CHAPTER 18

HOW ARE BEACHES SUPPLIED WITH SHINGLE?

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In Great Britain there are numerous types of shingle beaches, so of which are almost wholly formed of shingle, others have a large proportion of sand intermixed with the shingle, and there are some which a virtually sand beaches on which there is some shingle.

It is now generally assumed, but by no means always proved, tha shingle on beaches is moved almost exclusively by wave action. Curre action may sometimes be effective, but on most of the beaches in these islands the shingle is high up on the beaches and is often only touched at high water and after the waves have broken. Where shingle extends lower levels it may be subjected to the action of tidal currents, but unle these run with an unusual velocity they are unlikely, by themselves, to move the stones. If, however, these stones are disturbed by waves passing above them, then it is possible that a current may move them t some extent.

As a generalisation it is true to say that along our east coast beac materials, whether coarse or fine, move southwards. There are many exceptions to this, and contrary movements are nearly always the result of a change in the direction of the wind or of the trend of the coast. On the western part of north Norfolk the movement is usually to the wes and analogous conditions exist in the Moray Firth. On our southern, Channel Coast, the movement is mainly to the east, but along the inden shores of Devon and Cornwall local conditions often predominate. The west coast is more irregular. In the seas between Wales and southwestern England beach material generally moves up-channel, in Cardig Bay the movement is towards the north-eastern corner - Tremadoc Ba In the Irish Sea there is more complexity; along North Wales and parts Lancashire material tends to move east and south. St. Bees Head, Cumberland, forms a rough divide; to the north of it the movement is to the north-east. It is impossible to generalise for the west coast of Scotland; the very irregular nature of the coast means that local conditi must always play a major role. Some interesting local effects have been examined in the straits around the Island of Juna (Ting, 1936).

If we assume - allowing for local exceptions produced by details c topography - that there is a lateral movement of beach material in the directions just outlined, there should not be, at first sight, any great difficulty in accounting for shingle beaches and accumulations. But wh individual beaches are examined it is commonly found that there are severe complications. It is impossible in this paper to discuss details; but in the Chesil Beach, for example, the nature of the pebbles clearly implies that some come from rocks to the west of the beach, and others, especially the Portland Limestone pebbles, must come from the south-east. Moreover, there is a great likelihood that this is an over-simplification since it is possible that many of the pebbles are resorted and redistributed from former glacial or periglacial deposits. On the Sussex-Kent border there is the huge accumulation of Dungeness, and with it must be taken into consideration the old spits at Rye and Winchelsea, as well as those farther east at Hythe. The structure and history of all these have been frequently discussed, but no clear answer has yet been given about how the shingle of Dungeness crosses Rye Bay, which, presumably, it must do.

Some shingle beaches are contained between two rocky headlands, and if the beach material is the same as that of the enclosing rocks, and of those in the immediate neighbourhood, it is taken for granted that the wear and tear of these rocks have produced the shingle. If the dominant waves approach such a bay rather obliquely the shingle is usually more abundant to one side. Many of the bays on the south coast of the Lleyn Peninsula, and of Glamorganshire illustrate this point. The beaches are all in rather open bays and their nature is suggested in Figures 1 and 2.

On more indented coasts, with deep and perhaps narrow inlets, the small beaches which occur at their heads are nearly always assumed to be formed of fragments of the same rocks as those of the enclosing arms. This may well be true, but it is nevertheless an assumption, and more detailed investigations are required to prove these assumptions. It is one of the many ways in which in coastal matters, we regard as fact what is only impression.

The matter is more difficult on open coasts. Along the East Anglian coast from a few miles north of Yarmouth to the mouth of the river Orwell there is little doubt that the general travel of material is to the south. It is likely that this is the result of dominant waves set up by winds coming in from the quarter between, approximately, north and east. But anyone who knows this coast well will realize that contrary, northward, movements of shingle may prevail for days, or even weeks, (See below). Between Aldeburgh and the mouth of the Deben a great shingle foreland, Orford Ness, has grown up. If it is examined and mapped, the arrangement of the many fulls, or ridges, which compose it show that the foreland has grown from north to south. Its southern end is tapering, and just beyond the mouth of the Alde large masses of shingle, partly presumably the waste of the spit, have been thrown up at a place very appropriately called Shingle Street. The question is where did all the vast amount of shingle in Orford Ness come from? Historical records show that it has been gathering for roughly a thousand year and that its growth has been irregular. In that time we know that there has been great erosion of the cliffs of soft glacial beds and crags farther north. Cliffs, however, are not continuous along the whole length of coast between Aldeburgh and Yarmouth, and judging from thei present appearance, the amount of material in them which would be used to produce the 99% flint shingle of Orford Ness is not very great. Unfortunately, however, there are no quantitative measurements available, and even if some were attempted the variables, including rate of recession of cliffs, variability of the make-up of the cliff, and other factors, are so indeterminate over a long period that they are not likely to be of much use. From what is known with some certainty of the travel of beach material along Norfolk and Suffolk, it seems unlikel that, even discounting harbour projections at Yarmouth and elsewhere, *material from beyond Winterton (six miles north of Yarmouth) travels along the coast as far south as Orford Ness.

The rivers debouching on the coast all flow through flat country and are quite incapable of bringing down any coarse material to the sea In the past, at the close of the Ice Age, conditions were probably differ and then they may well have carried large supplies of shingle to the sea Orford Ness may now be in equilibrium in so far as gain and loss is co cerned, and fed sufficiently by the supply of material travelling laterall from the north along the coast to make up for the loss it suffers to Shingle Street. On the other hand the possibility of replenishment from off shore cannot be overlooked (See below).

On the north Norfolk coast there is an island, an off-shore bar, named Scolt Head Island (Steers, 1948). It has been the subject of a go deal of research, and has been well known to the writer for more than thirty years. It consists of a main sand beach, with some shingle near high water mark and a number of recurved ends formed like the moder western termination of the island, primarily of shingle. Dunes have b built on parts of the main beach and recurves, and within the island the is a magnificent series of marshes. Figure 3 shows a part of the newe western, end of the island. The main beach is on the north and the recurves and marshes on the south.

The main direction of movement of beach material is to the west fact established by a number of experiments. Occasionally westerly winds cause an eastward movement, but this is only temporary. The t

*These projections hold up sand rather than shingle, and thus render supply to Orford more problematical.

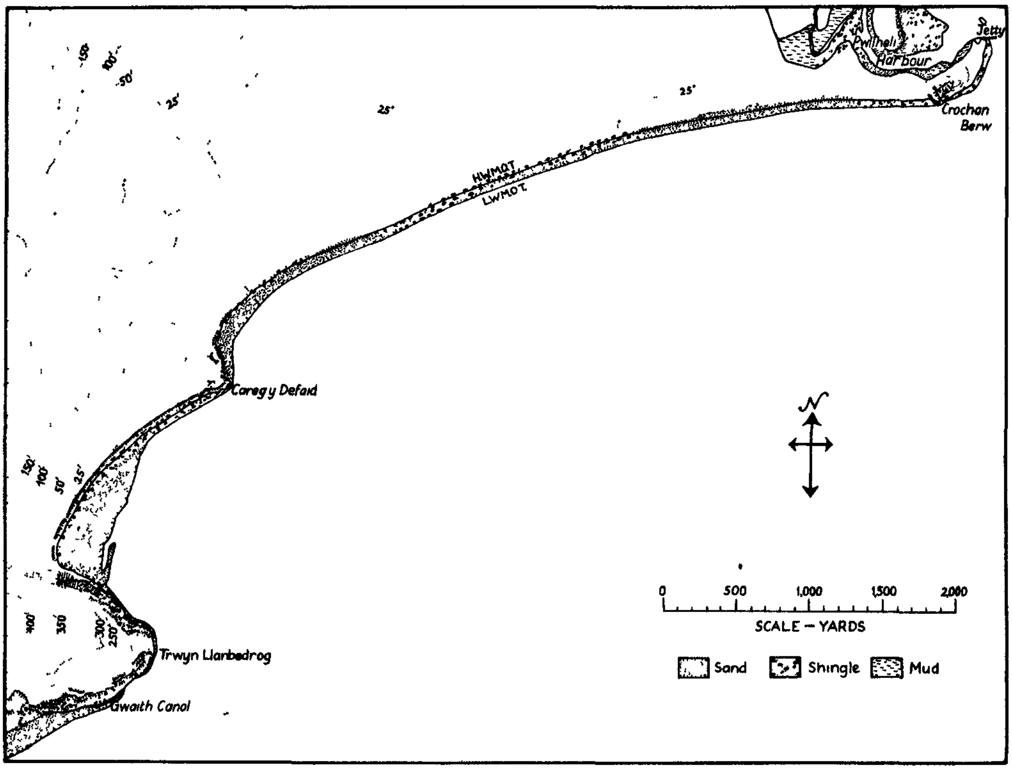

Fig. 1. Beaches near Pulwheli on the South coast of the Lleyn peninsula, North Wales.

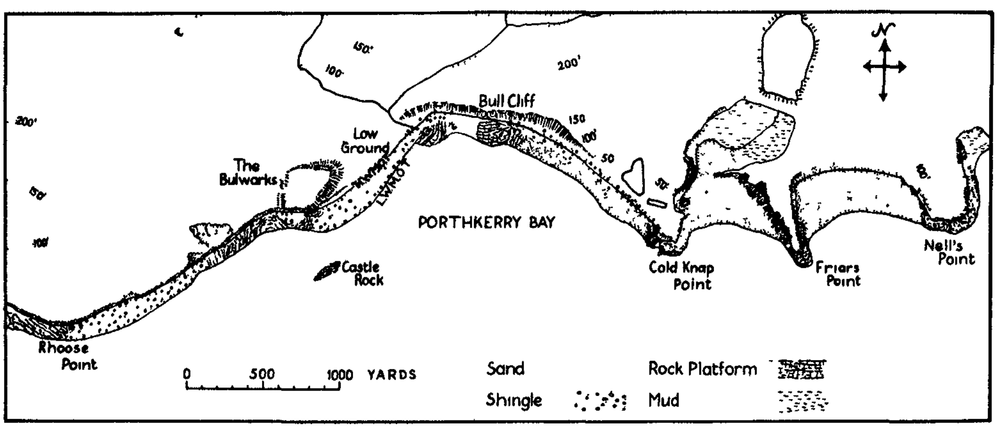

Fig. 2. Beaches on the coast of Glamorgan, South Wales.

current run parallel with the beach, and from approximately three hou before to three hours after the high water, the current runs to the eas against the growth of the beach. The shingle on the main beach, apart from a few small patches of coarse material lower down, is only touch round about the time of high water.

The east the island is separated from the adjacent shore by a ch Burnham Harbour, which is very shallow at low water, and winds abou extensive sand flats. Beyond this channel is an extremely flat sandy b a mile or more of which is exposed at low springs. There is very sca shingle on any part of this beach, and only a limited amount at its eas end, Wells Harbour, about two or three miles from Burnham Harbour Beyond Wells Harbour there is another very wide foreshore with a ver small amount of shingle, and this condition continues as far as the channel separating this part of the coast from Blakeney Point. It is or here that shingle is found in quantity, but it is more than doubtful if an it moves eastwards across Blakeney Harbour. It is most improbable that, even if any shingle crosses Blakeney Harbour, it travels even as as Wells.

To the west of Scolt Head Island the beach is remarkably free fr shingle until the mouth of the Wash is reached. There is some at Holr and more round the corner, south of Hunstanton. This emphatically does not move eastwards to feed Scolt Head Island, and the little there at Holme and Thornham seems to be stationary within certain limits, any that may move eastwards will feed the ridges (Fig. 4) forming Brancaster Golf links, and not cross the channel of Brancaster Harbou to Scolt Head Island.

How then is Scolt main beach supplied? Is it in a state of consta but slow wastage? Thirty years' knowledge of the island suggests that there is very little change in that time. This is also the view of other who know the island well. There is nothing to suggest that shingle rea the island from east or west. There is a slow landward movement of island as a result of storms over-rolling from time to time parts of th main beach and dunes, and in this way some of the beach shingle has b spread inwards. The great storm of January 31st - February 1st, 195 illustrated this very well.

Can shingle come from seaward? Since the beach is apparently fed by lateral travel, and since there is some loss by storms pushing shingle inland, it is at least a reasonable argument that some replenis ment comes from seaward. This, however, is not proof. But some considerable way towards demonstrating the possibility of such a sour of supply was made in 1956 when an experiment with radioactive shing

Fig. 3. Aerial photograph of the main beach and laterals enclosing salt marshes, Scolt Head Island, Norfolk (Photo Crown copyright; Dr. J. K. St. Joseph, Cambridge).

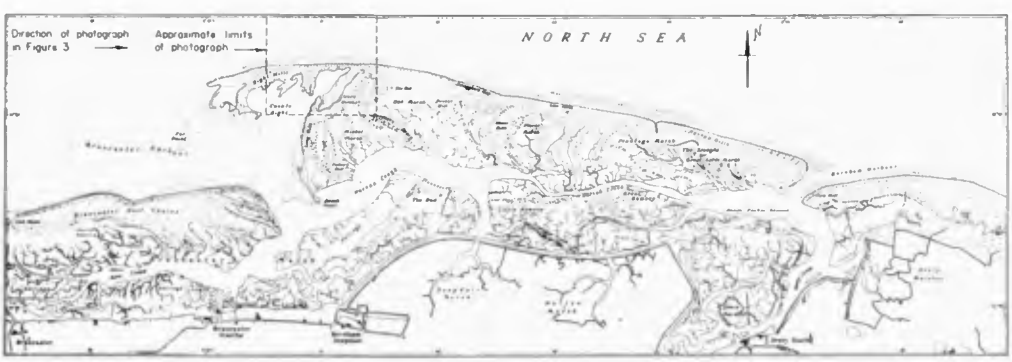

Fig. 4. Scolthead Island (Note area covered by aerial photograph in Figure 3).

was made (Steers and Smith, 1956). This was, in fact, the first time such an experiment had been made, at any rate in Britain. The beach pebbles are more than 99% flint shingle. For the purpose of the experiment softer sandstone pebbles, and artificial cement ones were use since each had to be bored with a hole half an inch deep and one-eighth in diameter. The pebbles averaged about two inches in major diameter and their specific gravity was approximately 0.2 less than that of flint.

Each pebble was then "loaded" with barium - 140, an isotope, the half life of which is twelve days. It decays by beta-emission and low energy gamma radiation into lanthanum - 140, with a half life of forty hours. The lanthanum emits gamma rays, the principal having an ener of 1.6 Me V. These were the rays used for detection under water.

About 1,200 pebbles were prepared, and they were dumped on Ap 5, 1956, from a boat at a point some 500 yards seaward from the avera high water mark off Scolt Head. The water at this point varies from 12 to 25 feet in depth according to the state of the tide. During the time the experiment ran the water was usually between 16 and 20 feet deep. The floor of the sea thereabouts is hard, consisting mainly of sand with some shingle. The place where the pebbles were dumped was marked by a buoy, and its position was fixed by triangulation from the land. When, later, observations were made from the boat, fixes were made by sextant to the surveyed points on land. Considerable care was taken in these observations, and errors arising from this source are negligib

No observations of the pebbles could be made until April 8 since the weather was squally, and on the night following the dumping of the pebbles the wind strength was 5 - 6 on the Beaufort Scale. On April 8 clear records were found that some of the pebbles had moved up to 200 feet south and west. Further observations were made on 9, 12, 20, and 23 April, and 5 and 15 May. The results were generally consistent and there is no doubt that a number of pebbles had moved inshore, in a direction a little west of south. The maximum distance measured was 260 feet. The observations made on 15 May also showed that a few pebbles had travelled about 450 feet to the north-west of the original dump, it is not certain at what stage in the experiment this movement occurred, but since the sea bed has been searched in <u>all</u> directions from the original dump on each date it seems that the movement took place rather late.

It is important to realize that this period - April 5 to May 15 - was not a stormy period, but one with a few squalls. Nevertheless, the pebbles were unquestionably moved over the sea-floor, and since the tidal current does not flow with a speed exceeding 2-1/2 feet per second it is most unlikely that the current itself was responsible for any movement. On the other hand, it might have helped the waves when they stirred up the bottom. Incidentally the waves during the whole of the experiment did not exceed a height of three feet.

The detection gear used for the experiment consisted of three Geiger counters enclosed in a brass cylinder one metre long. The sensitive length of the combined counter was 60 cms. It was mounted in a heavy metal sledge and had to be dragged over the sea floor. It was difficult in a choppy sea to sweep the floor carefully even over so small a radius as 200 feet from the original dump. Since the detector had to be within one foot of a pebble before it was "found" it will be appreciated that a good deal of patience was required.

This year the possibilities of using radioactive tracers have been extended. C. Kidson* has applied a new technique to shingle movement at the mouth of the River Alde near Shingle Street. The same isotope, barium - 140 was used, but a far simpler method of attaching it to the pebbles was adopted, namely by baking. Flint pebbles with a surface layer of ferric oxide were used, since it was found that the absorption of the isotope was greatest on them. Later work showed that the ferric oxide layer was unnecessary for this purpose. In all 2,600 pebbles were used. A similar method of under-water detection was used as in the Scolt experiment. As a result of the absorption of the gamma radiation from the tracer in water, the pebbles can only be detected about 10 inches away from the counter which was so mounted that when it was towed it travelled on runners which raised it two inches above the bottom.

Another part of the same experiment was the tracing of pebbles on the main beach and on off-shore shingle banks. For this purpose a scintillation counter mounted on a Dexion sledge was used. Marked pebbles could be detected at a lateral distance of fifteen feet, and buried ones at a depth of six to eight inches. Careful checks were made, as at Scolt, to record readings of pebble movement made from the boat. The movements on the main beach presented a less difficult problem.

At Orford Ness about 600 marked pebbles were deposited about 700 yards off shore in water varying, according to the tide, between nineteen and twenty-eight feet deep. Here, curiously, an entirely negative result was obtained. No movement whatever was detected, despite the fact that on several occasions wind strengths of more than twenty knots were recorded. No reason for the lack of movement can be given, but it does not follow that under more severe conditions, or even at nearby localities, movement would not take place.

*An account of this work is to appear in the Geographical Journal

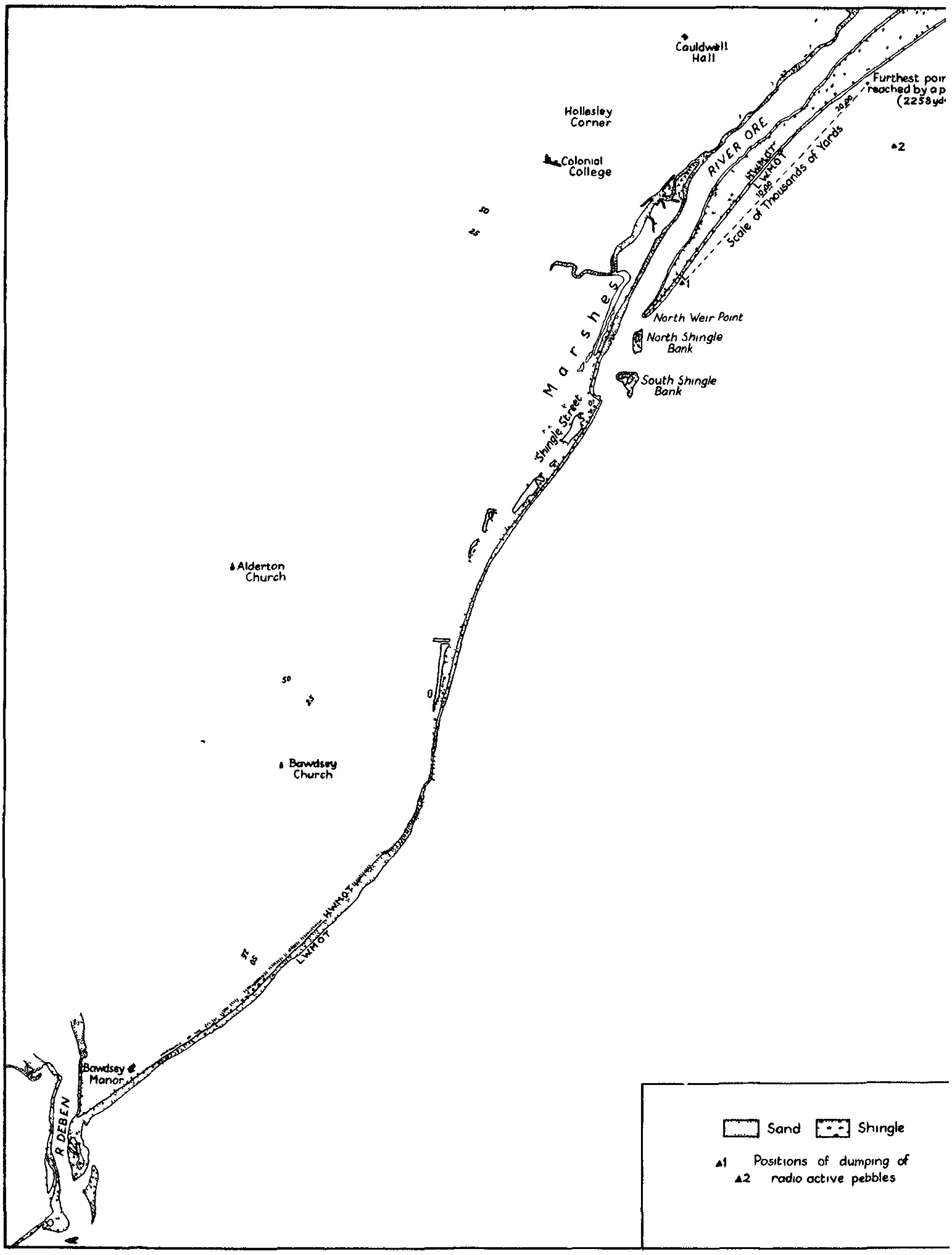

Fig. 5. The south end of Orford Ness, and Shingle Street, Suffolk, England. [To illustrate experiments made by C. Kidson (Nature Conservancy)]

The experiment of tracing pebbles along the main beach was revealing and even spectacular. About 2,000 were put down at low water on 23 January 1957 (See Figure 5). It has been said above that Orford Ness has been built from north to south, and that occasional reverse movements can take place. For the first few weeks of this experiment, south, south-west, and south-east winds prevailed. In consequence, the pebbles which were traced all moved northwards. The maximum amount moved, after four weeks, by one pebble was 2,258 yards. The mean distance of 93 was more than 600 yards northward. In the fifth week (20 - 26 February) the wind was in the north-east, and waves approached the beach with a marked northerly component. The strength of the wind did not exceed fifteen knots, and wave heights were never more than two feet. Even in this period there were winds from south-east, south, and south-west which, collectively, blew for a longer time than those from the north-east. Nevertheless, the north-east winds were the ones that mattered. The northerly drift of pebbles was arrested and reversed, and marked pebbles were found not only on the Orford beach, but on the isolated shingle banks in the haven mouth, and on the beach at Shingle Street. "From this evidence it would appear that waves approaching from a northerly quarter, combining with the tidal current (which, at springs, may reach a velocity of 7-8 knots on the ebb) in the entrance to the River Orę (=Alde) can move shingle from North Weir Point across the opposite bank. It would seem that the path of beach material which reaches North Weir Point, and continues in motion, is either up river under the influence of waves and the flood current, or, alternatively, to the shingle banks off shore, aided by the ebb tide. It is probable that the pebbles which reached the beach at Shingle Street had all arrived there by way of the off-shore banks."*

Although this experiment did not prove that the pebbles moved on shore from the point at which they were dumped, it did emphatically prove that the pebbles moved over the sea floor across a river mouth where ebb and flood currents may be very strong. In short, it showed very clearly indeed that the great masses of shingle at Shingle Street could easily have been transported from the other side of the haven mouth. Since, too, some at least of the marked shingle, travelled by way of the knolls in the haven's mouth, the experiment may be held to support the view that shingle can, under certain circumstances, travel on shore from the offing. This seems, at first sight, to contradict what has been said above about the Blakeney pebbles. Conditions are entirely different in the two places, and although I frankly admit lack of proof, I do not think any direct comparison is possible. In brief, each locality needs special study.

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* C. Kidson, in a private communication.

It cannot be claimed for the two experiments - Scolt and Orford that they have proved on shore movement, but it can certainly be said that they have made it reasonable to assume that such a movement can occur. There is no doubt that with lighter material than shingle on shore movement of this type is common. Near Claigan on Loch Dunvegan (Isle of Skye) there are two unusual beaches formed almost entirely of the white skeletons of lime-secreting organisms which live just off shore. The organisms are corallines and produce great quantities of a coarse organic calcareous sand which is spread on the sea floor, and sooner or later washed up to form beaches. This is a particular instance, and may be regarded on account of the nature of the material, as a special case. But there is little doubt that ordinary sand is washed up - the common occurrence of a beach consisting of sand as well as shingle combed down in a big storm and gradually rebuilt in more normal times proves this. A striking example was the almost complete loss of beach material from parts of the Lincolnshire coast in the great flood and storm of January 31 - February 1, 1953. This coast was surveyed regularly in succeeding years and even in the early part of 1957 one or two surveyed sections showed that conditions along them had not quite returned to those prevailing before the storm.*

Undoubtedly, there is much information to be obtained by the use of radioactive tracers. For reasons of health it is not possible at present to carry on experiments in many places, but even in these islands there are tracts of shore where they could be used without danger. No other means of marking, and identifying, pebbles is at all comparable. It is expensive to carry out big experiments, but if we are to find out just how our beaches are fed and depleted we must know far more about what happens in the water immediately off shore. That movement of material, including shingle, can take place can be demonstrated by careful echo sounding. W. W. Williams, of the Department of Geography at Cambridge, has shown how comprehensive a revealing this work can be on the Suffolk coast. But whilst it shows by change of contour that movement has taken place, it cannot of itself trace the movement of any group of pebbles.

My own conviction is that many beaches are fed from off shore, especially in places, like the North Sea, where there is good reason to suppose that glaciation has left plenty of mud, stones, and sand on the floor of the sea. But conviction is not enough. We have shown that under very ordinary conditions pebbles can move landward over th sea-floor; it remains to be proved that they do so in many other places

* Private note from Dr. C. King (Nottingham University) who has carried out much work on the Lincolnshire coast.

and in large quantities.

The composition of the pebbles of the shingle beach at Gunwalloe, in Cornwall, is relevant matter for a footnote to this paper. The beach was described by Clement Reid in the Quarterly Journal of the Geological Society, 60, 1904, 113, and also in The Geology of the Land's End District, Memoirs of the Geological Society, 1907. Reid made the following analysis of the beach pebbles: Chalk Flint 86%, Greensand Chert 2%; Quartz 9%; Grit 2.5%, and Serpentine 0.5%.

There is no exposure of Cretaceous rocks within many miles of the beach. The flints are sub-angular, weathered, and in general resemble those in the Eocene gravels of Devon and Dorset. Reid's conclusion was that "both flint and chert are derived, not directly from Cretaceous rocks, but through the intermediary of some Eocene river gravel." This led him to suggest an Eocene outlier in Mount's Bay, from which the stones were thrown up by storms and buoyed up by sea-weed. They were later subjected to beach-drifting and eventually reached their present position. After a discussion of the wider implications of his view he wrote "The little evidence yet available suggests that Eocene rivers radiated from the high ground of Dartmoor............and that one of these rivers turned southward to cut through the depression" between the Land's End peninsula and the main part of Cornwall.

In discussion, the possibility that the pebbles were brought by drift ice was mentioned, but it was argued that this was most unlikely because they occur in such large quantities in one place, whilst neighbouring bays and inlets yield few flints.

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