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GRAPHIC REPRESENTATION OF POST-GLACIAL CHANGES OF LEVEL IN NORTH-EAST IRELAND

HALLAM L. MOVIUS, JR.

ABSTRACT. Excavations of a series of Mesolithic sites in North-East Ireland have provided a wealth of new data bearing on Postglacial changes in the mutual relations of land and sea along the County Antrim coast north of Belfast. With respect to two of these stations—Cushendun and Larne—graphs have been constructed showing deposition with reference to time since the beginning of the Boreal climatic phase. On these graphs the horizontal coordinate represents the Postglacial sequence as established by pollen analysis, and the curves are tied in with this time scale on the basis of paleobotanical evidence. The vertical coordinate, or datum, represents contemporary sea level. The variability of the latter, which for purposes of the present study has been assumed to have been constant throughout Postglacial time, is discussed. The ecological conditions pertaining at the time of deposition have been established for the various horizons, as the result of detailed studies of the contained invertebrate faunas and the petrology of the sediments. On this basis the position of each with respect to datum has been plotted. The graphs thus constructed make possible the expression of a reasonably accurate curve showing the changes that have taken place in land level with relation to the sea at the localities in question. For the first time these permit detailed comparison of the movements that have taken place between the localities under consideration, as well as differences in the rate of accumulation. As the result of this study two significant facts have emerged: (a) In dealing with marine deposits of a soft and porous nature allowance must be made for the factor of compaction, which has had a negative effect on the intrinsic rate and amount of movement during the emergence. (b) Local differential crustal movements resulting from local faulting, apparently of variable amplitude, must be reckoned with in addition to the complex interaction of isostatic and eustatic factors. It is believed that ultimately it will be

INTRODUCTION

BETWEEN 1932 and 1936 the Harvard Archaeological Expedition to Ireland, which was sponsored by the Division of Anthropology at Harvard University, spent five field seasons excavating prehistoric sites in both Eire and Northern Ireland. The director of this expedition, Dr. Hugh Hencken, conducted the investigations of sites of the Neolithic and later

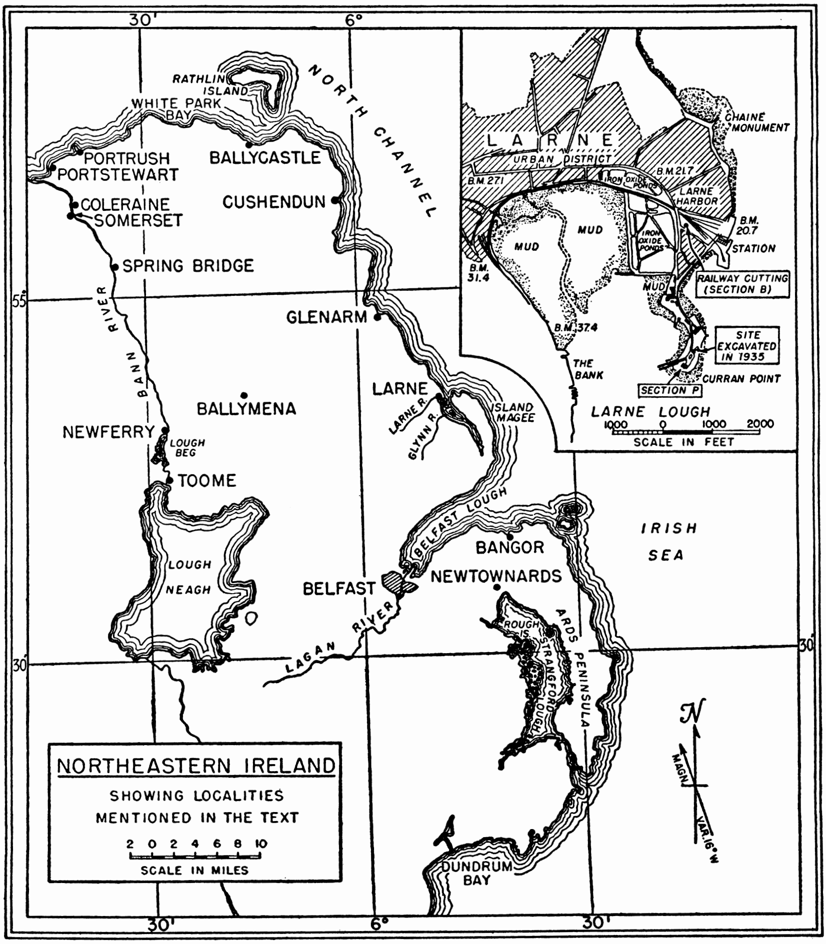

Fig. 1. Map of sites in northeastern Ireland.

periods; excavations at the Mesolithic localities were all in charge of the writer, who served as assistant director of the

possible to resolve the movements in question into their component parts, but only when a series of such graphs as those presented in this paper are available for a wide range of localities, not only in North-East Ireland but also in other parts of northwestern Europe. On the basis of the measurements thus far computed for coastal localities in County Antrim, the figures for the various Postglacial movements may be summarized as follows: (a) Submergence = approximately 45 ft. (13.75m.). (b) Emergence = approximately 30 ft. (9.15 m.). (c) Recent sinking = approximately 5 ft. (1.52 m.).

expedition. A total of six Stone Age sites was investigated, and on the basis of the stratigraphic evidence secured at five of them, all in North-East Ireland—Cushendun, Glenarm, Larne, and Island Magee, all in County Antrim, and Rough Island, County Down (fig. 1)—the chronology of the Irish Stone Age has been established (Movius, 1942, p. 126-148). At only three of these localities, however, is the Postglacial sequence sufficiently well documented to provide a partially complete record of the relative movements—submergence followed by emergence and finally by a recent phase of slight sinking—affecting the mutual relations of land and sea in North-East Ireland during Late Boreal, Atlantic and Sub-Boreal times. These localities are Cushendun, Island Magee and Larne. The fluctuations in level revealed by a study of each of these sections may be graphically shown (compare figs. 3 and 4), but before discussing the mechanical method adopted for constructing the graphs or diagrams as a whole, a brief summary of the sequence of Postglacial geologic and climatologic events established for the coastal region of North-East Ireland (Movius, 1942, p. 82-100; 1953a, pt. 1) will be given.

Stage of Postglacial emergence.—When Early Postglacial conditions were finally established the land stood at a height of 120 feet (20 fathoms) higher than at present with respect to the sea. At this time a partially complete land bridge existed between Britain and Ireland, and peat beds, now submerged, were formed at Belfast, Island Magee, Cushendun, and elsewhere on the coast.

Stage of Postglacial submergence.—A stage of relative submergence ensued during the time represented by paleobotanical Sub-zones VIb, VIc and VIIa (Boreal and Atlantic) in Ireland, and the sea invaded the bays and estuaries of the northeastern coast as far as the present 25- to 30-foot contour line. By far the most extensive deposit referrable to this stage is the "Estuarine Clay," an analysis of the fauna from which reveals that actually several oscillations occurred in the movement. In addition, current-bedded and intertidal sediments consisting of gravel and sand were accumulated at some localities. These have been incorrectly referred to as "Raised Beaches"; they contain Mesolithic implements of the Larnian culture in secondary position. During the lower part of Sub-zone VIIa (Early Atlantic) the Postglacial climatic optimum was attained in North-East Ireland.

Second stage of emergence.—It has been established that the maximum of the submergence took place during the transition between paleobotanical Sub-zones VIIa and VIIb in Ireland and was followed by a movement of emergence. Indeed the paleobotanical evidence shows that "by far the greatest part of the transgression falls in Boreal time, only the latest stages of it are Atlantic, and the regression began with the opening of the Sub-Boreal Stage" (Jessen, 1949, p. 137). Storm beaches were now formed by wave action on top of the submarine gravel and sand banks that had accumulated during the previous stage. These contain rolled artifacts of Late Larnian affinities in profusion. As a result of the movement, which was relatively more advanced in the north than in the south, and which was of a negative character south of the O-isobase or fulcrum on a line between Counties Sligo and Wexford, the land rose some 5 feet above its present height with respect to sea level.

Slight recent submergence.—Since the beginning of the last century there appears to have been a slight submergence—possibly a result of a general rise in sea level—taking place. The amount of this recent submergence, which has led to severe and extensive erosion at some localities, has been estimated at 5 feet.

The essential facts concerning the above sequence of Post-glacial events in North-East Ireland have been known for over 50 years. Recent intensive investigations at several localities have provided detailed information bearing on the rate and magnitude of the relative movements of land and sea, as set forth in this paper.

METHOD OF STUDY

The graphs reproduced in this paper were plotted following a method partly based on that originally devised by Praeger for representing the changes of level that have occurred at Alexandra Dock, Belfast, and at Curran Point, Larne, as revealed by the classic sections studied by him during the period 1890-1904 (Praeger, with Coffey, 1904, p. 153-155 and pl. 5). But the wealth of new data now available makes it possible to introduce several refinements, as discussed below.

Horizontal scale.—The horizontal coordinate represents geological time and is subdivided into the recognized climatic phases that have taken place during the period in question. The actual dates are based on the correlations with Fennoscandia, discussed elsewhere (Movius, 1940c; 1942, pt. 1, chap. 3). However, since the time scale for the early periods has been deduced from studies of the varved clays in northern Europe and extended into the British Isles mainly through the media of geological, climatological and paleobotanical synchronisms, it must be pointed out that the figures themselves are subject to errors, which can be expected to become greater the further back in time they are extended.[1] For the later periods—from the middle

[1] Radiocarbon dates measured by Libby from samples of Allerød age (=Zone II in the paleobotanical sequence) in Germany, England and Ireland are consistent in indicating a figure of about 8850 B.C. for this horizon, and provide "the first substantial evidence for the matching of

of the third millenium B.C. onwards—the archeological record furnishes an ever-increasingly reliable check, so that by the fifth century B.C. the dates may be considered reasonably accurate. Also indicated with reference to this time scale is the paleobotanical zone sequence in Ireland established by Jessen (Jessen and Farrington, 1938, p. 250-256; Jessen, 1936, p. 31-37; 1940, p. 38-51; 1949, p. 104-107; see also Mitchell, 1951, p. 121-123). The time span covered by the Postglacial climatic optimum, as well as that of the maximum of the subsidence in Ireland, both worked out on the basis of the data from the excavated sites discussed below, are likewise plotted with reference to the horizontal coordinate. In this manner actual deposition is shown throughout with reference to a uniform time scale, the controlling factor being the age of several of the deposits in question, which has been determined by paleobotany, and the dating of the maximum of the transgression by the same means at three other localities—Somerset and the Bann Estuary, near Coleraine in County Londonderry, and Portrush in County Antrim—in Northern Ireland (Jessen, 1949, p. 125-135).[2] This method of adopting a standard horizontal scale throughout all the graphs makes it possible to compare the movements and deposition at two or more sites at any given point in time. It is patently obvious that the thickness of the deposits at a site cannot serve this purpose, since these vary tremendously as between any two given localities, depending not only on local conditions but also on the character of the sediments themselves. Although

stratigraphic columns across so great a distance" (Flint and Deevey, 1951, p. 266). For a discussion of the climate in Britain during the time of the Allerød Oscillation, see Manley, 1951, p. 52-54; 1952, p. 126.

[2] Mitchell (1951, p. 196-198) does not follow Jessen with regard to the point in the pollen diagrams from North-East Ireland marking the transition from Zone VI to Zone VII. On the basis of his system for zoning the diagrams for the localities at Spring Bridge (on the Bann River, Co. Antrim, 6¼ miles south of Somerset and *above* the limit of marine transgression (Jessen, 1949, p. 124-125), Somerset, and the Bann Estuary, Mitchell would place the maximum of the transgression a short distance above the transition from Zone VI to Zone VII. However, the detailed paleobotanical evidence put forward in support of this argument, which concerns the rational border for *Alnus*, lies outside the scope of this paper. Since Jessen's interpretation is convincingly supported by the data from Portrush (not discussed by Mitchell), the present writer cannot agree that that maximum of the Early Postglacial submergence occurred early in the Atlantic period.

at the archeological sites discussed in this paper the position of only five horizons (Cushendun: 3 and Island Magee: 2) can be plotted with respect to the horizontal scale, the graphs are considered to be fairly accurately tied in with the sequence of Postglacial climatic events as the latter are at present understood by paleobotanists.

Vertical scale and variables involved in relating deposits to datum.—As stated at the outset, the purpose of the graphs is to make possible the expression of a reasonably accurate curve showing the changes that have taken place in land level with relation to the sea, based on the data from the localities listed above. In order to achieve this, a point on the Early Postglacial land surface in the measured section is taken as the "O-Point," and this is moved through time and space, the deposits which accumulated above it being plotted to scale and with reference not only to the depth of water in which each is believed to have been laid down but also to their position with respect to the horizontal coordinate as determined by pollen analysis. The net result is the section as it exists at present at a given site, shown in relation to sea level. In the case of Curran Point, Larne, where the bottom of the deposits was not exposed at the site investigated by the Harvard Archaeological Expedition to Ireland, the curve is constructed on the basis of the lowest point reached during the 1935 excavation.[3] It should be made clear that in graphs of this type the movements of the *surface* of the ground do not correspond with the curve thus constructed, since, owing to the constant accumulation of sediments above the "O-Point," the surface of the vertical section has been continually rising. Since it is believed that the old land surface originally occurred at an undetermined altitude above the sea prior to the marine transgression, an arrow is shown projecting upwards from the left margin of the curve.

It is appreciated that the interactions of the factors determining eustatic and isostatic control of the mutual movements of land and sea are very complex (Wright, 1925; 1928; 1937, p. 333-387; Daly, 1934, chaps. 1 and 2; Charlesworth, 1930,

[3] For a preliminary statement of results see Movius, 1942, p. 132-136; the detailed excavation report is forthcoming in the *Proceedings of the Royal Irish Academy*. In the present paper the latter, which is due to appear in 1953, is referred to simply as the "Larne Report."

p. 364-378; Godwin, 1943, p. 208-211; Farrington, 1945; Zeuner, 1952, p. 40), and that in point of fact the graphs establish only the *relative* position of one of these levels—in this case that of the land—with respect to the other. Thus, although we are dealing with at least two variables, a constant sea level has been assumed. If, on the other hand, the level of the land is shown as constant and that of the sea fluctuat-

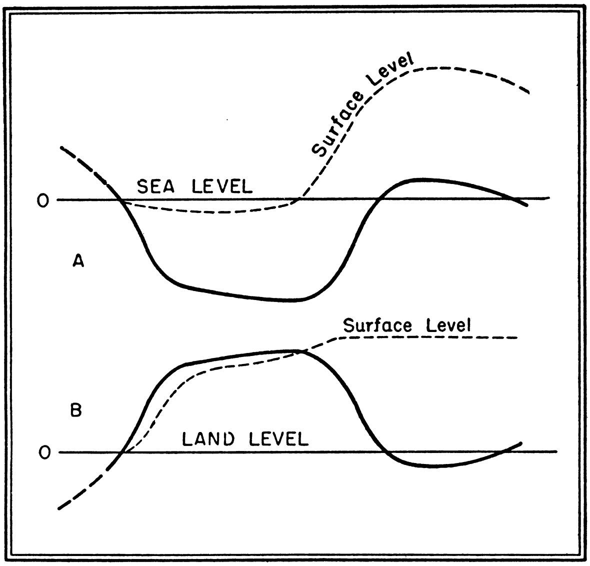

Fig. 2. Curves showing changes in mutual relations of land and sea.

A. Result obtained when it is assumed that the level of the sea has been constant and that of the land fluctuating.

B. If the level of the land is represented as having been constant and that of the sea fluctuating, the resulting curve is the reserve of that shown in A. (Compare Praeger, with Coffey, 1904, plate 5, figures 1 and 3.)

The dotted lines represent the *surface level* (i.e. the surface of the deposits) throughout the period in question. (Not to scale.)

ing, the resulting curve will be the reverse of that indicated on the graphs (fig. 2). It should be realized, however, that what appears on the graph as a slight relative sinking of the land is in all probability due to a rising of the sea. But the land was almost certainly moving too, as is indicated by the comparatively rapid submergence following the initial phases of the marine transgression. For the localities in North-East Ireland under consideration it is not proposed at this juncture to attempt to distinguish between relative movements of land and sea in absolute terms. It is believed that the establishment of a sufficiently large series of curves of the type shown in figure 3 from all parts of northwestern Europe, including the northern part of the British Isles,[4] will eventually provide the key to disentangling the relative movements of land and sea into their eustatic and isostatic components. At the moment our main concern is to compute the relative extent of the actual movements, rather than to attempt to resolve the parts played by the sea on the one hand, and the land on the other, into their respective roles.

The vertical coordinates on the graphs represent vertical measurements relative to ordinary high- and low-water level; mean sea level is shown by a dashed line. The relationship of the various deposits to datum is established in each case by the conditions prevailing when they were being accumulated. This evidence, which is discussed for each horizon at the various localities, has been provided by detailed studies of the marine fauna, the mechanical analysis of the sediments in question, and the paleobotanical data. Although the latter are mainly useful for providing the horizontal, i.e. chronological, control, as previously stated, they often furnish information that is of significance from an ecological point of view. But it must be emphasized that this method of tying in a given point or series of points in a section with reference to datum should *not* be regarded as absolute. Furthermore, datum itself cannot be considered as a constant.

Throughout this paper the heights given for the various Postglacial deposits with respect to sea level are based on the assumption that the local tide range has not altered materially since the beginning of Boreal times. But, as Godwin (1943, p. 204) has clearly stated, "this is an assumption not always easy to make on coasts where the growth or removal of spits and banks may easily alter the tide range by some feet." Indeed, since the tides along the coast of North-East Ireland are extremely variable at present, the probability is that this situation also prevailed in the past. In this connection, the present absolute height of high-water level with relation to O.D. (the

[4] For the southern half of Britain, as well as the North Sea region, a considerable amount of comparative data are available (Godwin, 1940a; 1941, p. 348-358; 1943; 1945), although these are not considered here in detail.

Ordnance Survey's Datum established in the last century as the level of low water of spring tides at Dublin) fluctuates along the coast in a manner which is by no means constant. At the localities under discussion, the figures for mean high-water level of ordinary summer tides are as follows: Cushendun, 3.07 m. (10 ft., 1 in.) above O.D.; Larne, 4.31 m. (14 ft., 1¼ in.) above O.D. Mean high-water level was computed at the time of the excavation during August-September of 1934 (Cushendun) and July-September of 1935 (Larne).

A second factor must likewise be considered. On the graphs (figs. 3 and 4) the coordinates representing high- and low-water level are shown as parallel; however, they may not have always been constant. This is especially true at the heads of deep bays or estuaries, where alterations in the volume of the tidal prism would change the range of variation between high and low tide by as much as a meter or so, depending on local conditions. In any case, owing to the rather scanty nature of such data as exist on this subject, it is impossible to compute the possible effect of this variable at any given locality.

Because of another factor, the difficulty of determining the exact figure for the maximum of the subsidence will be appreciated. For to fix the level at which the storm beach was formed in any given section with relation to the then-existing high-water level, it is necessary to allow for the action of storm waves. This factor, together with the extremely variable tides of the coast of North-East Ireland, clearly controls the height of a given "raised beach." Indeed, depending on local conditions, beach sediments could be terraced, either by aggradation or erosion, up to as much as 2.00 m. (6 or 7 ft.) *above* the ordinary high-tide level.

Throughout the present paper all figures referring to the probable amount of subsidence during the accumulation of a given layer, or the depth of water at the time it was laid down, are determined on the basis of ordinary high- or ordinary low-water level at the time of deposition. However, in view of the variables discussed above, it will be appreciated that accurate measurements of the amplitudes of the movement at any given locality are virtually impossible to compute, and that in comparing the figures at one site with those from another, a certain degree of allowance must be made for local factors influencing the height of the sea.

Finally, it should be stated that as the sea level itself has undergone a change since the end of Glacial times, all statements regarding depressions (sinking, submergence, etc.) and elevations (rising, emergence, etc.) of the land made in this paper are relative to present sea level. Thus, as a result of the fact that a considerable amount of water was still bound up in the form of ice inducing a general lowering of the level of the ocean, it is incorrect to assume that during the interval of the Early Postglacial emergence in the northern portion of the Irish Sea basin, (a) the land was 120 feet higher than it is today, or (b) that the sea was 20 fathoms shallower. In either case the net relative result would be essentially the same, but it cannot be too strongly emphasized that *both* factors were involved.

Effects of compaction.—Normally deposits of a soft and porous nature (peats, marls, silts and clays) have a high initial content of water. It is a well-recognized fact that when subjected to pressure, either as the result of accumulation in thickness or the superposition of coarser and heavier sediments, such deposits will suffer considerable compaction. This latter term, synonymous with "consolidation" in the geologic literature, is used here in preference to what Godwin (1943, p. 204) has referred to as "compression." In the case of certain marls and clays of the Great Lakes region of the United States, Twenhofel (1939, p. 532) states that some "are composed of as much as 70% water, and many fine-grained sediments contain more than 50%. Much of this water may be expected to be expelled, with a somewhat corresponding reduction in volume. The compaction due to crystallization and closer packing is also important, but is mostly overshadowed by that due to expulsion of water." In the case of North-East Ireland, however, the present data on peats, silts and clays of demonstrably Early Postglacial age are far too scanty to provide a basis for computing the actual degree of compaction which can be expected to have taken place since the time of formation. Although Skempton (1944, p. 124) has analyzed a sample of "Estuarine Clay" from Belfast, there is no way of knowing from what part of the section the sample in question was collected.

The first experimental work on compaction was published by Dr. Karl Terzaghi of the Harvard Engineering School in 1921 and 1923, who considered the practical aspects of the process from an engineering point of view, thus providing the basis for the new applied science known as soil mechanics (Terzaghi, K., 1925; Terzaghi, R., 1940; Skempton, 1944). According to Skempton (1944, p. 119), "the consolidation of an argillaceous sediment may be simply described as the process by which it is compressed from a mud into a clay and finally, if the weight of the overburden is sufficient, into a shale." Tests have demonstrated that the compactibility factor is greater in more colloidal clays than in sandy and silty materials. This is shown by the typical values of the liquid limit (or water content of a silt or clay at the point where the substance ceases to behave as a plastic material and becomes essentially a viscous fluid) of such sediments, which are: 30 to 40 for sandy clays and silts; 40 to 80 for normal clays; and over 100 for highly colloidal and organic clays (Skempton, 1944, p. 120). Whereas the data pertaining to the compaction suffered in nature by various types of silts and clays under the influence of increasing weight of the overlying deposits are still very meager, Skempton believes that they form "what may prove to be a basis for the systematic collection and correlation of other field observations on the natural compressibility of clays." Although the study of soil mechanics is still very much in its infancy, it is felt that at those localities under discussion where the sediments consist predominately of silts and clays the degree of compaction tends to offset substantially the figure for the amplitudes of the changes of level based on the exact measurements of the sections made at the time the sites in question were excavated. Therefore, if this factor is not taken into consideration in such cases, the extent of the uplift as revealed by the graph will be substantially less than the actual amount computed for an adjacent locality where the deposits are composed in the main of sands and gravels. But it seems apparent that the degree to which a given deposit has been compacted will vary depending on the thickness of the deposit in question, its composition, and the weight of the overlying sediments. In the discussion of the Larne section on p. 713-718, it will be demonstrated that the compaction factor has had a negative effect on the intrinsic rate and extent of the relative movement during the emergence.

THE LOCALITIES

Cushendun.—From a stratigraphical point of view perhaps the most complete record of Postglacial events in North-East

Ireland is revealed at this locality, which lies on the County Antrim coast some 22 miles due north of Larne (fig. 1). The site, first reported by Dwerryhouse (1923, p. 364-366) and investigated by Burchell (1931), was excavated by the Harvard Archaeological Expedition to Ireland in 1934 (Movius, 1940a). It is situated on the left bank of the Dun River approximately 150 yards west of the town of Cushendun, where the Postglacial terrace (*ca* +35 ft., O.D.) is well exposed.

In the excavation report on this site the stratigraphy of the Cushendun site is discussed in detail (Movius, 1940a, p. 24-34); it is as follows (fig. 3: upper):

(A)	Humus	(Horizon 4)	50 cm.
(B)	Upper gravel	(Horizon 3)	3.15 m.
(C)	Upper lagoon silt		77 cm.
(D)	Lower gravel	(Horizon 2)	3.58 m.
(E)	Lower lagoon silt	(Horizon 1)	46 cm.
(F)	Swamp peat		10 cm.
(G)	Resorted boulder clay		30 cm.
(H)	Laminated clay	} thickness undetermined	
(I)	Boulder clay		

Deposits G to I inclusive (resorted boulder clay, laminated clay, and boulder clay respectively) are omitted here, since they are not of direct concern with regard to constructing the graph showing the changes of level that have taken place here during Postglacial times. This graph has been plotted showing the surface of the swamp peat layer (deposit F) directly below point Ⓐ at the excavated site as the constant. This tightly compressed peat was formed on an old land surface which, on the basis of the evidence of the underlying resorted boulder clay, formerly stood well above the then-existing high-water level. Pollen analysis shows that it accumulated during Sub-zone VIb of the Late Boreal Period in Ireland (Jessen, 1949, p. 136) prior to the submergence; later it was transgressed by the sea, resulting in the deposition of marine and other sediments 8.46 m. (27 ft., 9 in.) thick above it. Therefore, if its position with respect to sea level can be determined from the time of its formation down to the present day, on the basis of the character and age of each succeeding deposit that was laid down on top of it, this evidence plotted to scale on a diagram should allow the final expression of a reasonably accurate curve presenting graphically the changes of level that have taken place at the Cushendun locality since the time the peat layer was transgressed by the sea. As stated above, for the purpose of plotting this graph the convention of a constant sea level throughout the entire period has been assumed.

Overlying the swamp peat, which is 10 cm. thick, a stratum of lagoon silt (deposit E) 46 cm. thick was encountered. The nature of the sediments comprising deposit E and the contained mollusca prove that it was accumulated in a tidal lagoon during an early stage of the submergence. The common species are *Littorina littorea* L., *L. littoralis* L., *Ostrea edulis* L., *Cardium edule* L., and *Paphia decussata* L., a southern form. Oyster shells were fairly plentiful in the lower part of the deposit where they occurred fresh and *in situ* with their valves still together adhering to large stones. According to Mrs. McMillan (1940, p. 37), broadly speaking, all these mollusks are littoral forms, and although the number of species is limited, the assemblage definitely indicates sheltered lagoonal conditions at the time this stratum was formed. Indeed a detailed study suggests that the lower part of deposit E accumulated at or just below low-water mark, since all the remains of oysters were found here. But the upper portion is more strictly littoral in character, as demonstrated by the abundance of *Littorina littorea*; it is almost certainly an intertidal deposit laid down in brackish water. Probably the lower lagoon silt represents slow sedimentation within a lagoon formed behind a protecting barrier. It has also been assigned to Sub-zone VIb in Ireland, although slightly later than the peat (Jessen, 1940, p. 42; 1949, p. 136), and the fauna definitely suggests that a climate slightly warmer than that of the present time obtained during the period of its deposition. Flint implements of Early Larnian type were found in this layer—archeological Horizon 1 at the site.

A submergence of approximately 4.00 m. (*ca.* 13 ft.) is demonstrated by the fact that deposit E is overlain by a layer of very coarse angular to subangular gravel (deposit D) 3.58 m. (11 ft., 9 in.) thick. This contains Early Larnian implements in abundance (archeological Horizon 2 at the site), which for the most part are quite fresh and unrolled. But no trace of either bone or shell occurred in this deposit. These gravels, which are a dark reddish-purple color and are stratified horizontally, have been formed of material derived by the sea from the Old Red Sandstone formation of the Cushendun region. They consist of slightly rolled rocks and pebbles in a matrix of coarse sand. Since they are both underlain and overlain by intertidal lagoon deposits, the accumulation must have taken place during a time of submergence, and such conditions of a sinking coastline would have been ideal for rapid erosion on the headlands. The nature of this deposit indicates rapid deposition near the then-existing low-water level *in tempo* with the sinking, which appears to have been a comparatively sudden event (Movius, 1940a, p. 30-31), and the archeological evidence supports this view. For it is apparent that the Early Larnian flint artifacts from this horizon were introduced by the sea when it rapidly invaded abandoned occupation sites along the Late Boreal coast and swept up the refuse material, transporting it by swift currents to a position further inland. On the basis of the pollen preserved in contemporary lagoon silts found elsewhere in the Cushendun region, which correspond in elevation with these gravels, Jessen considers that the Sub-zone VIb/VIc transition occurred at spectrum 8, or near the base of the upper quarter of this deposit (Jessen, 1949, p. 136). High-water level of the present day occurs near the base of deposit D at a depth of 7.80 m. (25 ft., 7 in.) below point Ⓐ.

That the lower gravels at Cushendun were accumulated during a comparatively short period of time is clearly demonstrated by the fact that this horizon is overlain by a second layer of lagoon silt (deposit C), which Jessen has assigned to Sub-zone VIc in Ireland (Jessen, 1940, p. 44; 1949, p. 136). This situation is very clearly shown on the graph (fig. 3), where the sediment, which is 77 cm. thick, is accurately plotted with respect to both the depth of water in which it was laid down and the tentative Postglacial time scale.[5] No foraminifera or ostracoda occurred in deposit C; only two species of mollusks were found: *Cardium edule* L. (approximately 90 per cent of all specimens) and *Scrobicularia plana* da Costa (*ca.* 10 per cent). According to Mrs. McMillan (1940, p. 38), the presence of these two

[5] Godwin's (1943, p. 232) suggestion that the upper lagoon silt at Cushendun accumulated near the maximum of the submergence is apparently based on a misunderstanding of the paleobotanical evidence concerning the age of this deposit (Jessen, 1949, p. 138).

forms in quantity unaccompanied by any other mollusks indicates deposition near the low-water mark of a shallow tidal lagoon with a relatively flat bottom of sandy mud. Probably this was very nearly dry at low tide. The fact that the surface of this silt is slightly eroded suggests that a short time elapsed between its deposition and the time the basal levels of deposit B, immediately above, were laid down.

As discussed in the excavation report, (Movius, 1940a, p. 25-26), the upper gravels (deposit B) at Cushendun may be divided into two zones: the lower beds which are inclined and which dip at an angle of 20°-25° toward the south-southeast; and the upper beds which are nearly horizontal and which represent a true storm beach accumulation. The lower beds, thickness 1.85 m., were apparently laid down at or near the tidal inlet to a lagoon. The characteristic current and foreset bedding which they display indicates that they were formed as the result of the interaction of the sea and the then-existing Dun River prior to and at the time of the maximum of the submergence, an event that occurred during the transition from paleobotanical Sub-zone VIIa and VIIb (Atlantic/Sub-Boreal) in Ireland, as stated by Jessen (1949, p. 137; also Mitchell, 1945, p. 4 and 6).[6] The upper, more nearly horizontal beds truncate those of the lower series, and there seems to be little reason to doubt that they were built up above mean-tide level (and probably in the main above high-tide level) during the emergence. This portion of deposit B, which is 1.30 m. thick, is a true storm beach and it was formed by waves coming from the open sea under the conditions of a receding coastline.[7]

[6] At Cushendun the bulk of the sediments were accumulated during the interval of time represented by Sub-zones VIb and VIc. This situation contrasts markedly with what seems to have occurred in the Island Magee-Larne area, where comparatively rapid and extensive deposition took place somewhat later during Sub-zone VIIa.

[7] High-water level at Cushendun is 7.30 m. (23 ft., 11½ in.) below the top of the storm beach (deposit B) at the present time. This surface, which is estimated to have been 8.82 m. (28 ft., 11½ in.) above high-water level at the time of the maximum of the emergence, represents the highest point reached by storm waves at the site during the rising of the land. On the basis of the figures for Portrush (Jessen, 1949, p. 134) and White Park Bay (Coffey and Praeger, 1904, p. 194), at both of which localities the action of storm waves extends to a height of *ca.* 1.50 m. (5 ft.) above O.H.W.L., Jessen (1949, p. 137) has estimated the figure for H.W.L. at the Cushendun locality at the time of maximum transgression to be 6.50 m. (21 ft., 4 in.) above modern H.W.L. However, in arriving at

Indeed these beds, which constitute a prominent feature of the topography in the vicinity of Cushendun, actually represent a series of successive storm beaches built up by the sea and truncated from time to time by the severe wave action of great storms. In support of this view, it should be pointed out that the nearly horizontal surface of the rather extensive Postglacial terrace at this locality is broken only by a series of low more or less parallel beach ridges. Throughout deposit B, heavily rolled flint implements of Late Larnian type occur; it comprises archeological Horizon 3 at the site. The material from Horizon 1 is Neolithic of "Campignian" affinities and it comes from a layer of sandy humus (deposit A) 50 cm. thick which overlies the upper gravels. This layer, which has recently yielded a polished axe made of Tievebulliagh stone (Evans and Mitchell, 1943, p. 147, and fig. 1), was formed after the emergence had begun. This confirms the evidence from Newferry in the Lower Bann Valley (Movius, 1936; Jessen, 1949, p. 122 and 127), where there was also a Neolithic occupation in Ireland during Early Sub-Boreal (Sub-zone VIIb) time.

As discussed on p. 723-724, a comparatively recent sinking of the land has occurred, amounting to some 5 ft. (1.52 m.). On this basis, it may be assumed that at the maximum of the emergence point Ⓐ at the excavated site stood approximately 9.32 m. (30 ft., 7 in.) above the present level of high tide, and that during this period the surface of the peat layer directly below point Ⓐ stood at +86 cm. with respect to O.H.W.L. As shown on the graph, the total amount of submergence necessary to account for the accumulation of the sediments at Cushendun is very close to 7.90 m. (25 ft., 11⅜ in.), whereas measuring from the same datum, the total of the emergence at its maximum was of the order of 8.80 m. (28 ft., 10½ in.)— the difference between these two figures being —90 cm. (—2 ft., 11⅜ in.). In other words, at the maximum of the emergence, the surface of the peat layer (deposit F) had come back approximately to a

this figure, Jessen had used the level for the surface of the Warren as representing the top of the storm beach, instead of deducting 50 cm. for the thickness of the humus (deposit A), and furthermore he has failed to allow for the slight submergence of Recent time in computing the total amount by which the land has risen in this vicinity since the maximum of the Postglacial marine transgression. In any case, it is believed that the figure of 7.90 m. (*ca.* 26 feet), which is shown on the graph (fig. 3) and the computation of which is explained above, is probably a great deal more accurate.

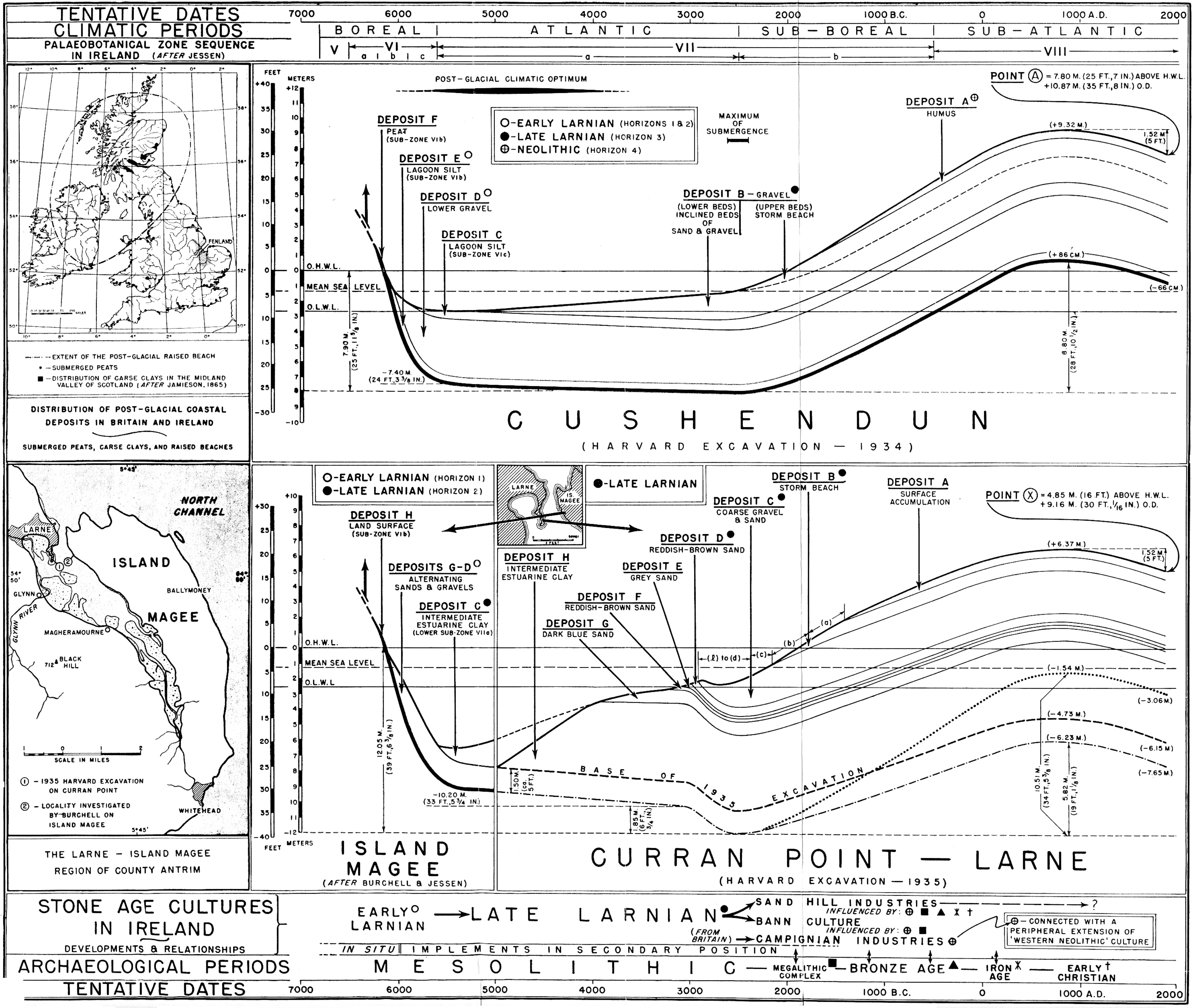

Fig. 3. Graphic representation of Postglacial changes of level at Curran Point, Island Magee, and Cushendun, County Antrim.

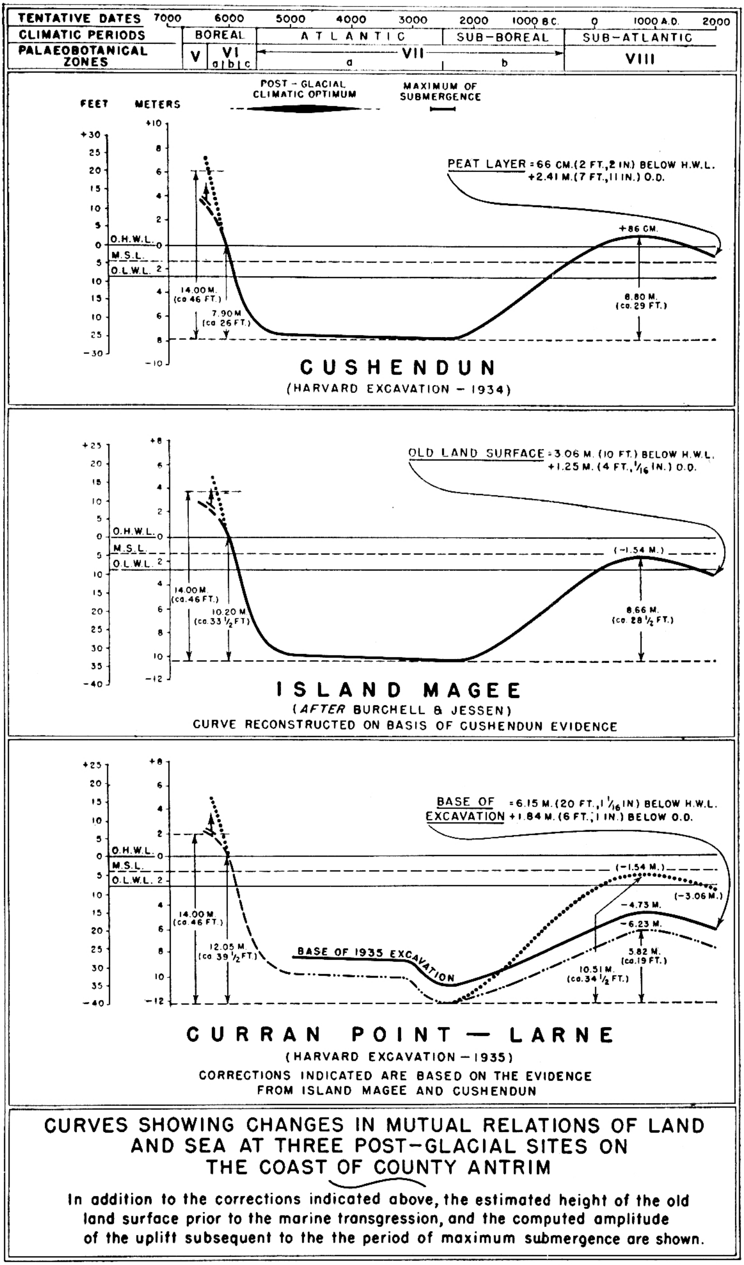

Fig. 4. Graphic representation of Postglacial changes of level at three coastal localities in County Antrim.

level at which it could have been formed with respect to the sea prior to the submergence. As the result of the recent sinking of the land, it lies below the high-water mark today for a second time.

Curran Point, Larne.—This locality, which is situated in County Antrim approximately 20 miles north of Belfast, is the classic site of the Irish Stone Age. It was discovered in 1863 (Movius, 1953b) and excavated in 1935 by the Harvard Archaeological Expedition to Ireland. Over 5500 flint artifacts belonging to the Late Larnian culture were found. Previously the most thorough stratigraphic studies of the Curran deposits were those of Swanston (1886), Praeger (1890), and Coffey and Praeger (1904), but during the past 75 years many papers have been published on the "Larne Gravels" (Movius, 1942, p. 318 for a select bibliography). As previously stated, the detailed report covering the results of the 1935 excavation (summarized in Movius, 1942, p. 132-136) will be published by the Royal Irish Academy.

Curran Point is a long, tapering, sickle-shaped spit (figs. 1 and 3: inset map), which forms an extension of the coast southward into Larne Lough, an inland body of water shut off from the sea by Island Magee. The Curran, or *Corrán* (Irish for sickle), rises from 10 to 20 feet above the present sea level and is approximately three-quarters of a mile long. Praeger's main investigations were conducted at section B (fig. 1), which was formerly exposed at the "Railway Cutting," in the northern portion of the Curran deposits. At the site excavated in 1935, which consisted of a pit 5 m. square, the Early Postglacial raised beach has an elevation of +30 ft. O.D., or approximately 16 ft. above average high-water level. The section, which is shown in figure 3: lower, is as follows:

(A)	Surface accumulation	40 cm.
(B)	Storm beach material	90 cm.
(C)	Inclined beds of gravel and sand	2.95 m.
(D)	Fine reddish-brown sand	55 cm.
(E)	Hard gray sand	20 cm.
	[High-water level during Aug.-Sept. 1935 (—4.85 m.) coincides fairly closely with this deposit.]	
(F)	Fine reddish-brown sand	15 cm.
(G)	Dark blue sand	85 cm.
(H)	Estuarine clay	Thickness undetermined

The fauna from each of these deposits has been carefully studied, and a mechanical analysis has been made of soil samples taken at frequent intervals throughout the section (appendices 2-5 of the Larne Report). These data permit the construction of a very accurate graph showing the deposition in relation to the changes of level which have occurred at this locality during Postglacial times. It is to be regretted that the presence of an old land surface resting on boulder clay at the base of the Postglacial marine deposits could not have been established, but the ever-increasingly rapid seepage of water into the base of the pit, as well as the extreme toughness of the basal deposits, made this an impossibility due to the lack of special pumping and boring equipment. Thus, for the "O-Point" on the graph, the lowest level in deposit H penetrated by boring—5.00 m. below the top of the estuarine clay, and 11.10 m. below the top of the section—has been taken to serve this purpose. Furthermore, it is safe to assume that this sediment was laid down during the period represented by the early portion of paleobotanical Sub-zone VIIa (Atlantic Period) in Ireland, following the correlation with the nearby section at Island Magee discussed on p. 719-722 (see also Jessen, 1949, p. 139-140, and appendix 1 of the Larne Report). Although numerous samples of deposit H were taken for paleobotanical analysis, the pollen frequency in each instance was too low for counting. But the ecological conditions at the time of deposition can be established fairly satisfactorily on the basis of the evidence of the very rich marine fauna collected in the estuarine clay, which includes 81 species of mollusca and 78 species of foraminifera. According to Mrs. McMillan (in Movius, 1953a), these data prove that the basal portion was accumulated in a maximum depth of 2 to 3 fathoms (3.65 m.-5.50 m.) of water, whereas the upper part was deposited in water approximately 1 fathom (1.83 m.) deep. However, the conclusions based on the mechanical analysis of this sediment (Benninghoff, in Movius, 1953a), which simply states that deposition took place "in water several fathoms deep," are less precise. Apparently deposit H was laid down during a period of relative stability with respect to the mutual relation of land and sea, although it is likely that a very slight amount of relative sinking was taking place at this time, in all probability due to a slowly rising sea level. On the basis of this evidence, the period represented by deposit H has been plotted on the graph (fig. 3). This horizon belongs to the intermediate zone of the estuarine clays of North-East Ireland, during the deposition of which the Postglacial climatic optimum in Ireland was attained.

While the accumulation of the dark blue sand (deposit G), which is 85 cm. thick, was in progress, there was a gradual silting-up at the Curran locality. The lower portion of this deposit was laid down in water approximately 1 fathom deep; whereas samples from the top indicate sedimentation just below the level of ordinary low water, as shown by the marine fauna (mollusca: 64 species; foraminifera: 68 species) studied by Mrs. McMillan (in Movius, 1953a). The sedimentary analysis demonstrates that toward the top of the deposit the clay content decreases and in the upper levels the sediment is composed predominantly of sand. According to Benninghoff (in Movius, 1953a), this indicates that a relative emergence was taking place, and "that the then-existing strand-line was approaching the vicinity of the site." In other words, a gradual silting-up of this portion of Larne Lough was going on under conditions of relative stability.

Deposit F, an horizon of fine reddish-brown sand 15 cm. thick, was accumulated at or near the level of ordinary low water, as shown by the occurrence throughout of razor clam shells (*Ensis siliqua*) *in situ.* And Benninghoff's analysis of the size grades of the sand particles suggests that the beach was now closer to the site than it had been during the deposition of the two preceding beds. The overlying hard gray sand (deposit E) represents an accumulation on the lower portion of a tidal beach. It is 20 cm. thick and coincides with O.H.W.L. of the present day, which occurs at —4.85 m. (—16 ft.) with respect to datum. By the time deposit E was laid down there is nothing to indicate that climatic conditions differed from those of the present. The marine fauna from the hard gray sand is all *in situ*; according to Mrs. McMillan (in Movius, 1953a), it includes 9 species of mollusca and 34 of foraminifera. The occurrence of many specimens of *Ensis siliqua* and *Phacoides borealis* show that deposition was taking place on a sandy foreshore exposed at low water, since normally *E. siliqua* does not range below this depth. An analysis of this sediment by Benninghoff indicates the type of sorting normally found on the lower portion of a tidal beach.

Throughout the period represented by deposit D (a second layer of reddish-brown sand) gradual deposition continued under conditions of relative stability; this 55 cm.-thick layer was formed on the lower portion of the then-existing beach. This conclusion is based on an analysis of the very abundant fauna (mollusca: 79 species; foraminifera: 32 species) collected in the deposit. That beach conditions prevailed at the time of accumulation is indicated by the finding of a large stone at a depth of 4.35 m. with barnacles (*Balanus balanoides*) adhering to it, since these barnacles do not range below low-water level.

As shown on the graph, the evidence of deposits H to D inclusive reveals that there had been a gradual building-up of sediments going on. But at the beginning of the time represented by the accumulation of the overlying inclined beds of coarse gravel and sand (deposit C), this period of relatively stable conditions came rather abruptly to an end. In fact there is a slight unconformity between deposit C and the underlying beds. Deposit C, which is 2.95 m. thick, is composed of some ten layers, as indicated in figure 3: lower. Considering these beds in ascending order, the conditions which prevailed at the time they were formed based on Benninghoff's analysis (in Movius, 1953a) of samples of each sediment may be summarized as follows:

(l) At or near O.L.W.L. (Sinking had begun.)
(k) A tidal beach deposit—probably near O.L.W.L.
(j) Deposited near O.L.W.L. on a tidal beach.
(i) Probably formed at a low level on the beach.
(h) Probably laid down in an intertidal pool.
(g) Deposition at or near O.L.W.L.
(f) Accumulated on an intertidal beach.
(e) A typical lower beach deposit.
(d) Laid down on an intertidal beach.
(c) *Lower*: An intertidal gravel bar.
Upper: An upper beach deposit—near the level of O.H.W.

Now if each of these sediments is very accurately plotted on the graph (fig. 3), the resulting curve clearly demonstrates that during the period represented by beds (l) to (d) inclusive, a total sinking of the land relative to the sea occurred which amounted to 1.85 m. (6 ft., 3⁄4 in.).[8] Throughout, the nature of the bedding suggests that deposition was going on under littoral conditions *in tempo* with the submergence. Since the sands and gravels comprising bed (c) indicate that the sinking had now ceased and that a progressive building-up process was under way, the height of the submergence must have taken place during the time this layer was being laid down. That this event may be assigned to the transition between paleobotanical Sub-zones VIIa and VIIb (Atlantic/Sub-Boreal) in Ireland has been clearly demonstrated by Jessen (1949, p. 125-137). It is on this basis that the point on the graph showing the maximum of the sinking, as revealed by the Curran deposits exposed at the 1935 excavation, has been plotted.

With the exception of a few specimens from the basal portion of deposit C, all the mollusca and foraminifera from this horizon are worn and derived from deeper water outside the lough. However, certain critical forms occur in beds (l), (k) and (j) which provide important ecological data. In bed (l) several complete specimens of *Phacoides borealis* found *in situ* demonstrate that deposition did not occur at a level on the beach higher than at or near the low-water level. Furthermore, in beds (k) and (j) several large stones were found with fresh, unworn barnacles (*Balanus balanoides*) adhering to them. Since these are *in situ* their occurrence proves that this portion of the section represents a tidal beach deposit, for barnacles are never found above high-water level. Therefore, the evidence of the fauna confirms the fact that a submergence, i.e. a rise in sea level relative to the land, had commenced at the time the lower horizons of deposit C were being accumulated.

A storm beach built up by the waves close to high-water level during the emergence is represented by deposit B.[9] A slight unconformity exists between this layer and the underlying inclined beds of coarse gravel and sand; indeed, the surface of

[8] In no instance were the fractions of inches which appear in this paper obtained by direct measurement; they result from conversions into feet and inches of figures given in the metric system in which the meter = 39.37011 inches.

[9] At the excavated site on Curran Point O.H.W.L. is at present 4.45 m. (14 ft., 7⅛ in.) below the top of the storm beach (deposit B). At the maximum of the emergence, it is estimated that this surface, which represents the highest point reached by storm waves at the site during the uplift, was 5.97 m. (19 ft., 8¼ in.) above modern O.H.W.L.

deposit C was somewhat eroded before the formation of the storm beach began. The shells from this horizon are all very heavily rolled and represent common littoral species found today in the Larne region. According to Benninghoff (Movius, 1953a), the coarseness of the sand from the lower portion of deposit B results from the fact that the fine-grained sediments have been "largely washed away by storm-wave action, the agent of deposition." Deposit B, which is 90 cm. thick, is overlain by 40 cm. of recent surface accumulation, which at point ⊗ at the excavated site occurs at a height of 4.85 m. (16 ft.) above ordinary high-water level.

The comparatively recent submergence of the land with respect to the sea now going on all along the Antrim and Down Coasts has led to the erosion of the steep scarp that can be seen at present on the seaward portion of Curran Point (see p. 724), and for this reason point ⊗ at the excavated site is shown on the graph 1.52 m. (5 ft.) below the height which it must have attained during the maximum of the emergence—6.37 m. (21 ft., ¾ in.)[10] above O.H.W.L.

Island Magee.—Opposite Larne, but separated from Curran Point by the narrow entrance of the lough (fig. 3: inset map), a very important Postglacial section was investigated during construction operations in the harbor at Island Magee by Burchell (1931, p. 270-281; 1932; 1933; 1934). Baden-Powell (1937) has published the marine fauna collected by Burchell at this locality, and Jessen has determined the paleobotanical age of one of the deposits investigated by him in the immediate vicinity of the harbor in 1934 (appendix 1 of the Larne Report; Jessen, 1949, p. 139-140). Although Burchell has given no measurements for the thickness of the individual beds, the section is recorded as follows:

[10] This figure is somewhat greater than G. B. Wright's estimate that a submergence of 5.50 m. (18 ft. below present H.W.L.) would account for the formation of the Curran gravels (Wright, 1937, p. 382). On the other hand, it is not as great as the figure computed by Praeger, 7.92 m. (26 ft.), on the basis of the evidence obtained at the Railway Cutting (section B on fig. 1), where the surface of the raised beach is stated to be 1.83 m. (6 ft.) higher at present than at the site excavated in 1935 (Praeger, with Coffey, 1904, p. 153). Furthermore, at the latter locality no evidence of a storm beach was observed. Presumably the difference in level between these two localities has resulted from the "loss" of elevation at the site excavated by the Harvard Expedition due to compaction, as explained on pages 726 and 727.

(A)	Raised beach gravels	Horizon 3
(B)	Black sand	
(C)	Intermediate estuarine clay (*Note*: This is called deposit A by Jessen.)	Horizon 2
(D)	Black sand	Horizon 1 (These beds apparently correspond to deposits B and C in Jessen's section.)
(E)	Subangular black gravel and sand	
(F)	Fine black sand	
(G)	Subangular black gravel and sand	
(H)	Land surface with tree roots and hazel nuts	
(I)	Boulder clay	

High-water level coincides approximately with the surface of deposit C (Jessen's deposit A). The surface of the boulder clay is stated to be 46 cm. (1 ft., 6 in.) below present low-water level, and the overlying deposits (G to B inclusive) are some 3.06 m. (10 ft.) thick. The three horizons from which archeological material was recovered are indicated above; Horizon 1 is Early Larnian, and Horizons 2 and 3 are Late Larnian (Movius, 1942, p. 136-139). The marine fauna from deposits C, F and G has been intensively studied, and by virtue of its pollen content deposit C has been assigned to the lower part of paleobotanical Sub-zone VIIa in Ireland (Jessen, 1949, p. 139). These data make it possible to compare the Island Magee stratigraphy with that exposed at Curran Point at the site excavated in 1935, and to plot on the graph presenting Postglacial changes of level in North-East Ireland that portion of the Island Magee section which is missing at the latter locality, as shown on figure 3.

Deposits A, B and C may be equated with deposits B to H inclusive at Curran Point. Horizon 3 (deposit A) yields archeological material identical with the Late Larnian from the extensive accumulations of sand and gravel on the opposite side of the lough. Deposit B probably has its counterpart in the dark blue sand (deposit G) at the site excavated in 1935, which in turn very likely corresponds to the black sand (deposit F) at the Railway Cutting site (section B) investigated by the Belfast Naturalists' Field Club in 1889 (Praeger, 1890, p. 203 and pl. 1). The estuarine clay (deposit G) at the latter locality may be correlated with deposit H at the Harvard site and with deposit C at Island Magee. Indeed the marine fauna, as well as the depth of water (2 to 3 fathoms) during the period of sedimentation, provide very convincing evidence that the estuarine clay at Island Magee, in which flint artifacts have been collected (Burchell and Whelan, 1930; Burchell, 1932), is the counterpart of deposit H at Curran Point. Furthermore, as in the case of the Curran clay, the mollusks and foraminifera from this level at Island Magee indicate that at the time of its deposition slightly warmer conditions prevailed than at present. Although forms found today on the coasts of North-East Ireland predominate on the whole, the presence of *Modiolaria costulata* and *Tapes* (*Paphia*) *decussatus*, both of which have a normal southern range (Cooke, 1914, p. 115), point to a somewhat more equable climate. According to Baden-Powell (1937, p. 92-93), the invertebrate fauna from this horizon shows no indications of a cold climate. The question of correlating these two deposits is further discussed by Mrs. McMillan in appendix 2 of the Larne Report; this authority has also informed the writer by correspondence that she would be inclined to correlate the estuarine clay deposits of Curran Point and Island Magee on faunistic grounds. In any case, Mrs. McMillan does not believe that the dark blue sand (deposit G at the excavated site) and the Island Magee estuarine clay (deposit C) can be directly correlated, since the evidence of the fauna demonstrates that the former stratum is rather later in date than deposit C at Island Magee. Therefore, it may be concluded that, although much detailed work remains to be done on the Island Magee section, the estuarine clay deposits at the two localities were laid down at the same time under almost identical conditions, i.e. in a depth of not more than 2 to 3 fathoms of water. As Baden-Powell points out (1937, p. 95-96), this fact indicates that the two deposits are comparable in age with the intermediate estuarine clay of the Irish coastal sequence (Praeger, 1888, p. 31; 1892, p. 214, 226, 234).

Now the establishment of a basis for correlating the Island Magee section with that revealed at the 1935 excavation at Curran Point is important for the following reasons: (a) the stratified archeological material from the two localities yields a complete record of the development of the Irish Mesolithic; (b) the lower portion of the Island Magee section furnishes the key for completing with a reasonable degree of accuracy the graph showing the changes of level that have taken place in the Larne region during Postglacial time; and (c) on the basis of our present data, the correlation of the two sections affords the only direct evidence by which the paleobotanical zone sequence established in Ireland may be related directly with the climatic record, as revealed by the marine fauna of Praeger's estuarine clay series of the coastal sequence. Whereas the Island Magee estuarine clay contains sufficient pollen grains for counting, it lacks the critical faunal assemblages for positive climatic determination. On the other hand, deposit H at the excavated site at Larne is poor in pollen—too few for counting—but it is very rich in those critical mollusks and foraminifera which serve as reliable climatic indicators. Although the pollen frequency in deposit C at Island Magee is admittedly low, Jessen had assigned this stratum to the early portion of paleobotanical Sub-zone VIIa in Ireland, since high amounts of pine and alder occur (appendix 1 of the Larne Report; Jessen, 1949, p. 139). As stated above, this horizon has yielded implements typical of the Late Larnian culture.

During the 1935 excavation at Curran Point, no strata were reached which may be correlated with deposits D to G (alternating beds of black sand and subangular black gravel and sand) of the Island Magee section. That this portion of the section was accumulated between tide marks is demonstrated by the littoral character of the fauna collected by Burchell from the lower levels (deposits F and G). Baden-Powell (1937, p. 96) concludes that it corresponds with the lower estuarine clay —*Scrobicularia* Zone—in Praeger's sequence (Praeger, 1892, p. 214). Now Burchell (1934, p. 369) reports birch, pine, elm, alder, oak, a high frequence of hazel and traces of willow from a land surface (deposit H) at the base of this horizon at Island Magee, and it seems very probable that this indicates an accumulation during the early part of Sub-zone VIb time in Ireland. On this basis, the beds of black sand and gravel are very likely of the age of Sub-zones VIb (late portion) and VIc. Such a dating agrees very well with the implications of the archeological material collected by Burchell in Horizon 1 (deposits D to G) at this site. The implements are unrolled, patinated blue to black, and are of Early Larnian type, comparable to Horizons 1 and 2 at Cushendun (Movius, 1940a, p. 67). Furthermore, as at Cushendun, the beginning of the marine transgression at Island Magee is manifest in the littoral character of the basal deposits—alternating beds of black sand and subangular black gravel and sand—as well as in the contained fauna. These early littoral deposits overlie an old land surface (deposit H in Burchell's section) on which hazel nuts were found, and from which tree roots were observed to extend down into the underlying boulder clay (deposit I).

In this connection, it should be noted that at the Railway Cutting site (section B, fig. 1) a second layer of black sand (deposit H) occurred below the estuarine clay; this in turn overlay a stratum of coarse black gravel (deposit I), the lowest level reached during the 1889 excavation (Praeger, 1890, p. 203-208 and pl. 1). In this deposit a few hazel nuts and several flint chips, believed to be of human origin, were found. Since *Spirorbis*, corallines, *Littorina obtusata*, and *Balanus*—all intertidal forms—occurred in the black gravel, it is possible that this layer is the counterpart of the basal gravels and sands (deposits F and G) at the Island Magee locality. If so, deposit I at the Railway Cutting site demonstrates the establishment of littoral conditions on the Larne side of the lough at the beginning of the Postglacial submergence, just as at Island Magee, and supports the correlation between the lower portion of the Island Magee section and Curran deposits at the site excavated in 1935.

Having discussed the basis on which the Island Magee deposits have been correlated with those recorded by the Harvard Expedition at Curran Point, the method of plotting the lower portion of Burchell's section on the graph showing Postglacial changes of level (fig. 3) should be explained. Actually for the key to this problem the well-documented Cushendun evidence was used. At both sites an old land surface that may be assigned to the Late Boreal Period is overlain by shallow water sediments—the lower lagoon silt (deposit E) at Cushendun and the basal deposits of the alternating beds of black sand and gravel (deposits G to D) at Island Magee. Now the swamp peat layer (deposit F) at Cushendun is lying at present approximately 66 cm. below ordinary high-water level below point Ⓐ at the excavated site, and the total amount of submergence necessary to account for the character of the sedimentation at that locality is estimated to have been a total of —7.90 m. in relation to O.H.W.L. of the present day. On the other hand, the old land surface at Island Magee is stated to occur at 3.06 m. below average high-water level, a difference of —2.40 m. with respect to the same horizon at Cushendun. Thus the curve showing the submergence at Island Magee is plotted on the assumption that there was a total change in mutual relations of the then-existing sea level with respect to the land of —11.20 m. (—36 ft., 9 in.). Admittedly the total thickness shown as represented by deposits G to D at Island Magee is entirely arbitrary; a figure of 1.50 m. (approx. 5 feet) was arrived at purely on the basis of the fact that the corresponding deposits at the Railway Cutting site—deposits H: 2 feet, and I: 2 ft., 6 in. (base not reached)—must have a comparable thickness. If so, the graph showing the lower portion of the Island Magee section works out extremely well with regard to plotting the estuarine clay (deposit C), which had a total thickness of 1.25 m. (4 ft., 1¼ in.) at the nearby section investigated by Jessen, and which at both localities was laid down in a depth of water not exceeding 2 to 3 fathoms (12 to 18 feet) during the early part of paleobotanical Sub-zone VIIa in Ireland. Furthermore, it seems to fit reasonably well with the Larne curve (fig. 3) in that deposit C at Island Magee falls opposite its counterpart, deposit H (estuarine clay), at the Curran site. In any case, it is to be hoped that futher work on the Island Magee section will provide accurate measurements for the individual deposits. However, the graph has been constructed as nearly correct as possible on the basis of the existing data, including those recorded by Jessen in 1934.

EVIDENCE FOR RECENT SUBMERGENCE

Marine erosion now taking place at many localities indicates that the coast of North-East Ireland has been sinking slightly during Recent times. As Knowles (1914, p. 90-91) has pointed out, along the County Antrim side of Belfast Lough the gravels of the Early Postglacial raised beach are being gradually swept away by the sea; he states that in 1910 he talked with a man living between Carrickfergus and Kilroot who "remembered the land reaching out a considerable distance into the present sea, and that what would be the equivalent of a good-sized farm of land had been washed away by the sea within his own memory." On the opposite side of the lough Staples (1869, p. 42) records similar observations with reference to the foreshore near Holywood, County Down. However, the most striking evidence is cited by Andrews (1892; 1893) who describes how the stack of an old windmill pump in an abandoned sandstone quarry at Cultra Bay, one mile northeast of Holywood, was surrounded by 3 ft. of water and situated over 50 ft. from the shore at high tide. In this instance it is estimated that between 1829 and 1892 some 5 acres of land were washed away in this vicinity and that the sea encroached on the land by from 100 to 150 ft. These observations may be confirmed by comparing the old maps and charts showing the coastline of Belfast Lough with more recent editions of the same sheets.

Coffey and Praeger (1904, p. 153 and 156) cite further evidence of a small relative sinking movement during recent times. At Alexandra Dock, Belfast (see Praeger, 1888, for section) a layer of beach sand 2 ft. thick containing derived shells is overlain by 6½ ft. of mud, the surface of which is at present between tide marks and which is full of littoral burrowing mollusks (Praeger, 1888, p. 30; 1892, p. 233-234). Furthermore, near Portrush, County Antrim, the sea is cutting a low scarp in the raised beach and overlying dune deposits (Jessen, 1949, p. 135). With reference to Larne, where wave action is eroding the deposits of Curran Point at present, Coffey and Praeger (1904) state that following the Postglacial submergence, the land rose "slightly higher than at present—probably about 5 ft. above its present level. A slight movement in recent times has left the surface as we now find it." At Cushendun the low erosion scarp on the seaward side of the Postglacial marine terrace (Jessen, 1940, p. 51) was also formed as the result of this recent submergence, which was apparently more intense in Scotland than it was in Ireland. For Callander (1929, p. 318-322) cites a great deal of very convincing evidence showing that a general sinking movement of the land has taken place throughout northern Britain since Iron Age times.

MEASUREMENTS OF POSTGLACIAL CHANGES OF LEVEL

In order to obtain some idea of the magnitude of the difference between the figures for the total submergence and the total emergence in the Larne region, as a basis for comparison with the figure of —90 cm. (—2 ft., 11⅜ in.) demonstrated in the case of Cushendun (see p. 712), the line representing the old land surface at the base of the Island Magee section has been projected on to the Curran Point portion of the graph. At the outset it must be clearly understood that this line, which falls 1.50 m. (*ca.* 5 feet) *below* the lowest point reached during the 1935 excavation, represents only an estimate of the probable depth at which the boulder clay might be expected to occur had it been reached in 1935 at the base of the Curran Point section. Furthermore, although it is believed that the position of this horizon is plotted reasonably accurately with respect to sea level in so far as the Island Magee section is concerned, this does not necessarily mean that it can serve as a basis for computing the measurements of a section on the opposite side of Larne Lough. In the first place, whereas there is no reason to doubt the fact that the Curran deposits ultimately rest on boulder clay at the excavated site, as is the case at section P on the nearby tip of Curran Point (fig. 1; Coffey and Praeger, 1904, p. 170), it does not follow that this horizon was above the then-existing sea level at the excavated site at the time the sinking began, although presumably this was the case, But, for purposes of the present discussion, it is assumed that littoral deposits underlie the estuarine clay at the Curran locality (fig. 3), just as they do elsewhere in the Larne region, and that they date from the early stages of the submergence. In the second place, the old land surface at Island Magee is at present only 3.06 m. (10 feet) below O.H.W.L., or a total of 4.69 m. (15 ft., 4½ in.) *above* the point indicated on the graph for the corresponding level at the Curran Point locality. In other words, the actual curve showing the changes of level at Island Magee cannot possibly agree with its projection as shown on the graph (fig. 3), since this follows the curve for the base of the deposits at the excavated site. The essential point to be stressed, however, is that the magnitude of the figure obtained by this very rough and ready method for computing the changes in level at Larne—12.05 m. (39 ft., 6⅜ in.) minus 5.82 m. (19 ft., 1⅛ in.) equals 6.23 m. or 20 ft., 5¼ in.—is many times in excess of that obtained at Cushendun. Since the computed figure for the total amount of submergence at Larne is 4.15 m. (13 ft., 7⅜ in.) greater than that for Cushendun, whereas the reverse is true with regard to the emergence (difference = 2.98 m., or 9 ft., 9⅜ in.), it can only be concluded that the old land surface at the latter locality actually lay somewhat higher at the time the transgression was getting under way than in the case of Larne. With regard to the difference in total movement during the emergence, however, it seems probable that two additional factors are involved:[11] (a) the silt and clay beds at Larne were actually compacted an appreciable amount due to the weight of the overlying deposits, which would tend to have a negative effect on the intrinsic rate and amount of movement during the emergence; and (b) the amplitude of the emergence tends to decrease somewhat along the east coast of Ireland from north to south (Hull, 1872, p. 113; Coffey and Praeger, 1904, p. 152, 157, 200; Martin, 1930, p. 494-500; Wright, 1928, p. 100; 1937, p. 369; Movius, 1942, fig. 11, p. 79, 85, 292). Indeed, southward along the east coast this feature, its height steadily decreasing, has been traced as far as Wexford Harbour, where the O-isobase has been drawn (fig. 3: inset map). Toward the northwest the Postglacial raised beach is again found. But the situation on the west coast roughly parallels that of the east, and the O-isobase passes through the southwestern portion of County Sligo, as shown on the map. It is therefore apparent that a general submergence has been under way in Ireland during protohistoric and historic times, but this movement has been very much more extensive in the south and west than it has in the north and east of the island. Thus the Early Postglacial raised beach has a tendency to occur at progressively higher elevations at the more northerly sites in County Antrim than elsewhere, and there are good indications that this situation existed even before the Recent Period of relative sinking got under way. In other words, the degree of isostatic uplift following the maximum of the transgression has been always greater toward the north and east of Ireland, in those regions peripheral to the main center of ice dispersal, just as in the case of Britain and Scandinavia. However, within the area under consideration, i.e. between Cushendun on the north and Larne on the south—a total distance of approximately 22 miles—this factor is considered to be of almost negligible importance. It could account only for a maximum difference in elevation of less than half a

[11] Inasmuch as the Cushendun site occupies a relatively exposed position on the coast from point of view of storm wave action, whereas Curran Point is very well sheltered, the fact that high-water level at the former locality is at present 1.24 m. (4 ft., ¼ in.) *lower* with relation to O.D. than it is at Larne tends to offset any possible discrepancy due to storm wave action during the time the Postglacial raised beach was being formed.

meter or so. Therefore differences in level of the land of only a very slight degree as regards these two localities can be attributed to variations in the extent and amplitude of the emergence.

On the other hand, the question of a possible compaction of the clays and silts in the Larne region is considered a major factor. Praeger (1892, p. 226) states with reference to the "Estuarine" deposits at Maghermorne, situated on the western shore of the lough only 3 miles from Curran Point, that "the bed has probably a considerable area, and extends out into the sea, its surface slightly above low-water level. It would probably still lie concealed . . . were it not for the steady advance of a high spoilbank from the adjoining chalk quarries, which, encroaching on the sea, has thrust the clay upward to a height of several feet above high-water mark all around its margin." Thus these clays are known to have "slumped" and to have been compacted laterally during Recent times under the weight of quarry debris; certainly the figures discussed above would indicate that this or a very similar process was operating also in the past under the weight of marine gravels, sands and other beach deposits. Indeed the extreme toughness of this sediment, which increased markedly toward the basal layers of the pit at the excavated site, reflects the great pressure to which deposit H must have been subjected by the time the emergence of the land was getting under way. On this basis, the possibility that the total measured height of the emergence at its maximum does not represent the true figure for the amplitude of this movement at the Curran Point locality cannot be ruled out.

SUMMARY AND CONCLUSIONS

The data relative to changes in the mutual relations of land and sea during Postglacial time in the Cushendun and Larne-Island Magee regions of North-East Ireland may be summarized as follows:

> 1. Following the phase of relative emergence dating from Pre-Boreal—Early Boreal times (Zones IV and V and Sub-zone VIa), a comparatively rapid sinking movement was initiated during the interval of time represented by Sub-zones VIb and VIc (Late Boreal Period) in Ireland. The evidence from Cushendun indicates

that this amounted to about 7.40 m. (24 ft., 3⅜ in.), while the figure for the Larne region is estimated to be approximately 10.20 m. (33 ft., 5¾ in.). Paleontological and paleobotanical data demonstrate that the first Postglacial expansion of warmth-loving forms occurred at this time. Early Larnian implements are found in secondary position in the coastal deposits which accumulated during this stage.

2. By the beginning of the Atlantic Period (Sub-zone VIIa), the sinking movement had almost come to a standstill; it reached its culmination—maximum for Cushendun, 7.90 m. (*ca.* 26 feet), and for the Larne region, 12.05 m. (*ca.* 39½ ft.)—during the time represented by the transition between Sub-zones VIIa and VIIb (Atlantic/Sub-Boreal) in Ireland.[12] At the Curran Point locality, excavated in 1935, there is clear evidence of a slight secondary sinking movement during this interval amounting to 1.85 m. (*ca.* 6 feet). The Postglacial climatic optimum was attained during the early portion of paleobotanical Sub-zone VIIa; by the time of maximum sinking climatic conditions very similar to those of the present had been established. Deposits laid down at this time yield Late Larnian material in secondary position.

3. The early portion of Sub-zone VIIb, after the movement of emergence had gotten under way, witnessed the introduction of a food-producing economy with the first arrival of Neolithic settlers in Ireland toward the end of the third millenium B.C.[13] Storm

[12] At Belfast (Praeger, 1888; 1892, p. 333-334; 1902; with Coffey, 1904, p. 152-153) there is a peat bed 1 ft., 6 in. to 3 ft. thick, which is both underlain and in turn overlain by littoral deposits. This bed was therefore formed near the then-existing O.H.W.L.; it dates from Sub-zone VIa in Ireland (Charlesworth and Erdtman, 1935; Jessen, 1949, p. 136). The present position of this peat with respect to sea level indicates that a total sinking of at least 13.75 m. (*ca.* 45 feet) has taken place at the head of Belfast Lough.

[13] Actually the date for the transition from Atlantic to Sub-Boreal time is based on the archeological evidence. In Ireland several of the localities excavated by the Harvard Expedition have a direct bearing on this problem. At Newferry, County Londonderry (Movius, 1936; Jessen, 1936; 1949, p. 122-123, 135, 137), a Neolithic development, known as the Bann Culture, began in Early Sub-Boreal times just above the transition between Sub-zones VIIa and VIIb in terms of the pollen diagrams, and soon after

beaches containing very heavily rolled Late Larnian artifacts were being built up at this time. A slow emergence of the land continued during the development of the Early and Middle Bronze Age, which occurred in the later part of Sub-zone VIIb. At Cushendun the total extent of the emergence is 8.80 m. (28 ft., 10½ in.), but at Larne the figure computed on the basis of the 1935 data—5.28 m. (19 ft., 1⅛ in.)—obviously should be corrected to allow for the compaction factor, as discussed on p. 726-727. However, until this index has been computed by a specialist on engineering geology, it is possible only to suggest that the true figure should be of the order of 10.50 m. (34 ft., 5¾ in.) by comparison with the Island Magee and Cushendun evidence. This rough and ready method indicates that the estuarine clay has been compacted by approximately 4.70 m. (15 ft., 4½ in.), a figure which is considered to fall well within the range of probability by Dr. Terzaghi, in view of its present thickness of at least 6.00 m.[14] The correction

the beginning of the marine regression. That Neolithic settlers reached North-East Ireland shortly after the movement of emergence was under way is further supported by the evidence from Cushendun and Glenarm in County Antrim, and Rough Island in County Down (Movius, 1937, p. 200-208; 1940a, p. 63-67; 1940b, p. 129-132). Now Jessen (1949, p. 246, and pl. 16), apparently following Brønsted (1938, p. 129), feels that this important Atlantic-Sub-Boreal transition level may be placed as early as *circa* 3000 B.C. The present writer, however, is reluctant to accept such an early dating. Following Childe (1947, table 3, p. 333), who gives a date of *circa* 2300 B.C. for the Windmill Hill Culture; Fox (1943, p. 9), who estimates a maximum age of *circa* 2400 B.C. for Neolithic "A" in the Lowland Zone of Britain; Piggott (1949, p. 68), who believes the first agricultural settlements were established in southern England soon after 2500 B.C.; and Hawkes (1940, p. 142 and table 4), who suggests *circa* 2500 B.C. as a reasonable figure, and allowing for the inevitable time lag for the diffusion of this new economy to Ireland, it seems improbable that the Irish Neolithic could have begun much before the end of the third millenium B.C. (Movius, 1942, fig. 59, p. 255). In this connection, it is interesting to note that Glob (1952, p. 76) in his recent book on the Neolithic antiquities of Denmark gives a date of *circa* 2500 B.C. for the beginning of the Early Neolithic Period.

[14] The surface of the Postglacial marine deposits at section B in the Railway Cutting occurs at an elevation of 6.70 m. (*ca.* 22 feet) above O.H.W.L., or 2.25 m. (7 ft., 5 in.) *higher* than the corresponding level at the Harvard site. Since storm wave action has played only a very minor role as an agent conditioning the deposition of the Curran, the difference in elevation at the two localities cannot be attributed to this factor. Only

on this basis is indicated on the graph shown in figure 4.

4. Shortly after the beginning of Zone VIII (Sub-Atlantic), when the Late Bronze Age began in Ireland, according to Jessen (1949, p. 161 and pl. 16), the land must have attained a level approximately 1.52 m. (5 feet) higher than that of the present with respect to O.H.W.L. A slight sinking movement, which appears to be still going on, has taken place during historic times, as shown on the graphs.

On the basis of the above summary of the salient evidence from only three sites, the urgent need for detailed investigations of additional sections in North-East Ireland will be only too apparent. In this connection, the Island Magee and Belfast localities should be given a high priority. For, not only does the latter site demonstrate that there was a submergence of at least 13.75 m. (45 feet), as stated above, but also if Praeger's section showing the lower, middle and upper Zones of the estuarine clay, overlying a Sub-zone VIa peat, are plotted accurately on a graph, the resulting curve seems to provide very clear evidence for the occurrence here of differential movements of the Earth's crust during the time of the submergence. If this should be confirmed by future research, it is likely that variations in the density and weight of the Earth's crust at different points along the Irish coast have contributed to local faulting. Thus it appears that the crustal recoil of the land in this region, ultimately consequent upon the recession of the ice sheets, not only resulted in general subsidence in areas peripheral to the centers of ice dispersal but also that they induced local phenomena with local movement in the regions thus affected.

Subsequent to the beginning of Postglacial time, the crustal recoil was greatly accelerated as the land became liberated from its load of ice. Matter in depth was being squeezed into the formerly basined area—in this case northern Scotland—which began to rise. The extent of this uplift was greatest in the central part of the depressed region (Wright, 1937, fig. 127;

0.91 m. (3 ft.) of estuarine clay was found near the base of the deposits at the Railway Cutting site; therefore, it is probable that the compaction of the silty and clayey deposits at the 1935 locality has been the major cause of the difference in height, although even the section B sediments must have suffered a certain amount of compaction.

Movius, 1942, fig. 7). But at the same time the seas were rising, too, and local faulting, resulting from the stresses of the more widespread crustal movements in the area peripheral to the Scottish Highlands, was taking place. As Daly (1934, p. 53) has stated, the history of deleveling is due to the extremely complex interplay of several factors: (a) crustal recoil of the land; (b) eustatic rise of sea level; and (c) regional alterations in the form of the sea level itself (discussed on p. 704-706); as well as a fourth factor, not listed by Daly, consisting of (d) local differential movements resulting from local faulting. Indeed, as von Post (1952) has shown in the case of Sweden, the fact that such regional crustal movements, apparently of variable amplitude, must be reckoned with, in addition to the interaction of isostatic and eustatic factors, often leads to a very complex situation.

Now it is unlikely that the actual amount by which the sea level rose during Early Postglacial time (i.e. since the beginning of the Finiglacial Stage in Scandinavia) was greatly in excess of 20 m. (65½ ft.), according to Daly (1934, p. 52). On this basis, it is apparent that Godwin, who continually refers to a relative change in the mutual relations of land and sea in southern Britain and the North Sea (Dogger Bank) region of the order of 52 m. (170 ft.) as being due entirely to a eustatic rise of sea level, the major portion of which occurred during Late Boreal times (Godwin, 1943, p. 236; 1945, p. 63-67), has not considered the possibility that isostatic movements probably also took place well *outside* the limits of the area basined at the time of the last ice advance (Zeuner, 1952, p. 40). Nevertheless, in his earlier papers Godwin has consistently maintained that *both* isostatic and eustatic factors have operated in the British Isles (Godwin, 1940a, p. 297; 1940b, p. 397; 1941, p. 356-357), just as they did in Scandinavia.[15] Actually, however, there has been a widespread tilting

[15] Recent investigations in southern Sweden (von Post, 1938; Florin, 1944) and western Norway (Faegri, 1943, p. 36-50) have shown that the Postglacial fluctuations of level due to temporary resubmergence of the isostatically uplifted area, resulting from concomitant crustal movements (von Post, 1952), are extremely complex. Further north in the Gulf of Bothnia, where the rate of the regression has been studied by Lidén (1938) and Hyyppä (1937, p. 195-201), the local differential uplift during the last 40 years shows a tendency to vary more than is the case in the rate of the whole emergence, which has lasted at least 12,000 years (Sauramo, 1939a, p. 9). According to Sauramo (1939a, p. 14) the actual

away from the centers of the glaciated tract—one in northern Europe and a second one in central Scotland—the entire area affected having been strongly updomed. In this manner the flow of magma in the subcrustal zone must have caused a general sinking in the entire area of the North Sea Basin, southern Britain, the Irish Sea Basin, and southern Ireland. In addition, local faulting in North-East Ireland appears to have resulted from the stresses of these more widespread crustal movements. This region has also been affected by the updoming movement referred to above.

The strong probability that both eustatic and isostatic factors were operating together during a large part of the Early Postglacial Stage is indicated by the comparatively rapid nature of the submergence, which is clearly shown by the Cushendun and Island Magee sections discussed in this paper. For it is considered improbable that a relatively sudden sinking of 7.40 m. in one case, and 10.20 m. in the other can be accounted for adequately on the basis of eustatic factors alone.[16] Furthermore, the evidence from Belfast provides a good indication of the fact that this movement was in reality of the order of approximately 14 m. (*ca.* 46 feet), as indicated on the graphs shown in figure 4. Following this movement there was a slow but steady eustatic rise possibly amounting to as much as 2 m. During this interval, beaches subsequently raised above sea level by continued isostatic movement were formed. But the intensity of this uplift movement decreased markedly toward the south, as shown by the position of the O-isobase of the Postglacial raised beach (fig. 3: inset). Finally, in historic times there has been a small amount of eustatic transgression of just over 1.50 m. Thus the Early Postglacial marine transgression in northeastern Ireland is considered to have been

velocity of the uplift in southern Finland indicates that the recent movements of the Earth's crust in this region must be conceived of as having been of the magnitude of earthquakes. In any case, as this authority has clearly stated, the relative changes of level during Late Glacial and Early Postglacial time throughout northern Europe have been caused "partly by the eustatic rise of the sea-level, partly by the isostatic upheaval of the earth's crust" (Sauramo, 1939b, p. 60).

[16] Differences with regard to the figures for the amplitude of this movement arise mainly from the fact that the height of the original old land surface, which was transgressed by the sea during the early stages of the submergence, differed considerably at each site that has been investigated. However, this does not affect the trend of the graphs at any given locality.

caused by a eustatic rise in sea level, which for a period of several millenia overtook the progressive recovery of the land in that region, following the general depression of Late Glacial time. To further complicate the picture, it seems probable that superposed on the isostatic and eustatic pattern of widespread fluctuations we have also to reckon with differential crustal movements of local origin.

The evidence secured to date shows that the combination of factors determining control of the movements affecting the mutual relations of land and sea is so complex that, until a very great deal of additional material is available, it is doubtful if the two can ever be disentangled on an objective basis, in cases where both have operated simultaneously. At present all one can do is to express an opinion concerning which factor—eustasy or isostasy—has in all probability been dominant in a given instance. In so far as the present paper is concerned, an attempt has been made only to establish the *relative* position of land- and sea levels in North-East Ireland during Postglacial time. When a series of such curves is available covering a wider range of localities in this region, as well as other parts of northwestern Europe, it may be possible to resolve the movements in question into their component factors. In this regard, detailed investigations of changes of level at Early Postglacial coastal localities in Scotland and northern Britain along the lines proposed by Godwin (1940b, p. 397) would provide interesting material for comparison. Furthermore, many of the Scottish localities are extremely rich from an archeological point of view.

The results of Jessen's paleobotanical investigations in North-East Ireland (Jessen, 1949, p. 125-144, 228-230) confirm Godwin's conclusions based on a study of the coastal peat beds of the North Sea region (Godwin, 1945, p. 63, 67; Conway, 1948, p. 220), namely, that we must abandon the concept that the beginning of the Atlantic Period witnessed the development of an extensive and widespread marine transgression. For, in reality, the major part of this movement had already occurred prior to the Boreal/Atlantic Transition (B.A.T.) horizon, and it is only the culmination of the movement that took place toward the end of Atlantic time. Furthermore, the climatic optimum had passed in North-East Ireland at least a thousand years before the maximum of the transgression was attained. Prior to this submergence the greater part of the area now covered by the Irish Sea must have been dry land. As pointed out elsewhere (Movius, 1942, p. 88), the 20-fathom isobath (implying that the sea was 120 feet, or *ca.* 36.50 m., lower than at present) would result in the establishment of a partial land bridge between southwestern Scotland and North-East Ireland. Since Godwin (1940a, p. 287; 1941, p. 355; 1943, p. 234-245) has demonstrated a net relative sinking of some 170 feet, or 52 m., for the North Sea (Dogger Bank) region during roughly the same interval of time, this figure seems quite reasonable, although there is as yet no direct proof that the transgressive movement in the Irish Sea basin amounted to more than 46 feet (14 m.). However, there are a good many indications that the 20-fathom figure is substantially correct. On this basis, one can attempt to reconstruct the conditions in the area at this time—an important consideration since it was during the Early Boreal Period that the first immigrants arrived in Counties Antrim, Londonderry and Down from Britain. The low coastal belts were at that time considerably extended, and nearly the entire area between Inishowen and Islay must have been dry land.[17] At no stage, however, did the whole area constitute an unbroken land bridge, since even during the maximum of the emergence, the sea was present in a long narrow estuary or "river," which received the drainage of the surrounding land (Charlesworth, 1930, p. 386). The partial connection was broken, and although large tracts of what is now dry land were submerged, conditions substantially like those of the present day resulted from the Postglacial marine transgression. When the partial connection with Scotland was severed, the present coastlines were established in all essential respects. In some cases these features were somewhat inland with respect to their present position, especially in the case of various bays and inlets, but this situation was rectified once the movement of relative emergence got under way during Sub-

[17] Compare Charlesworth, et al., 1935, p. 483. The present-day ranges of the species of Lepidoptera common to Britain and Ireland further indicate the former existence of the partially complete land bridge between Islay, in the west of Scotland, and Inishowen in County Donegal, according to Ford (1945, p. 309-324) and Beirne (1943, p. 47; 1947, p. 355; Charlesworth, 1950, p. 66; Deevey, 1949, p. 1348-1350). This fact is likewise confirmed by the distribution of the bats found in both areas, as Beirne (1948) has shown, thus supporting the bathymetric data (Hull, 1912, p. 7 and pl. 1).

Boreal times. As previously stated, it was at this time (*ca.* 2200 B.C.) that the first Neolithic settlers reached the shores of North-East Ireland.

So many variables are involved in determining measurements of changes of level that perhaps it will seem that their degrees and complexities are such as to vitiate the computations themselves and to preclude the formulation of even tentative conclusions regarding the amplitudes of the movements in question. But this is far from being the case. Although there is much that cannot be explained on the basis of the existing data, the broad picture as regards the relative movements of the land with respect to the sea during the Postglacial Stage in North-East Ireland has been known since 1904 (Coffey and Praeger, 1904, pl. 5), and recent work has served only to close in a few of the most obvious gaps.

On the basis of the figures discussed in the text, the measurements of changes of level during the Postglacial Stage in North-East Ireland may be summarized as follows:

(a) *Submergence*—approximately 45 feet.[18]

Cushendun	7.90 m., or 25 ft., 11⅝ in.
Larne-Island Magee	12.05 m., or 39 ft., 6⅜ in.
Belfast (see p. 728)	13.75 m., or 45 ft., 1¼ in.

(b) *Emergence*—approximately 30 feet to about H.W.L.

Cushendun	8.80 m., or 28 ft., 10½ in.
Larne—Island Magee	10.51 m.,[19] or 34 ft., 5⅜ in.

At the time of the maximum emergence the surface of the Postglacial marine deposits (deposit B) at Cushendun stood at 8.82 m. (*ca.* 29 ft.) above H.W.L., while the corresponding level in the Larne region is computed to have been approximately 10.67 m. (*ca.* 35 ft.) with respect to H.W.L.

(c) *Recent sinking*—approximately 5 feet at all localities.

Present elevations of surface of marine deposits above H.W.L. computed to be as follows:

Cushendun	7.40 m., or 23 ft., 10½ in.
Larne (Harvard Site)	9.15 m.,[20] or *ca.* 30 ft.

18 It is interesting to note that this figure *decreases* from south to north—toward the center of greatest isostatic uplift.

19 This figure allows 4.70 m. for the compaction factor (see p. 729).

20 Actual height at present: 4.45 m., or 14 ft., 7⅛ in.

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Peabody Museum of Archaeology and Ethnology
Harvard University
Cambridge, Massachusetts