

MIGRATION OF BEACH MATERIAL IN THE KYLES OF BUTE AND LOCH STRIVEN AREA, SCOTLAND, AND IN NORTH WALES.

By ARCHIE LAMONT, M.A., B.Sc., Ph.D., F.G.S.

"Thou hast made poor sand check the proud sea, e'en where it swells and gathers."—George Herbert.

Migration of beach sand and gravel on a coast is chiefly controlled by the direction of incidence of waves. If waves produced by the prevailing wind strike a coast-line obliquely, then sand and gravel are carried up the beach in the direction in which the wave-front is travelling. When the wave recedes the water and transported material tend to run down the beach, under the influence of gravity, in the direction of greatest slope. Sand grains and pebbles are thus carried along a coast in a series of zig-zags, or of parabolas (Text-fig. 1). Where, however, the prevailing waves strike a coast at right-

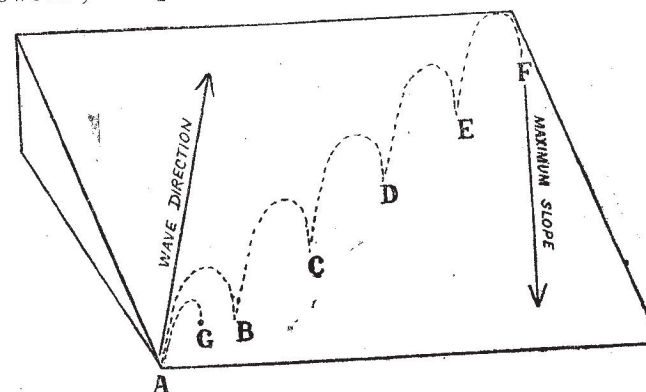


Figure 1.—Diagram of beach of low inclination showing parabolic path followed by a sand grain during transport by successive waves from A to F. The path of a heavier grain from A to G, during the advance and retreat of a single wave, is also shown. For beach-drifting, waves must strike the shore obliquely.

angles, detritus is only moved up and down the beach and under suitable conditions accumulation takes place.

The predominant winds in the northern hemisphere are those from the south-west and the north-east. Cyclones are usually elongated in these directions. North-west and south-east winds are less frequent, although it is they that predominate in the southern hemisphere.

Some areas are protected from certain winds by the intervention of land masses. Where the wind blows over wide areas of sea, larger and more powerful waves are the result. At any point, therefore, the migration of beach material depends upon the winds to which the neighbouring sea is exposed and upon the length of fetch of the waves which beat upon the coast. The eastern coast of England is sheltered from south-west winds, so that on it the north-easters are most powerful. This leads to the great southward travel of shore material, which can be seen in Yorkshire in the southward diversion of the Humber mouth, or in East Anglia in the south-south-westward prolongation of the estuary of the Alde. On the east side of Ireland, a general tendency to southward migration can also be seen, but where headlands cut off the north-easterly waves, those from the south-east induce movement in a northerly direction. The contrasting orientations and directions of growth of sandspits in the shallow submerged estuaries of County Dublin have been explained by the effect of promontories and islands in selecting the waves that sweep in upon different parts of the coast. W. Vaughan Lewis's hypothesis in the Proceedings of the Geologists' Association, in 1938, that sandspits and sand beaches accumulate at right angles to the greatest length of fetch of storm-waves has been amply borne out. It is, however, interesting to turn to a fiord area like that of the Kyles of Bute and Loch Striven, where the movement of shore sand and gravel is at a glance

seen to be very complicated indeed. Certain winds may be intercepted by high hills at one point and not at another; lengths of wave-fetch change sharply as the coast-line twists and turns.

RAISED-BEACH CLIFFS IN RELATION TO WAVE-ATTACK.

On the east side of Bute, the north-easterly waves are the most potent, and those fetching from as far as Wemyss Bay or the Cloch have made their mark in eroding the Ascog seaboard. Toward Point intervenes to shelter Rothesay Bay from their full force, but north-east waves of shorter fetch have played their part in the erosion of the Craigmore and Battery Place raised-beach cliffs. The greater height of the Battery Place cliffs seems to be due to the fact that they were also exposed to the onset of maximum waves from Loch Striven, which did not take effect further east than Glenburn. At present both the Loch Striven waves and the north-easters combine in driving detritus towards Rothesay, both on the east and west sides of the Bay. As this process was also going on in raised-beach times, it is not surprising that much of Rothesay, between the Harbour and Townhead, is built on sand and gravel provided in this way.

The east side of Ardbeg Point, unlike the rest of Rothesay Bay, is not sheltered by Bogany Point from east-south-east waves which fetch from as far as Skelmorlie. This helps to build up gravel towards the Point, on the north side of which there is the advantage of the detritus brought by the Ardbeg Burn. This detritus does not travel far since the coast on each side of the mouth of the burn is at right angles to the Loch Striven waves. Farther west in Kames Bay, however, the shore is not in the line of onset by the northerly waves from Loch Striven; and from the Steamboat Pier westward there is marked westward migration of gravel, as can be seen from the accumulations on the east side of the

Old Quay and east of M'Intyre's slip. On the coast east of Port-Bannatyne there has been much erosion by easterly and north-easterly waves, especially in 25-foot beach times when the cliff in front of the Kyles of Bute Hydropathic was cut. This cliff is of mainly slaty material in contrast with the more resistant grits further east, and its stability was lessened by the manner in which the cleavage dips away from the attacking waves. Dr. J. G. C. Anderson has clearly shown in North-West Arran how much more stable are schistose rocks where the dip is towards the coast. The shelving descent of the schists in the Skeoch Wood also provides evidence of this. The material eroded from in front of Kyles of Bute Hydropathic from 100-foot beach times onward has mostly gone to the construction of the east side of the tombolo* which joins the former islands of Mid Bute and North Bute, and which, between the Old North Bute Parish Manse and Acholter Farm, forms a north-west--south-east ridge over 100 feet above present sea-level. It is of interest to note that on the south (golf course) side of the road westward from Bannatyne Mains farmhouse, the 100-foot beach is backed by quite a marked cliffy feature. The north side of Kames Bay is also a scene of migration of gravel and sand towards the Port-Bannatyne tombolo. The stretch from the Old Mill cottages to Ettrickdale presents a particularly oblique front to easterly waves penetrating between Toward Point and Ardbeg Point, and here very active erosion has had to be arrested by the construction of a sea-wall fronted by large boulders. Between Ettrickdale and Ardmaleish roadfoot there is also much south-westward movement, and slumping and erosion of the red boulder clay, characteristic of this part of North Bute,

* Tombolo is the name for a bar or isthmus of sand and gravel connecting a former island with the mainland, e.g., the Sutton tombolo joining Howth to the mainland of Eire, and the Llandudno tombolo which unites the great Ormes Head with North Wales—or the tombolo may link together two islands, like the one between Miquelon and St. Pierre in the gulf of St. Lawrence.

for long has provided its quota of material. It is interesting to note that at the mouth of the Ettrickdale burn a lobular asymmetrical delta is being built up partly of detritus from the burn and partly of beach-drift material temporarily held up on its way to the inner reaches of the Bay. The mouth of the burn is diverted south-westward by the beach-drift.

North-east of Ardmaleish roadfoot the coast is exposed to south-easterly waves of long fetch from the Largs area. Gravel banks built by these waves formerly enclosed the Black Dibs. Part of these can still be seen on the site of the former lobster hatchery, but there has been much erosion in recent years. The supply of fresh material from off-shore boulder-clay is probably steadily falling.

Between Undraynian Point and Ardmaleish Point, which form a blunt spur of land, worn down by the earlier passage of ice, the eastward facing shore is being eroded by the oblique incidence of waves both from the Bogany and the Loch Striven directions. At Ardmaleish Point itself, at the north corner of the flattened spur, trains of stones seem to be travelling from the point westwards into the Kyles, but this migration is soon counteracted by waves coming down the Kyle, so that at the site of Corlaich one sees the Corlaich Burn and the Allt Seònaid flowing straight across the shore without diversion. North-east of Shalunt Farm, however, the more easterly of the two stream mouths is turned towards the north-west; and a small gravel-bar has been built between it and storm-waves from the Port Lamont direction. As far as the saw-mill due north of Shalunt Farm there is considerable accumulation, which has gone on from 25-foot beach times, as can be seen from the sand and gravel covering the red boulder clay of the fields which are wider and richer than at Shalunt Cottages further south, or Rhudan further north. Material migrating down the south side of the Kyle

before waves of north-westerly fetch seems to be held up here by easterly waves.

DELTAS AND LAMDAS.

On the other side of the East Kyle, between Strone Point and South Hall, one sees somewhat the same kind of hold-up of beach material by easterly and, this time, south-easterly waves, so as to give a coastal outline divided up into a series of steps (Text-fig. 2). The delta of the Inverneil Burn is only a little bit asymmetrical, the south-west side being somewhat longer than that which faces to the south-east at right angles to constructive waves from Ardyne Point. In 100-foot beach times, however, before the deposition of the material which now forms Ardyne Point, it appears that the mouth of the Inverneil Burn was more strongly turned westward by south-east waves of long fetch.

Notable for its symmetry is the perfect "delta" form of Bargehouse Point, 500 yards west of South Hall House. But it is a delta without a river, and seems to have been formed where the average of forces making for detrital migration from the north-west is exactly balanced by movement from the south-east. Such a "delta without a river" requires a new name, and that of "lamda" is suggested, where the upper limb of the Greek letter lamda indicates the position at which contending lines of fetch meet. Likewise symmetrical, but this time built about a river mouth, is Altgaltraig Point, roughly a mile south-east of Colintrave.

At Colintrave itself, we find a combination of asymmetrical delta and a lamda*. The story seems to be that in 25-foot beach times and earlier, when the sea covered the Burnt Islands (summit levels 22, 21 and

* The finest example of combined delta and lamda in the Scottish Highlands is probably that at Ullapool on Loch Broom. In that case the delta is more symmetrical than the one at Colintrave, projects further into the loch, and has its wave-built lamda to the east of the river mouth.

20 feet), the north-westerly fetch from the mouth of Loch Riddon kept the outflow of the Milton Burn diverted towards the south-east. Subsequently, following emergence of the Burnt Islands and seaward up-building of the lamda of Rhudha Bodach, the strength of the north-westerly and westerly waves has been diminished, so that south-easterly waves from the Shalunt direction have been able to drive some of the delta material westwards into the Colintrave lamda. The westward limb of the lamda, it may be noted, faces

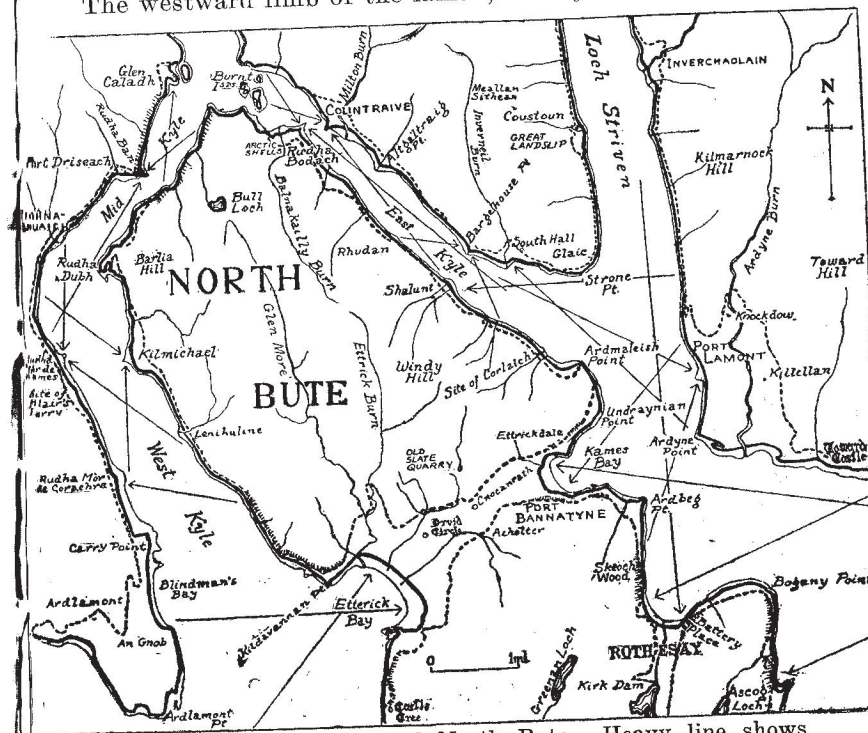


Figure 2.—Coastline of North Bute. Heavy line shows high water mark; fine line, low water mark; broken line, landward boundary of raised-beach deposits; vertical lines, cliffs of 25-foot beach. Lines of fetch of waves at right angles to which accumulation is taking place also are indicated. It is hoped to describe the complex Ardyne Point and Ardlamont areas of deposition in a subsequent paper.

towards the direction of maximum fetch from Eilean Mòr, the largest of the Burnt Islands. The upper limb of the lamda is represented by Colintrave Pier.

In Balnakailly Bay, the Balnakailly Burn flows due north without deviation, but there is some eastward migration of detritus towards the Rudha Bodach lamda. The thick accumulation of micaceous silt with arctic fossils, at the mouth of the Balnakailly Burn, evidently gathered in front of maximum waves fetching from the north-north-west in 100-foot beach times, while the Burnt Islands were still submerged.

The stability of the lamdas of Rudha Bodach and Colintrave might be endangered in the event of the construction of a Kyles of Bute bridge. If this were built from the position of Colintrave Pier to the shore south of the Rudha Bodach lamda, and if the approaches to the bridge were of solid structure, the Rudha Bodach lamda, in whole or in part, would be cut off from the along-shore drift coming from the south-east and so would tend to be reduced in size. This would, in turn, throw the Colintrave lamda open to stronger action by westerly waves. On the other hand, if the bridge were built from the Rudha Bodach lamda to a point north-west of the Colintrave lamda, and if a solid structure crossed the beach there, the whole of the Colintrave lamda and the seaward part of the delta of the Milton Burn would become subject to removal by south-easterly waves, since these would no longer be counterbalanced by the north-westerly waves. A metal bridge offering as little interference as possible to the waves would seem to be indicated.

MID AND WEST KYLES.

Unlike the former strait between Ettrick Bay and Port-Bannatyne, the Mid Kyle has remained remarkably free of detritus. Although in 100-foot beach times waves fetching from the top of Loch Riddon beat upon

the cliffs behind Buttock Head, it is true to say that the sides of the Mid Kyle have never been exposed to waves of such long fetch as the south-westerners which enter Ettrick Bay from between Ardlamont Point and Inchmarnock and by which the north-south coast for two miles south of Ettrick Bay is being strongly eroded. Again, the mud carried down by the River Glendaruel is quickly flocculated on contact with the salt water of Loch Riddon; and none of the larger streams of the neighbourhood, like the Acharosson Burn or the Allt Osd or the Glenmore Burn, flow into the Mid Kyle, though they have sources near it. The amount of material migrating on the shores of the Mid Kyle is small but interesting. At Tighnabruaich, south of the Pier, streams where they cross the beach form small symmetrical deltas, but a trend of movement to the north-west can be made out where gravel and sand are banked up on the south sides of pipes or groynes. In raised beach times there appears to have been more movement than at present, as may be seen from the thick 25-foot beach at Port Driseach, where sand and shingle were piled up by waves crossing the formerly submerged north-west corner of Bute between Barlia Hill and Rudha Dubh.

As one goes east from Port Driseach, a rocky promontory runs out into the Mid Kyle. The roadway has had to be blasted into the steep rock. Sitting on the eastern side of this solid cliff is the little wave-built lamda of Rudha Ban. The abundance in it of white vein-quartz pebbles, from which it takes its name, indicates the extent to which the materials composing it have been pounded by the waves so as to grind away much of the micaceous schist material which one would expect to find. Rudha Ban is evidently situated where waves of north-easterly and south-westerly fetch can be regarded as exerting equal force.

In the West Kyle, Rudha Mòr de Kames and the

Kilmichael lamda in Bute are the equivalents of Rudha Bodach and the Colintrave lamda of the East Kyle. The Kilmichael lamda is complex; there is an old lamda dating from the 100-foot beach sea, now perched upon the rocks which it helped to shield from erosion, and seaward of it a new lamda is forming. Other lamdas are Rudha Mòr de Corachra and the two projections south of Carry Point. None of these is associated with a river. The Carry coast and Blindman's Bay have been the scene of beach-drift accumulation since raised beach times.

On the west shore of North Bute, from Kildavanan to Kilmichael, migration of shore material is predominantly north-westwards. The mouth of the burn at South Wood of Lenihuline is diverted towards the north, but there is little accumulation till one gets to Kilmichael. The writer recently found a 5-inch cobble of Ailsa Craig riebeckite-microgranite north of Kilmichael at a place just east of Rudha Dubh*. Whether its transport was by means of floating ice, or by ice and then by beach-drift, remains an open question. But in favour of the latter suggestion is the fact that large erratics of North Arran granite, well seen at Kildavanan, are rare farther north.

LOCH STRIVEN.

A detailed account of detrital migration in Loch Striven has not been completed. In some ways there is a comparison with Lake Michigan, but Loch Striven is more difficult because of the deviation from a north to a north-west trend in the section of the loch which separates the mountain of Ardbeg on the west side from the mouth of Invervegain Glen on the east. Northward migration on the east side, under the influence of prevailing south-westerly winds, is well displayed in the asymmetrical delta of Ardtarig, at the mouth of Glen

* Glacial erratics of the Ailsa Craig microgranite have also been found as far afield as Aberystwyth, Dublin, and Londonderry.

Tarsan (Text-fig. 3). In outline and history it compares closely with the lop-sided delta of Ardkinglas, near the head of Loch Fyne. The northward diversion

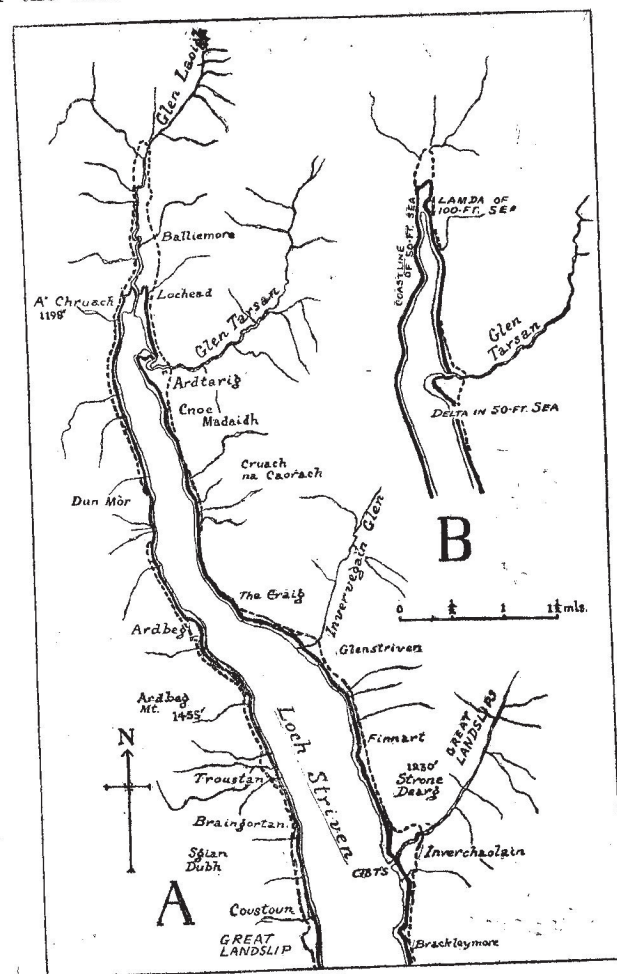


Figure 3.—Coastline of Loch Striven. A shows the asymmetrical delta at the mouth of Glen Tarsan, due to the preponderance of waves fetching from the south. B shows the more symmetrical delta in the 50-foot sea, when the loch extended $1\frac{1}{2}$ miles further north than at present.

of the stream mouth at Ardtarig House dates at least from 50-foot beach times. There is no such great northward movement of detritus on the west side of the loch. As far as the section for more than a mile south of Dun Mòr is concerned, under the onset of north and north-easterly winds the main migration seems to have been southward towards the little platform of shore material at Ardbeg, where the shore turns south-east and there is some complication by moraines. In the accumulation of 100-foot beach material south of Coustoun there is also a complicating factor—a great landslide. On the east side of the mid section of the loch, the mouth of the burn flowing from Invervegain Glen is turned slightly north. Farther south a small strip of 25-foot beach and modern beach has accumulated where the direction of the lochside changes. South of Finnart, what seems to be a lamda occurs apparently where the wave fetches from the mid and south sections of the loch balance each other. One mile south of this the mouth of the stream from Inverchaolain Glen is scarcely diverted to one side or the other. Here, in 100-foot beach times, in a small bay which was sheltered from north-westerns, the south-south-west waves built up a terrace of beach deposits. The delta at Inverchaolain, Dr. J. N. Marshall points out, is suffering erosion, as can be seen from the exposure of cists in the 25-foot beach. He regards the cists as burial in nature and probably belonging to the Late Bronze or Early Iron Age period. The former greater extension of the delta into Loch Striven may be attributed to the large amount of detritus at one time available from the landslips in Inverchaolain Glen.

A PIONEER ACCOUNT OF BUTE RAISED BEACHES.

Before leaving the question of the migration and accumulation of coastal material in and around the northern part of Bute, it may be permissible to quote John Blain's pioneer account of the Bute raised beaches and more especially of the Port-Bannatyne tombolo.

Blain, who died in 1820, includes his statements about rise of the land and deposition of beach gravels in his "History of Bute," which received its final revision after July, 1818, but large parts of which must have been written earlier. The work remained in manuscript till 1880, when it was published by W. C. Harvey, Rothesay.

"At the summit of the ground in that part of Bute between the bays of Kames and Aitrick [Etterick]—particularly on that side towards Kames—there appeared great ridges of gravel whereon a thin turf of earth and herbage had arisen, each exceeding by far the breadth of any corn-ridge ever made in such a soil, not uniform in their breadth, but all parallel to one another and appearing as if they had been formed at the head of a bay . . . it is pretty evident that they have been thrown up by the sea when it was 50 or 60 feet higher than the height to which it now rises. The regular succession of these banks, one below another, indicated that here the withdrawing of the sea had for a time been slow and gradual from the point of greatest altitude until it had fallen a good many feet lower. These banks, which until lately were left in their original state, have been within these few years levelled to bring them into a situation for producing corn, except one small part planted with trees.

"When the sea was so high as to cover this part of the island the isthmus between the bays of Kilcattan and Stravanan on the south end, and the tract from the bay of Scalpsie to Rothesay, must likewise have been overflowed; consequently what is at present one island was then four.

"Other and still more indisputable proofs are at hand towards ascertaining the fact that the sea was much higher about Bute and in the West of

Scotland in general than we now find it. One is the banks of shells, many of them immense, found near the coast in corn-fields and other places to which the highest tides do not now reach. Instances of these are frequent in and about the island, as on and near the point of St. Ninian's, in Inchmarnock, at Kildavanan, at Ardsclapsie, at Achawillig, opposite to Rothesay, and in the island of Meikle Cumbray.

"Another and most convincing piece of evidence is the high and steep banks of earth or rocky cliffs frequently observable at a little distance from the sea, against which the waves have washed, and have been the cause of shaping these banks and cliffs into their present form. I cannot, therefore, agree with those who presume our earth rose inch by inch from the sea, if they insist that it rose by equal degrees, for to me it appears that the waves must have beaten against the now deserted banks and precipices during perhaps 2000 years, unless we can suppose, either that the rocks have been at some time of a softer texture than they are at present, or that they have vegetated and thereby shot up higher by slow degrees, as some naturalists allege—but which the nature of the rocks by the sea-coast, compared with those of the higher grounds will not permit us to believe—was the occasion of forming the banks and cliffs. . . .

"Another thing which may be considered very remarkable is that the water did not still continue to wash the banks and cliffs, but, on the contrary, where the bottom did not lie at a great depth, the sea had receded quickly from its banks and left a skirt of flat ground, sometimes of considerable extent, between the present banks and the former high water marks. I do not see that this can be accounted for any other way, than by supposing

that the sea has, at particular periods of time, sunk five or six feet of its perpendicular height with much greater precipitancy, than it had done in any period during 2000 years preceding . . . the waters have not fallen equally in equal times, but sometimes faster at one time than at another."— ("Blain's History of Bute," pp. 111-113).

John Blain thus gave one of the earliest accounts of raised beaches, and recognised differential rates in the movement of the land. It is remarkable that such a well-known geologist as John Macculloch, a younger contemporary of Blain's, should have been somewhat less clear about them. In 1819 in "A Description of the Western Islands of Scotland including the Isle of Man," vol. i., pp. 271-274, Macculloch, while he recognises that the Spar Cave on the Loch Slapin side of the Strathaird promontory in Skye, has been cut by waves, thinks that the sea is now excluded from it and other raised beach caves by debris fallen from the old sea cliffs. In 1810 Leopold von Buch in Germany, in a passage of his work quoted recently by K. F. Mather and S. L. Mason in "A Source Book of Geology" (1939, p. 209), discusses the raised beaches of Sweden on which Celsius had started his observations sixty years earlier; but in this country Blain was well abreast of his time. He scores particularly in his recognition of the old beach ridges heaped by the waves sweeping into Kames Bay from the east and so building part of the Port-Bannatyne tombolo. Some of these ridges are still clearly recognisable, especially between Kames Castle gatehouse and the Old Mill cottages. In the impounding of the dam for the Old Mill, one can still see how one of the ridges was made use of. These ridges need not be thought of as formed one at a time, but rather as existing in contemporary groups, some covered by the tide, as in the case of the ridges shown in the accompanying profile through the centre of the

beach at Abergele, North Wales, made by the writer in 1941 (Text-fig. 4).

NORTH WALES SAND AND GRAVELS.

It may be of interest to add a comparative account of the migration of detritus on the North Welsh coast. This coast is cut off from south-west waves so far as the stretch between Llandudno and Prestatyn is concerned, and in the westerly part the work of the north-easterly waves is predominant. As one goes eastward from Llandudno, however, the length of fetch of north-easterly waves is steadily diminished, so that east of Tan Penmaen Head, the north-west waves prevail, and the main migration of beach material is in an easterly direction. This finds expression in a series of asymmetrical deltas, the most western of which is seen at Llandulas, where a series of lobes of gravel directed eastward, or

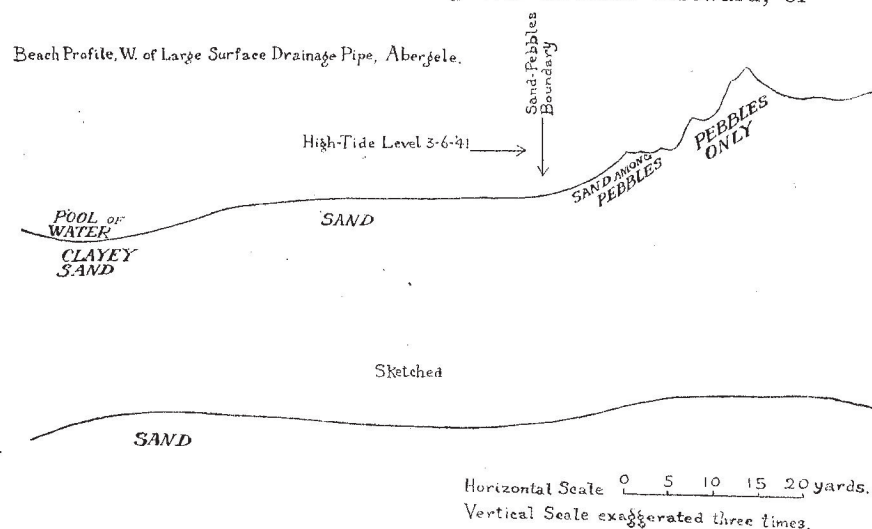


Figure 4.—Profile through the beach-ridges, west of Pen-sarn, Abergele, North Wales. Such ridges are characteristic in areas of accumulation, but are consistent with some lateral migration, as is the case at Pen-sarn. The lower part of the diagram shows the seaward continuation of the profile.

even east-south-east, and colonised by wild geranium, horn poppy and sorrel, lap round the mouth of the River Dulas and divert it to the east. At low-water mark, north-east of Pen-sarn, Abergele, one can also see sand heaped up on the west sides of drain pipes running approximately north-north-east, so that the eastwards migration may be looked on as affecting the whole width of intertidal shore. The same story is told by the short spit which overlaps the west side of the mouth of the River Clwyd at Rhyl. Still more marked are the claw-like forms of delta-material at Prestatyn, which are moving yet more rapidly eastward. Here the approach to the English coast has greatly shortened the fetch of north-east waves and so left the north-westers practically all-powerful (Text-fig. 5).

At Tan Penmaen Head pebble-trains are given off both to east and to west. Farther west in Colwyn Bay, and in Penrhyn Bay (between Rhos-on-Sea and the Little Ormes Head), there is much westward migration. Ormes Bay, on which Llandudno stands, is more exposed to the north-west than Colwyn Bay, but on its western margin, sand and gravel can often be seen heaped up on the eastward sides of north-east running groynes. This shows how strongly the sand migrates in a westerly direction where sheltered from north-west waves by the rugged hill of Great Ormes Head. It is in the centre of the bay, however, and along its eastern shore that gravel and sand are heaped up highest, i.e., where the effect of both north-westerly and north-easterly storms is fully experienced.

The groynes directed in a north-easterly direction in the west part of Ormes Bay, protect the promenade of Llandudno from erosion by north-north-west waves. The natural curve of the shore would probably be more concave than the present outline of the promenade. There seems to be no great danger to the permanence of the latter, but a more considerable supply of detritus

at the west end might be of value. Such a supply from the cliffs of Pen Trwyn and the Happy Valley area has been curtailed by sea-walls, road-construction, and artificial drainage. The Llandudno Pier is of open iron-work and does not greatly hinder movement of sea-floor material past it, so that some small amount of debris continues to reach the tombolo from the north-west.

The Llandudno tombolo has a height of about 19 feet on the north side and falls away towards the south-west. The south-west side is instructive. An advance upon the natural shore-line curve has been made by the erection of an esplanade with a sinuous frontage (Text-

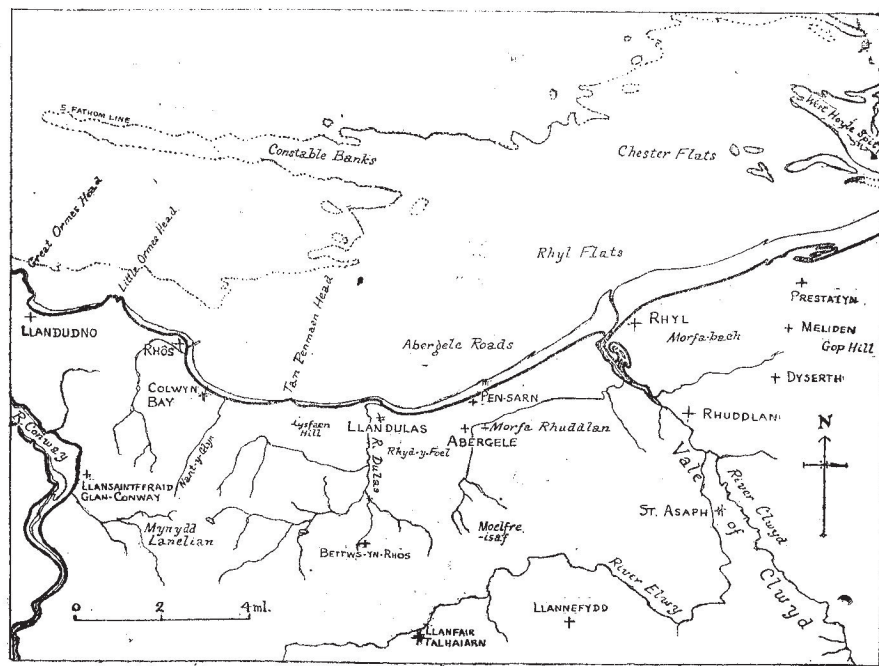


Figure 5.—Coastline of North Wales from Llandudno to Prestatyn. Tan Penmaen Head forms a "divide," west of which most material moves westward, and east of which easterly migration becomes more and more marked.

fig. 6). The projections—like the Bandstand embankment on the east side of Rothesay Bay—are especially exposed to erosion by waves. In the Llandudno instance the operative waves come from west-north-west. The supply of new material in the area has been restricted by the building of a sea-wall for a distance of one-third

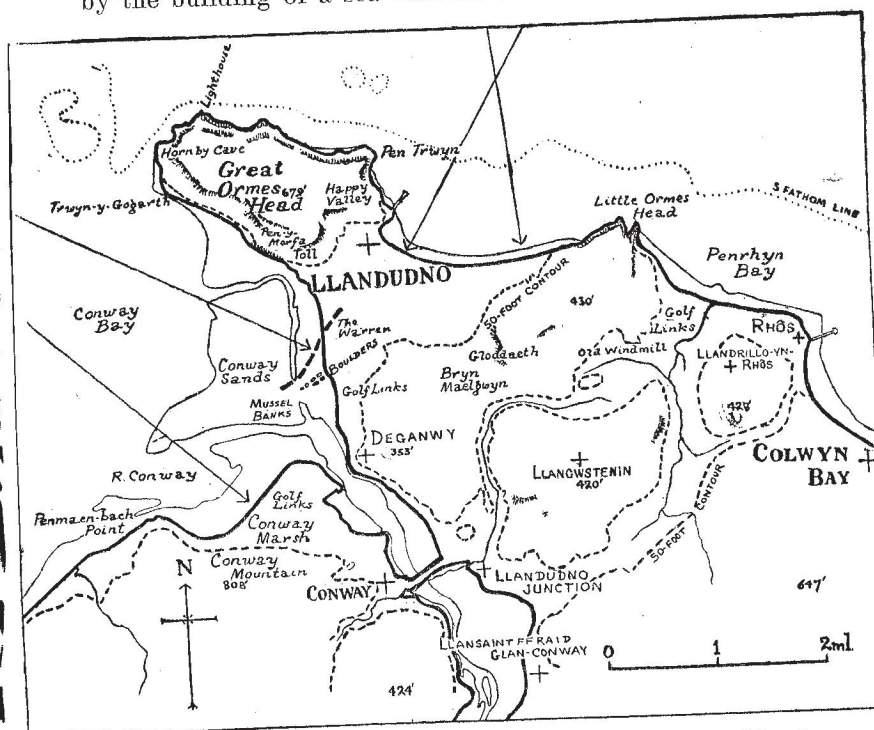


Figure 6.—The Llandudno tombolo and Conway Marsh sandspit. The 50-foot contour line roughly indicates the boundaries of loose sand and gravel, and also one or two(?) old courses of the river Conway to the sea at Penrhyn Bay. The heavy broken line shows the outline of the old coast south-west of the Warren sandhills. The lines of north-westerly fetch of waves, as drawn, do not intersect Puffin Island, which lies $3\frac{3}{4}$ miles due west of the Llandudno tombolo, and north-eastern Anglesey. Long fetches from the north-west, contrasting with short fetches from south and west in Conway Bay, produce much southward beach-drift on the west side of the tombolo.

of a mile west-north-west of the Toll, where erosion from steep cliffs and by hill creep was formerly very active. It is, of course, important that this southern rampart of the Great Ormes Head should not be worn back, as it intercepts north-west waves and others more nearly west-north-west from attacking the tombolo. From the bulge in the coast south of the Toll house there has been extensive erosion, which has been met by not very successful buttressing. A concave curve instead of the present convexity would probably provide the best protection for the road, though this would involve some encroachment on the Gogarth Hotel grounds. Against erosion of the sinuous esplanade, groynes running south-west have been built, and material accumulates, as one would expect, on the north-west sides of these, but finally all tends to be carried to the beach in front of the high sand hills of the Warren. This is demonstrated by the numerous pebbles and boulders of concrete found everywhere along the coast north of the Conway mussel banks.

The building of a mole from the side of the Great Ormes Head at Pen-y-morfa, where stone could easily be quarried, would be one solution of the problem of erosion on the half-mile stretch further south, since this would intercept the west-north-west waves, but it also seems desirable that the esplanade frontage should be in the form of a smooth curve. At the north end of the esplanade there is a cusp of cobbles and boulders, and on the foreshore a gravel ridge pointing east-south-east. With added protection on the north-west, the latter would probably grow in height under the constructive onset of south-south-west waves.

FORMER COAST SOUTH OF LLANDUDNO.

The high sand hills of the Warren (Text-fig. 6) have a straight north-west face which confronts at right angles the approach of north-west winds. This is seen to be the direction of stability for such a ridge. If it

had not been at right angles to the winds and waves by which it was built, the sand would have tended to migrate to one side or the other, i.e., to north-east or to south-west. Significantly enough, this line of sand hills does not extend north-eastward into the wind shadow of the Great Orme. Its line, if continued to the south-west, would take us to the western end of the boulder-clay mussel banks of the Conway Sands. The present sudden truncation of the sand hills to south-westward suggests that they may well have extended further in that direction, and it is assumed that the original longer ridge of sand hills was built by sea and wind at a time when a boulder clay headland occupied the position of the mussel banks. The boulder clay outcrop south of the Warren still gives a residual bouldery promontory. The present north-south orientation of storm-beach ridges presumably dates from after the retrogression of the headland.

John Speed's map of Caernarvonshire, published in 1610, provides strong evidence of this former headland. The map has been reproduced in H. R. C. Carr and G. A. Lister's "The Mountains of Snowdonia in History, the Sciences, Literature and Sport," published in 1925 by John Lane. It shows the south-west coast of the Great Ormes Head extending for two miles south-east from Ormes Head Point, which is represented as lying between Hornby Cave and Trwyn-y-gogarth, then the coast turns at right angles to its previous course to run south-west for three-quarters of a mile to a promontory which projects westward on the old map beyond the eastern extremity of the land on the west side of the Conway mouth. Judging from the old map one also concludes that the Golf Links or Conway Marsh sand spit accumulation has come into existence in the past three centuries. The scale is poorly observed since from the headland to "Llansanfraid" (Llansantffraid Glan Conway) works out at only $1\frac{1}{2}$ miles instead of about

three miles, but the direction of the 1610 coast is very suggestive since, unlike the modern coast, it runs at right angles to the line of maximum fetch of north-west waves coming in past Puffin Island and Anglesey.

The highest sand hills of the Warren lie in the north-centre of the modern bay between Great Ormes Head and Penmaenbach Point, and we may attribute the building of the Warren sand hills to the same north-western waves which are still building the spit which carries the Conway Marsh golf links. On the north side of the Conway mouth, the desirability of a retaining wall or small esplanade to continue the boulder clay promontory a little further west, or at least to prevent further erosion, is at once evident. Continued erosion of the promontory would lead to erosion further north in the loose sands of the tombolo. The building of a wall or mole would be easy, as there is a stiff clay foundation and a local supply of large boulders. North of the mole much sand would soon accumulate, and this would be bound together under the roots of marram grass, white roses, and dewberry plants, all of which grow so well on the Warren.

Unlike the strongly rockbound Port-Bannatyne tombolo, that of Llandudno on its south side is in some danger of erosion. The Llandudno tombolo also differs in that it carries a considerable town on its sunny and well sheltered north-west margin against the rising ground of the Great Ormes Head. At Port-Bannatyne, in the corresponding position, there is only a scattering of settlement. But the general similarity in orientation and accumulation of the Port-Bannatyne and Llandudno tombolos provides a link between Scotland and Wales.

REFERENCES.

For references to works on the migration and deposition of beach material, see A. Lamont, "Some Shore Features in South-East Ireland," *Scottish Geographical Magazine*, vol. 55,

(1939), November issue. Further references and an application of this work, by the same author, to the interpretation of beach sands containing oil accumulations in certain North American oilfields will be found in a review of "Stratigraphic Type Oil Fields," in the *Journal of the Institute of Petroleum*, May, 1942.

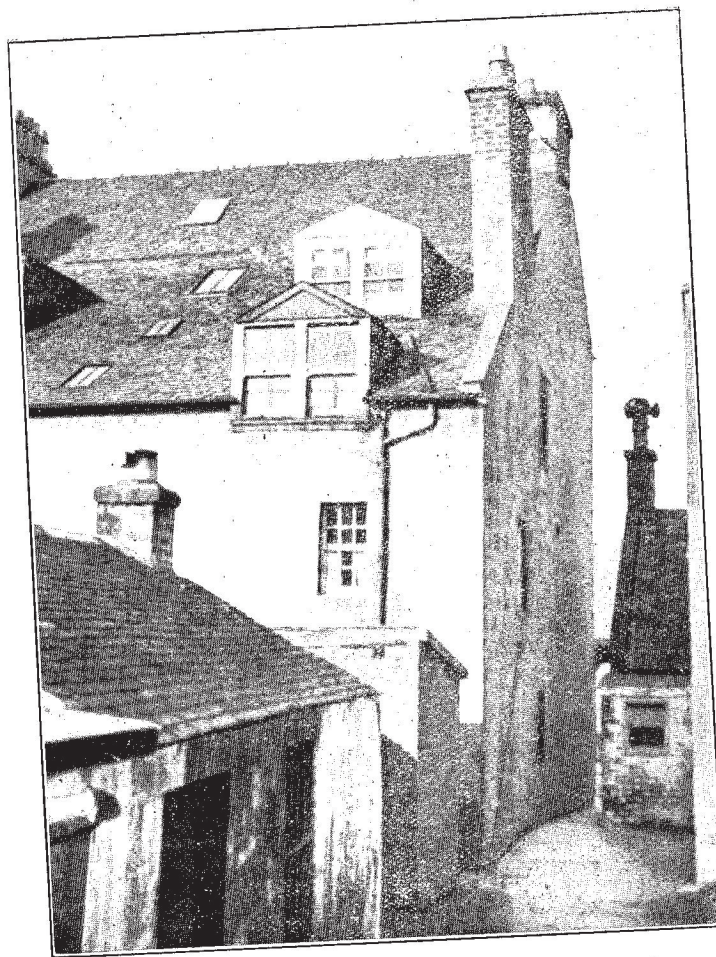


THE BELLMAN.

The late Mr Robert Brown was the last official Town Crier of Rothesay. He held this post from 1874 until 1902.



The larger of these buildings, situated at the corner of Stuart Street and High Street, was erected in 1628 and was known as the Drovers' Inn. The smaller building, known to many as Slaven's Fruit Mart, was removed in 1938, and in its place stands a replica of Rothesay's Old Mercat Cross.



ROTHESAY'S OLDEST INHABITED HOUSE.

In this photograph can still be traced what was the Manse of the High Kirk of Rothesay. It was in this Manse that the Rev. Dr. M'Lea resided. See Transactions. vol. 7, p. 20). This is now part of the tenement in High Street known as Campbell's Land.