Geological outline of Ireland

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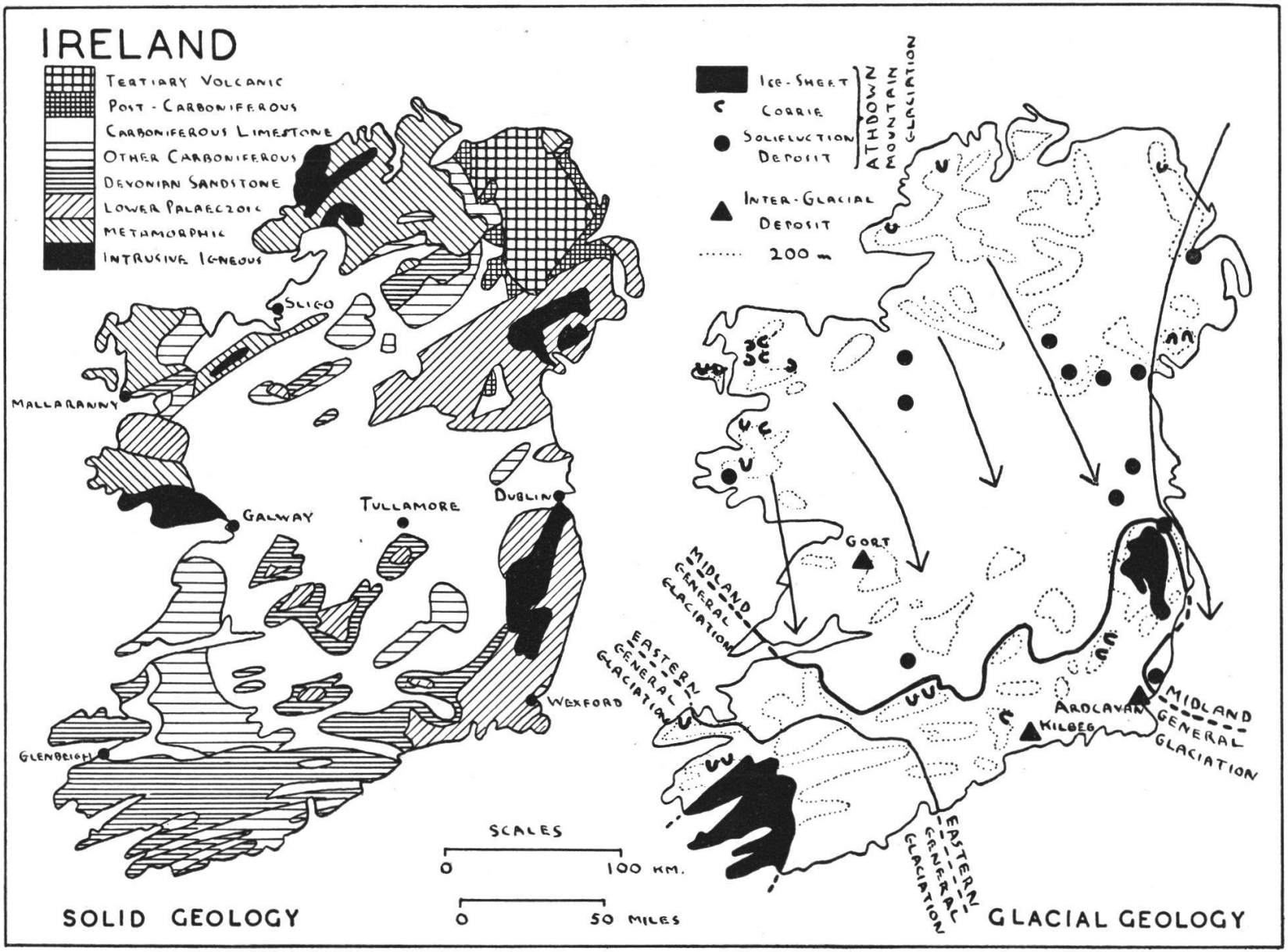
It is probable that the depression that now holds the stretch of water that separates Ireland from Great Britain has been in existence since the Pliocene period, and that Ireland has been either a peninsula or an island throughout most of late Tertiary and Quaternary time. To-day Ireland is an island roughly elliptical in outline with a longer axis (N.N.E — S.S.W.) of about 480 km and a shorter axis (W.N.W — E.S.E.) of about 300 km. It is on the whole a relatively low-lying country consisting of a central plain (which lacks a clearly-defined water-shed) surrounded by a marginal rim of higher ground. Only one mountain peak exceeds 1000 m in altitude and most of the country lies below 200 m.

The oldest rocks, metamorphic rocks of Pre-Cambrian age, quartzites, schists, gneisses and granites with here and there a few bands of crystalline limestone, are found along the north-west margin of the country. Later earth movements have folded and elevated these rocks but although slopes in places are steep and heights of 750 m are attained this region has very few alpine plants of interest. A corrie wall cut in schist on Slieve League in Donegal and the schistose cap of one of the Twelve Pins in Connemara alone carry fairly rich groups of alpine plants. As a region the north-west is characterised by extreme exposure and high precipitation, and where the ground is not covered by blanket bog the soil is either thin and acid or else entirely absent due to glacial scouring.

Ireland was submerged below the waters of the Lower Palaeozoic geosyncline and in this sea extensive marine deposits, chiefly of arenaceous and argillaceous nature, together with a limited amount of contemporary igneous lavas and ashes, were laid down. At the end of the Lower Palaeozoic Era Ireland was crushed by pressures moving from the north-west and the south-east, and both the Pre-Cambrian rocks and the Lower Palaeozoic deposits were folded into the ridges and troughs of the Caledo-


IRELAND
TERTIARY VOLCANIC
POST - CARBONIFEROUS
CARBONIFEROUS LIMESTONE
OTHER CARBONIFEROUS
DEVONIAN SANDSTONE
LOWER PALAEOZOIC
METAMORPHIC
INTRUSIVE IGNEOUS
SLIGO
MALLARANNY
GALWAY
TULLAMORE
DUBLIN
WEXFORD
GLENBEIGH
SCALES
0 100 KM.
0 50 MILES
SOLID GEOLOGY
ICE-SHEET
CORRIE
SOLIFLUCTION DEPOSIT
ATHDOWN MOUNTAIN GLACIATION
INTER-GLACIAL DEPOSIT
200 m
GORT
MIDLAND GENERAL GLACIATION
EASTERN GENERAL GLACIATION
ARDCAVAN
KILBEG
MIDLAND GENERAL GLACIATION
EASTERN GENERAL GLACIATION
GLACIAL GEOLOGY

nian mountain system running north-north-east and south-south-west. Into the heart of a large fold in south-east Ireland a great bathylith of granite was intruded, and thus the high ground of south-east Ireland as well as that of north-west Ireland owes its origin to this period of folding. The upland rocks of Lower Palaeozoic age on the whole yield clayey soils rather deficient in lime. The lowland rocks are often deeply covered by drift; where they are not so covered they yield a non-calcareous loam. The rounded slopes of the granite hills of south-east Ireland are largely covered by blanket-bog and only a very few alpine plants are found.

The Devonian period saw Ireland emergent above the seas, and under continental conditions extensive deposits of Old Red Sandstone were formed. At one locality in south-east Ireland a fresh-water lacustrine deposit has yielded remains of *Archaeopteris hibernica, Bothrodendron, Felicites, Lepidodendron* and *Sphenopteris.* In the Carboniferous period Ireland was again submerged below the sea and a typical sequence of deposits was laid down. At the base there is a sandstone and this is followed by a thick development of limestone reaching possibly a total depth of 900 m. In the extreme south of the country the limestone passes over laterally into shale or slate. Resting on the limestone are a further series of sandstones and shales. All these deposits are of Dinantian age and above them are Namurian sandstones and shales followed by Westphalian coal measures. At the end of the Carboniferous period Ireland was again affected by mountain-building pressures, this time acting from north and south. From the consequent folds that run east and west erosion has dissected out the mountain ranges of Armorican age that exist in the south-west of the country, where anticlinal ridges of Devonian sandstone separate synclines in which remnants of Carboniferous deposits are preserved.

Since the end of the Carboniferous period it is probable that Ireland has been flooded by the sea only to a limited extent at limited times, and as a result denudation of the uplifted Carboniferous rocks, which probably originally covered the entire country, has been very severe. In the north-west the same denudation has further removed the Lower Palaeozoic rocks to expose the basal Pre-Cambrian strata. The Upper Carboniferous rocks survive only

in limited areas giving uplands covered by blanket-bog or acid soils. The main limestone is exposed over most of the central plain and the other low-lying parts of the country. On the lowlands the solid rock is often deeply covered by drift in which limestone debris is abundant. Where the amount of clay in the drift is high clayey soils are produced; elsewhere both on the porous limestone drift, and on the limestone itself calcareous loams are formed. Towards the south of the central plain the crests of the anticlines of older rock produced by the Armorican folding project up through the limestone; from the mountainous rim of Ireland the Carboniferous deposits have been almost completely removed by denudation.

On the south shore of Galway Bay a karst-country of bare limestone rises from sea-level to over 300 m. This is the Burren, famous for its mixed assemblage of northern and southern plants. Near Sligo the limestone is capped by cherty shales which form cliffs with narrow ledges at about 400 m. This is Annacoona, where the richest group of alpine plants growing in Ireland today is found.

Except for one small area about 75 km north-west of Dublin post-Carboniferous rocks are confined to the north-east of Ireland. The Permian, Triassic and Jurassic periods are represented by scattered out-crops with no great thickness of deposit, but in the extreme north-east an extensive area of Cretaceous (Senonian) chalk with a thickness of about 30 m lies buried below later basalt. The surface of the chalk had been deeply weathered before there were in Eocene time in Ireland, as well as in Scotland and in Iceland, extensive outflows of lava reaching in places a total depth of about 100 m. The outflow of basalt appears to have continued over a long period, and under tropical conditions the surfaces of earlier flows were weathered to bauxite and laterite. Plant fossils accumulated in small ponds on the weathering surfaces and these were preserved beneath later flows. After flow had ceased an area of subsidence at the south end of the volcanic region was partly filled by clays in early Tertiary time. Modern Lough Neagh occupies part of this depression at the present day. Plant fossils also occur in these clays, which are 400 m thick. These plant fossils must derive from the circumpolar flora of the early Tertiary because among the trees present in the

clays and the inter-basaltic beds are *Platanus, Sequoia, Libocedrus, Podocarpus, Dewalquea, Ostrya* and *Pittosporum. Cupressus* occurs in the inter-basaltic beds only, and *Ginkgo*, very common in the corresponding beds in Scotland, is unknown in Ireland. To-day the lavas form a plateau of modest elevation on which there is an extensive development of bog; the edges of the plateau are cliffed in places and where drainage is good and peat formation impossible, groups of alpine plants are to be found.

At the time that these lavas were being poured out in the north-east intrusive rocks were injected a little further south. The Mourne mountains are a granite bathylith belonging to this period, while immediately to the south-west gabbro occurs. These intrusions of plutonic rock which form the youngest of the Irish hills are almost devoid of alpine plants.

It is to the existence of the lava flows that the Permian and Mesozoic rocks in the north-east of Ireland owe their preservation from denudation. The extent to which Mesozoic rocks may formerly have existed in other parts of Ireland is still a matter of debate. Dissected peneplains and terraces undoubtedly exist in a number of parts of Ireland but study of these is still only in its infancy and it is impossible to say anything about their age. There are many curious features about the river systems which drain the central plain, and it has been suggested that these rivers were initiated on a now vanished series of rocks and that their present courses have been superimposed on the underlying older rocks.

In the absence of fossiliferous deposits nothing is known of the flora or fauna of Ireland during the later Tertiary era. During the ice age the basin of the modern Irish Sea was filled with ice on more than one occasion. Ice that had crossed the sea floor occasionally mounted on to the surrounding coasts and deposited shelly materials. One locality not far south of Dublin has yielded a number of well preserved molluscan shells and these include *Voluta lamberti, Nassa reticosa, Nucella tetragona, Ocenebra tortuosa, Natica multipunctata* and *Cardita senilis*, all forms typical of the Red Crag, a Pliocene deposit of East Anglia. Thus there is reason to believe (as mentioned above) that the channel between Ireland and England has been occupied, at least intermittently, by sea water since the Pliocene period.

Very little is known of the early stages of the Pleistocene period in Ireland. The plains of western Europe were the home of many large Pleistocene mammals and of the palaeolithic hunters who preyed on them. Towards the north-west the plains ended at the scarp of older rock that separates the Mesozoic lowlands of south-east Britain from the Palaeozoic and older rocks of the highlands to the north and west. Palaeolithic man did not pass this boundary, and of the mammals whose modern distribution is southern only the Spotted Hyaena *(Hyaena crocuta)* made its way into Ireland, where its remains have been found in one cave only. All the other Pleistocene mammals of Ireland were northern forms. A plant deposit is known at Gort in western Ireland and this is now being studied by Professor Jessen and Dr. Farrington. Geological evidence suggests that this deposit must belong to an early stage of the Pleistocene period and among the plant remains Professor Jessen has noted *Abies alba*, *Picea abies* and *Rhododendron ponticum*.

Along the eastern half of the south coast of Ireland there is a wave-cut rock platform with overlying unfossiliferous beach deposits about 3 m above modern sea-level. This shore-line is older than any known Irish glacial deposit, though the boulders in the beach do include rocks of distant origin. Similar shore-lines can be traced along the south coast of England and round the Bristol Channel into Wales, along the north coast of France from Calais to Brittany, and in Yorkshire at Sewerby. While it would be imprudent to claim that because these shore-lines lie at about the same height above modern sea-level they must all be contemporaneous their detailed examination should give much information about the history of the Pleistocene period. It is possible that the beach and shoreline in Ireland belong to the Great or Mindel-Riss Interglacial period.

At a few localities near Wexford this beach is directly overlain by a deposit of glacial origin largely composed of local materials. The relations of this deposit have not yet been adequately studied but it may be the equivalent of the Enniskerry Mountain Glaciation which Dr. Farrington has recorded not far south of Dublin. Resting on this deposit in Wexford and clearly younger than it is a boulder clay which is characteristically tough in texture, dark in colour, and without many stones. It is always

calcareous and a high proportion of the stones that do occur are of well rounded and striated limestone. Such a boulder clay is the typical deposit of the Eastern General Glaciation, the earliest important glaciation of Ireland which has yet been recorded. This ice had its origin in north-west Ireland and in Scotland, and Scottish ice swept down the Irish Sea along the east and south coast of Ireland carrying Scottish erratics (including Ailsa Craig micro-granite) almost as far as Cork. A similar boulder clay is also found on the west coast of Wales. It is probable that the extreme south-west of Ireland was not covered by the ice of this general glaciation whose limit is indicated on the map.

After the main advance of the Eastern General Glaciation local ice-caps again became important giving rise in south-eastern Ireland to the Brittas Mountain Glaciation and in south-western Ireland to the Greater Cork-Kerry Glaciation. In this glaciation ice-caps appear to have formed on the higher ground in the south and moving outwards to have covered the lower ground with a rubbly drift essentially composed of local material. This drift is best seen in the south of Ireland where it lies beyond the end-moraine of the later general glaciation; in many places the drifts of this Brittas Mountain Glaciation rest on the drifts of the Eastern General Glaciation. While similar ice-caps of local origin probably existed in the north of the country also it is at present impossible to be positive about this, nor do we know the extent to which the country as a whole was covered by ice at this time. Consequently no indication of the extent of this glaciation is given on the map. Dr. Farrington is of the opinion that areas of high ground lying between the Brittas and the Greater Cork-Kerry centres were not covered by the ice of the Brittas Mountain Glaciation, and further that there may be in the south of Ireland limited areas which due to chance features of relief were never covered by ice at any time. On the west coast of Wales a rubbly drift essentially of local origin similarly overlies the calcareous boulder clay of the earlier Irish Sea ice. This tripartite glaciation probably corresponds to the Riss Glaciation of the Alps.

A plant deposit at Kilbeg in south-east Ireland may be provisionally assigned to the Mindel/Riss Interglacial period. Here below 10 m of drift of local origin a deposit of peat 2 m thick

was found, containing macroscopic remains of *Abies, Betula, Pinus* and *Taxus.*

At Ardcavan, near Wexford, Dr. Farrington discovered a much altered fresh-water deposit resting on the drift of the Brittas Mountain Glaciation and covered by a heavy solifluction deposit. The fresh-water deposit recorded a change from arctic to temperate conditions and while most plant debris other than pollen was unidentifiable pollens of *Alnus, Betula, Corylus, Pinus, Quercus, Salix* and *Ulmus* were present in quantity. There was no pollen of *Abies* or *Picea.*

As the Southern Irish End-Moraine that marks the southern limit of the advance of the ice of the Midland General Glaciation (shown by a heavy line on the map) lies only a few kilometres north of Ardcavan, the heavy solifluction deposit overlying the temperate mud is almost certainly contemporaneous with the advance of this ice. Indeed the gentle slopes of the surfaces of the drifts of the Eastern General Glaciation and of the Brittas Mountain Glaciation are probably largely due to the severe frost action that must have accompanied the advance of the later ice. The subdued topography of these older drifts is in marked contrast to the fresh topography of the younger drift of the Midland General Glaciation, and the Southern Irish End-Moraine must be the equivalent of the line of moraine in Jutland that separates subdued topography to the south and west from fresh topography to the north and east. Broadly speaking the Midland General Glaciation is the equivalent of the Würm Glaciation of the Alps. It may be noted here that frost cracks, stone stripes and stone polygons are almost unknown in Ireland.

During the Midland General Glaciation ice again formed in the west and north of Ireland and in Scotland and moved south across the Irish midlands and down the Irish Sea. During its retreat it left the central plain encumbered with drumlins, moraines and esker ridges which surrounded many basins and generally impeded the drainage. The beginning of the retreat of this ice initiated the late-glacial period and is contemporaneous with the beginning of the Gothiglacial phase in Scandinavia. At first severe conditions prevailed and stone-free clays were laid down in many lake-basins while the plant cover was still incomplete. During this phase (Zone I) Professor Jessen considers that Ireland was

covered by an open tundra vegetation of a limited number of species including *Salix herbacea* and *Empetrum nigrum.*

With a continued amelioration of climate the plant cover became almost continuous and an organic mud with temperate fossils accumulated. This phase (Zone II of Jessen) is certainly contemporaneous with the Alleröd phase of northern Europe and at this time Ireland was an oceanic sector of the sub-arctic *Betula*-region of north-west Europe. There were copses of *Betula pubescens* and stretches of open country which in the west were covered by heaths rich in *Empetrum* and elsewhere by a vegetation of grasses and herbs whose character cannot be closely defined. *Betula nana* (not found in Ireland to-day) was present at this time, and fossil finds of the pollen of *Helianthemum* show that this genus was much more widely distributed than at the present day. *Rangifer tarandus* and *Cervus giganteus* were in north-west Europe at this time, and in Ireland the latter was extraordinarily abundant so that it is well named in English the Irish Giant Deer.

Just as in Scandinavia and in the Alps more severe conditions returned and ice formed once more. In Scandinavia the ice advanced as far as the Ra, the Mid-Swedish and the Salpausselkä moraines and in the Alps to the Gschnitz moraines. In Ireland a small ice-sheet formed on the mountains in south-east Ireland, the Athdown Mountain Glaciation, and it is probable that the Lesser Cork-Kerry Glaciation took place at the same time. The corries of the Irish mountains have been occupied by ice more than once, but the fresh moraines that lie in many of them probably date from this time. On the lowlands at the same time (Zone III of Jessen) the vegetation was clearly more northern in character than in the preceeding period, though oceanic influence was maintained. Tree-growth was still more restricted, though *Betula* copses may have survived in some sheltered localities. Solifluction was a common phenomenon and the country for the most part carried an open tundra-like vegetation with patches of sub-arctic heaths containing among other plants *Salix herbacea, Dryas octopetala* and *Betula nana* with in the west much *Empetrum nigrum.* The areas of ice, the corries and the solifluction deposits of this period are shown on the map. There is no doubt that the alpine plants found in Ireland to-day are survivors from this periods and that they have survived in localities where

absence of continuous soil cover has prevented a dense canopy of vegetation from overshadowing them and where steep slopes have prevented the formation of blanket-bog. Height above sea-level has little influence on survival.

When this ice began to fall back the Finiglacial phase opened and the post-glacial amelioration of climate began. At this time the main postglacial eustatic risce in sea-level had not yet begun and the level of the sea must have been rather low. What the level was is not easy to say, but such plants as *Corylus, Pinus, Quercus, Ulmus* and *Alnus,* and such animals as *Cervus elaphus* and *Sus scrofa* can hardly have entered Ireland except over dry land. To-day the shallowest part of the channel that separates Ireland from Great Britain lies between the north of Ireland and Scotland, and it is probable that the last severance took place in this vicinity early in the Boreal period. In Pre-Boreal time (Zone IV of J e s s e n) dry land may have stretched quite a long way down the floor of the modern Irish Sea.

It is clear that in Denmark and in Germany closed woodlands of *Betula* and *Pinus* existed even in late-glacial time. In western Europe, in southwest Norway, in Ireland, in western Britain and perhaps in western France *Pinus* did not appear until late Boreal time, and it is probable that it was the spread of *Corylus* early in the Boreal period that formed the first closed woodland in western Europe. Thus to the end of the Pre-Boreal period, by which time the climate had become warm enough for *Cladium mariscus* to enter Ireland, large stretches of open countryside survived in this country and perhaps throughout western Europe also.

Thus there was still opportunity in western Europe for plant migration at a rapid rate, a rate that was no longer possible in eastern regions where closed woodland was already long established. In the late Pre-Boreal period Lusitanian plants would still have had opportunity to spread up the western margin of Europe, a margin whose modern embayments had not yet been filled by the later eustatic rise in sea-level. When the westward advance of the forests met the eastward advance of the rising sea-level the Lusitanian fringe may have been cut up into the relict patches in which we find the plants to-day. T h u s t h e L u s i t a n i a n e l e m e n t s i n t h e I r i s h f l o r a m a y b e r e l i c t s n o t f r o m

the remoteness of pre-glacial or inter-glacial time but from the open landscape of western Europe in Pre-Boreal time. The later eustatic rise in sea-level must have severed Ireland from Britain early in the Boreal period and after that severance few plants or animals can have entered the country.

There is some molluscan evidence that the water temperature of the sea in north-east Ireland was rather warmer during the Atlantic period than it is at the present day, and indeed Dr. Praeger has been hailed by some as the discoverer of the climatic optimum because of his early studies of the Atlantic estuarine clays of Ireland. The submergence of the Irish coast reached its maximum at the end of the Atlantic period, and since then there has been isostatic recovery, perhaps interrupted by a small later submergence.

Since the beginning of the Sub-Boreal period the natural types of vegetation originally present in Ireland have tended to move towards a uniformity of reduced interest for a number of reasons. The climate on the whole became cooler and moister, and the areas covered by bog expanded markedly. With the first arrival of Neolithic farmers at the beginning of the Sub-Boreal period the attack on the native woodlands began, and this has gone on with ever increasing intensity until to-day Ireland is one of the most treeless countries of Europe. The few weeds and aliens that have been introduced by man have made little compensation for the progressive reduction of the variety and interest of the Irish flora.

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