Discussion.

The PRESIDENT moved a vote of thanks to the Author for his Paper. The President.

The AUTHOR exhibited a number of lantern-slides illustrating the construction and effects of protection-works on the foreshores of several places on the east coast of England. The Author.

Mr. A. T. WALMISLEY remarked that at the present time the question of coast-erosion was of paramount importance. The best protection to a cliff was no doubt a marine drive or parade at its foot: whether bounded by a curved or a vertical wall on the sea side, it protected the toe of the cliff inland against undermining. He was pleased to see that the Author had brought forward the instructive example of Lowestoft. At the south end of Lowestoft the wall was built submerged in the beach, without being carried down to a solid foundation, the beach in front of it being relied upon to prevent the undermining of the toe of the wall. The contractor, when he built the wall, was told that on no account might he use the foreshore beach-material for making concrete, and naturally he concluded that the Corporation would protect this beach from being carried away. They were not early enough, however, in laying down an efficient system of groynes, and the result was that the beach was lowered, and the toe of the wall became exposed and subsequently undermined; further, the wall being vertical, or nearly so, when the water in rough weather ran up, it fell on the parade behind, and the surface of the parade being a thin covering, like a pie-crust, it gave way, the material behind the wall working itself out under the base of the wall. Where there was a parade running along the inside of the top of a vertical wall against which the sea broke, the road must be strong enough to withstand the water falling on the surface, and allow it to drain away without doing damage. He had no sympathy with the open system of groynes proposed by Mr. Dowson and put down, he believed, as an experiment in the estuary of the River Ribble—a kind of cage system; neither had he any sympathy with the system of groynes put down between Bognor and Littlehampton at a very acute angle with the foreshore. He believed that the success of a groyne depended on its being carried well into low water and also well up to the full or above high water, with a sea-wall or revetment at the top. It had been argued that the reason Mr. Dowson recommended the system of groynes that he Mr. Walmisley.

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Mr. Walmisley. proposed, and the object of putting the south-coast groynes at an acute angle with the foreshore, was to prevent the flow of the water from being stopped. The aim was to collect beach-material without stopping the water. The best way of effecting that was not by a system of construction of that kind, but by not building the groyne too high. The top of the groyne should follow the storm-angle of the foreshore, and the groyne should not be higher than 2 feet to 2 feet 6 inches above this inclined surface. It was found by experience that the best angle for a groyne was at about 85° with the direction of the flood-tide, facing the direction of its flow, and, where the foreshore permitted it, he believed the adoption of that plan was very successful. The Author suggested it was advisable or expedient in some cases to make a hole in the groyne to allow material to get from one side of the groyne to the other. If the hole was to be made between high- and low-water levels, Mr. Walmisley differed from that view. Perhaps the Author intended that the hole should be made above high-water level; but if it were made between high and low water Mr. Walmisley would not like to put it in any groyne he constructed, because he thought it would produce scour that would do more harm than good.

Mr. Marriott. Mr. WILLIAM MARRIOTT observed that he had a fairly intimate knowledge of the whole of the coast-line of the north-east of Norfolk, especially of the works at Sheringham, and indeed he had had the privilege of paying his share of the cost of those works. A great deal of coastal land had been lost in Norfolk, especially of late years; much of the loss, however, was due not to erosion but to the water coming down the cliff and bringing away the top of it. A good deal of what was termed erosion was not erosion at all. A study of old maps, dating back about 500 or 600 years, would show that there had been more gain than loss. A map of Yarmouth, dated about the year 1100, showed the sea coming right up to Norwich; in fact, the River Bure did not then go out into Breydon Water at all, but fell into the sea somewhere near Caister. He believed that was correct, because, in constructing foundations, he had found old alluvial deposits which confirmed it. The Author was quite right when he said that exceptional erosion occurred in cycles. At California, a little village on the coast, a great deal of trouble was caused to the railway 15 years ago. The line ran close to the edge of the cliff, the boundary fence being only about a yard from the edge of the cliff. Some small groynes were built and no trouble was experienced for 15 years, and then suddenly 8 feet of beach was lost in two nights. There was also some erosion due to the shifting of sandbanks at sea. The Yarmouth roads were

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formed by the sandbanks off the coast—the North Scroby, the Cockle, etc.—which shifted about, and at times the beach was altered as the result of these changes. It could be seen at various states of the tide, when the waves were breaking. A good deal of beach had been lost at times through the material being taken for local use as road-metal; in fact, all the roads for miles inland used to be made of beach-material, which was a very bad material for the purpose on account of its roundness. Now the local authorities were taking the matter up, and it was impossible even to get shingle in Yarmouth unless the Borough Surveyor was satisfied that it was not to be taken out of the town. With regard to Sheringham, the Author, for obvious reasons, had not gone into detail quite as much as he might have done. At Sheringham, when Mr. Marriott first knew it, the old east groyne was in existence and there was a fine beach. The old sea-wall, which stood splendidly, was built of flints and lime; so that it could be understood that the sea did not often come up against it. Then, for the protection of his own property, and for making a little promenade, Mr. Upcher put up groyne No. 2, as he had a perfect right to do. If engineers injured the property of a neighbour they had to pay for the damage, but it appeared that a private individual could put up a groyne and rob his neighbour's land, and nobody could prevent it. Groyne No. 2 was responsible for the loss of the beach, and Mr. Marriott and others tried in vain to prevent the local authorities from doing what they proposed to do. A member of The Institution, now dead, put up a large sea-wall, and wanted also to put up groynes, but the fishermen thought they would injure their boats and were opposed to them. The authorities were told plainly, before the Local Government Board inspector who came down to inquire into the matter, exactly what would happen, but it had no effect, and so all the beach was lost, as the Author said. That went on for years; a good deal of underpinning of the wall became necessary; and there were grave fears that the £17,000 to £20,000 that had been spent would all disappear into the sea. Fortunately the Author was called in, and the results of his work had been very satisfactory; but Mr. Marriott was afraid that even with the groynes Sheringham would never get the beach it once had, because when once a beach was lost it could not be obtained again. He believed he was right in saying that much the same thing had happened at Lowestoft. The plans of the engineer really included groynes, but the authorities would not have them. In that way engineers were sometimes placed in great difficulties because the local authorities would not carry out their plans in their entirety, and would not take any responsi-

Mr. Marriott.

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Mr. Marriott. bility for the results of modifying them. Under such conditions an engineer's life became anything but a happy one. He knew Lowestoft for many years before there was any trouble with regard to the sea. At the north end the sea was only trying to get back its own. No doubt originally the sea came right up to the high ground at Bellevue Park, and he thought all between that and the present high-water mark had been reclaimed from the sea. He would like to know whether the Author did not think that the beginning of the encroachment was due to the building of the Claremont Pier. Most of the work had been done to the south of that pier. He mentioned that point specially because the Author had referred to a place that he himself had known ever since he was a boy, called by the Author Westward Ho! Pebble Ridge, but which he himself knew as Northam Pebble Ridge, which was its name long before "Westward Ho!" was written. The Pebble Ridge had been in existence for hundreds of years, and so secure did it seem that he remembered perfectly well in his young days houses being built at the back of it. Those who knew Westward Ho! would remember the Lower Lodge and Pebble Ridge Terrace perfectly well, and no one ever dreamed of the massive Pebble Ridge ever being driven in. Colonel Molesworth tried to boom Westward Ho! as a seaside place and put up a pier —which was now gone: as soon as the pier was put up the Pebble Ridge began to recede, the Lower Lodge and half the terrace was destroyed, as well as the Golf Club-house, and up to the present day there had been more or less encroachment. He had always considered that the construction of the Westward Ho! pier had something to do with changing the direction of the current, and perhaps members who were accustomed to fighting the sea would be able to offer some remarks on that point. One important class of protection had not been mentioned, namely, wind-drift. He had the honour of being a member of a Commission which dated back to 1600 or earlier, called the Sewers Commission for the Eastern Hundreds of Norfolk. The Commission was composed of gentlemen who had an interest in land; in fact, it was necessary to have a land qualification to be a member of the Commission. Along the coast of Norfolk between Happisburgh and Winterton there was nothing but low sand-hills; and when he mentioned that some of the land inside was 17 feet below Ordnance datum, it would be seen that the Commissioners had a very serious duty to perform. In Stow's *Chronicles* (1618 edition) there was an account of a tremendous inundation in the year 1608, which practically swamped the whole of that district, destroying amongst other things a church near Potter Heigham, whose

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ruined tower could be seen to-day. The Commission had rating- Mr. Marriott.
powers over low lands right up to Norwich. All lands lower than 10 feet above Ordnance datum, according to their distance from the sea, were rated, on a differential rating. There was not much money available except what was raised by the rate, and out of that money about 15 to 20 miles of coast had to be protected. Last year less than £300 was spent in labour, and about the same amount in fagots, so that a great deal was done with very little money. There was no engineer on the Commission. He did not say that the Commissioners always did what was right, but they managed to get a very good result with very little money, using fagots largely to arrest the wind-drift on the beach. A certain quantity of sand was carried backwards and forwards by the wind, and by planting marram-grass, putting fagots in places, and using sugar-bags filled with sand, they had managed for hundreds of years to keep the sea out. An interesting instance of the drifting of sand was to be seen in the district. The little River Thurne used to run out to sea direct instead of going round to Yarmouth; there were the remains, on the coast, of a perfect delta of reeds and rushes, and the place had been entirely closed by sand-drift; now, instead of going out to sea, the river ran the other way into the Bure. At California, near Caister, advantage had been taken of that wind-drift, and small groynes had been put up, consisting of simple rails and sleepers. The groynes had not been taken beyond high water. Sometimes 8 feet of beach had been made very quickly, and the consequence was that the high-water mark was kept back. It was true that periods occurred when beach was lost, but it was soon recovered. To prevent the cliff itself from being taken away, fish-baskets had been filled with weak concrete—about 9 or 10 to 1—tied together with wire and old iron, and laid down in the form of a slope, so that on the rare occasions when the tide did come up so high it simply ran up the slope and expended itself. So far that plan had been fairly successful. There were three questions he wished to ask the Author. First, what did he consider was the range of the utility of a groyne? Mr. Marriott had heard many opinions, and so far as his experience went, it seemed to be about equal to its length. Secondly, did the Author agree with carrying groynes right up into the bank? Personally he was strongly in favour of that, but some of his colleagues were in favour of stopping short of the bank. When they stopped the groyne short they had to lengthen it later on. Thirdly, at what angle did the Author consider a groyne was best placed for the accumulation of beach?

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Mr. Wheeler. Mr. W. H. WHEELER agreed with the Paper so thoroughly that he found very little in it to criticize. There was one point, however, which he wished to submit for consideration, and that was the question of the length of groynes. The Author had carried his groynes to low water in several cases, if not below it, and the question was whether the extra length was worth the extra cost. His own idea was that if a groyne were carried to half-tide level it would be sufficient. No doubt a long groyne did collect some extra shingle, but the great bulk of the shingle was collected above that point. A bank of shingle 8 or 10 feet high and 200 or 300 feet in width, raised by means of a groyne, afforded sufficient protection for a cliff, or beach, or sea-wall; and, by carrying the groyne out longer, not only was money spent for which a due return was not received, but also the neighbouring shore was being robbed. It was quite true that there was not enough shingle to go round for the protection of everybody, and therefore he thought that in designing groynes some consideration should be given to land-owners to leeward. Lately he had had to consider that matter in connection with a frontage near Hornsea, where the Author had constructed some groynes. After going very carefully into it and examining the groynes all along the Holderness coast he came to the conclusion that 300 feet would be sufficient for the protection of the part of the coast he had to deal with. He was not dogmatizing in the matter, because at one time he had agreed with Mr. Walmisley and the Author that a groyne should be carried right down to low water, but he was rather inclined now to alter that opinion. With regard to the remark about the quantity of shingle not being sufficient, he thought the law at present was that the Board of Trade might intervene, on the representation of the frontagers, and, if necessary, stop the removal of shingle. He considered the law should be that no shingle or beach-material whatever should be removed without the consent of the Board of Trade. There were places where the shingle was so abundant and so valuable for concrete that its removal might be permitted, but it should not be done without the permission of the Board of Trade. He could illustrate that point by a case in which both he and the Author had been concerned. Some land had been laid out for building purposes at the top of a cliff, and roads made, and the safety of those roads and of the houses depended on the safety of the cliff, which in turn depended on the retention of a large bank of shingle in front of the cliff. A contractor bought a short length of frontage and with it the right to take the shingle. He had no sooner obtained the beach than he accepted a contract for several thousand tons of

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shingle for building a sea-wall in the neighbourhood. If the removal of that shingle had been allowed it would have been dangerous to the cliff and the houses; and the owner of the land commenced an action in the Chancery Division for an injunction to prevent it from being done. The judge, after hearing the greater part of the evidence, thought it was not a case for the Court but for the Board of Trade, and he reported the matter to the Board of Trade. An inquiry was held, and the removal of the shingle all along that part of the coast was stopped. It was only stopped, however, by the expenditure of several hundred pounds, and he did not think any landowner should be put to that expense under such circumstances. Mr. Wheeler.

Mr. A. E. CAREY remarked that since the last occasion on which the subject was before The Institution, in 1904, it had been considered by several societies, including the Royal Society of Arts, and on each occasion a large amount of fresh matter of great interest had been elicited. The reason for that he thought was not far to seek. As the Author pointed out, the circumstances of each case of sea-defence were nearly always peculiar to that particular spot. During the last 12 months he had had to advise on the defence of more than a dozen localities on the English coast, and he had found no two cases exactly alike. Local information was often inaccurate. A short time ago, on the Yorkshire coast, he asked a member of the local lifeboat crew what the rise of the tide was on that coast, and without a moment's hesitation he was told that it was 20 feet. In the course of the day he put the same question to a fisherman, who did not exactly know, but thought it was about 12 feet. He noticed that the Author used the term " prevailing wind " frequently in the Paper. There was one point in connection with that which was worth consideration. In Mr. Halligan's Paper on "The Bar Harbours of New South Wales," discussed recently, there was an extremely valuable point. Everyone who was accustomed to watching the changes along a sea-coast knew that a first-class gale would produce in a few hours effects, in regard to movement of the littoral drift, far greater than a second-class gale would produce in a very much longer time. Obviously the energy in foot-pounds of the wind-force and consequent wave-action was a direct measure of the work done in the shifting of shingle on a coast-line. Granting that the range of tide, the angle of the wave-stroke, and the other contingent conditions were uniform, it would be expected that the results would be proportional. Mr. Halligan in his Paper gave a Table of the total travel of the atmosphere—obtained by multiplying the speed of the wind by the period of its duration—and in discussing Mr. Carey.

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Mr. Carey. prevailing winds and littoral phenomena that was a very telling way of looking at the matter. It was the expended energy, the work done by the wave-action, that had to be specially studied. On the east coast, as everywhere else, the prevailing winds as far as time was concerned were south-westerly to westerly, but their action was to a large extent nullified by the fact that they were off-shore winds. The contour of the coast-line above and below water-level, the effect of currents set up by headlands, the varying size and character of the drift, and a hundred other things, came in to modify the local conditions in every case. The conditions of sand-travel had been investigated very thoroughly by Dr. Vaughan Cornish. Dr. Owens read a Paper before the Research Department of the Royal Geographical Society, in February, 1910, which was also of great interest, showing much observation. In previous discussions the Author had apparently taken the view that the primary cause of the movement of littoral drift was the action of the tide, but in this Paper he rather modified that, and admitted that many other conditions had to be taken into consideration. The movement of littoral drift on a given sea-coast was the resultant of all the forces that were operating. With regard to groynes, it seemed to Mr. Carey that every spot had to be studied very carefully before laying down any broad rules. He believed that groynes ought to be carried up to the sea-wall or whatever the protection might be, and that they ought to be carried well below low water. It might be laid down broadly that groynes were best designed when the accumulations of shingle on the windward and leeward sides were most uniform, and when they were so designed as to do the least damage to the land or property to leeward of them, consistent with efficient service. If in laying out a system of sea-defences an engineer was perfectly callous about the land-owner to leeward of him, his task was no doubt greatly lightened, but he was not a public benefactor. In that connection Mr. Carey thought a system of central organization would be extremely useful, and would prevent the great scandal, as it really was, of allowing one landowner to carry out works which were absolutely detrimental to his neighbours. Recently he had had occasion to study with great care the coastal regime of Belgium and Holland, and he could not help being struck with the scrupulous care taken there to protect each frontager against individual action. He thought the Paper was rather like *Hamlet* without the Prince of Denmark, on account of the omission of any reference to what might be called remedial dumping. Where the circulating medium of defence—sand or shingle—was deficient, it seemed to Mr. Carey that one of the most essential and important considerations of

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anyone who had to lay out works was the necessity of supplying material to make up the depleted foreshore. Mr. Carey.

Dr. J. S. Owens observed that on p. 95 the Author stated that the strength of the flood-tide along the coast was superior to that of the ebb, but he thought there was a point which explained the superior effect of the flood-tide other than the volume of the Atlantic referred to lower down in the Paper. Considering the tide from low water, when the tide began to flow the ebb-current did not reverse at the same time as the water-level began to rise, and similarly at high water the flood-current did not reverse when the tide began to fall. The effect was therefore that for some time before high-water, and for some time after, the flood-current was always in operation: that was, there was always a current flowing in the flood direction over that particular zone of the foreshore when covered by water, and consequently the ebb-current had no chance, as it never flowed over that particular part of the foreshore near high-water mark. At the top of p. 97 there was a paragraph which struck him as being very important. The Author there enumerated three points which he said must be constantly borne in mind. Dr. Owens would like the Author, if possible, to clear up a little ambiguity in the matter, because he could not quite make out what was meant. The first point put forward was, "That all beach-material is the result of the breaking away of cliffs or land." If that meant the breaking away of cliffs or dry land, he could not agree with it. If it was meant simply to exclude the sea-bed as a source of beach-material, as he assumed it was, he thought there was no question at all that a large quantity of foreshore-material came from the sea-bed. Then the Author said, "Shingle travels along the coast between high- and low-water mark." That was true; but it travelled elsewhere also. He did not know whether that was intended to eliminate any other part of the sea-bed except between high- and low-water marks. If it was, he could not agree with the Author on that point either. He thought the shingle had a much wider range of travel than merely between high- and low-water marks. The third point put forward by the Author was, "That no shingle is procurable by tidal or wave action from the deep sea for the building-up and preservation of foreshores." In Dr. Owens's view it was a mistake to eliminate the possibility of obtaining material from the sea. He would like to have it made clear whether the expression "deep sea" meant the abysmal depths of the ocean, or whether it meant the sea beyond low-water mark. If it meant beyond low-water mark, then he knew, from observation, that a large quantity of material was brought in. On several Dr. Owens.

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Dr. Owens. parts of the coast he had seen hundreds of tons of large stones brought in from beyond low-water mark, and the evidence that they were brought from beyond that point was that they all came in with large streamers of *Laminaria digitata* attached, which weed did not grow on the foreshore. On the Norfolk coast last summer he took particular notice of the shingle, and observed that a very large percentage of the stones showed the remains of the attachments of that weed. When there was any little storm from seaward there was a large deposit of these stones, which did not come from the foreshore, where no such stones were to be found. That, he thought, was positive proof that the stones came from seaward. It might be quite compatible with the Author's point if by "deep sea" was meant very deep water. On p. 97 the erosion which was found on the lee side of a high groyne was referred to, but a cause of that erosion which he had seen in actual operation was not mentioned. Sometimes the beach collected up to the top of a groyne on the windward side, and then, with the wind and sea from a particular direction, the waves rushed up the windward slope and fell over the top of the groyne. He had observed a very considerable fall of water over such groynes with each wave, the water plunging on to the sand and shingle below, which was carried away with the backrush of the wave. That, however, was only one of the causes. He agreed with the Author that the main cause was simply the checking of the littoral drift. On p. 99, referring to the design of sea-walls, he did not know whether the Author meant that a vertical sea-wall was as good as a wall which was elliptical in section, but if that was intended he could not agree with it, because, from his own experience, the rebound of the waves from a vertical sea-wall upon a sandy foreshore was a very serious agent in causing erosion; so much so, that he had often had to take the precaution of protecting the toe by putting in some kind of concrete apron to take that rebound. In the case of timber breastworks he had had to put in a similar concrete apron. Consequently, in his view, a vertical wall was not the best for an erodible sandy foreshore. It might be satisfactory where there was a considerable depth of water at high water and the foreshore was shingle; but where there was not, and where the foreshore was sandy and easily eroded, he thought either the shape of the wall should be such as to break up the backwash of the wave by means of steps, or—which was probably better, and certainly cheaper—the face should be curved so as to lead the current from the backwash tangentially to the foreshore at the toe. With regard to the danger from the washing-away of the backing of sea-walls, there was a

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precaution which he had taken, and which he thought was rather a good one, when the wall enclosed a space between it and a cliff. If a wave struck the wall, broke over, and dropped on to the backing, there was danger of the water rushing along the back of the wall; but by putting short cross walls or counterforts across the space occupied by the backing, that current could be checked. The Author stated that the question of the design of groynes resolved itself into the provision of such stability as would eliminate all risk of overturning under certain conditions. That was part of the truth only; there were a great many other points which, in Dr. Owens's view, were extremely important in the design of groynes, and several of them had been referred to by other speakers. He did not think for a moment the Author intended to eliminate these, but the length of groyne—and particularly whether the groyne reached well above high-water mark or not—was of great importance. The method of termination at the seaward end was of equal importance, as was also the question whether projections were allowed upon the sides of the groyne or not, because projections at the side tended to cause swirls and eddies which resulted in erosion. Another important thing was provision against under-runs in an erodible foreshore. Dr. Owens.

Dr. VAUGHAN CORNISH desired to follow his friend, Dr. Owens, on the point of the transport of shingle by the flood- and the ebb-tide respectively. The Author stated that the strength of the flood-tide was superior to that of the ebb, and that the correctness of that statement was easily proved by placing a log of timber in the sea and measuring the distance travelled up and down the coast with the flood and the ebb. He did not think that experiment had been actually carried out around the coast in any such complete way as would be necessary to prove the Author's statement as a general proposition; neither was he aware of any theoretical reason why the log should on the whole travel farther with the flood than with the ebb. But whether it was so or not—whether the flood was stronger than the ebb, or whether the ebb was stronger than the flood—there was an advantage of opportunity on the part of the flood-tide which gave it an inevitable advantage over the ebb in the transport of shingle, and it was very important that that perfectly general principle should be laid down clearly. In the open sea the current of the tide flowed from mean sea-level past high water to mean sea-level, and then the ebb-current flowed from mean sea-level past low water to mean sea-level. It was known as a matter of observation that shingle lay mainly on beaches above mean sea-level. Therefore, off headlands and salient Dr. Cornish.

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Dr. Cornish. positions, where the run of the tides was very nearly the same as it was in the open sea, the flood-tide current was running over the shingle almost the whole of its time, and the ebb-tide current was returning backwards over a part of the beach which had very little shingle. Consequently, the shingle on headlands was, so to speak, stroked only in one direction, which must determine the resultant motion to be in the direction of the flood-tide. In bays and inlets, and in those rare positions which were called tidal nodes, such as that near Dungeness, the current of the flowing tide was turned before its time—it turned between high water and mean sea-level, and the ebb-tide current therefore set in before mean sea-level was reached. The extreme case, reached only in a few positions, was where the tide turned exactly at high water, so that the average level of the water during the ebb-current was the same as the flood-level of the water during the flowing current, and only in that extreme case had the ebb-tide an opportunity of acting upon the shingle equal to that enjoyed by the flowing tide. In no case that he was aware of had the ebbing tide a superior opportunity of acting upon the shingle. As he had said, the advantage of the flowing tide was greatest at the headlands and less in bays, the opportunity of action of the ebb-tide being more nearly equal in the bays than at the headlands. It followed from that, apart from any of the known co-operating circumstances, that there would be a transport of shingle from the headlands and an accumulation of shingle in the bays, because the resultant motion would be less in the bays, for the ebb-tide carried the shingle back more effectively than at the headlands. With regard to the accumulation of shingle in a bank or beach, he would like to point out what, as far as he was aware, had not been pointed out hitherto before any learned society, namely, that a somewhat similar principle applied. The ordinary wind-waves of the sea had a proper action to drive sand or shingle in the direction of their motion, quite apart from any motion of translation which they might under certain circumstances happen to possess. That advantage was due to the fact that the vertical and horizontal currents of the waves did not set in at the same time. The forward current commenced at mean sea-level. When that forward current set in, the upward current of the wave had already commenced, for the upward current commenced at the trough and finished at the crest. Thus, when the forward action of the wave commenced, the sand was already in suspension, having been churned up by the upward current which had already set in. Similarly the shingle was already loosened from its bed and in a condition in which it was easily moved,

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and therefore the forward current of the wave acted with the greatest advantage. When the crest of the wave had passed, the downward current commenced, and that had been going on some time when the trough of the wave was reached and the backward current set in. Thus when the backward, that was the seaward, current of the wave set in, the sand had already in large part subsided, the water was clarified, and the agitated shingle had once more bedded itself on the bottom and become interlocked, so that when the seaward current of the wave set in, it acted under a very great disadvantage, because it had not the same opportunity for moving either the sand or the shingle. Therefore both in the case of the wave which was called "the tide" and the waves which were caused by wind, the circumstances that the vertical and horizontal currents did not set in at the same time, and the particular order in which the vertical and horizontal currents succeeded one another, gave alike a perfectly general and an extremely effective advantage in the transport of shingle to the current which flowed in the direction of the wave's advance. Dr. Cornish.

Mr. C. W. Darley remarked that the subject dealt with in the Paper was, he thought, almost peculiar to England, as there were very few other countries where the same trouble was experienced. In the district under consideration the coast was largely made up of glacial deposits and materials which were broken down by the sea and moved by the currents—no doubt the flood-current chiefly—along the coast; so that by preventing, by means of groynes, the travel of the material, the coast could be properly protected. Personally, he had no experience in this country, but he wished to point out that although groynes were effective in dealing with heavy shingle, as a rule they were not effective in dealing with light material where the influence of any current was felt. He had had a large experience of river-protection, and had been frequently asked why he did not adopt groynes, which had been so successful on the coast of England. He had seen groynes tried by private landowners along the river-banks in New South Wales, but he had never seen one that was of the least benefit. On the contrary, they generally set up a counter action, and a hole was dug immediately below by the current of the river. The only protection he had found of any use at all in the case of rivers, particularly through alluvial country, was that afforded by loose stone. On many miles of the rivers where the land was valuable, protection had been afforded in that way. On the Hunter River, 100 miles north of Sydney, where the banks were undermined during floods, it was found that loose stone, with Mr. Darley.

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Mr. Darley. a line as uniform as possible, was the most effective and the cheapest protection that could be adopted. If further scour took place, the stone subsided and arrested it. He mentioned that to show that in all cases groynes for defence-work were not effective. With regard to material being brought in from the sea, there were many cases on the coast of New South Wales which afforded evidence that sand was brought in from a source some distance out in the sea. On one part of the coast, about 40 miles in length, after every gale a large quantity of black sand, containing a good deal of gold, was found. It was brought in and deposited along the beach, and was generally found 12 or 18 inches below the surface of the siliceous sand. It was deposited in a layer about 6 to 12 inches thick between low-water and high-water mark, and a very good living was made by a large number of men by washing the sand for the gold. Working by a very primitive method, they could easily earn 10*s*. per day. There was no sand of that kind on the coast, and no cliff breaking away, nor was there any place where that sand could be found; and therefore it must come in from some distance out to sea. In his opinion the sand was stirred up in the sea at a considerable depth, and was carried by wave-action on to the coast.

Mr. Hawksley. Mr. CHARLES HAWKSLEY, Past-President, remarked that his firm acted professionally for the Lowestoft Water and Gas Company, whose works were situated at the southern end of the sea-wall which the Author had built. That wall did not go sufficiently far southward to protect the shore opposite the gasworks, and since the wall was built there had been considerable erosion of the coast in front of those works. The Company had obtained parliamentary sanction to assist the Corporation of Lowestoft financially in the matter of protective works, which had been carried out by the Corporation during the last year by extending the wall constructed by the Author, but setting it in somewhat more landward. In front of the wall five or six groynes had been constructed running seaward from the wall. The result was that the erosion had ceased, and there had been instead a making-up of the coast by the shingle intercepted and accumulated by the groynes.

The Author. The AUTHOR, in reply, remarked that Mr. Walmisley had referred to the angle at which groynes should be laid down, and had suggested that the angle might be put at 85°. His own view was that the farther groynes were taken out into the sea the better. If the engineer had the money to expend, the farther out the groyne extended the better, and he thought it was generally admitted that the best direction was practically at

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right angles to the shore-line. Mr. Walmisley had also referred to the disadvantage of a hole in a groyne about high-water neap-tide level. In the case of Sheringham, there was a hole in groyne No. 4 at high water of neap-tides, which had been very effective in allowing the beach to go through to groyne No. 3. In that case the shingle had not yet begun to travel round the end of the groyne, and it was desirable to fill No. 3 through the hole. Now, both groyne No. 4 and groyne No. 3 were overflowing, and the beach was gradually arriving at the old east groyne, where the difficulty had been for so many years. With regard to Mr. Marriott's observations on the erosion of cliffs, the Author's view was that there was no erosion on cliffs which were not washed by the sea. Erosion was not found on railway-embankments or on cliffs away from the sea, because the material fell and formed a slope at an angle of, say, 45°, which became covered with grass or bush. But naturally, where the sea eroded the toe of the cliff, there was trouble at the top, and the only thing to do was to put in a sea-wall or a groyne. Mr. Marriott had alluded to the outlying banks on the coast of Norfolk. Of course, during a gale of wind there would be considerable erosion going on within the banks, because the race of the tide would then be considerably more than if no such banks existed. He knew the coast Mr. Marriott had referred to, between Happisburgh and Winterton, including of course Palling and Winterton, where the sand-hills were advancing seaward to the extent of at least 10 to 15 yards every year. There were lifeboat-houses at both Palling and Winterton which had been absolutely covered in by the sand accumulating there, and it had cost the Lifeboat Institution a large sum of money annually to remove the sand in order to form a passage to the sea. At Winterton the old lifeboat-house, which formerly stood on the brink of high water, was now 365 feet distant from that point, thus showing the distinct advance of the land seaward. Occasionally there was a heavy scour, such as had taken place at Caister within recent years, but his own view was that the beach would continue to grow out. The Claremont Pier at Lowestoft was built at the same time as the groynes shown in Fig. 7, Plate 3, extending southward to Pakefield. That pier had accumulated beach on its southern side, so that it had done no harm, and it was an advantage to have the pier there. It was built by Mr. Jaffrey, and since its construction, which commenced about the year 1903, the beach had certainly accumulated in its neighbourhood. With regard to the utility of groynes, as he had pointed out in the Paper, all depended on the angle of strike of the waves. If they struck obliquely, groynes need not be nearly so long as if they struck end on. He had gone into

The Author.

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The Author. that matter pretty fully in the Paper. At Lowestoft North Denes there were some very long large groynes—about 290 feet in length. The waves came from about north-east and struck very obliquely, and they would run along the wall were it not for the length of the groynes. The question whether groynes should be carried up to the sea-wall and down to low water was clearly dealt with in the Paper. It was absolutely necessary to carry the groynes up to the wall, because in the event of getting an abnormally high tide the beach was likely to be carried round the end of the groyne unless there was a wall there to prevent it. With regard to Mr. Wheeler's question as to the length of groynes, the Author had expressed clearly the opinion that, the longer the groyne, the better it was for the purpose of collecting material. Respecting Mr. Wheeler's intention to carry out works in the immediate neighbourhood of Hornsea and to run the groynes down to half-tide level instead of low-water mark, as the Author had done, the Hornsea groynes had collected beach to a height of 11 feet, and he hoped Mr. Wheeler would be equally successful. With regard to Mr. Carey's reference to dumping material on the beach, anyone could get a beach by dumping material; the difficulty was to get it without dumping. In the cases mentioned in the Paper there was in certain instances very little shingle to be obtained in the neighbourhood, but the beach had been accumulated by means of groynes. Dumping had been tried in many places, as at Folkestone, and it had proved successful where the material was retained by groynes. With regard to Dr. Owens's question as to the travel of shingle or beach-material between high and low water, of course a certain quantity of shingle came in from the deep sea, which shingle had previously been carried out by the waves during very heavy gales. Onshore gales did occasionally drive boulders, with seaweed attached, on to a foreshore. Had these travelled any distance the seaweed would have been worn off. He did not think, however, that any large quantity of shingle was collected from the deep sea. In the West of England, say Land's End, which was surrounded by the deep sea, he did not think any beach-material was ever collected. A little sand was obtained occasionally, but there was no shingle at the foot of the cliffs. With regard to shingle being at a lower level on the lee side of groynes, the groynes instanced in the Paper showed no lowering of the shingle on their lee side; the shingle was level with the top of the groyne on both sides, and he thought that properly-designed groynes should have that result. As to walls, he maintained that vertical walls were efficient, and the whole of the walls referred to in the Paper were vertical. At Sheringham the

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beach had been lifted 11 feet against the vertical wall built by the late Mr. Jaffrey, to which Mr. Marriott had alluded, and he thought that was sufficient to show that a vertical wall was quite efficient, besides being less expensive to construct. Foreshores naturally eroded in a manner similar to the adjacent cliff, and produced beach material. Dr. Cornish's remarks with reference to wave-action were very interesting. If the master of a sailing vessel were asked which tide carried him the farthest, he would pin his faith to the flood-tide rather than to the ebb. Stone groynes, such as had been referred to by Mr. Darley, were of course very effective. Mr. Darley had mentioned that he had never been able to collect light material by means of groynes. In the case of the spur groyne to the south of Lowestoft harbour very fine sand was collected to a height of 12 feet in 12 months, and the low-water mark was driven back 150 yards; that showed that very fine sand could be collected. All the groynes on the south beach had collected nothing but fine sand. With reference to Mr. Hawksley's remarks on the protection of the gasworks to the south of the sea-wall at Lowestoft, the fact was that in 1902 the foreshore there did not belong to the Corporation, and consequently they were unable to extend the wall. As to the expense of doing so, they rather hoped to obtain a contribution from the Gas Company, which at that time was not forthcoming. He was glad to hear that arrangements had now been made for the continuation of the wall and the groynes, and that the work had proved effective. The Author.

Correspondence.

Mr. E. T. Beard remarked that the action of the sea in destroying cliffs was greatly assisted by rain, frosts, and springs. Marine denudation wore down the cliffs to a level surface below the waves: subaerial denudation, on the contrary, produced a picturesque shore. The two worked together, destroying the cliffs in proportion to their hardness and the strength of the waves. On rocky coasts the waves forced water into the joints and fissures of the rock; this compressed the air contained in these fissures; and on the waves receding, the air forced out the water. The constant repetition of this process loosened material, and caves and hollows were formed at the foot of the cliff, which was gradually weakened until it fell. Where possible, such places should be filled up by a strong wall to Mr. Beard.

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