of Ireland). In the drier soils they formed scattered clusters, separated by *Empetrum* heaths. In the wetter soils and in the lakes, highly varied marsh and aquatic vegetations became established, indicating a rather high trophic level.

#### 4.3. Younger *Salix herbacea* Period

Zone III of JESSEN (1949) and MITCHELL (1956), Nahanagan Stadial (MITCHELL 1976), equivalent to the Younger Dryas Stadial of the northwest European continent, about 10900–10200 years before the present. Period of climate deterioration, last phase of the last glacial period.

The Younger *Salix herbacea* Period is represented in the profiles Roundstone I 6 and II 11. In many places in Ireland the contribution of *Betula* to the 'pollen rain' decreased substantially, the macroscopic remains of the tree birches becoming rare. SMITH (1970) therefore thought – as Jessen did – that the tree birches could only survive in sheltered places. In zone III of the Roundstone diagrams a decrease of *Betula* can be observed indeed, but the minimum lies on such a high level, that it is doubtful that in Connemara the tree birches were in retreat to such a considerable degree as Smith supposed. On the other hand part of the birch pollen found in this zone could have been produced by dwarf birches (*Betula nana*). The *Betula* decrease in the diagrams probably would have been more marked if Jessen had drawn into his counts the pollen of many herbs which – as appears in more recent research – occur abundantly in zone III of many Irish profiles (SMITH 1970). The fact that the total pollen production in Connemara decreased considerably during the Younger *Salix herbacea* Period is clearly shown by the maximum of *Pinus* pollen; the pine had not yet reached these regions at that time and its contribution to the 'pollen rain' was caused by long distance transport.

Moreover, Jessen found in zone III at Roundstone a high pollen frequency for *Empetrum nigrum* and *Myriophyllum alterniflorum*. Relatively numerous were the spores of *Polypodium vulgare* and *Dryopteris* sp., while *Lycopodium selago* was represented as well.

Among the macroscopic remains in zone III at Roundstone Jessen recorded *Salix herbacea*, *Carex* sp., *Potamogeton natans*, *Batrachium* sp. and *Viola palustris*, as well as the mosses *Drepanocladus exannulatus*, *Polytrichum juniperinum* and *Rhacomitrium lanuginosum*.

Elsewhere in Ireland in this zone remnants have been found of *Betula nana*, *Dryas octopetala*, *Artemisia* sp., Caryophyllaceae, *Thalictrum alpinum*, *Saxifraga hypnoides*, *Polygonum viviparum*, *Koenigia islandica*, *Sedum rosea*, *Armeria vulgaris*, *Oxyria digyna*, *Arenaria ciliata* and *Selaginella selaginoides* (JESSEN 1949, WATTS 1977).

Although the oceanic influences continued, this period was colder than the preceding one. Clusters of birches held their own in more or less sheltered places. Tundralike vegetation spread again, in Connemara especially *Empetrum* heaths with *Salix herbacea* and probably also *Betula nana*. In the lakes impoverished waterplant communities rich in *Myriophyllum alterniflorum* held out against the climatic conditions.

#### 4.4. The Postglacial Birch Period

Zone IV of JESSEN (1949) and MITCHELL (1956), Pre-Boreal, 10200–8800 years before the present.

This period is represented in the profiles Roundstone I 6 and II 11. According to SMITH (1970) and WATTS (1977) modern diagrams of other places in Ireland show that early in the Pre-Boreal Period *Juniperus* expanded and reached a maximum. The Roundstone diagrams of Jessen show an increase of *Betula* and *Salix* and a decrease of the non-tree-pollen. In particular the representation of *Empetrum nigrum* decreases. On the other hand pollen of the *Erica* type is present for the first time, while the pollen of *Calluna vulgaris* appears just before the end of the period. The representation of the ferns (*Polypodium vulgare* and *Dryopteris* sp.) locally decreases; elsewhere it remains stable.

In the sediments in question the macroscopic remains of *Betula pubescens* reappear, proving that the tree birches recolonised the region. Further, Jessen reports the presence of macroscopic remains of *Salix herbacea* (for the last time), *Eleocharis multicaulis*, *Menyanthes trifoliata*, *Nymphaea alba*, *Myriophyllum alterniflorum* and *Potamogeton natans*. From finds elsewhere in Ireland maxima for *Filipendula* and *Littorella* are reported (SMITH 1970), just as the first appearance of *Prunus padus*, *Sparganium angustifolium* and *Cladium mariscus* (rapid rise of temperature!). Also remains of *Populus tremula*, *Salix caprea* and *Salix cinerea* were found. In the open water *Ceratophyllum demersum* appeared (MITCHELL 1951, SMITH 1970).

In Connemara, birch and willow woods, probably preceded by a *Juniperus* zone, have gradually spread over the landscape in the Pre-boreal Period. At the beginning many open terrains remained free for *Empetrum* heaths and some *Salix herbacea* overgrowth, but the area of these late glacial relic communities decreased markedly. In pools and ponds a richly variegated water vegetation could settle once more.

All indications point to rapidly rising temperatures. The trees could not advance to the north as fast as the temperatures allowed them, but the herbs, especially the water plants, could and did spread quickly over the landscape. The tundra character of the vegetation soon disappeared.

#### 4.5. The Hazel-Birch Period

Zone V of Jessen and Mitchell, Early Boreal, 8800–ca. 8300 years before the present.

In addition to both Roundstone profiles this period is represented in the Dolan profile as well. While in this zone the non-tree-pollen decreases and *Betula* somewhat enlarges its influence, the pollen of *Corylus avellana* appears in the picture. *Empetrum nigrum* decreases markedly, while *Calluna vulgaris* spreads rapidly, especially in the Dolan region. In the Dolan profile pollen grains have been found of *Artemisia* sp., Campanulaceae, Compositae liguliflorae, *Plantago major/media*, *Rumex acetosa/acetosella*, *Empetrum nigrum*, *Lonicera periclymenum*, *Spergula arvensis* and *Thalictrum* sp.; relatively numerous are the grains of *Plantago maritima*. The Cyperaceae decrease and *Myriophyllum alterniflorum* disappears. The pollen of *Filipendula* sp. (almost certainly *F. ulmaria*, in view of the soil conditions), *Typha angustifolia*, *Cladium mariscus* and *Nymphaea alba* is still found, as well as spores of *Lycopodium selago* and *Isoetes* sp. Whereas in the Roundstone profiles fern spores are rarely found, in the Dolan area *Polygonum vulgare* and *Dryopteris* sp. are still moderately represented. Notable are the high percentages of *Sphagnum* sp. in the last mentioned area (comparison with the Roundstone profiles is impossible as Jessen does not mention Sphagna in his diagrams). Moreover in this zone spores can be found which presumably originate from *Osmunda regalis*.

In the Roundstone profiles Jessen further found macroscopic remains of *Betula pubescens*, *Betula alba*, *Populus tremula*, *Juniperus communis*, *Empetrum nigrum*, *Calluna vulgaris*, *Erica cinerea*, *Erica tetralix*, *Cladium mariscus*, *Eleocharis multicaulis*, *Rhynchospora alba*, *Viola palustris*, *Nymphaea*



*alba*, *Naias flexilis*, *Potamogeton natans* and *P. polygonifolius*. At the same time in profile Roundstone II the remains of the mosses *Campyllum stellatum*, *Dicranum scoparium*, *Hypnum callichroum*, *Rhacomitrium lanuginosum* and *Sphagnum imbricatum* were recorded.

Elsewhere in Ireland the presence in this zone has been reported of *Cornus sanguinea*, *Crataegus monogyna*, *Naias marina* and *Osmunda regalis*, while the first macroscopic remains of *Pinus sylvestris* were found (JESSEN 1949, MITCHELL 1951, SMITH 1970).

Several species represented in this part of the profile make it clear that the climate in the Early Boreal Period was already nearly as warm as it is today. Only the limited spreading velocity of several trees prevented a quick adaptation of the forest composition.

In Connemara the forests developed gradually at the cost of the open communities of the dryer soils, among which were the last *Empetrum* heaths with some *Juniperus*. In the forests the birches formed the most important component; some willows and possibly some poplars also were present. Gradually *Corylus avellana* penetrated into these woods. In ponds and pools the eutrangent waterplant communities remained stable; only *Myriophyllum alterniflorum* declined, probably crowded out by other aquatic species. At the same time the palynological data make clear that some *Sphagnum* species had settled locally, indicating a beginning impoverishment of the biotope. *Calluna vulgaris* expanded and here and there the bell-heather appeared.

#### 4.6. The Hazel-Pine-Period

Zone VI of Jessen and Mitchell, Late Boreal, ca. 8300–7400 years before the present.

This period is represented in both Roundstone profiles and in the Dolan profile. In all these places the representation of *Corylus* in the fossil pollen increases quickly and already reaches a high maximum in the lower part of the zone. Consequently the *Betula* representation decreases and the non-tree-pollen falls back to low values. Meanwhile *Ulmus*, and very soon after that *Quercus* as well, appear. In the higher parts of zone VI *Corylus* gradually retreats, whereas *Ulmus* and *Quercus* extend their representation considerably. At the same time *Hedera helix* appears. The percentage of *Pinus* pollen increases to such a degree, that it must be accepted that the pine had made its entry in the landscape. The increase of the non-tree-pollen in this period is remarkable (mainly *Calluna vulgaris* and Gramineae). This time the presence of *Erica* sp. can be deduced not only from the macroscopic remains, but also from the pollen. The Sphagna extend their area vigorously, although with considerable oscillations. The first Droseraceae (*D. rotundifolia*, *D. anglica*) appear. At the top of the zone *Rhynchospora alba* is represented for the first time.

In the lower part of zone VI of the Dolan profile *Nymphaea alba* and *Potamogeton* sp. still reach rather high percentages, and *Isoetes* (probably *I. lacustris*) is still present. Shortly after that, however, these species disappear almost entirely and seem to be replaced by *Cladium mariscus* and other Cyperaceae. In addition to the pollen of *Filipendula* (*F. ulmaria*?) pollen of the *Potentilla* type appears (*Potentilla* sp., *Comarum palustre*?). Meanwhile the ferns have fallen to low values and include now, in addition to *Polypodium vulgare* and *Dryopteris* sp., also *Pteridium aquilinum*. Spores of the *Osmunda regalis* type continue to be represented.

In profile Roundstone I 6, mainly in the lowest part of this zone, Jessen found many rhizomes of *Cladium mariscus*. Towards the top of the zone *Phragmites australis* appeared as a peat builder here. In the *Phragmites* peat Jessen found spores of *Osmunda regalis* and *Sphagnum* sp. Moreover Jessen reported the pollen of *Succisa pratensis* (*Scabiosa succisa*). In zone VI of the profile Roundstone II, in which *Phragmites* had not yet reached the peat building stage, Jessen found the macroscopic remains of *Betula pubescens*, *Calluna vulgaris*, *Erica cinerea*, *E. tetralix*, *E. mackaiana*, *Eupatorium cannabinum*, *Leontodon autumnalis*, *Cladium mariscus*, *Myriophyllum alterniflorum*, *Naias flexilis*, *Nymphaea alba* and *Potamogeton polygonifolius*. Moreover remains of the moss *Hypnum callichroum* were

found. In zone VI of the Dolan profile, here and there, *Sphagnum* leaves were already present.

Elsewhere in Ireland in this zone the first *Alnus glutinosa*, *Ilex aquifolium*, *Taxus baccata*, *Viburnum opulus* and *Eriophorum vaginatum* have been reported (JESSEN 1949, MITCHELL 1951).

During the Late Boreal Period the climate most probably was warm and strongly oceanic. In Connemara the birch forests were replaced by thick *Corylus* forests, in which *Quercus*, *Ulmus* and *Pinus* were beginning to infiltrate. The ivy made its entrance in these woods and along the wood margins *Pteridium aquilinum* settled. At this time many lakes and ponds filled up with organic material and changed into reed and sedge fields and even *Sphagnum* bogs. As a consequence the 'pollen rain' once more became richer in nonarboreal pollen\*. In the remaining open waters mildly eutraphent to mesotraphent water plant communities remained, although their pollen production was low. The vegetation had adopted a mosaic-like pattern.

#### 4.7. The Alder-Elm-Oak-Pine-Period

Approximately zone VIIa of Jessen, zone VII of Mitchell, Atlantic Period, 7400–5000 years before the present.

This period is represented in both Roundstone profiles and in the Dolan profile. The *Corylus* pollen remains dominant in a constant or somewhat declining position. *Ulmus*, *Quercus* and *Pinus* expand their representation in the pollen or stabilize it. The pollen of *Fraxinus* appears in low quantities. *Betula* remains stable at modest percentages. At the bottom of the zone the pollen of *Alnus* appears and then expands its representation, not reaching, however, a dominating position. *Hedera helix* remains stable.

In the Dolan profile some isolated and high maxima for the pollen representation of the Compositae liguliflorae and the Campanulaceae (*Jasione/Wahlenbergia* type) have been recorded. Just under the top of the Atlantic zone of the Dolan profile a single large pollen grain of Gramineae type appears, resembling the pollen of primitive cereals; moreover some pollen grains of *Plantago lanceolata* and *P. coronopus* are present. This is in agreement with observations elsewhere in Ireland (MITCHELL 1956). The heath species do not show remarkable changes; *Calluna vulgaris* dominates and the *Erica* type continues to be represented. In the Dolan area the Cyperaceae seem to show a certain decrease, but thereafter they quickly recover. In the Atlantic zone *Cladium mariscus*, like many other more or less eutraphent water plants, disappears. The pollen of the *Potentilla/Comarum* type decreases rapidly; on the other hand *Hydrocharis morsus-ranae* makes its appearance and some *Potamogeton* is present.

The *Sphagnum* produce, at least in the Dolan area, considerably fewer spores (possibly as a consequence of wetter conditions); *Rhynchospora alba*, however, remains stable. *Narthecium ossifragum* appears explosively and reaches a high maximum, subsequently returning to moderate values.

In the Atlantic zone of profile Roundstone II Jessen found macroscopic remains of *Pinus sylvestris*, *Calluna vulgaris*, *Phragmites australis* (from now on the most important peat builder in profile II 11), *Eleocharis palustris*, *Menyanthes trifoliata*, *Nymphaea alba*, *Potamogeton polygonifolius*, *Erica tetralix*, *Erica cinerea*, *Erica mackaiana* and *Oxycoccus palustris* (*quadripetalus*), and also of the mosses *Campyllum stellatum*, *Scorpidium scorpioides*, *Sphagnum imbricatum* and *S. palustre*. Moreover for the first time *Eriocaulon septangulare* was recorded.

Elsewhere in Ireland *Eriophorum angustifolium* was reported for the first time (MITCHELL 1951).

\* The increase of the *Calluna* pollen can better be explained by the expansion of *Calluna* on temporarily dissicated *Sphagnum* peats than by a heath undergrowth in the surrounding forests as Jessen supposes. Probably the grass pollen was mainly derived from the reed fields, but it is not out of question that a part of it came already from the grasses of the early *Sphagnum* communities.

The Atlantic Period is in Ireland the time in which the raised and blanket bogs began to develop (JESSEN 1949, MITCHELL 1965b, 1976). The appearance and expansion of *Oxycoccus palustris* and *Narthecium ossifragum* is most certainly connected with this; to a lesser degree the same can be said of *Rhynchospora alba* and *Erica tetralix* (which can grow on mineral soils as well), and of *Eriophorum angustifolium*, *Scirpus caespitosus*, *Molinia coerulea* and *Schoenus nigricans*, which were reported elsewhere in Ireland as appearing for the first time in this period.

The Irish climate in the Atlantic Period was warm and highly oceanic (moister than in the Boreal Period). In Connemara the woods developed the character of mixed deciduous forests (*Ulmus*, *Quercus*, *Corylus*, *Betula*, immigrating *Alnus* and *Fraxinus*\*) with some *Pinus*. Many lakes in the midst of the forest were filled up more and more by sedimentation of mud and organic material; consequently the plant communities of the very shallow waters and the peat soils could expand: the Potametea, especially the Hydrocharition (*Hydrocharis morsus-ranae*), the Littorelletea, especially the Littorellion uniflorae (*Potamogeton polygonifolius*), the Phragmitetea (*Phragmites australis*), the Parvocaricetea, especially the Caricion davallianae (Cyperaceae, *Campylium stellatum*, *Scorpidium scorpioides*), the Scheuchzerietea (*Rhynchospora alba*, *Eriophorum angustifolium*, *Molinia coerulea*) and the Oxycocco-Sphagnetea (*Narthecium ossifragum*, *Erica tetralix*, *Oxycoccus palustris*, *Eriophorum vaginatum*, *Scirpus caespitosus*, *Calluna vulgaris*, *Sphagnum imbricatum*). At the end of the Atlantic Period the Scheuchzerietea and Oxycocco-Sphagnetea began to expand over the near-by hill slopes; with this the first blanket bogs came into existence. Here and there the last remnants of the communities of the deeper and more or less eutrophic waters were still present (Nymphaeion with *Nymphaea alba*); *Menyanthus trifoliata* might have been present in open places in both Phragmitetea and Parvocaricetea and Scheuchzerietea.

At the end of the Atlantic Period primitive man made his first efforts to practise agriculture and cattle-breeding; cereals and herbs stimulated by human and cattle trampling (*Plantago lanceolata*, *P. coronopus*) appeared in the landscape.

#### 4.8. The Alder-Oak-Period

Approximatively zone VII b and VIII a of Jessen, the first part of zone VIII of MITCHELL (1956), 5000–2700 years before the present, Sub-Boreal Period (dating according to the northwest european continental chronological system; see section 3, last paragraph).

This period is represented in the profiles Roundstone I 2 and II 5 and in the Dolan profile. In the lower part of this zone a vigorous decline of the *Ulmus* representation can be recorded, immediately followed by a *Pinus* maximum. Especially in the Roundstone profiles the *Pinus* peak comes through saliently, but it is still clearly recognizable in the Dolan area. After this maximum the representation

\* The species involved here are probably *Ulmus glabra*, *Quercus petraea* and in a lesser degree *Quercus robur*, *Corylus avellana*, *Betula pubescens* and possibly also *Betula pendula*, *Alnus glutinosa* and *Fraxinus excelsior* (cf. TANSLEY 1949, CLAPHAM et al. 1962, MOORE 1967).

of *Pinus* falls quickly at first, and then more gradually; towards the middle of the Sub-Boreal Period a value of nearly zero is reached (some authors place the end of the Sub-Boreal Period here).

After the *Ulmus* minimum a certain recovery of the elm takes place, but subsequently a steady decline can be observed. The representation of *Quercus*, high in the beginning, shows a decreasing trend as well. *Corylus* and *Betula* remain stable, the former on a considerably higher level than the latter. The alder extends its influence until about the middle of the Sub-Boreal Period; a gradual decline follows. After a slight expansion *Fraxinus* establishes itself at a modest level. Incidentally, the pollen of *Fagus sylvatica* appears, most certainly brought in by long distance transport (in that time the beech expanded on the near-by European continent and penetrated into southeast England). In very modest quantities pollen of *Ilex aquifolium* was observed in profile Roundstone II 5. It is not until this time that *Hedera helix* appears in this profile.

In the Sub-Boreal Period the non-arboreal-pollen shows a distinct increase. The Gramineae expand. In the Dolan profile *Plantago lanceolata* appears once more after having been suppressed temporarily by the *Pinus* maximum; now it expands considerably, along with *Plantago coronopus*. Occasionally the pollen of *Plantago maritima* is present. In the profiles Roundstone II 5 and I 2 *Plantago lanceolata* does not appear until after the *Pinus* maximum. In the Sub-Boreal zone the pollen of *Artemisia* sp. appears for the first time, as well as that of *Rumex* (*R. acetosa*, *R. acetosella*) and *Urtica* (*U. dioica*, *U. urens*). *Pteridium aquilinum* extends its representation substantially. The pollen of Cerealia is still barely present; just before the top of the zone some pollen of the *Hordeum* type can be found.

The Cyperaceae are well represented. They show an erratic course with high peaks; particularly in the Dolan profile an expanding trend is noticeable. Incidentally some pollen of *Cladium mariscus* is present. The pollen of *Hydrocharis morsus-ranae* and *Potamogeton* sp. maintains its modest to low representation.

On the other hand the Ericaceae (mainly *Calluna vulgaris*, but *Erica* sp. as well), just as the Sphagna, show considerable expansion. *Rhynchospora alba* expands its representation and reaches high percentages. *Drosera rotundifolia* and *D. intermedia* appear once more. The representation of *Narthecium ossifragum* is increasing and reaches a second peak just below the top of the zone. Both in the Dolan profile and in the profiles Roundstone I 2 and II 5 *Myrica gale* appears in the Sub-Boreal section. Near the top of the zone in the Dolan profile there is an isolated low peak of *Pinguicula vulgaris*.

In profile Roundstone I 6 Jessen found *Pinus* stumps at about the depth in the profile where he recorded the maximum of the *Pinus* pollen. In profile II 5, however, no macroscopic remains of *Pinus* could be located. Jessen could establish that in profile Roundstone II 5 *Phragmites australis* took on the role of the most important peat builder during the Sub-Boreal Period; moreover the peat sediments from this time contain many *Sphagnum* remains and locally rhizomes of *Cladium mariscus* are present. Further Jessen found macroscopic remains of *Potamogeton polygonifolius*, *Menyanthes trifoliata*, *Schoenus nigricans*, *Molinia coerulea* and *Myrica gale*. In the Dolan profile here and there some *Sphagnum* leaves are present in the Sub-Boreal zone.

Elsewhere in Ireland the first remains of *Prunella vulgaris*, *Callitriche autumnalis* and *Blechnum* sp were reported (MITCHELL 1951).

The climate during the Sub-Boreal Period was still warm. There are indications that a part of this period was somewhat dryer. The short expansion of *Pinus sylvestris* could be connected with this. However, the possibility that the initial influence of man on the forests temporarily stimulated expansion of pine is not to be excluded.

In the Sub-Boreal Period the forest area in Connemara diminished gradually, partly due to clearance by neolithic and bronze age man, but more so as a result of the expansion of the soligenous and ombrogenous bogs; the former factor possibly has stimulated the latter (decreasing evaporation leads to increasing humidity and to a declining trophic degree). Mainly the elm, and later on the oak

as well, lost ground. The pine completely disappeared from the scene (this event can be placed at about 4200 B.P., at least in central Ireland; MITCHELL 1965a). In the moister forest zones the alder continued to spread, but only temporarily, as later on this tree had to concede ground as well. *Fraxinus* (*F. exelsior*?) consolidated its position; perhaps it was stimulated by man\*. Locally *Ilex aquifolium* in this period made its entry in Connemara (elsewhere in Ireland it appeared much earlier) and *Hedera helix* remained stable. As the area of the forest borders expanded, *Corylus avellana* and especially *Pteridium aquilinum* showed an increase.

The increase of grass pollen could have had more than one cause: the expansion of the reed swamps, the increase in area of the ombrogenous bogs (*Molinia coerulea*) and the clearing of the forests by man. The increase of *Plantago* species (especially *Plantago lanceolata*) and of *Artemisia* sp., *Rumex (acetosa/acetosella)*, *Urtica (dioica/urens)* and *Pteridium aquilinum* reveals, that human influence surely was of importance; here it concerns the activities of neolithic and bronze age man, who most probably mainly bred cattle in these regions. MITCHELL (1965b) dates the significant rise of *Plantago lanceolata* and *Pteridium aquilinum* to about 3800 B.P., at the beginning of the Middle Bronze Age agricultural phase.

Again remnants of *Hydrocharis morsus-ranae*, *Menyanthes trifoliata*, *Phragmites australis*, *Cladium mariscus* and *Potamogeton polygonifolius* indicate the presence of mesotraphent shallow water and fen communities (Potametea, Phragmitetea, Parvocaricetea). During the Sub-Boreal Period the Scheuchzerietea and Oxycocco-Sphagnetea showed a vigorous expansion (*Rhynchospora alba*, *Drosera intermedia*, *Schoenus nigricans*, *Molinia coerulea*, *Drosera rotundifolia*, *Narthecium ossifragum*, *Calluna vulgaris* and *Erica* species). The ombrogenous bogs expanded, even partly over former human settlements and megalithic tombs (MITCHELL 1951).

The expansion of *Calluna vulgaris* may also be partly the result of the development of Nardo-Callunetea: the Nardetalia, arising on the mineral soils along the borders of the bogs, and perhaps the first Vaccinio-Genistetalia, coming into existence on the near-by dryer soils stimulated by cattle-grazing.

In this period *Myrica gale* penetrated the Parvocaricetea; in the same communities *Pinguicula vulgaris* can be found. There are insufficient indications for the presence of Franguletea (in which *Myrica gale* eventually can appear as well).

#### 4.9. The Alder-Birch-Oak-Period

Approximately zone VIII b of JESSEN (1949), upper part of zone VIII of MITCHELL (1956, 1965a, b), 2700–1700 years before the present, Early Sub-atlantic Period.

\* According to MITCHELL (1965b) and SMITH (1970) the ash expands more easily in a secondary forest. MOORE (1967), however, thinks that the post-Atlantic Irish ash woods belong to the Corylo-Fraxinetum, being no pioneer community, but a real locally vicariating climax forest in the place of the Fagetalia which came into existence on the continent at about the same time. The first important expansion of *Fraxinus* has been dated by <sup>14</sup>C-analysis between 4900 and 4200 B.P., during the neolithic farming period (MITCHELL 1965b).

This period is represented in profile Roundstone II 5 and in the Dolan profile. In the latter profile the spectra from 60 up to and including 100 cm beneath the surface come from an auxiliary profile at about 150 m distance (see section 3). The trend in the pollen flora, found in the Sub-Boreal parts of the profiles, continues in the early Sub-Atlantic parts: the non-arboreal pollen gradually increases at the expense of the tree pollen. *Ulmus* declines to very low values; *Quercus* decreases. On the other hand *Fraxinus* continues to expand somewhat. The remaining trees show a stationary state; *Corylus* continues to dominate, although with vigorous fluctuations. *Hedera helix* remains stable. Gramineae and Cyperaceae are increasing. *Plantago lanceolata* and *Rumex (acetosa/acetosella)* appear regularly.

The pollen of *Potamogeton* sp. disappears from the picture, followed by that of *Hydrocharis morsus-ranae*. In contrast *Myrica gale* and the Cyperaceae (*Rhynchospora alba* and *Cladium mariscus* not included) reach a maximum, after which, however, there is a substantial decline.

In both the Dolan and Roundstone profiles remains of *Sphagna* and *Molinia coerulea* are numerous from the bottom of the early Sub-Atlantic zone and upwards, indicating that these species were the most important peat-builders since early Sub-Atlantic times. Also in the early Sub-Atlantic peat sediments Jessen found some remains of *Schoenus nigricans*.

The climate of the Sub-Atlantic Period was less warm, wetter and probably more windy than it was in preceding periods. During the Early Sub-Atlantic Period (approximately coinciding with the Iron Age and the Roman Age on the continent, in isolated Ireland, however, covering the last phase of the Bronze Age and, after c. 300 B.C., the Iron Age; MITCHELL 1965a, b) the developments which could be observed in the Sub-Boreal Period continued: a fluctuating, but steadily increasing human influence on vegetation can be ascertained, as well as expansion of the bogs and a gradual decrease of the forest area. A short phase of re-expansion of the secondary woodland, including a last and faint *Ulmus* recovery and a rather high *Fraxinus* maximum, can be placed in the Irish Iron Age, about the beginning of the Christian era (MITCHELL 1965b, 1976). The disappearance of the last plants belonging to open water communities creates the impression that in the Dolan area either open water was no longer present or that the trophic degree of the remaining ponds and lakes had declined to such an extent that they hardly could support such communities any longer.

#### 4.10. The Herbs-Heather-Period

Approximately zone VIIIc of JESSEN (1949), zones IX and X of MITCHELL (1956), 1700–0 years before the present, Late Sub-Atlantic Period.

This period is represented in the Dolan profile. The non-tree-pollen expands explosively and reaches 95% of the pollen sum. The pollen of the elm disappears and the representation of the other trees is reduced to minimal values. *Ilex aquifolium*, *Hedera helix* and *Polypodium vulgare* leave their last traces. *Pteridium aquilinum* remains stable, but declines substantially in the uppermost part of the profile.

On the other hand the Gramineae and the Ericaceae show a considerable increase. *Plantago lanceolata* expands vigorously, followed to a somewhat lesser degree by *Rumex*, *Artemisia*, *Urtica* and the Compositae liguliflorae and tubuliflorae. Pollen of the Cerealia now is clearly present, including *Secale cereale*. In the uppermost 10 cm of the profile the cereals reach their highest values; here *Chenopodiaceae* are represented also.

In the late Sub-Atlantic part of the profile the pollen of the *Potentilla/Comarum* type returns, reaching a maximum in the uppermost part of the profile. *Filipendula* (probably *F. ulmaria*) reappears. From now on pollen of Umbelliferae, Rubiaceae, Ranunculaceae and Cruciferae is present as well. *Myrica gale*, after having been reduced to low values, maintains its modest position. The Cyperaceae (*Rhynchospora alba* not included, *Cladium mariscus* having fallen under the palynologi-

cal perception level) show a considerable expansion followed by decline. *Rhynchospora alba* and *Narthecium ossifragum* maintain their positions with considerable fluctuations; in the uppermost part of the profile, however, their representation decreases. The *Sphagna* continue to extend their representation, except in the uppermost 10 cm of the profile. *Drosera intermedia* and *D. rotundifolia* remain stable to the end. *Calluna vulgaris* reaches a high representation, except in the uppermost 10 cm; the pollen of the *Erica* type remains stable at about the same level. *Lycopodium selago* now enters in the picture. Finally, in the uppermost 10 cm of the Dolan profile a clear increase of the *Pinus* and *Fagus* representation can be noted.

The macroscopic remains in the Dolan profile point to a *Sphagnum-Molinia* peat with many Cyperaceae.

Elsewhere in Ireland MITCHELL (1951) reported for this period the first presence of *Chenopodium album*, *Polygonum convolvulus* and *Polygonum persicaria*.

In the onset of the Late Sub-Atlantic Period, about 500 A.D., the great land clearance in Connemara began. The disappearance of the forests must be attributed nearly exclusively to human influence. The cause can be found in the fact that early in the 6th century numerous monasteries came to prosperity which developed intensive agricultural activities. The earliest written sources testify that Ireland had become an agrarian country as early as in the 7th and 8th century (MITCHELL 1956, MOODY & MARTIN 1967). As a result a distinct expansion of the synanthropic herbs can be noted: *Rumex acetosa* and/or *R. acetosella*, *Plantago lanceolata*, *P. coronopus*, *Urtica dioica* and/or *U. urens*, Chenopodiaceae, Cerealia, *Artemisia* (probably *A. vulgaris*) and to a certain degree also the other Compositae (CASE et al. 1969).

The sampling spot of the Dolan profile is situated in a rather extensive peat complex in which a prolonged process of peat building has taken place. There-

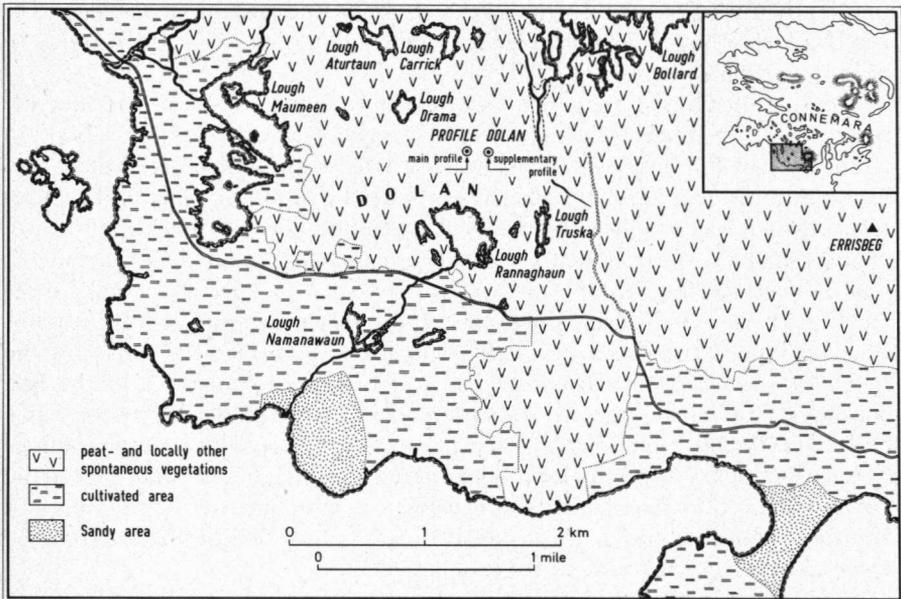


Fig. 4.

fore, for thousands of years natural causes have prevented forest development in this area. The bog cannot be used for agrarian purposes except for extensive grazing. Consequently, the disappearance of tree pollen in the late Sub-Atlantic part of the profile, and the appearance of pollen of culture-related herbs cannot otherwise than reflect events occurring at a greater distance. The position of this open vegetation with respect to the prevailing winds makes this quite possible: in the last one and a half millennium, the originally wooded zones where the vegetation was seriously disturbed by man were most probably situated where they are today, namely, in a strip of 1 to 1½ kilometre along the coast, southwest of the sampling spots of the Dolan profile, at a distance of 1 to 2 kilometres (*fig. 4*). Even today, although the population density has decreased substantially compared with the years before the Famine (1840–1850) one can find on this coastal strip *Plantago lanceolata* in the pastures, *Plantago coronopus* and *Artemisia vulgaris* along the paths, Chenopodiaceae in the potato-fields, *Urtica dioica*, *U. urens* and *Atriplex patula* in manured and otherwise enriched places, Compositae and Umbelliferae in arable lands, pastures and along roads, etc. Today the main cereal crop is oats which is used as food for horses; formerly rye was cultivated as well.

The increase of the pollen representation of Gramineae and Cruciferae and of *Filipendula* (*F. ulmaria*?) in the uppermost parts of the Dolan profile must be attributed largely to human influence. A part of the Cruciferae pollen could have been produced by food crop plants and pasture weeds (e.g. *Camelina sativa*, *Brassica* species, *Cardamine* species, *Capsella bursa-pastoris*), another part, however, could have been derived from the coastal communities (distance 2 to 3 km), as the former coastal forest belt had disappeared and the strong sea winds could transport the pollen far inland (*Cochlearia* species, *Cakile maritima*, *Raphanus maritimus*, etc.).

A part of the Gramineae pollen found in the youngest sediments undoubtedly was produced by the Scheuchzerietea and Oxycocco-Sphagnetea in the bog and by the near-by Phragmitetea (which were situated at the lake shores and along a brook at a distance of about 500 meters from the sampling place). The Cyperaceae pollen was produced by the local vegetation (*Eriophorum vaginatum*, *E. angustifolium*, *Scirpus caespitosus*, *Rhynchospora alba* etc.) and by Phragmitetea and Parvocaricetea growing nearby. The presence of *Myrica gale* points to the fact that Parvocaricetea were not far away; the presence of pollen of the Ranunculaceae type (*Ranunculus flammula*?) might confirm this. The pollen of the *Potentilla/Comarum* type (*Potentilla erecta*, *Comarum palustre*?), of the Rubiaceae type (*Galium palustre*, *G. hercynicum*?) and the hardly recognizable *Pedicularis* pollen (*Pedicularis palustris*, *P. sylvatica*?) could have been produced by both Parvocaricetea and Nardo-Callunetea in the neighbourhood. Indeed the presence of *Lycopodium selago* and *Calluna vulgaris* points to the proximity of Nardo-Callunetea though the *Calluna* pollen could also originate from the Oxycocco-Sphagnetea around the sampling spots.

The plant communities in the nearest surroundings of the Dolan sampling spots (Scheuchzerietea, Oxycocco-Sphagnetea) are represented by the pollen of

*Rhynchospora alba* (nowadays in the area this species reaches a mean cover percentage of 10%, rising locally to 25%), *Drosera intermedia*, *Molinia coerulea* (present cover 15 to 20%), *Narthecium ossifragum* (5%), *Drosera rotundifolia*, *Erica tetralix* (5 to 10%) and *Calluna vulgaris* (10 to 15%). Also part of the *Potentilla* type pollen might possibly come from this vegetation (*Potentilla erecta* in the drying peat hummocks). Finally, the *Sphagnum* spores can be considered to have been produced by these communities.

About 1600 A.D. the landscape in Connemara was practically treeless (MITCHELL 1965b). During the last two and a half centuries *Pinus sylvestris* and *Fagus sylvatica* have been planted in Ireland (MITCHELL 1951, 1956, 1965a; SMITH 1970). The influence of this on the composition of the pollen assemblages in the youngest sediments is noticeable even in the marginally situated, but palynologically very susceptible open landscape of Connemara (zone X of Mitchell).

#### 4.11. Vegetation development in Connemara since the Late Glacial Period

The abundance of the representatives of many plant families, genera and species in the palaeo-vegetation can be reconstructed from the quantities of their palynomorphs and macroscopic remains in successive sediment layers. In an effort to reproduce this development graphically for SW Connemara, we classified the taxa in question in seven groups (fig. 5):

1. typical late-glacial species (species no longer found at lower altitudes after the end of the Late-Glacial Period),
2. species from lakes and ponds,
3. species from the reed swamps,
4. species from the fens,
5. species from bogs and heaths,
6. species from woods and forests,
7. the heliophilous and synanthropic species.

We found that each of these groups had its own optimum period; moreover within each group certain developments were ascertained (fig. 5).

*Group 1) The late-glacial species.* These were limited to the Late-Glacial Period and to the outset of post-glacial times. The optimum fell in the Bølling/Allerød (Woodgrange) Period.

*Group 2) Species from lakes and ponds.* These appeared in the Bølling/Allerød Period and disappeared gradually in late Flandrian times. The optimum fell in the Younger *Salix herbacea* Period (mainly *Myriophyllum* communities) and in the Pre-Boreal and Boreal Periods. It mainly concerns the species of the Potamoetea, incidentally also the species of the Littorelletea, all of which belong to the communities of the eutrophic and especially mesotrophic waters of relatively little depth. The sequence of events within this group was influenced not only by the rising temperatures of the early Flandrian Period, but also – and mainly – by the declining trophic degree of the remaining open waters and the decreasing water depths. In late Flandrian times the remaining lakes had become too poor to support significant waterplant communities.



*Group 3) Species from the reed swamps.* These appeared in the early Flandrian Period and remained stable until recent times. The optimum occurred from the early Atlantic Period until early Sub-Atlantic times. It mainly concerns the species of the Phragmitetea; they belong to the communities of the eutrophic and especially mesotrophic very shallow waters. The succession of species within the group is influenced not only by the initial temperature increase, but also – and not in the last place – by the decrease of the water depth and the fall of the trophic degree. The latter as well as the encroachment of other peat communities finally led to a clear decline of the group as a whole.

*Group 4) Species from the fens.* Less sensitive to the temperature development than the species of the reed communities, the fen species appeared as early as the Bølling/Allerød Period. Some of these species have continued until recent times. The optimum of this group fell in the period from Boreal to late Sub-Boreal times. Here we are primarily concerned with the species of the Parvocaricetea; they belong to communities of comparatively eutrophic to mesotrophic marshy environments. The succession of species within the group, especially in advanced Flandrian times, was influenced by the declining trophic degree. The group as a whole gradually was crowded out by the bog communities; here again the impoverishment of the biotope played an important role.

*Group 5) Species from bogs and heaths.* The cold-resistant species of the moist heaths showed an optimum from the Older *Salix herbacea* Period to early Boreal times, after which most of them disappeared. In the Boreal Period bog communities made their first appearance, expanding their area until recent times. The optimum of these communities was in the Sub-Boreal and Sub-Atlantic Periods. A declining trend during the later development phases as shown by the previous groups, cannot be observed. Within this group we are mainly concerned with the species of the Scheuchzerietea and Oxycocco-Sphagneteta, to a lesser degree also those of the Nardo-Callunetea, which probably were present on the mineral soils in the border areas of the bog or were stimulated by cattle grazing on the near-by dryer terrains.

*Group 6) Species from woods and forests.* After tree birches in the Allerød Period had penetrated Connemara, where they formed more or less scattered clusters in the midst of the *Empetrum* heaths, real forests came into existence in the Pre-Boreal Period. The forest species had their optimum from late Boreal to late Sub-Boreal times. Their succession within the group was determined mainly by the rising temperature, the increasing humidity and the limited migration velocity of the species. The group as a whole was gradually crowded out by the expanding synanthropic and bog communities in late Flandrian times.

*Group 7) The heliophilous and synanthropic species.* Some of these species showed an increase in the early Flandrian Period when the temperatures already had reached higher levels, but when the density of the forests was still low. Subsequently these species vanished from the scene, returning accompanied by other species in the late Flandrian Period when man was clearing the forest. The optimum of this group therefore fell in late Sub-Atlantic times.

The developments described above are those which took place in regions some

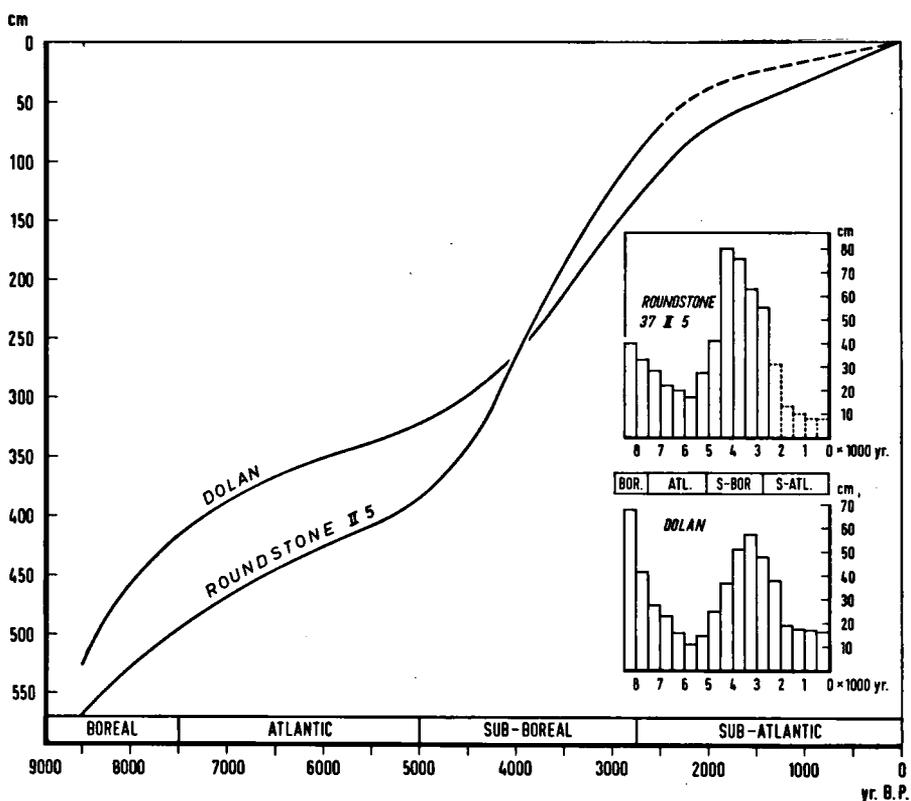


Fig. 6. Sedimentation rate at the sample locations Roundstone II 5 and Dolan.

distance from the coast. VAN GROENENDAEL et al. (1979) showed from the recent vegetation, that as a rule lakes and ponds on the coastal strip are enriched by eolian supply of mineral material (especially where chalk beaches occur) and consequently did not reach the oligotrophic stage.

### 5. The rate of peat development

From the chronological division of the profiles the sedimentation rate can be deduced approximately (no  $^{14}\text{C}$  data are currently available). Originally the Roundstone and Dolan sampling areas were occupied by open waters where detritus gyttjas were formed. During the Boreal Period organic production was high. Subsequently the annual production of organic sediment diminished in proportion to the decline of the trophic level of the lakes. The sedimentation rate reached a minimum at the end of the open water phase in late Atlantic times (fig. 6).

At the end of the Atlantic Period the fen communities reached the central parts of the lakes in question, approximately at the sampling spots (which were placed where the mineral subsoil was situated at maximal depth). This led to a consider-

able increase in the sedimentation rate. In consequence the organic production reached a new peak during the Sub-Boreal Period.

As the trophic degree continued to decline (under the influence of the abundant precipitation of the strongly marked oceanic climate) and the *Sphagnum* communities reached dominance in the vegetation, the sedimentation rate decreased once more during the late Sub-Boreal and Sub-Atlantic Periods. The impression of this decrease might be exaggerated somewhat by the shrinking of the upper peat layers, caused by the artificial draining of the bog in recent times: the turf pits were drained as much as possible in order to improve their accessibility which has led to a general lowering of the water level in the bog.

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