SECT. II.—OTHER SELECTED PAPERS.

No. 1,436.—“The Lagoons on the South-east Coast of Ireland.”

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A DESCRIPTION of the lagoons and banks on the south-east coast of Ireland, with suggestions as to their origin, may be interesting to the members of the Institution, as a supplement to Professor Prestwich's Paper, “On the Origin of the Chesil Bank.”¹

The lagoons to which attention is directed all lie between Brattin Head, co. Waterford,² and Cahore Point, co. Wexford³ (Plate 7). These include the Tramore lagoon, called the “Back Strand,” co. Waterford, and those in co. Wexford, called Ballyteige Lough, Tacumshin Lake, Lady's Island Lake, and Wexford Harbour. Reference will also be made to Waterford Harbour and Bannow Bay, and suggestions given as to the reasons why lagoons did not form in them also. Bannow Bay, indeed, might be called a lagoon, but it is very different to the others mentioned. Previous, however, to entering into the subject of the lagoons, it will be necessary to give a short résumé of the geology of the country.

In these portions of the counties of Waterford and Wexford, granite and other igneous rocks occur, with derivate or sedimentary rocks, of the Cambrian, Cambro-silurian, and Carboniferous ages, partially covered with more or less recent drifts. The older Palæozoic rocks are partly metamorphosed, and much broken up and displaced by faults; the Carboniferous rocks are faulted in a less degree; while the drifts are only slightly disturbed. The drifts may be classified as follows:—Glacial drift. Sands and other marine accumulations formed during the Esker period, when the sea stood about 350 feet⁴ higher, relatively to the land, than at present. Sands and other marine accumulations of the “age of the 100-feet⁴ sea beach,” when the sea stood for some time between 90 feet and 120 feet⁴ higher than at present. Sands, &c., of the

¹ *Vide* Minutes of Proceedings Inst. C.E., vol. xl., p. 61.

² Admiralty Charts, Ireland, sheet xiv.

³ *Ibid.*, sheet xv.

⁴ These heights are above the Ordnance datum, not above the mean tide; consequently, on some portions of the coast of Ireland, when the tide rises high, these ancient sea beaches seem to be at different levels.

"age of the 25-foot sea beach," thrown up when the sea was stationary, between 20 and 30 feet higher than at present. Estuarine accumulations; and, finally, more recent drifts.¹

The present lagoons, although their basins were probably formed during the "age of the 25-foot sea beach," occur on the sites of very ancient hollows or valleys. Subsequent to the metamorphism of the Cambro-silurian rocks, but prior to the Carboniferous rocks being deposited, denudation excavated valleys and hollows in the pre-existing rocks, along lines of weakness principally due to faults, breaks, and shrinkage fissures. These hollows were more or less filled up by rocks of the Carboniferous age; and between the end of that period and the dawn of the Glacial, the newer rocks were also faulted, and other valleys eroded, all to be afterwards partly or wholly filled by glacial accumulations. Of the glacial drifts, a considerable portion seems to have been denuded and rearranged, during the "Esper sea period" into shingle, gravel, and clay; and those at low levels still more recently, while the sea was stationary at about 100 feet, and at about 25 feet higher than at present. During both these latter times, drift of the Esper period was also denuded, the bays now lagoons having been excavated principally in it and the newer drift, during the "age of the 25-foot sea beach." For then, as now, the sea cliffs from Cahore Point to near Bannow Bay were principally formed of drifts belonging to the Esper period, or 100-foot beach age, while those to the west of Bannow Bay were more or less hard rocks. After the "age of the 25-foot sea beach" the land gradually rose until it was at least 30 feet higher than at present, at which time the bays were filled by estuarine or land accumulations. Afterwards the land slightly sank.² None of the lagoons, here or elsewhere in Ireland, are in the deltas of rivers, from the nature of the river valleys; as the detritus brought down by the head-waters and mountain tributaries of the large rivers is deposited in one or other of the flat reaches along their courses, and little or none of it is brought down into their estuaries. Thus the bars of these lagoons have a different origin from those in the South of France along the margin of the tideless Mediterranean sea.³

¹ The ages of the drifts have been discussed in a Paper by the Author on "Glacialoid or rearranged Glacial Drift" ("Geological Magazine," March and April 1874).

² Vide Paper on "The Estuary of the Slaney," read, March 1875, before the Royal Geological Society, Ireland.

³ Vide Minutes of Proceedings Inst. C.E., vol. xxviii., p. 287.

Some of the lagoons have permanent open channels through their inclosing banks; while the outlets from others are temporary and changeable, being at one time open, at other times closed, and variable as to position. The origin of the banks is apparently due to the effect, at the different periods of rest, of a tendency of all gradually subsiding, or of sometimes rising tidal seas to form a terrace at high-water mark. On open coast lines, all marine denudation on the cliffs seems to be accomplished by the incoming tidal waves, this being at its maximum when assisted by storms. But the drifting of materials to fill up hollows is a distinct though concomitant operation. The operation of three distinct forces transports the materials, namely, that of the incoming tidal waves, that of the waves formed by winds in shallow water, and that of the wind carrying materials on the land. The first has usually the greatest influence, as it acts twice daily, while the others can only be in force during gales and storms; wind also forms the ground swells. If the prevalent winds on a coast blow in the same direction as the set of the "flow" tide, both act in concert, and the drift is increased accordingly. If, however, they act in opposite directions, the effects of the wind temporarily modify the effects of the tidal waves; but as one is a daily worker, while the other acts only occasionally, all the work done by the wind, within reach of the tidal waves, is more or less obliterated. It is remarkable, even during heavy gales, how much power the incoming tidal waves have, compared with that of the waves raised by the wind. This was exemplified in Ballyteige Bay, during the winter of 1873-74, while the iron vessel "Calcutta" was beached broadside to the shore. The wreck was visited a week after it had been driven ashore, during which time a steady, heavy gale had blown from the W.S.W., in a different direction to the incoming tidal waves, which here set from the E.S.E. During this week a considerable sandbank formed between the vessel and the shore, the major portion of the sand being banked behind the W.N.W. end of the vessel, while there was scarcely any sand behind the E.S.E. end, which showed that the drift from the tidal waves was greater than that of the wind waves.

Wind when acting by itself has considerable power, and to it are due the height and character of many of the lagoon banks, as during low water it carries from the exposed shores a large quantity of sand above the reach of the waves, while the materials in the banks are drifted thereby from one place to another, and piled in high hills and ridges, sometimes from 50 to 100 feet high, or even

more. The wind often, however, modifies its own work, as the sand driven up by one gale may be carried to sea by another from a contrary direction.

When the sea-margin is denuded into a flat, a few feet higher than the strand, it forms a rampart or beach, of shingle, gravel, sand, or seaweed on the margin of the flat. This, although ever slowly retreating backwards, is still, as a general rule, growing higher and higher from the drift of the waves and wind; while behind it water may collect from land drainage or the sea going over the bank during storms or high tides, and thus many lagoons are formed. Some bays are gradually filled up with slightly sloping muds or strands, while others change into lagoons. The latter change in some is due to a shoal forming off a shore-reef, which afterwards is modified into a spit, that gradually increases in length, until eventually a bank incloses a lagoon. Other bays seem to change into lagoons on account of a river or stream flowing in a contrary direction to the waves of the incoming tides; consequently a shoal, and eventually a bank, appears at the meeting of the currents, which increases in length until a lagoon is inclosed. Other lagoons seem to be due to off-shore shoals, being modified into bars as the land gradually rises.

From the above description of the origin of the inclosing banks of lagoons, it is apparent that they can be formed during either the falling or the rising of the relative level of the sea.

Whichever of the above processes may have given origin to the inclosing bank of a lagoon, the lagoon itself is, all the while, being gradually silted up. This in the Irish lagoons, on account of the nature of the river valleys as previously mentioned, is rarely promoted much by the wash from inflowing streams. The lagoons do, however, receive a little from the waste of the marginal lands; but they seem to be principally filled by detritus carried into them by the sea during storms and high tides, or by materials drifted into the basins by the wind; the wind, however, will often modify its work by blowing out again some of the sand. This, especially in some localities, takes place in hot summer weather, when the evening off-shore winds blow over dry portions of the lagoon bottoms. In some lagoons a small part of the material consists of minerals deposited from the water when evaporating; while in favourable situations marshes will form, which eventually change into peat bogs.

Some bays do not form lagoons, as for instance, Dublin Bay. In this bay, but especially towards its head, circumstances would seem to have been favourable for the formation of a lagoon. There

indeed appears to be an incipient bank;¹ but this has evidently lost its original condition, on account of the artificial works from time to time executed in the bay. In rock-bound bays there seems to be a scarcity of materials to produce a bank; while in some long, narrow bays, especially if a large stream or river flows into them, although materials are plentiful, it is impossible for a lagoon to form; if the shore of the bay opposite to the drift of the incoming tidal waves is of such hard materials that it resists denudation, and consequently the stream channel cannot be obliterated and moved backwards before the advance of the inclosing bank, but the outcoming waters are forced to act on the materials carried in by the tide, and to spread them out more or less. On this coast Waterford Harbour belongs to this class, being rock-bound on its east shore opposite the drift of the incoming tidal waves. Consequently a bank cannot grow out from its western shore, the river channels not being able to cut into the shores and move eastward. Near the mouth of Waterford Harbour a bank has commenced to grow from the west shore opposite Broomhill; but the force of the ebb tides, combined with that of the waters of the Suir and the Barrow, has spread the material out, producing shoal water between Duncannon and Woodstown strands. At Bannow Bay a bank has grown from the western shore towards the north-east, from the headland, on the south-west of Bannow Island, and deflected the channel of the river, first due east, and then close to the shore of the island. Between the island and the mainland shingle beach has been cast up by the sea. In this bay a typical lagoon would have formed long since, but for the rock-bound island and rocky shore which prevent the channel of the stream moving eastward. Consequently the bar cannot exceed its present limits.

THE BACK STRAND AT TRAMORE.

The most westerly of the lagoons to be described is that called the Back Strand, at Tramore.² This occurs in the site of an ancient valley, as, prior to the Glacial period, a deep hollow, denuded in faulted and broken ground, extended from the town of Waterford to Tramore Bay. This valley was filled by glacial drift, while subsequently it was partly re-excavated during the "Esker" and "100-feet beach" seas, as the drift in the hollow

¹ Clontarf and White Banks, Chart DUBLIN BAY.

² Charts, sheet xiv.

was more susceptible of denudation than the adjoining rocky coasts at Newtown and Brownstone Heads. The present lagoon was probably for the most part excavated during the "age of the 25-foot beach," as in various places around it traces of the raised beaches can be found.

On this part of the coast the drift from the incoming tidal waves is from west to east, while the more prevalent wind-formed waves set in the same direction, consequently there is a general eastward drift of the banks. It would seem probable that when the land rose relatively after the "age of the 25-foot sea beach," the bay became filled with alluvium and bog, while subsequently, when it again came under the influence of the sea, a shingle beach was cast up along the margin of the flat, which in time, by the processes previously described, became the inclosing bank of a lagoon. Shoals could scarcely ever have existed in the bay, to be modified into a bank, on account of the hard nature of the coast to the westward, and consequently of a paucity of materials to form them. The site of the bank must have been originally much more seaward, as peat and estuarine accumulations occur outside it.¹

The streams flowing into the lagoon would never have been large, consequently the washing from them has always been small. The principal one flows into the eastern side of the lagoon, so that the channel from the lagoon was probably always at the east end of the inclosing bank. In this and all the banks hereafter mentioned, the materials are principally Æolian or blown sands, derived from drifts. When, however, sections are cut into them by the sea, they seem to have a foundation of shingle or coarse gravel.

BALLYTEIGE LOUGH.

The next lagoon, to the east, comprises the Ballyteige Lough and Broadwater. These exist on the sites of Pre-glacial valleys, as an ancient hollow extended up Duncormick Bay, and a second up Broadwater. The valleys seem to have had vicissitudes similar to those mentioned as happening at Tramore Lagoon, and subsequently, when the land rose after the "age of the 25-foot sea beach," there seems to have been a bay extending up to Duncormick, and a second through the Broadwater to near Bridgetown, with an island (Inish) opposite the mouth of the

¹ Peat is said to be found in deep water in the bay, but of this the Author has no personal knowledge.

latter. Here also the "flow" tide runs from west to east; yet, on account of the Saltee Islands, and various rocks and shoals off Crossfarnage Point, there is an inland current running about from east-south-east to west-north-west, which causes the main drift of the lagoon bank to be in that direction, although the drift due to the waves formed by the prevalent winds should be the opposite way.

The origin and time when this bank was formed are uncertain; evidently at one time the Broadwater formed an independent lagoon. Of the present lagoon bank, the western end is much newer than the eastern, as it is daily extending westward, the stream channel retreating before it, as the coast opposite is boulder-clay drift, which is easily denuded. From the appearance of the ground it seems probable that the present lagoon did not formerly extend as far west as Duncormick Bay; but that afterwards, on account of the drift of the bank towards the westward, it grew beyond the mouth of that bay and gradually reached its present extent. It cannot, however, go much farther in the present direction, as the boulder-clay drift, a little to the west, is replaced by Cambrosilurian and other rocks.

The bank of this lagoon may have begun as a spit on the shore rocks near Crossfarnage Point, and gradually grown towards the north-west, across, but off, the mouth of the bay of Broadwater, after which it was deflected westward, margining the coast. It appears, however, more probable, that, after the last elevation of the land, when it was sinking, and again came within the influence of the tidal waves, there was a low flat, on the margin of which a beach was formed, which gradually grew into a bank on account of the drift from the east-south-east, the bank at first extending from Crossfarnage towards the north-west, but since having slightly moved inland, and extended toward the west, margining the land.

It has already been pointed out that the main drift of the sand is from the east-south-east, while the drift due to the prevalent winds and wind-waves is in a contrary direction. These, consequently, at times, have acted against one another, and the effects have been, that, although the main channel from the lagoon seems always to have been to the west, yet, at times, other embouchures have opened through the bank during storms. Such channels were at one time open, but at others closed by the drift of the tidal current.

This lagoon, from the narrows a little east of Duncormick Bay, eastward, has been reclaimed during late years; but the reclamations have not been as successful as might have been expected.

TACUMSHIN AND LADY'S ISLAND LAKES.

Between Crossfarnage and Carnsore Points are the Tacumshin and Lady's Island Lakes.

They are similar to the lagoon of Ballyteige, as they occur in the sites of ancient hollows, and, although in part excavated during the "age of the 25-feet sea beach," yet, so far as known, there is nothing against these inclosing banks being very recent, and having been piled up by the action of the present sea; but the depth and nature of their estuarine accumulations have not been ascertained. The banks, however, must originally have been farther seaward, as under them and outside are peaty estuarine stuffs; besides, hereabouts the sea is rapidly encroaching on the land, and, as it cuts away the cliffs, it moves the lagoons' banks back.

On this portion of the coast the drift of the banks is complicated on account of the prevalent winds blowing from the south-westward, while the drifting action of the incoming tidal waves is in various directions; during flood tide, the current inshore being westward for more than half the tide, while for the rest of the tide it is eastward, and this varying in the spring and neap tides. At Lady's Island lagoon there is no regular embouchure, while at Tacumshin the channel is often closed up. At Tacumshin there is a considerable stream flowing into the north-west part of the lagoon at Tomhaggard. This follows a channel, locally called a "pill," obliquely across the muds nearly to the east of the basin, where it turns at a right angle and meets the bank at its centre, proceeding thence along the bank to the west end. From this it would appear that the principal drifting of the bank is from the east towards the west. The west channel seems generally to have remained open; nevertheless it has often been closed up, on account of artificial cuts being made in other places.

Into the Lady's Island lagoon only small streams flow, and, as they do not contain sufficient water to keep any particular channel permanently open, they often close quite rapidly, to be opened again, sometimes in the old, but more usually in new places. Such channels may be cut by the dammed-up water when it rises too high, by high tides, by storms, but more generally by the hand of man. The inclosing banks of both these lagoons probably originated as beaches on the margin of flats; that at Tacumshin appears to have increased afterwards principally from east to

west, while the bank at Lady's Island Lake may have grown similarly or been piled up from seaward by the action of the waves and wind. A fruitless attempt has been made to reclaim Tacumshin lagoon, and since then the driftage of the bank westward has been considerable.

Formerly some lagoons existed between Carnsore Point and Greenore, but their inclosing banks have been pushed far inland and only traces of them remain, consisting of small bogs or marshes behind ridges of Æolian drift, with submarine bogs to seaward.

WEXFORD HARBOUR.

The last lagoon to be mentioned is the estuary of the River Slaney, known as Wexford Harbour. With the silting up of this lagoon, and the formation of the inclosing bank, the Slaney can have had very little to do, as the river brings down only small quantities of detritus into its estuary. This lagoon, like the others, occupies the site of an ancient valley. One, by geological evidence, existed here before the Carboniferous period, while the present lagoon was a bay at the "age of the 25-foot sea beach," having been excavated in drifts belonging principally to the "Esker" and the "100-foot beach" periods. Here, as elsewhere, after the "age of the 25-foot sea beach," the land rose relatively till it was at least 30 feet higher than at present, which is proved by the submerged peat in the lagoon and the submarine bogs out to sea. This ancient peat is recorded from the following places:—at the west engine-house on the North Flats, or "intake" (in the north-west part of the lagoon), bog 5 feet thick was found 16 feet below the surface of the mud, or 21 feet below the level of high water. The bogs at Curracloe and Ballinesker to the north-east of the lagoon are said to have been proved 20 feet deep, but here the peat was not "bottomed," as at that depth, turf, mud, and water burst up in the bogholes and flooded out the turf-cutters. Peat also exists off the shore under a depth of 4 fathoms of water between the main land and the shoal called Rush Bank, to seaward of an ancient lagoon south of Cahore, now a bog and marsh.

The Wexford lagoon is separated from the sea by two banks; one extending in a gentle curve northward from the Rosslare Coastguard Station to Rosslare Point, and the other in a curve southward from Ballinesker to Raven Point; the extreme length from the land on the south to that on the north being 10·5 miles.

These banks are of Æolian drift, as is also for the most part the spit of land to the south-west of the Rosslare Bank, but not entirely, as the portion next the South Flats is sand, gravel, and clay, probably accumulated during the "age of the 25-foot sea beach." Of the area inside these banks considerable tracts, to the south (South Flats), and to the north (North Flats), have been inclosed within the last thirty years; but, before this was done, in the north part of the lagoon there were several islands, principally masses of the "Esler period" drift (marl), that had escaped the denudation of the sea of the "25-foot beach," while, in the Raven Bank, there were three breaches through which boats could pass at high water. There is also a tradition that formerly the principal channel into the harbour had its embouchure at Curraclloe. On this coast the main drift is from south to north, in the direction of the incoming tidal waves.

Possibly the banks that now divide the lagoon from the open sea may have begun as shingle beaches on the margin of a flat; but probably during the "time of the 25-foot sea beach," when the marine conditions and operations were nearly the same as they are now, there must have been, as effects thereof, off-shore shoals somewhat similar, but more inland, to those that now exist between Greenore and Cahore Points. Such shoals, as the land rose and the inshore current of the tide decreased in force, would be moved inland, and eventually modified from detached shoals into more or less continuous banks; and if the present sea bottom relatively was elevated 42 feet (7 fathoms) somewhat similar banks would be formed, crossed by two well-marked channels, one opposite the embouchure of Wexford Harbour, and the other to the north at Rush Channel. If, therefore, during the "time of the 25-foot sea beach," shoals existed off the mouth of the inner bay, they, as the land rose, would be modified into banks, through which there would be channels, the deeper probably being at the centre and to the northward. That at the centre ought to become deeper and deeper as the land rose and the out-flowing current had increased power of denuding, while the north channel would silt up from the drift of the sand.

When the banks were formed they inclosed a lagoon which afterwards became a marsh, and eventually a peat bog; while subsequently, as the ground gradually sank, the sea began to flood the land inside the banks, the water at first flooding the bog in the vicinity of the channel, and afterwards extending, till eventually most of the old area again became a lagoon; not, however, all, as the banks were gradually moving in on the bogs; while portions,

such as the bog of Curracloe, to the north-east, were never flooded, but continued growing from the time when peat began to form in the lagoon to the present day.

As the sea rose, the banks moved inland; and since the land ends of these banks could not retreat as quickly as the open portions, and as the points of each bank at the central channel were also kept back by the force of the water flowing out of the lagoon, they necessarily form gentle curves. The previously mentioned breaks or shallows through the north portion of the banks, between the Raven Point and Curracloe, were probably kept open by the more prevalent wind-waves on the waters of the lagoon, as, since the north flats have been reclaimed, the drift of the sands northward has closed them up.

The Rosslare Bank of late years has been much denuded and in places breached; this seems in a great measure to be due to the back "counter" current generated by the present form of the Dogger Bank.

Previous to the reclamation of the North and South Flats, the outflow from Wexford Harbour was much greater than at present, and its force seems to have been about equal to that of the incoming tidal waves, consequently the Dogger Bank, as represented in Commander Fraser's chart (1844), Plate 7, was a massive sand-bank, due east of Rosslare Point. Now, however, it appears, from Staff-Commander Kerr's chart (1873), that within the last thirty years, since the outflow from the lagoon has been lessened by the reclamation of the Flats, the incoming tidal current has changed the Dogger Bank from a massive shoal to a long, narrow bank extending nearly south-west and north-east, overlapping the south end of the Raven Bank. On the Dogger Bank, a long, narrow island has been piled up across the site of a former channel; while the Hantoon channel between the bank and Rosslare Point is nearly silted up, and off the land the Lucifer shoal is gradually being carried away.

The study of the drift of sand on a sea-coast, and the growth of the inclosing banks of lagoons, seems of importance not only to the geologist, but also to engineers, otherwise great labour and cost may be incurred [to no purpose, while reclaiming lagoons, or improving the embouchures of harbours. Consider the case of Wexford Harbour. The northward drift, as just now pointed out, is always bringing up materials, part to increase the dimensions and length of the Dogger Bank, and part to supply the materials for the "shifting sands" of the bar. To improve the entrance, it would be necessary to stop this drift, as much as possible. As the

main drift of the sands is known, this, in a great measure, might be accomplished by erecting a groyne, or breakwater, from Rosslare Point eastward across the Dogger Bank, on the south side of which all the drift due to the incoming tidal waves would lodge, the only materials left to form the "shifting sands" being the drift due to wind, or brought by the outflow from the lagoon. Such a groyne, for a long time, would effectually stop the tidal northward drift; but eventually, when the ground behind it was silted up, it would be necessary to increase its length, as otherwise the sands would creep round it. The groyne should be concave to the driftage, or have transverse groynes from it, as it is apparent from structures already made that if convex, the sand in a short time creeps round it.

In general groynes are very costly, consisting as they do of strong stone ramparts. These, however, are often destroyed by their own weight, and even if effectual, are in a short time buried in sand or other drift. To stop the drift, in many places, it is only necessary to make an impediment, as a nucleus, which subsequently would grow into a permanent breakwater. The combination of piling and sheeting is effective for this purpose in many places on the south-east coast of England; or fascines might be used, as seems to have been a custom with the ancient Irish. Even at the present day the latter have served to repair breaches in river and tidal embankments after piling at vast expense had failed.

Now to refer to the connection between the drift of sand and the reclamation of lagoons. At Ballyteige Lough the reclamation of the flat has not been so effectual as might have been expected. The works to reclaim the flat were a canal from Bridgetown to Duncormick Bay (B to A), to catch and divert the land drainage; an embankment across the narrow part of the lagoon, east of Duncormick Bay, in which there are tidal sluices to drain spring and surface waters off the reclaimed land; and the heightening of all low parts of the bank to prevent the sea coming in. At first these works appeared to be sufficient; but, on account of the flats being cut off and the area of water diminished, the outflow in the narrow portion of the lagoon between Duncormick Bay and Barmouth is now unable to carry away the sand blown or swept by the tide into it, consequently it has greatly silted up, and the fall is insufficient to drain the flat. The rise and fall of the tide outside the inclosing bank is 13 feet, while in the narrow between Duncormick and Barmouth it is 6 or 7 feet; it is therefore proposed to run a canal from the centre of the flat to Crossfarnage Point (D

to C). Another plan may be suggested, namely, a canal across the sandbank south-west of Richfield (in the vicinity of the line EF). The mouth of such a canal would be liable to be closed by, first, tidal drift from the east-south-east; secondly, by the wind-wave drift from the west-south-west, and, thirdly, by the land drift due to wind blowing the sand into it. The first of these might be prevented by erecting two or three groynes at intervals to the east of the mouth of the canal; the second, probably, by one groyne erected on the west of the mouth; and the third by planting belts of the *Pinus Austriaca* (the Austrian, or black pine), that have been found so effective to stop the blowing sands at Bundoran, co. Fermanagh, or by a box tunnel through the sand. Such a canal would involve a comparatively small cost, and it would start from nearly the lowest part of the flat.

In the attempted reclamation of the Tacumshin Lake, no catchment canal to carry off the land drainage was made, or no account seems to have been taken of the drift of the bank; therefore the latter silted up the embouchure, and the former flooded the reclaimed lands. On account of the drift in opposite directions on this part of the coast, different schemes might be suggested for reclaiming this lagoon.

The majority of those who took part in the discussion on Mr. Prestwich's Paper considered that the main drift of sea beaches is due to wind waves. This is contrary to the Author's observation,¹ and apparently to the results of the experiments on waves made by Mr. J. Scott Russell, M. Inst. C.E.² This eminent observer classes the great tidal wave in the "Waves of the first order," or "Wave of Translation," while storm waves nearly all belong to the "Second order," the exception being those portions that break on a coast beach, which then change to a wave of the first order. Mr. Scott Russell also shows that waves of the second order have little or no carrying power; consequently the only portion of the wind waves that can affect drift are those that have changed to waves of the first order, which necessarily are very local in their action.

Even on a coast that has not been carefully studied, the prevailing direction of wind and the normal direction of the drift of the sea beach can be seen at a glance. The prevalent direction

¹ *Vide* "Tidal Currents *versus* Wind Waves," read before the Royal Irish Academy. Proceedings, vol. ii., ser. ii., No. 5, January 1876.

² *Vide* Report of the British Association for the Advancement of Science, 1844, p. 311.

of the wind being indicated by the leaning of the trees, and the normal condition of the drift of the sea beach by the double-knee at the mouths of the streams; which are often in contrary directions.

On the shore of Lyme Bay there can scarcely be drift in two directions, as the meeting of the currents would form a "race," while the two drifts would run the shallow soundings out seaward, and possibly might form an off-shore shoal; the last, however, is not a consequent result. Neither does it appear possible, judging from the present condition of the Chesil Bank, that the large shingle could be drifted along the beach from north-west to south-east, because the pebbles decrease in size from the south-east to the north-west. This conclusion seems evident as large pebbles, in the ratio of their size and weight, are carried higher and farther along a beach than smaller and lighter ones. This can be seen by watching wave action. A large pebble if set in motion by a wave, is carried along with it, but when the wave retreats the pebble is left behind, while the small fragments, although carried also by the wave, are drawn back by the "backwash;" thus the larger get higher up and travel faster than the smaller ones. Off Beer Head there is a "revolving tide" (Admiralty chart, England, sheet iii.), the "flow" tide splitting; part running to the north-east, part towards the east, while a "drain" runs nearly due south. This must prevent a continual drift along the beach from Budleigh Salterton to Chesil Beach, therefore the pebbles of the Chesil Beach probably come from the south-eastward, across the bay in the tidal current. Mr. Scott Russell has proved that a wave of the first order on entering a sheet of water does not diffuse itself equally in all directions, but that in one direction there is an axis along which it "maintains the greatest height, has the widest range of translation, and travels with the greatest velocity." The tidal wave divides after passing Start Point, the main current making nearly direct to Portland, while branch currents feather from the main current north-eastward towards the shore. But the directions of the branch currents are complicated on account of the bays and estuaries between Start Point and Axmouth. It has been proved by observations that the tidal current increases from Start Point to Portland Bill, as the "flow" tide approaches the "nodal" or "hinge line" of the tide in the English Channel; which lies between Swanage Bay on the English coast and a point west of Cape Barfleur, this line being also where "the tidal stream is greatest." If the on-shore offshoots increase in the same ratio the main current would carry in it

the larger pebbles, while its offshoots, as they gradually decreased in power toward the west, would drift smaller and smaller fragments. By such a process the shingle from the ancient sea beach would be largely imported into the Chesil Bank, as the "raised beaches are of frequent occurrence between Plymouth and Torquay." Also as the south-east end of the bank near Chesilton is exposed to the force of not only the tidal wave, but also of the most effective wind waves, the largest and highest beach ought to be cast up at that place.

In Wexford Bay, between Greenore and Cahore Points, the normal course of the tidal wave is from south to north, while the most effective storm waves occur when the wind is blowing from north-east to north-north-east. The beach is fine gravel or sand except in a few places, but for the 3 miles south of Cahore there is a well-marked shingle or coarse gravel beach, and in this beach are found numerous rock fragments that must originally have come from Greenore Point or from the country to the south of it near Carnsore. These seem all to have come across the bay in the tidal wave, or from the Dogger Bank, north-east to the Blackwater Bank, and along the latter northward, as no pieces of the Greenore and Carnsore rocks are found on the beach between the Dogger Bank and the Cahore shingle beach. Some, possibly, may have come in the older drift (boulder clay); this, however, seems improbable, as in the old drift can only be found fragments of rocks that occur in the country to the north or east, and never of those to the south. During the winter of 1875-76 the continuous and heavy winds from the north-east stopped the northward driftage, and forced the sand into the north channel out of the Wexford lagoon; raising its bed, so that it is nearly impassable to the shipping frequenting the port. The water from the lagoon has however opened a new channel, nearly on the same site as one that existed prior to 1845. This new channel has been marked on the Admiralty Plan of Wexford Harbour (A.D. 1873), by Mr. T. Winder, Engineer of the Ballygeary Harbour Works.

This communication is accompanied by a series of Charts, from which Plate 7 has been compiled.