Discussion.

Mr. W. H. Preece, C.B., Vice-President, said the members were greatly obliged to the Author for his interesting Paper, forming a contribution at once scientific and practical, and one that no doubt would elicit a discussion which would be valuable to the profession. He therefore proposed a hearty vote of thanks to Mr. Wheeler for the labour that had evidently been bestowed in preparing the Paper. Mr. Preece.

Mr. W. H. Wheeler said he wished to direct attention to the natural harbours formed by sand-spits, several examples of which were to be found on the coasts of America,[1] as those formations afforded examples which might be imitated with success in the improvement of river outfalls and harbours in situations where they were liable to be blocked by the travel of sand and shingle. These spits consisted of long, narrow banks of shingle or sand, which, commencing at some salient point on the coast, ran for a considerable distance in a direction parallel to the general coast-line, frequently curving round inwards at the extremity in the form of a hook, leaving a protected bay or harbour inside. The line of formation was almost invariably coincident with the run of the flood-current. These long, narrow spits formed natural breakwaters, and although exposed to the storms and waves of the open ocean, maintained their position in a remarkable manner, affording protection to the bay or mouths of estuaries across which they extended, from the incursion of the waves, to which their broad mouths exposed them, and in many cases also serving to deepen the navigable channels to which they gave access, and preventing the entrance into the estuaries of littoral drift. An examination of the conditions under which these sand-spits were formed, and the protection they afforded, confirmed the opinion expressed on a former occasion, that where it was desired to protect the mouth of a river or estuary from the drift of sand or shingle, and to maintain a deep channel, a single curved pier with the concave bend on the interior, extending out from the shore on the side of the estuary from which the flood-tide came, Mr. Wheeler.

[1] "Littoral Movement on the New Jersey Coast," by Lewis M. Haupt, Transactions of the American Society of Civil Engineers, vol. xxiii.; "Geological History of Harbours," by N. S. Shaler, Report of the Geological Survey, U.S., 1894: Washington.

Downloaded from http://ftp.nowpublishers.com/jmipi/article-pdf/125/1896/33/2692546/imotp_1896_19557.pdf by gu

Mr. Wheeler. would be more effective in maintaining the channel and giving shelter to the entrance, than the plan that had been so frequently adopted of running out two piers at right angles to the shore. With the single curved pier, the drift would be arrested; and the tendency of any material that continued to travel, would be to extend out in the same direction as the piers: the flood-current working round into the channel, would maintain deep water at the outfall, while the ebb, running along the concave side of the pier, would concentrate its energy always in the same direction.

Admiral Sir George Nares. Admiral Sir GEORGE NARES, K.C.B., said the propositions put forward in the Paper were very startling to him, as a nautical surveyor who had all his life studied the movement of beach material. He would deal with the propositions *seriatim.* The first was, "that the vast deposits of sand and shingle in bays and sheltered places on the coast, are due to causes which occurred in remote ages, and which are no longer in operation." The accretion on some parts of the coast, and the wasting of others were ever continuing, ever producing changes; and he saw no signs of finality. The present sand-filled bays and estuaries were in almost all cases only the advanced sea-edges of far more extensive accretions, whether caused naturally or artificially, that occurred in remote times—a product of materials derived from the wasting of the sea-floor and the erosion of the sea-coast, carried shoreward by the action of the waves or wind-blown, and the alluvium carried down from the uplands. These bays and estuaries in their turn, if left to nature, would, in time, in many cases, be silted up, and form dry land, as surely as the large rivers were ever extending their deltas seaward. The second proposition was "that the drift which travels along a coast is due to the erosion of the cliffs, and is derived from the wasting of the land, and not from the sea-bed." The bottom of the sea, where subject to wave-action, and the deeper parts where subject to sea-currents of sufficient strength, were ever wearing out, the waste of the bottom being driven up on to the beach. The third proposition was "that the quantity of drift is limited, so that it may be entirely stopped or its movement controlled." That was not the case. Sand-motion along-shore, whether produced by wave-action or sea-current, was continuous, and could only be controlled by further works. As to Madras Harbour, he had been a member of the last commission of inquiry; and they prepared the India Office for the time, within a generation, when some younger engineers would have to carry out further works. On that coast, the sea-currents set along the land towards the south for seven and a half months, as compared

Downloaded from http://ftp.nowpublishers.com/jmipi/article-pdf/125/1896/33/2692546/imotp_1896_19557.pdf by gu

Admiral Sir George Nares.

with the northerly run of four and a half months; yet, on account of the shorter period being accompanied by southerly or on-shore winds, the long period by more or less off-shore winds, the resulting carrying force was far in excess towards the north. The movement of the sand was still going on, and at the same rate as ever. At Port Said, it was a mistake to suppose that the littoral drift had been stopped; it would certainly continue so long as the alluvium-laden waters of the Nile discharged into the Mediterranean. But it had been fairly controlled by being allowed to run through the West Pier, and deposit its load in the sheltered water where it was readily removed by dredging. The case of shingle was slightly different from sand; but generally wherever shingle collected there was a sandy foundation, and as this was subject to accretion and rose higher and higher, so the shingle rose with it. He had had to watch the movement of material along-shore at Harwich. So long as the supply continued, no extension of the Landguard groyne would ever stop the movement of the shingle to the southward, for with the advancement of the groyne, the sandy foundation rose and afforded a raised base on which the shingle could rest and accumulate. If it were wished to stop the shingle at the groyne, the groyne would have to be extended as fast as the sand and shingle collected on its northern side; but this could have no possible effect in stopping the quantity coming from the northward, so long as the source of its supply was not cut off. The whole gist of the Paper was in the fourth proposition: "The travel of the material along the coast is due to the wave-action of the flood-tide." He knew of no sufficient wave-action emanating solely from the movement of tidal water along-shore to account for the transport of material that actually took place. Given a straight beach and an equal run of the ebb- and flood-tides along it, their transporting power would be practically equal; and some other primary cause must be looked for. His observations convinced him that the wave-action caused by along-shore winds was the chief moving power in transporting the shingle and sand, as low down as the wave-action extended. Below the wave-action, the tidal or other currents exercised a considerable transporting power. In this zone, the flood-tide usually exercised the greatest power; not merely because it was the flood-tide, but because, by the run of the tide up-river and over the shoals shorewards, it was drawn in closer to the coast, and so ran with a stronger velocity along-shore than the ebb-tide, which, affected by the out-river run, trended away from the shore, and encouraged an eddy close to the coast,

Downloaded from http://ftp.nowpublishers.com/jmipi/article-pdf/125/1896/33/2692546/imotp_1896_19557.pdf by gu

Admiral Sir George Nares. which in its turn produced a longer run of the water in the true direction of the flood. This was notably the case at the mouth of the Humber, and at Landguard Point, Harwich. With regard to the remark that on the east coast of England the general drift was towards the south, in a direction contrary to the prevailing south-westerly wind, if the prevailing wind was an off-shore wind, it was unable to create an effective wave-action, and necessarily could not combat with the prevailing on-shore winds, which in the North Sea were from the north-east. Again, if a tidal current were the primary cause, then a continuous current in one direction all the year round should produce an equal or greater effect. There were many cases where that was not the case. At East London, on the south-east coast of Africa, there was a continuous ocean current setting to the southward. The tide struck the coast at right angles, and practically there was no constancy in its littoral movement close along shore; if anything the ebb ran to the northward. Yet the preponderating movement of the beach material was from the southward, in direct disagreement with the movement of the sea-current. That was decidedly due to the prevailing southerly winds being along-shore or on-shore winds, and the northerly winds being off-shore winds. The on-shore southerly winds produced a strong current inside the outer surf line, which gave rise to a great disturbance and carriage of beach material to the northward. With winds fairly direct against the land, this surf current on the south side of the harbour ran to the northward, and in the small embayment on the north side of the harbour to the southward, the two meeting off the harbour mouth. The fifth proposition was that the movement was only in the zone between high- and low-water mark. That was fairly true as regarded shingle; but the littoral movement of sand was met with at greater depths, and as low as wave-action extended. Below the wave-action, tidal or other currents caused a movement, but they often counteracted one another, and so led to the idea that in deep water transporting power was at a minimum. The movement of material along the sea-bottom was often considerable. In the English Channel it was so great in parts that, at some of the light-vessels electrically connected with the shore, the steel-wire covering of the cable was being worn out fast by the continuous rubbing movement of the passing sand. As instances of isolated sandbanks, there was the Varne Shoal in the English Channel, Smith's Knoll and Leman and Owers, off the east coast, each surrounded by water 100 feet deep. Although the motion due to the sea currents appeared to be fairly balanced,

Downloaded from http://ftp.nowpublishers.com/jmipi/article-pdf/125/1896/33/2692546/imotp_1896_19557.pdf by gu

there was at the bottom a large movement backwards and forwards of the material composing those shoals. Finally, "that channels can be effectively deepened on sandy coasts by dredging, and if properly directed will remain stable," applied only to cases where the depth was below wave-action, and where the flood and ebb tidal currents ran practically at right angles to the coast-line. The success of the Mersey dredging was due to this. If there were any littoral run of the tidal currents in disagreement with the prevailing wind-action, dredging would be the more necessary to maintain the channel. He knew of no channel through sand subject to a direct cross-wave action, which was maintaining its depth unless it were walled. Admiral Sir George Nares.

Mr. E. D. MARTEN wished to mention a practical example within his own knowledge having a considerable bearing upon the question under discussion. The River Severn was canalized for 42 miles above Gloucester; but below Gloucester it remained in its natural condition for about 25 miles, after which it became estuary and Bristol Channel, the navigation from Gloucester to the estuary being continued by a ship-canal. From Gloucester up to Tewkesbury the water was upheld by a weir which was overtopped by spring-tides, sometimes to the height of 6 feet, which proceeding up the river 13 miles to Tewkesbury, and occasionally overtopping the weir there, reached Worcester, 16 miles higher up. These high tides were laden with alluvium, which was dropped along the first 2 miles of the channel above the weir at Gloucester. During a dry summer 250,000 tons were thus brought up and dropped, which were washed out again during the following winter. But in a very dry summer the accumulation in the 2 miles nearly encroached on the proper navigable depth of the river at that place. The deposit resembled grey butter in consistency; and he had always considered that if it were left to cake and dry for a long geological period, it would turn out to be the very material now known as the lower lias clay. He had recently found, on the geological map, that about 40 miles down the Bristol Channel there was a large area of lower lias clay, so that probably an erosion of the cliffs of the lower lias clay produced the material which had given so much trouble on the Severn. For the last fifty years engineers had been trying to devise some means of getting rid of this source of anxiety, but hitherto unsuccessfully. Mr. Marten.

Rear-Admiral WHARTON, C.B., said he only spoke as a sailor who had travelled about the world and had kept his eyes open, and from his position naturally took a great interest in the Rear-Admiral Wharton.

Downloaded from http://ftp.nowpublishers.com/jmipi/article-pdf/125/1896/33/2692546/imotp_1896_19557.pdf by gu

Rear-Admiral Wharton. questions under discussion. He thought the Author had attempted to prove too much in trying to reduce rather complicated movements to very simple formulas. In his statement that the deposits of sand were not due to causes at present in operation, he could hardly mean what the words appeared to imply, because the rest of the Paper showed that there was an enormous amount of sand, shingle, and other matter constantly in movement; and, given a certain number of thousands of years, what was now going on was, he thought, quite sufficient to fill up an estuary like Morecambe Bay. The sand and shingle (mostly sand) travelling along the coast, under whatever action, turned into the bay and naturally could not get out again. If Morecambe Bay were now cleared out, even in the course of their own lives there would be such a vast deposit of sand as to make it intelligible that in a few thousand years or less the bay would present the same appearance as it did now. A modified equilibrium was reached in all those cases; and the deposit did not go on so rapidly as it did in the earlier stages. With regard to the proposition that the continuous travel of drift along the coast was due to the wave-action of the flood-tide, he did not understand what the Author meant by the wave-action of the flood-tide. The flood-tide was a great wave in the ocean, several thousand miles long and a few feet high. In the English Channel, where it was retarded by the friction of the bottom, it was 200 or 300 miles long and a few feet higher; but how it could give off small waves to break upon the shore he did not understand. The waves that broke upon the shore were, according to his idea, due to the wind. It might be distant wind, or wind at some other time; but he could not understand how any wave, except an extremely long one, could be caused by a tide. He agreed with Sir George Nares, and other distinguished men, that the main motive power in moving drift along the coast was that of the waves breaking upon the shore at an angle from the direction in which the waves were the heaviest. It need not be the prevailing winds, because, as Sir George Nares had pointed out, in the North Sea, although the prevailing wind was from the south-west, it was an off-shore wind, and therefore could have but little effect. But the north-east wind struck also at an angle on the shore, and was the predominant wind, so far as works were concerned; and he knew of no place where the movement of the sand was not in accordance with the action of those winds. The Author had given instances round the coast of England. It was curious how, in many cases, the movement of the drift accorded with the general movement of the flood-tide, and no doubt the

Downloaded from http://ftp.nowpublishers.com/jmipi/article-pdf/125/1896/33/2692546/imotp_1896_19557.pdf by gu

Rear-Admiral Wharton.

flood-tide would have a greater effect than the ebb-tide; but he felt convinced, from his observations, that it was the waves, striking from the direction in which they were heaviest, that had the predominant effect. He could hardly understand the statement in the Paper about the permanence of the sandbanks. The great sandbanks in the North Sea remained chiefly as they were; and it would be astonishing if those enormous banks, many miles long and containing millions of tons of sand, were constantly moving, changing, and disappearing. The actions of currents and winds over a great length of time, were more or less uniform; and therefore the banks, heaped up by the action of the winds and currents, might naturally be expected to remain more or less the same. The astonishing thing to him was the amount of change that did take place in them. In the many surveys on the English coast, enormous changes were always observed. The survey of Yarmouth Roads had been completed this year, and it was difficult to recognize the sands. Where ten years ago there were deep channels, there were now banks; the shallow channels had deepened out, and the sands had been entirely changed. Millions of tons had moved. That was not incompatible with the sands remaining mainly in the same places; but it showed that the movement of sand was not confined to the area between low- and high-water marks, because the banks were all covered by 6 or 8 feet of water. In places where there were 20 or 30 feet ten years ago, there were now only 2 or 3 feet. It was the same in the Downs. The shape of the Goodwin Sands was entirely different from what it was a hundred years ago. Although they were formed on a great chalk bank, which kept them from moving very far, still the movement of the Goodwin Sands was as much as half a mile out and in. They were nearer the land than they had ever been, so far as any reliable charts could show. The consequence was that the channel inside was clear, and the shallows of 8 or 9 feet that existed a few years ago had been entirely swept away by the velocity of the current.

Mr. Deacon.

Mr. G. F. Deacon did not take the view of some previous speakers as to the Author's propositions, though he agreed that some of them required limitations, and others slight amplifications. The first proposition no doubt referred to sheltered places, towards which there was no littoral drift in the present day; and that being assumed, he thought the proposition was perfectly true. That the drift travelling along the coast was entirely due to the erosion of the cliffs was not correct, unless the enormous quantities of gravel brought down by some rivers, were intended to be

Downloaded from http://ftp.nowpublishers.com/jmipi/article-pdf/125/1896/33/2692546/imotp_1896_19557.pdf by gu

Mr. Deacon. included in that erosion. The drift from these two sources compensated for the loss from the gradual degradation of the shingle into sand fine enough to be carried by the waves into comparatively deep water, and deposited beyond the reach of tides and waves. He agreed with the proposition that the quantity of drift was limited, and therefore its prevention was a conceivable possibility; for example, by very long groynes extending into deep water all round the coast, works that engineers were not likely to have the opportunity of constructing. He assented to the proposition that littoral drift was confined to the zone lying between low- and high-water mark, provided a margin of a few fathoms above and below high and low tide respectively, was included. But when the Author extended his principles to a particular case, Mr. Deacon ceased to agree with him. He had stated, for example, that he had taken samples of water carried in over the bar of the Mersey on the flood-tide, and found them clear. Mr. Deacon had done the same, not only over the bar, but in many other parts of the Mersey. The bar was 11 miles from the entrance to the Mersey; and an enormous quantity of sand and silt was picked up between the bar and the entrance, and carried into the river. He had found that on a 21-foot spring tide, 100,000 tons of sand and silt were carried into the river. The Mersey, nevertheless, did not silt up, because the scouring energy of the flood-tide was equalled by that of the ebb-tide, reinforced by the land water, and by going down-hill instead of up. The tide rose in the upper reaches of the Mersey several feet higher than it did at the bar; and the greater head thus attained enabled it to carry the same quantity of silt down that was taken up by the greater initial velocity of the flood-tide. When divers went down on a flood-tide, they stood in rushing particles of sand of considerable size. The 100,000 tons he had mentioned did not include that bottom sand. A large proportion of the sand and silt was deposited before the tide had ebbed, and a nearly corresponding quantity was taken up, from the low-water channel which, owing to this erosion, travelled across the whole width of the estuary; and so an interchange took place, which was a balance of the accretion against the outward scour. In the Mersey, as in other estuaries, a regime had been reached, in which the bed had silted up to such a gradient, that the efflux was just competent to undo the silting performed by the influx. This regime would evidently be stable until a change in the conditions occurred. Accordingly, whatever might have been the original source of the sand and silt in Liverpool Bay, it was certain that the sand and silt now composing the

Downloaded from http://ftp.nowpublishers.com/jmipi/article-pdf/125/1896/33/2692546/imotp_1896_19557.pdf by gu

banks below high-water level in the Mersey estuary, had travelled to Liverpool Bay and back again an incalculable number of times. Mr. Deacon.

Mr. W. MATTHEWS (of Westminster) desired to draw attention more particularly to the movement of littoral drift along the coast, and the effect of running out a breakwater or pier across an active shingle drift. It had, he believed, been previously held that movement of shingle and drift along the coast was produced entirely by wave-action. The Author had referred to "further observations and new facts which have since become available" which appeared to him to demand a modification of the conclusions hitherto entertained; and he laid down the proposition "that while wind and waves are the agents which operate in eroding the cliffs and producing the drift, the regular and continuous travel of the material along the coast is due to the wave-action of the flood-tide." He inferred from a subsequent statement in the Paper that the Author entertained the view that the active agency in the propelling of littoral drift along the coast, was not wave-action, as hitherto regarded by some of the oldest and most experienced members of the Institution, but that the effects were produced by the action of tiny waves given off from the main body of the flood-tide. Along the south coast of England the flood-tide ran from west to east, on the east coast from north to south. Along the south coast, the littoral drift was also from west to east, and on the east coast from north to south; therefore the Author was right in his assertion that the travel of the beach on the English coast was in the same direction as the flood-tide; but Mr. Matthews dissented altogether from the proposition that that action was produced by the little waves given off by the flood-tide, and maintained that it was entirely due to wave-action. That view, he thought, could be supported by looking at what actually occurred. The heaviest seas on the south coast were those from the south-west; and on the east coast from the north-east. The direction of those seas corresponded with that of the flood-tide; and when a flood-tide and a heavy sea ran in the same direction, there were heavier waves. When the tide ran in opposition to the sea, there was a short choppy sea, the tide tending to run down the waves. He thought it was entirely due to the wave-action that the drift coincided with the direction of the flood-tide, and that the action of the little waves had no material influence in propelling the beach. No doubt many had stood, as he had, on the shores both of the east and south coasts during an absolute calm, when, without a ripple on the water, the tides were running as usual: there was no wave disturbance, and no travel Mr. Matthews.

Downloaded from http://ftp.nowpublishers.com/jmipi/article-pdf/125/1896/33/2692546/imotp_1896_19557.pdf by gu

Mr. Matthews. of the beach on the coast. With a long period of east winds, especially on the south coast, the shingle was driven back against the normal travel; and for a time the groynes were filled up higher on the east side than on the west. For that time, at all events, the shingle travelled in direct opposition to the flood-tide. Still the balance of the travel throughout the year was from west to east on the south coast, and from north to south on the east coast. He thought, therefore, that the results were well accounted for by wave-action alone. The Author had referred to a somewhat limited extent of shingle travel. At Hastings, the breadth of the shingle was from 200 to 250 feet. A large groyne was carried out there from the shore into about 10 feet at low water of spring tides, to form an extensive strand upon which the fishermen could beach their boats. That groyne for a time stopped the entire flow of the shingle. By taking cross-sections at different times on the same lines, it was found that in twelve months the accumulation was 60,000 tons. At Shoreham, he found that to keep open the harbour, without increasing the depth, required the removal of 120,000 tons of beach per annum, 70,000 tons of which had to be removed from the entrance. That showed that although the travel was not very great, yet it amounted to a considerable quantity during the year. The beach accumulated towards the top during fine weather and off-shore winds; and when a gale occurred it clawed off the material, and flattened down the slope. At Hastings and Brighton, the storm angle of a beach after a heavy gale varied from 1 in 10 to 1 in 12. The Author appeared to entertain the view that after the construction of a breakwater or pier across an active shingle drift, there was for a period a growth of beach on the windward side of the pier, or on the side from which the travel proceeded; that the beach accumulated up to a certain point, when a condition of equilibrium was established, and after that no further accretion occurred. The Admiralty Pier at Dover had been given as an instance. Having been connected with the Dover works for the last five years, he entirely dissented from the Author's statement of the effect of running a work across an active shingle travel. The time, in that case, must inevitably come when the drift would cause such an accretion on the windward side as would necessitate an extension of the works, or the passage of shingle round the end of it. The Admiralty Pier at Dover was run out into deep water, and the shingle did not pass round the end of it; but that was to be accounted for on other grounds than those alluded to in the Paper. During the construction of the pier the harbour works at Folkestone

Downloaded from http://ftp.nowpublishers.com/jmipi/article-pdf/125/1896/33/2692546/imotp_1896_19557.pdf by gu

were in active progress. The shingle was trapped by the works that were carried out from time to time to the westward along the coast, and Folkestone retained the residue. At the entrance to Folkestone Harbour there were some acres of accumulation of beach to the westward of the west pier, which represented the growth of the drift. It was not, therefore, right to quote Dover as an instance where a work acted in the manner stated in the Paper. Only recently he had to examine the east cliff at Folkestone with a view of ascertaining whether there was any method of protecting it in consequence of the abstraction of the beach to the westward; and he had found that the base of the east cliff was absolutely devoid of shingle, which showed that the travel was most effectually cut off, and did not go to Dover. Sir George Nares had mentioned the interesting case of East London in South Africa. Within his personal knowledge, the breakwater, which ran out into 30 feet of water originally, did not stop the travel of sand; and at present the accretion extended from the end right along the coast. The growth of beach and sand was very deceptive to the eye with regard to the running out of a breakwater across the travel. As the shingle or sand gathered layer on layer, the actual progression outwards was smaller and smaller every year, although the quantity was the same, because it was distributed over a longer length; and that might account for a seeming period of quiescence in the accumulation. He believed that where there was a drift of shingle or sand, and it was required to run a work across it, and to keep the mouth of the harbour open, it could only be done by an adequate backwater as at Yarmouth. In that case, the entrance ran out across an active shingle travel from north to south. The north pier overlapped the south, and by that means the shingle passed on its natural course across the harbour mouth, which was run down, and the entrance kept open by the backwater. At Lowestoft, where there was no backwater, the entrance could only be kept open by very expensive dredging. Mr. Matthews.

Mr. E. B. Ellice-Clark said the Author of the Paper had mentioned observations which he had made in conjunction with Sir John Coode and Mr. Matthews at Hove; and he thought that the bare figures might be misleading, unless the whole of the circumstances in connection with the travel of shingle at Hove were made known. While generally agreeing with a number of the propositions laid down by the Author, he thought the proposition that the travel of shingle was due almost entirely to the action of the flood-tide, was untenable in the face of the observations which had been made at Hove. His own experience Mr. Ellice-Clark.

Downloaded from http://ftp.nowpublishers.com/jmipi/article-pdf/125/1896/33/2692546/imotp_1896_19557.pdf by gu

Mr. Ellice-Clark. was confined to the portion of foreshore lying between Selsey Bill and Brighton, and from Deal to Margate. To build up any theories upon general statements, unless accompanied by details, might lead to entirely false conclusions; but his experience might be of some value, being founded upon observations carefully recorded, and extending over a period of fourteen or fifteen years. The observations made on the Hove, Aldrington, and Brighton beach furnished a typical case of what was going on all along the south coast of England. For more than 150 years there had been a constant accretion of the beach in front of Aldrington, the adjoining parish to Hove, and Brighton. It was recorded that in 1704 and 1705 tremendous gales, on the top of spring tides, denuded the whole of that foreshore; but subsequently, up to about 1876, great accretions took place. About that period, however, groynes were erected at Lancing; and the Shoreham Harbour Trustees threw out a long pier, which practically stopped the flow of beach. In January, 1880, 27,000 tons of beach were removed from 770 lineal yards of foreshore at Hove during one series of spring tides, as ascertained by a comparison of cross-sections taken of the foreshore about six weeks previously to that great gale, and immediately afterwards. The denudation of the beach continued very rapidly; and in 1883 Sir John Coode, in a report upon some works which Mr. Ellice-Clark had advised the Hove Commissioners to carry out, recommended that groynes and a sea-wall should be constructed. When the wall was about 10 feet above the normal level of the beach, the reflex action was so great in one part that, on the occurrence of a strong south-westerly wind during a spring tide in the summer, the beach was rapidly taken away from the face of the wall and the foreshore. Drastic measures had to be adopted to save the wall, because the denudation had removed the surface of the shingle down to within 10 or 12 inches of the foundations. A portion of the wall was secured by piling it in front; but it occurred to him that if shingle were deposited in front of the wall, there was every chance of its coming in, thus forming an artificial beach, and when the groynes were constructed it would be held in position. He thought the artificial deposition of shingle for sea defence some distance from the foreshore had never been previously attempted; 25,000 cubic yards of shingle were deposited from 400 to 800 yards from the face of the wall, at an angle of about 120° from the position it was hoped it would eventually occupy. The shingle could be seen 4 or 5 feet above low water at ordinary spring tides. During the prevalence of calm weather, the artificially deposited shingle was only flattened. If there was any

Downloaded from http://ftp.nowpublishers.com/jmipi/article-pdf/125/1896/33/2692546/imotp_1896_19557.pdf by gu

truth in the theory laid down by the Author, that the shingle was moved by the flood-tide, and not by the wind-waves, a good deal of the shingle so deposited would have been removed; but for about six weeks after the shingle was deposited there was no movement whatever. About the middle of September, however, the equinoctial gales set in at the top of spring tides; and the beach came rapidly up to the face of the wall. That demonstrated that the travel of the shingle, on that part of the coast, was due, not to the flood-tides, but entirely to the waves breaking upon the foreshore. Those who had had the management of the foreshore at Brighton and the adjoining districts, held that a good deal of shingle came up from deep water. That, he thought, was erroneous; because in the five or six years during which there was no travel of shingle at Hove from west to east, no shingle came upon the foreshore, as determined by accurate observations. He thought the whole of the shingle passed Brighton from west to east, that the flood-tide had little or no effect upon it, and that its travel was due to the waves. On the west side of Selsey Bill there was a great amount of beach. All round the bay eastward as far as Bognor, there was very little beach; but at Felpham, which adjoined Bognor, there was an enormous quantity of beach; and this, he thought, showed that the beach, though it travelled across that bay, travelled in very shallow water. It was not at all, to his mind, at variance with the proposition originally laid down by Sir John Coode, and which had been emphasized by Mr. Matthews, that the flood-tide had very little to do with the movement of shingle. Mr. Ellice-Clark.

Mr. J. WOLFE BARRY, C.B., Vice-President, said judging from his own experience, he must demur to some of the general propositions put forward by the Author. He should not contradict the view that the drift along the coast might be controlled, because that depended on the works that could be undertaken and were financially possible; but that it could be stopped, he ventured to think was a mistake. Some *caveat* ought to be entered against any general proposition of that sort, lest it should be relied upon as correct in dealing with matters of great importance. He was not prepared to say that littoral drift could not be stopped in certain places; but as a general statement it should be received with much caution and qualification. An interesting example was afforded by the history of the entrance of the Suez Canal into the Mediterranean, which had given engineers of all nations plenty of opportunity for discussion and consideration, and had been viewed not altogether without alarm by some of those interested in the future of the canal. Mr. Wolfe Barry.

Downloaded from http://ftp.nowpublishers.com/jmipi/article-pdf/125/1896/33/2692546/imotp_1896_19557.pdf by gu

Mr. Wolfe Barry.

From the very first, the same operations of nature were foreseen as had been proved by experience to exist and continue, namely that the great quantities of alluvium discharged from the mouths of the Nile, travelling under the influence of the prevailing winds, would endanger the entrance to the canal. It was anticipated that this drift could be dealt with by long moles deposited in the sea; and it was hoped that they would stop the travel of the sand until it reached so far seaward that possibly a more rapid current would take it away into deep water where it would be no longer dangerous. Periodical surveys showed that the shore had continuously advanced, and was still advancing seaward against the windward side of the western mole; and whereas when the works were started, the line of high water was at the site of the lighthouse, at the present time it was at least half a mile further out. The decrease in depth extended beyond the end of the long western breakwater; and the entrance to the canal was now dependent upon dredging, which, though not a serious amount in so large an enterprise, formed a considerable item in the ordinary expenses. With this large advance of the shore within the short history of the Suez Canal, it could scarcely be said that the deposits of sand and shingle were due to causes in remote ages, which were not at present in existence. These operations of nature were evidently still active; and it was impossible, in a situation such as Port Said, to stop the travel of shingle or sand except by building out large piers and groynes further away to windward, which, after all, only put off the evil day. He therefore entirely agreed with what Mr. Matthews had said, for really, after all, it was only a question of time when such examples of littoral drift would have to be dealt with in some way or other. It might be possible under certain conditions—by moles prolonged into a current of water which would sweep away shingle to a distance—to keep the entrance of a harbour open; but he wanted to protest against a generalization on such a point as that. Every case must depend upon its own conditions; and it would be exceedingly dangerous to assume that causes of deposit, such as he had alluded to, were no longer in operation. The French engineers of the Suez Canal, in concurrence with the International Commission, had dealt with the shoaling of the water round the end of the western breakwater at Port Said, by the removal of the deposit which was constantly coming from the westward in a novel manner. They had from time to time taken off portions of the crest of the breakwater in lengths of 200 or 300 yards, and allowed the sea to carry the sand over and lodge it temporarily to leeward of the breakwater. As the

Downloaded from http://ftp.nowpublishers.com/jmipi/article-pdf/125/1896/33/2692546/imotp_1896_19557.pdf by gu

quantity of sand to be dealt with was more or less constant, it was considered much better, and more economical, to let the sand come over the breakwater into a place sheltered from the westward, where it could be easily removed by dredging, rather than dredge in the open sea. That system had proved a great success, and was still being adhered to. This showed their entire appreciation of the fact that that travel had to be systematically dealt with; and he thought it would last as long as the Nile continued to bring down alluvium. In this instance there was no flood-tide to influence the travel, which must be traced to winds and waves, as had been so well alluded to by Mr. Matthews, with whose remarks he agreed completely. As to treating such matters as of small importance, he noticed that the Author himself stated that, in the Chesil Bank, 3,750,000 tons had been moved in one gale, which certainly was not an insignificant quantity for engineers in dealing with harbours which had to be maintained, or works which had to be designed to control such a state of things. Although he agreed with the fifth proposition, "That the regular and continuous movement of sand and shingle along a coast takes place only in the zone lying between low-water and high-water mark," it was necessary for engineers to recognize that the high-water and low-water lines were often continually changing in such places. As the deposit took place, the high-water line went further seaward, and with it the low-water line; and, therefore, the movement alluded to by the Author as between high-water and low-water mark, although true as between those points, yet as measured from any fixed point on the shore, it might shift much further seaward as the deposit took place. Though some of the propositions might be true in particular places, he did not think that the generalizations in the Paper ought to be accepted as governing laws in dealing with harbours and mouths of rivers. By a tidal wave he always understood that great operation of nature which was visible in the distance between points of high water along a coast or estuary at the same time. The tidal wave originated in the ocean, and was there of enormous length and insignificant in height, becoming proportionately shorter and higher as it approached shoal water. Even in places like the Bristol Channel, it was 20, 30, or 40 miles long; and he did not understand what was meant by the little waves given off by such a wave as that. Waves produced by wind were most potent agents, which determined and controlled the travel of shingle in various directions; and he quite agreed with Mr. Matthews that the action of the waves produced by the wind, plus the motion of the flood-tide, was a very much more potent agent

Mr. Wolfe Barry.

Downloaded from http://ftp.nowpublishers.com/jmipi/article-pdf/125/1896/33/2692546/imotp_1896_19557.pdf by gu

Mr. Wolfe Barry. in moving shingle or sand along a coast, than if the influence of the waves produced by the prevailing wind was antagonistic to the action of the tide. In one case it was wind plus tide, and in the other case it was wind minus tide. The expression "tidal wave" was very often used in newspapers in an incorrect manner, as for instance a ship being struck by a tidal wave. He confessed that he did not understand the Author's theory that a tidal wave gave off subsidiary waves, and so produced a travel of shingle along the shore; and he should need further evidence before accepting it as an engineering fact.

Mr. Sawyer. Mr. E. E. SAWYER was glad to find the Author's propositions were not allowed to go forth as approved by the Institution. He had laid down general propositions on matters which could not be so treated. In regard to each of his propositions, examples might be found to which they applied, and many others to which they did not apply. Take for instance the third proposition: "That the quantity of drift is limited, so that it may be entirely stopped or its movement controlled." In some cases it might be entirely stopped, as in the case of Dover, owing to special circumstances; that its movement could be controlled, engineers dealing with harbours where there was a littoral drift had been trying to show ever since they had considered the subject, and they had in certain cases succeeded; but that certainly could not apply to every case. The eighth general proposition was, "that harbours should be so projected as to derange the main set of the tidal current as little as possible"; and in No. 1 of the particular propositions it was laid down "that piers were not to cause an eddy current at the entrance to the harbour." In some cases it might be possible; in other cases it was not. In projecting two piers from a sandy coast, where the tidal current flowed parallel with the coast, the pier-heads could be put at an equal distance from the coast, and so parallel to the current; or one pier could be put ahead of the other; so that in every case, especially as the ebb-tide in very few cases flowed in an exactly opposite direction to the flood-tide, there must at times be eddies about the pier-heads. The second particular proposition stated that the harbour entrance "should be sufficiently large to prevent any strong set into it on the rising tide, and to allow of its being filled with a smaller velocity of current into it than the flood-tide has in front of the entrance." Of course this should be the case where possible. But an engineer was not often free to decide how wide the entrance was to be, especially with regard to harbours that had natural openings. For example, at Durban Harbour, Natal, there was a natural entrance

Downloaded from http://ftp.nowpublishers.com/jmipi/article-pdf/125/1896/33/2692546/imotp_1896_19557.pdf by gu

Mr. Sawyer.

which had been made through the sand into a large back bay. At Madras, there was simply an entrance between the pier-heads. The flow of the tide into a harbour depended on the height of the flood-tide above low water, the width and length of the entrance channel, and the area that had to be filled inside; and he did not see how that could have any relation to what was called in the Paper "the current of the flood-tide," or how that current could have anything to do with it. It might in some exceptional cases, but in most cases it would not, and as a general principle it was inapplicable. Not only in the Mediterranean was there no rise or fall of tide: at Rio Grande do Sul, on the south coast of America, there was no tide. The maximum variation in level was 2 feet to 2 feet 6 inches, which depended upon the direction of the wind. He had had to project a harbour there, where the entrance was 1,500 metres wide and 10 miles long, and where there were enormous lakes at the back; but the great littoral drift along that coast could not be attributed to the "current of the flood-tide." The third proposition for laying out harbours was "that the piers should project from the coast into water of sufficient depth to be free from the action of littoral drift;" and it was added, "sand and shingle have never been found to work round a pier having a depth of 4 fathoms." He hoped more instances would be cited to prove the incorrectness of this assertion. He knew of two, one of them at East London, referred to by Mr. Matthews, where there was 36 feet of water at the pier-head, yet the sand came round it. At Durban Pier also, further up the same coast, there was at least 5 fathoms of water originally, and the sand went round it quite steadily, although there was no large accretion of sand in the outer angle of the pier. The Author had tried to lay down general propositions and rules for things which must be dealt with individually in each case. Madras and Port Said had been mentioned, which were supposed to prove the accuracy of the propositions. Sir George Nares had said that Madras Harbour did not support them; and Mr. Barry had said that Port Said Harbour did not. If Mr. Matthews had referred to Colombo, he might have said the same thing; but he showed that Dover Pier had not done what the Author assumed of Ymuiden Harbour. He was certain that the engineers would not agree that the silting was due to the shape given to the walls, but would attribute it to littoral drift, the sand coming into the harbour round the pier-head. The Author, besides trying to prove too much, had proved too little; for in each case where he stated the littoral drift had been stopped, he was bound to show what had become of it.

Downloaded from http://ftp.nowpublishers.com/jmipi/article-pdf/125/1896/33/2692546/imotp_1896_19557.pdf by gu

Mr. Smythe. Mr. A. J. Hamilton Smythe wished to refer to the injuries affecting the stability of the adjacent land, which might be produced in certain conditions by artificial interference, either with the natural course, or with the rate of progress, of the littoral drift. A landslip occurred a few years ago at Sandgate, which was attributed to land-springs, and was dealt with by intercepting the drainage, which improved the district very much; but he thought it was doubtful whether the whole cause of what occurred was due to the action of land-springs. They had existed for ages, and many periods of wet weather had come and gone. At the time the slip occurred, certain peculiar conditions, artificially produced, seemed to have had a considerable effect upon the result. The prevailing wind was from the south-west, and there was a considerable travel of shingle along the coast. The superficial geology of the district consisted of the lower greensand formation known as the Hythe and Sandgate beds—beds of greensand overlying thin saponaceous strata known as "blue slipper," which, when charged with water, reduced considerably the friction between the sand-beds and the underlying beds. When the railway was made to Sandgate about twenty-five years ago, Hythe station was founded on a bed of rock, which proved to be only 6 or 8 feet thick resting on the "blue slipper," and it suddenly cracked, carrying the buildings forward. In the same way, the weight of the railway embankment so disturbed the equilibrium of the material on which it rested that the embankment subsided, and the ground rose between the railway and the sea. Shorncliffe camp was about 250 feet above the sea; then came a sort of foothill formed originally by detritus from the face of the cliff, next came the space on which Sandgate lay, and then the sea. In the normal condition, there was a considerable accumulation of shingle from littoral drift on the shore. In the original line of the coast between Hythe and Sandgate, there was a slight concavity, terminated in the east by the small headland where the life-boat station stood. The course of the littoral drift was towards Folkestone. For some years after the construction of the sea-wall between Hythe and Sandgate, there was a gradual reduction in the accumulation of shingle along the shore in front of Sandgate. The further progress of the drift was checked by the gradual extension of the railway-pier at Folkestone, where the shingle accumulated to a large extent. Either the rate of progress of the littoral drift along, and eastwards of the sea-wall towards Folkestone, had become greater than that of the compensating supply of shingle from the west; or, owing to the alteration of the direction of the current by the new sea-wall, from a sweep outwards to

Downloaded from http://ftp.nowpublishers.com/jmipi/article-pdf/125/1896/33/2692546/imotp_1896_19557.pdf by gu

a direct scouring action upon the shingle, the deposit in front of Sandgate was considerably reduced. When the landslip took place the foot-hill subsided. There was no subsidence between it and the sea, nor was there an uprising; but there was a general disturbance which cracked a number of buildings about the town. The slip might be directly due to the artificial disturbance of the equilibrium previously existing between the pressure of the mass of shingle on the foreshore, and the weight of the material in the foot-hill, facilitated by the wet weather and the land-springs. Mr. Smythe.

Mr. W. SHELFORD said the object of the Paper appeared to be in the first place to minimize the great masses of deposited shingle and sand which they were accustomed to consider exceedingly large, with the intention of showing that engineers might control the drift which remained, either by the use of the suction-dredger or by properly designed piers. With this object, the Author had sought to establish various propositions, the first of which was a little startling, and related to geology rather than engineering—"That the vast deposits of sand and shingle in bays and sheltered places on the coast are due to causes which occurred in remote ages, and which are no longer in operation." As they were close to two interesting deposits, he should like to put that proposition to a practical test. The first one was in the English Channel, where there were great masses of sand and shingle stretching from the Downs northwards to Yarmouth Roads, and beyond. Moreover, the harbours and river mouths on the northern coast of France, and on the coasts of Belgium and Holland, were sand-blocked. He had been accustomed to consider that that great mass of material was due to the débris resulting from the destruction of the connection of England with the continent, which, though having taken place in a somewhat remote age, was not much beyond the historical period, because the Goodwin Sands were on the foundation of an island which had been an English parish. According to the Author's theory, the flood-tide, or according to some speakers, the wave-action, came from the south in one direction, and from the north in the other direction, into that area. In either case, whether the littoral drift was due to the flood-tide, or the waves (he thought the latter himself), it seemed impossible that that great mass of material—the ruins of the connection between the island and the continent—could have got out of that area; but, on the contrary, the drift from north and south had probably increased it. The second deposit was in the Irish Channel, about which they did not know quite so much. From the Dee on the Mr. Shelford.

Downloaded from http://ftp.nowpublishers.com/jmipi/article-pdf/125/1896/33/2692546/imotp_1896_19557.pdf by gu

Mr. Shelford. south, to the Solway on the north, all the rivers, including the Mersey, Ribble, and others, were blocked with sand in great masses. Similarly there, the flood-tide and prevailing wind came round the north coast of Ireland, and also round the south coast into that area. It seemed to him that that material, which had probably originally come down the rivers, had remained there for ages, and that it could not get out on account of the action the Author had spoken of, which, on the contrary, had rather increased it. He did not think the Author intended to refer to any remote geological period, but to a period in which the causes, although not actually in operation at present, were analogous to those now in operation. The Author had stated more than once that the quantity of drift was limited. No doubt there were cases where it was limited, as for example, at Spurn Point. In 1869, Mr. Shelford submitted a Paper to the Institution on the "Outfall of the Humber,"[1] in which he described the then condition of Spurn Point as being exceedingly attenuated by the carting away of the comparatively small quantity of 30,000 tons of shingle per annum for road-making. The Board of Trade had stopped the removal, and at the same time instructed Sir John Coode to make groynes to intercept the shingle which remained. Before those groynes were put there, Spurn Point was travelling southwards across the Humber, by the drift of shingle from the north to the other end, where it remained. After the groynes had been in operation for some twenty-five years, the survey was re-made, and showed that the whole of the shingle had been intercepted, and that not only had the continuation of Spurn Point southwards, which had been going on for centuries, entirely ceased, but that it was slightly receding. That was an enormous advantage to the navigation of the Humber, and showed how limited the quantity of shingle was, and how a small engineering work could control masses of shingle. Similarly, in Liverpool Bay, where the bar was now being so successfully lowered by a suction-dredger by Mr. Lyster, he believed the success was due to the fact that the removal of the *débris* was quite equal to its supply—the supply being due only to the drifting of the sand into the channel, whence it was carried down by the ebb-tide and deposited in still water on the bar. He quite agreed with what had been said about the wave-action of the flood-tide. He hoped the Author would reconsider that point, for he thought there could be no doubt it would be easy to explain some of the phenomena that had been mentioned in a more simple manner.

---

[1] Minutes of Proceedings Inst. C.E., vol. lxxviii. pp. 472, 493, and 515.

Downloaded from http://ftp.nowpublishers.com/jmipi/article-pdf/125/1896/33/2692546/imotp_1896_19557.pdf by gu

Mr. W. H. WHEELER, in reply, said in introducing this Paper, he naturally felt he was opposing the tradition of the last fifty years, and that he might be thought presumptuous in setting up new theories in opposition to such eminent men as Sir John Coode and others; but he remembered that engineering was a progressive science, and that engineers were not in the habit of taking anything for granted. If the President had acted only on tradition, he would never have built the Forth Bridge. All he asked was that engineers would look at the facts he had cited and the inferences he had drawn, and give them a fair consideration. The Paper was written for a practical purpose. Certain harbours had been great failures, others great successes. He had tried to ascertain the reason; he had stated the facts, and tried to fit them to his theories. Many of the speakers had looked at the subject from a different standpoint. The Paper had not been written for geologists, to whom a million years were of no account. Engineers had to provide for much shorter periods; and if the harbours they designed lasted a hundred or two hundred years, it mattered little what would happen in a million years. To his mind, previous theories on the subject were utterly unsatisfactory. They had been taught to believe that the movement of littoral drift was due to wave and wind action; the same thing had been said by eminent men in the course of the discussion; but he was still undaunted. The south coast and the east coast had been referred to by Mr. Matthews; he did not venture upon the west coast, and had not considered the other parts mentioned in the Paper. He had given a great number of instances in the Paper, in every one of which the movement was coincident with the flood-tide. If it was a mere coincidence, it was a very singular thing. He hardly knew of an instance where the continuous movement of drift (he did not refer to the accidental effect of storms) along the coast was not in the direction of the flood-tide. There was another curious coincidence with regard to the wind. When the winds were the most active, blowing on the shore, they took the beach away; and when the wind was least effective, blowing off the shore, the beach grew up. Those coincidences did not seem to fit the wind theory, and he had tried to find a better one. It had been suggested by Admiral Wharton that, if Morecambe Bay were now emptied, it would fill up again in a thousand years. It would in a sufficient number of thousand years, because climatic changes would have taken place that might lead to the same results; but under present operations, those great masses of sand could not accumulate in any reasonable period such as they had to consider. He had been asked how a tidal wave could do what he had stated. He accounted for it thus: A tidal wave coming up a sea like the Mr. Wheeler.

Downloaded from http://ftp.nowpublishers.com/jmipi/article-pdf/125/1896/33/2692546/imotp_1896_19557.pdf by gu

Mr. Wheeler. English Channel or the Irish Sea, did not advance with its crest at right angles to the coast, but went forward in a convex form. The centre of the channel being the deepest, there was the least friction; and this part of the wave moving more quickly than that at the sides, advanced until the side of the wave coming to an angle of 45° or less to the coast, flowed off at that angle and struck the coast; and as it struck the beach in shallow water, the wave was reflected back again, and that set up a number of small waves moving backwards and forwards, oscillating waves, becoming waves of translation and capable of moving material. Anyone looking at the sea on a perfectly calm day when there was no wind, a boat in the offing lying perfectly still without rising or falling, might see small waves perpetually striking the beach and moving the shingle. If stones were marked they might be seen travelling along. In his Paper he had mentioned instances in which, upon a calm day, stones weighing 6 lbs. had been lifted up by those little waves. It could not be the wind, because the movement of the stones was continuous. He could only account for it on the theory that they were small waves given back by reflex action, striking the beach, and so moving backwards and forwards. Controverting the statement in the Paper that the movement of the littoral drift was between the zone of high- and low-water mark—a different question from the movement of the channels in deep water—Sir George Nares had instanced the fact that the cables from light-ships were cut by the continual action of the sand going backwards and forwards. That movement was, no doubt, continually going on; and he had given an instance, at the mouth of the Gironde, where it was proved that the sand went backwards and forwards. That oscillating movement, different from the drift of which he had spoken, kept the channels open. The flood-tide carried the sand forward, and the ebb-tide brought it back again; it went seesawing and was never deposited. That was the great distinction to be drawn between tidal and tideless rivers, which Mr. Shelford had pointed out some years ago.[1] His statement about the Mersey had been challenged by Mr. Deacon. One of his propositions was that the matter that accreted in estuaries did not come from the sea, but from the land; and in support of that he had mentioned that the water coming in over the bar of the Mersey was perfectly clear, having no alluvial matter in it. He had also taken observations, and had found that there was a certain quantity of sand carried in with the flood-tide; and he went on to say that an equal quantity was moved

[1] Minutes of Proceedings Inst. C.E., vol. lxxxii., p. 2.

Downloaded from http://ftp.nowpublishers.com/jmipi/article-pdf/125/1896/33/2692546/imotp_1896_19557.pdf by gu

Mr. Wheeler.

out at the ebb-tide. Did not that prove the argument advanced in the Paper? If the matter carried into the estuary was carried out again at the ebb-tide, that appeared to support his view that the matter accreted in the estuary did not come from the sea, but from the land. His statement that the littoral drift was produced by the wasting of the cliffs was also challenged by Mr. Deacon, who said that if there was no wasting of the cliffs, littoral movement would still go on, and it might travel all round the coast of England. He thought it was amply proved that if the supply of littoral drift was cut off there was no further movement, the beach became bare and denuded; and therefore it would be utterly impossible that it should travel if the supply from the cliffs was cut off, at any rate it could never travel all round the coast of England, because in every part of England it was moving in a different direction. It was stated by Mr. Matthews that Dover Pier had nothing to do with the stopping of the drift. He admitted, as the Author had said, that the shingle did not travel round the pier into the harbour; but he said that it was not Dover Pier that had stopped it, but Folkestone Pier. He did not care whether it was stopped at Folkestone or any other place near; it supported his argument that by running out a groyne the travel was stopped, and showed that the shingle was under control, and that was all that was wanted. It was stated by Mr. Matthews that the shingle was effectually cut off, and that the amount grew smaller and smaller each year, which went to establish his proposition, and he had cited the cases of Yarmouth and Lowestoft where the shingle travelled round the ends of the piers. Neither of those cases complied with his conditions, because neither of these piers was carried into deep water. He had made it an essential condition that the piers to be successful should be carried into deep water. The remarks of Mr. Ellice-Clark had tended to establish the proposition contained in the Paper, because he had said that although the tide had nothing to do with it, when the gales blew on the foreshore they cut the foreshore out. That was the proposition he had been trying to establish. Facts were also quoted by Mr. Ellice-Clark to establish another proposition in the Paper, viz., that no shingle came from deep water. In speaking of the Suez Canal, Mr. Barry had endeavoured to show that the deduction drawn in the Paper from that canal was wrong; but he had gathered from the Blue Books and the Government Reports, that when the pier was first run out the accumulation was very rapid, and that it then became less and less. [Mr. Barry here observed that the deposit was quite as great now, but was removed more quickly by

Downloaded from http://ftp.nowpublishers.com/jmipi/article-pdf/125/1896/33/2692546/imotp_1896_19557.pdf by gu

Mr. Wheeler. the dredging.] One of the Royal Engineers sent out to investigate, gave the accumulation as being very rapid after the walls were first made, stating that the material travelled through the walls owing to the blocks being laid loosely, but that since the shore had grown up, this had to a certain extent stopped the drift. The matter there, however, was not sand or shingle, but alluvial matter out of the Nile, carried in suspension, not rolled along the bottom, and it could hardly be taken as an instance of tidal drift. While not agreeing with the Paper, Mr. Shelford had brought forward an instance that helped the Author, viz., that of Spurn Point. The shingle went across the Humber, and became detrimental to the navigation; groynes were put in, and they stopped the travel of the shingle. That, therefore, established the fact that the shingle was under control, and that, if proper works were erected, the travel could be stopped.

Correspondence.

Mr. Allen. Mr. G. T. Allen considered it was difficult to agree entirely with the views that the operations of nature were now so small that their results were comparatively negligible, and that the effects of former action only had to be dealt with. From his experience in the Island of Sheppey, there had been an enormous amount of material abraded from the cliffs at Warden. In comparing an old chart of the island, of about 1574, with the latest ordnance map of the district, he found there had been an abrasion of about 1,400 yards in width, amounting to a loss of 380,000,000 cubic yards in about 320 years, or considerably over 1,000,000 cubic yards every year. The annual width of the erosion, from the above figures, was over 13 feet, which was about double the rate given in the Paper for the erosion of the coast between Bridlington and the Humber; and this, coupled with the height at Warden, above 100 feet, made the actual rate of erosion five times as great. The material of which the cliffs were composed was clay, which, with the continual washing, was reduced to mud, sand, and shingle, the latter containing innumerable fossils, which denoted that the climate at one time was of a tropical nature.

Mr. Caland. Mr. P. Caland agreed with the Author that the drift along sea-coasts was not generally derived from the bottom of the sea, but from the erosion of cliffs and strands in high tides and storms, the larger pieces being slowly reduced by the sea and ultimately

Downloaded from http://ftp.nowpublishers.com/jmipi/article-pdf/125/1896/33/2692546/imotp_1896_19557.pdf by gu