Discussion.

The PRESIDENT, in moving a vote of thanks to the Authors, observed that the Papers dealt with a subject of much interest in this country: the great loss of land which occurred through erosion on the coasts, in North Norfolk particularly and on the South Coast was well known. In his experience groynes of themselves did not form a protection against erosion of the coast; it was necessary to have behind them either some high land or a wall, in order to prevent the full of the beach from being constantly driven back, and thus to make the groynes effective. The President.

Mr. GRANTHAM wished to draw particular attention to the sections of groynes shown in Figs. 2 and 3, Plate 1. Groyne No. 6 at Lancing was typical of ten groynes put up in 1893. A bank of shingle 10 feet wide was made in front of low-lying land, and the groynes were then put down. At first the high tides just took the top off the bank, but after a time, when the groynes began to do their work, the shingle accumulated, and for a long time now the tide had not gone near the shingle bank; in fact, bungalows and a small sea-wall had been erected on the bank, and they were not affected by the sea. After 30 years such an accumulation of shingle had occurred that complete protection was obtained, and this showed that it was possible to secure protection solely by means of groynes. Groyne No. 6 at West Wittering showed similar results. The shaded portion on the diagram indicated the quantity of shingle. At Wittering a bank 60 to 90 feet wide had accumulated in the last 20 years, and the sea-front was entirely protected. Mr. Grantham.

Mr. HOLLINGWORTH thought he ought to offer an apology for having ventured to submit to a scientific Institution a Paper which contained no mathematics, on a subject such as the tides. He was afraid that, if he had included mathematics, he could only have impressed the very young. He remembered having heard in his youth a Paper upon tunnels, which described the almost super-scientific methods used to secure accuracy. When the tunnel-headings met they were only $\frac{1}{2}$ inch out. At the time he was depressed at the thought of his own efforts with the theodolite; but afterwards he learned two facts which the Author thought too trivial to mention: before the tunnels met, an advance heading was driven, and the Mr. Hollingworth.

Mr. Hollingworth.

junction was made with a neat S curve. He did not wish to decry scientific methods, but he thought that simple methods, like the advance heading in question, served a very useful purpose. He therefore suggested that the best way to understand the tides was to watch their action in miniature on the foreshore. For instance, if there was practically a flat calm, just a few yards out the water washed gently to and fro with practically no rise of the surface, but if a large stone were thrown in, the water would bank up behind the stone. The important deduction was that the essential action of the tide was the horizontal motion—the rise was purely a local accident which was comparatively immaterial. For that reason he thought there was much tidal action going on in the ocean which was not suspected because it was not indicated by the rise of tide. So far as he was aware that had never been investigated, and those who were chiefly interested—the masters of sea-going vessels—certainly did not think that such a thing could happen. One occasionally heard that a vessel got out of its course and met with disaster from some unexplained causes. Naturally it was difficult for a landsman to hear of a ship getting out of its course unless there was a disaster. He had heard of a case where a liner bound for Colombo picked up the coast 20 miles to the north, in spite of the fact that the wind and current were expected to set the vessel to the southward. Although his informer had had that experience 30 years ago, Mr. Hollingworth did not think he suspected even now that it could have been due to any sort of tidal action. If the tide curves were consulted, it would be seen that at Bombay, Aden, and Bushire, there was a very large diurnal inequality at some period of the month. That meant that in the Indian Ocean there must be a vast quantity of water running north at certain times. Robert Louis Stevenson also mentioned an inexplicable incident that occurred to him in the Marquesas.[1] He was sailing south, with the south-east trade wind and a current setting to leeward, hoping to make an island in the Paumotu Archipelago; but, when land was sighted, it was found that they were about 30 miles to windward. Stevenson, though he was an engineer's son and brought up in an engineer's office, had no suspicion that tidal action could exist there, simply because the rise and fall in that part of the world was only a foot or two. Many of the facts cited in his Paper had not been obtained from his own observation. They were, however, given on very good authority, namely, the Minutes of Proceedings of The Institution. He did not know whether the members

[1] "In the South Seas."

—especially the London members who had the large Institution library at hand, realized what a mass of information on every subject was contained in those volumes, and how accessible it was. For many years they had formed the only technical library within his reach. Mr. Hollingworth.

Commander H. D. WARBURG, R.N., remarked that the old conception of the tide as a single wave travelling about the ocean had long ago been superseded by the work of Sir G. H. Darwin and his followers. The tide as it existed actually consisted of a number of waves of different periods. There were diurnal waves which caused diurnal tides and which were the predominating feature in some localities. In this particular part of the world the semi-diurnal waves were the predominating feature. He agreed with Mr. Hollingworth in his statement as to the obscurity of scientific writers; but that arose in a way which he thought could be explained, although it should not exist. The tide wave, as he had previously said, consisted of a considerable number of constituents. For predicting purposes they could only consider waves which were unvarying and which were of harmonic shape; but the waves as they existed were not unvarying and their shapes were not harmonic —at least not in shallow water. The mathematician, therefore, substituted fictitious unvarying harmonic waves for the real variable non-harmonic waves, and unfortunately, scientists wrote as though these fictitious waves really existed. That the tide was horizontal motion, or primarily horizontal motion and not vertical motion, was a heresy which he could not accept. The horizontal motion arose from the tide. What happened was that, as either any one of the component waves or the combined tidal wave, as it existed, reached shallow water, its speed decreased and its height increased; consequently the surface slope became steeper and streams developed. Streams were of two types. When the wave approached an open coast, slack water occurred at high and low water, and the stream reached its maximum velocity at half tide, as would normally be expected, from the water running down the slope. If on the other hand, there was a long deep inlet with approximately the same depth as the sea outside, the slack water occurred at half tide, and the stream reached its greatest velocity at high water and low water. That was normal and in accordance with theory. A good example of that occurred in the Gulf of Corryvreckan on the West Coast of Scotland, where there was a tremendous stream running in and out at high water and low water and absolutely slack water at half tide. Mr. Hollingworth's finding that the flood stream was the predominating factor in drift was quite in accordance with theory, because as the wave got into shallow water and its shape changed, Commander Warburg.

Commander Warburg.

the front slope became steeper than the rear slope; consequently the speed of the flood stream was greater than the speed of the ebb stream, and had a greater effect in moving sand, shingle, etc.; in fact, in that way and in every conceivable way, observation was in accordance with the modern theory of tides, and he was afraid it was not in accordance with the theory put forward by Mr. Hollingworth.

Sir Maurice Fitzmaurice.

Sir MAURICE FITZMAURICE, Past-President, remarked that he would hardly have ventured to say very much about Mr. Grantham's Paper but for the fact that the history of many of the works to which the Author referred was in the possession of his office, and work had to be done in connection with the various schemes from time to time. The breach which occurred at the Spurn took place, as far as he knew, in 1848, but it was not until 1863 that the late Sir John Coode was called in to advise on the best way of making it good. The method adopted was correctly described by Mr. Grantham, and he proposed to make only a few additional remarks which might prove to be of interest. The width at the narrowest place, instead of being 5 chains as stated in the Paper, was really under 60 yards. It would naturally be a very serious matter for navigation in the Humber, considering the large drift travel that existed, if a breach occurred and an enormous quantity of sand was delivered into the river. Since 1863, care of the Spurn had been successively in the hands of Sir John Coode and the late Sir William Matthews, and at the present time his own firm still carried on the work. The matter was so important that it was necessary to keep on the spot an inspector, who went up and down both sides every day and sent in reports to the firm at frequent intervals. Much work was constantly being done there in the way of building new groynes, renewing old groynes, and making certain revetments which were necessary. The travel at that place was of the most extensive description he had ever experienced. Enormous waves of sand and fine shingle could be seen coming down. At times the groynes were completely submerged in the crests of those waves, and at other times they were exposed in the troughs. With the strong east and north-east winds which occurred the difficulty arose that occasionally sand and gravel in certain compartments between two groynes was scooped out; and it was necessary to fill the place between the groynes very quickly. He would refer later on to the method of doing that. In the case of Scarborough, after the reports were made by Dr. Lapworth and Professor Kendall, his partners, Mr. Maurice F. Wilson and Mr. A. T. Coode were asked to advise on the method of dealing with the subject. The only reason why he referred to the matter was that, if the description given in the

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Paper was read cursorily, the impression might be obtained (although certainly it was not stated in the Paper) that the movement of the sea wall there was due to the fact that groynes had not been put in. What had happened there, as Dr. Lapworth and Professor Kendall stated, was due to the fact that the sliding of the wall and ground was taking place on a plane at a considerably lower level than the bottom of the wall; and certain works were now being carried out in an endeavour to deal with that difficulty. The so-called Dymchurch wall, which was really a clay embankment covered with stone pitching, well maintained in some places and in others rather deteriorated, had lasted for a very long time. It was a very important protection against the sea, because Romney Marsh extended behind it for about 24,000 acres and was 8 to 11 feet below H.W.O.S.T. It would be appreciated, therefore, that much damage to property, stock, and human life would be caused if anything happened to that wall. Mr. James Walker, in his report on that wall in 1837, stated that the strength of the defences at that time was by no means suited to the magnitude of the property or its exposure. Personally, he would not like to use exactly the same language now, but he would certainly go very near it. In 1894 Sir William Matthews was consulted about the matter. Having inspected the place for several days, he considered the matter so serious that he advised that the opinion of a second engineer should be taken, and Sir John Wolfe Barry was consulted. In their joint report they proposed the erection of certain groynes with the object of helping to collect the little sand and gravel that was available. Mr. A. H. Case, M. Inst. C.E., who was looking after the undertaking at the time, carried out those works successfully. The place was protected to a certain extent from the south-west by Dungeness, which was a very large natural groyne that collected shingle and was probably the cause of places like Winchelsea and Rye being inland instead of being on the sea. Three or four years ago he inspected the beach to the east of Dymchurch, extending to the gas-works at Hythe, which was protected by so-called low groynes. He found the groynes all broken down and quite useless; in fact they were doing more harm than good because they were causing eddies and swirls to be formed which tended to scoop out holes and do damage to the beach, and the sea was extending inland. He believed certain works had been carried out there since. He quite agreed with the Author's statement that without groynes the sea walls at Hove, Brighton, and St. Leonards and Hastings would not exist. He thought there could be no doubt about that. The series of very large groynes at Brighton had completely trapped, for the time being, all the shingle coming from

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west to east, and until those groynes were filled up, not much shingle would pass. Practically no shingle was now passing or had passed Brighton for some time, and very little shingle existed along the shore for about 2 miles from Roedean to Rottingdean, the only drift being the flints which had come out from the erosion of the chalk foreshore at that place. He was sorry, however, he could not agree with Mr. Grantham in his very general statement: "Where cliffs form the background of the coast line, accumulation of drift caused by well-devised groynes will be sufficient to protect the base of the cliffs and prevent any further erosion, without building any sea-wall, revetment, or breastwork." He thought that was true in some cases, but it depended a great deal on the kind of cliff and on the exposure. It might be quite true in places like Chichester, where there was protection by the Isle of Wight from south-west gales, but there were many cases in which he would be extremely sorry indeed to proceed along those lines. There were a few points about groynes which Mr. Grantham had not mentioned, and to which he thought it would be useful to call attention. With regard to the material of which groynes ought to be made, where shingle existed, the greatest care ought to be taken not to make groynes of thin concrete, whether reinforced or otherwise, because the shingle would cut into it very soon. If reinforced-concrete groynes were erected, within a short time the steel bars would be exposed unless a great mass of shingle collected very quickly. He had recently seen some reinforced-concrete piles, driven on a shingly beach in Dorset, which had been cut into very quickly by the shingle. Engineers were rather inclined to use new materials for construction, and he therefore thought it wise to give that word of warning. Every care ought also to be taken to avoid projections, angles, or anything likely to cause swirls or eddies. He had seen groynes in which large masses of concrete had been put down to carry verticals, with the result that swirls and eddies were caused round the concrete which gradually undermined it, so that it eventually came to grief. Another point he wished to emphasize was that it was sometimes useful to be able to take off some of the top portion of a groyne. That, of course, was more easily done with timber groynes than groynes in which other material was used. At the Spurn, sometimes one compartment between the groynes would be quite full, while the one below had been almost denuded by the sea scooping the gravel out. Two or three of the planks were then taken off from the groyne above, and the sand and gravel immediately travelled down and filled up the empty compartment, which was thus protected very quickly from sea-action. On the other hand, if large quantities of gravel were

coming down, planks were put in, and a reservoir of material was thus obtained which it was possible to let down at any desired time. No groyning—or, in fact, any work—could be carried out at one point along a coast without its having in all probability an effect on the coast on each side of the place at which the work was done. If groynes were put in, sand was collected which would have gone on to a neighbouring place; or, if the sea was allowed to encroach too much, it might get to the back of the neighbouring land; so that it was necessary to think very carefully of what would happen on each side of the place at which work was carried out. Much damage could be done by carting away shingle from beaches, or by dredging in large quantities. Sir John Coode had mentioned, in an old report of 1863, that the first time he went to the Spurn he saw fourteen ships round Kilnsea loading up with gravel and taking it away—gravel which ought to have been allowed to come down along the Spurn for its protection. Sir John Coode also carried out some work at a small port in Dorset, and on referring to the old plans of the place Sir Maurice Fitzmaurice found that the beach was now 6 feet lower than it was 30 years ago, simply due to the enormous quantities of gravel and sand that had been taken away. The last case to which he wished to refer related to a very serious incident that happened on the Devon coast. A large quantity of gravel had been dredged not very far from a little fishing village, and subsequently he was sent there by the Board of Trade to hold an inquiry into the subject. About 80 feet of beach had existed, before dredging began, between high water and the village, which was protected by a small wall. A deep hole was dredged, from which 600,000 or 700,000 tons of gravel were taken. The hole was gradually filled up by the action of the waves, and the beach came away, the foreshore falling 10 feet in front of the village. As a result, instead of high water being 80 feet from the village it was right up against the wall, and during a heavy storm the waves completely destroyed every house. Knowledge about groynes and sea-protection could not be learned completely from books. In that respect he had been very fortunate. He had gone round many coasts with his late partner, Sir William Matthews, who possessed the keenest observation, he supposed, that any engineer ever had for detail in that connection. Sir William was always willing and, indeed, anxious to make his experience available to members at these meetings, and to those who had to carry on his work after him.

Sir Maurice Fitzmaurice.

Mr. Ernest Latham remarked that his experiences referred more particularly to the subject of Mr. Grantham's Paper. At Minehead, which was one salient of the Bristol Channel, there was a small

Mr. Latham.

Mr. Latham. tidal harbour and a big embayment. The coast ran round to Watchett, to form Blue Anchor Bay, which was probably 8 miles across from point to point. The travel of the beach material was from west to east. His firm had been faced with a difficult problem in advising the Somerset County Council. A county road ran along a portion of the embayment, and it had been originally carried on a shingle bank. In 1899, however, the late Mr. C. A. Brereton, M. Inst. C.E., built a bull-nosed sea-wall in masonry about 1,000 yards long, which stood for some years quite satisfactorily, and was in fact standing at the present time. Very careful foreshore sections were kept over a period of 21 years, and 2 years ago it was found that the foreshore had lost a depth of 15 feet vertically downwards at the face of the wall. The County Council, in order to maintain the county road, had constantly had to underpin the foundations of the wall. That was the situation when he was asked to advise them. Matters had gone so far that it was a question whether groynes alone would effect the desired object. In his experience groynes produced two results : accretion of beach material if there was any littoral drift, but also erosion on their lee side. He was doubtful of the expediency of putting groynes directly in front of such a wall. He considered that, on the balance, material would be accreted, but was concerned about possible erosion on the lee side. An experiment was made which he would describe, and the works were finished in January, 1922. A long groyne was put in, not in front of, but at the eastern end of the wall, in view of the fact that the travel was in that direction, and the owner of the adjacent land constructed a heavy reinforced-concrete wall as a return end. The groyne, which was an adjustable one, such as Sir Maurice Fitzmaurice had referred to, began to accrete material at the east end of the defences, but its effect was limited. In addition, two stockades, or wave-breakers, were built, one 20 feet and the other 50 feet in front of the wall. The result of those works during the last 23 months had been to maintain the foreshore-levels where they had been previously. The engineers had neither won nor lost ; but it was satisfactory to know that the open wave-breakers, with 10-inch spacing between the piles, did retain the beach material, in this case heavy shingle. Only one serious difficulty had been experienced. Shortly after the works were completed, erosion occurred behind the inner stockade. An experiment was again made by introducing at intervals along the face of the wall very short mass-concrete groynes only 20 feet long, 16 feet wide at their base, and having a gently curved crest in cross section. The greatest height above the base was only 7 feet. These groynes definitely accreted the heavy shingle coming from the

west, and scour on the lee side was eliminated. At Burnham, Somerset, where his firm had been advising for some years, there were difficulties of another character. The top of the tide came just above a low flat foreshore, consisting of vast quantities of silt and mud. The wind-waves just cut the toe of some low sand-hills which now covered the original defences of the sea-wall. In itself that was a small thing, but local landowners were becoming anxious, and they did not want to incur expense. There had also been over a period of 30 years a definite lowering of the foreshore by, as far as he could ascertain, about 7 feet. The south side of the Bristol Channel seemed, to his mind, to have been denuded consistently in recent years, and erosion was taking place. He would like to ask Mr. Grantham whether groyning was the right corrective in that instance; he rather doubted it. On the north side of the Bristol Channel, in the Burry Inlet, on the coast of Carmarthenshire, his firm had had a very difficult situation to face before the war. The ports of Llanelly and Burry Port were constantly and insistently blocked with sand. He had advised the Burry Port Harbour Company that, unless they could spend money, they would be sanded up. No steps had been taken, however, and the harbour did for a time silt up. The matter was serious, because those two ports exported much of the anthracite coal that came from South Wales. As far as could be traced, the entrance channels to Llanelly and Burry Port silted up periodically. There were three navigable channels—the North, Middle, and South; and each appeared to change roughly every 30 years. If that was so, it afforded definite proof of the idea which Mr. Grantham put forward, namely, that very definite movements were caused below low water by the flood-tide. It was an important fact, apart from theory, that if the flood-tide, which was there very insistent, was reduced to a 12-hour cycle, only 5 hours flood occurred against 7 hours ebb. Movements of sand certainly took place below low-water mark. Turning to the East Coast, he asked what Mr. Grantham's experience of groynes at Canvey Island had been. At Fobbing, immediately to the west, there were no groynes, but much erosion had occurred. On the previous day he had examined some maps of 1836; they bore little relation to the maps of the present day, because all the saltings had been lost since that date. It had become so serious a few years ago that three of the landowners, on the advice of his late partner, Mr. Carey, called in Messrs. Coode, Son & Matthews, who suggested that, where underwater erosion continued, stone—Kentish rag-stone preferably—should be dumped. That had been done, and had undoubtedly strengthened the defences; but after a time it was desired to build a

Mr. Latham.

Mr. Latham. deep-water quay there, and that stone, from his point of view, had been rather a nuisance, as it had had to be removed from sites where it was desired to sink caissons for concrete columns to carry the superstructure of the quay. He would like to know if, under those conditions, with very steep underwater slopes, Mr. Grantham could suggest any course other than the continual dumping of stone, which, from a navigation point of view, was a nuisance. The Port of London, quite rightly, objected to anything on the foreshore of the Thames estuary which they could see; and he himself objected to things which were below water and could not be seen. With regard to the very narrow neck at Spurn Head, he had had a similar case in miniature on the Orford peninsula, in Suffolk, which the War Office acquired in 1914, and in connection with which that Department asked him to assess the probable necessary outlay on the coast-defences. The shingle bank there was one of the most extraordinary formations on the coast of the North Sea. At Slaughden, a little village just south of Aldeburgh, only a few yards separated the North Sea from the river Alde. He had observed, while on holiday there, that some local builders were in the habit of removing the shingle; he had called attention to that, and it had been stopped. If it had continued, it would have meant the diversion of the river and the shortening of its outfall by about 7 miles. At Frinton he had tried to build up a sandy foreshore without groynes, and, in a measure, he had succeeded, by putting in a stepped reinforced-concrete apron, which had accumulated sand. The works carried out were now completely buried by the sand. In tidal estuaries and rivers groynes did not function quite as they did on an open foreshore. The 90 miles of foreshore between Maldon and Clacton was the site of a number of interesting experiments by landowners. He would like to hear Mr. Grantham's view of half-tidal, triangular-shaped groynes, coupled with the planting of spartina grass, as a specific for collecting silt where the saltings were eroded. This had been adopted by one landowner near Brightlingsea.

Mr. Rutter. Mr. C. H. RUTTER observed that he took a particular interest in that part of the South Coast a few miles eastwards of the Lancing foreshore, and also immediately to the east of the boundary of Brighton and Rottingdean. He could confirm what Sir Maurice Fitzmaurice had said as to the denudation of the foreshore in the latter locality owing, undoubtedly, to the massive groynes constructed by the Brighton Corporation. That denudation was, he thought, more particularly due to the effect of the very long groyne constructed on the parish boundary, which extended so far into

the sea that any shingle passing its end was carried a considerable distance before it reached the shore; thus the whole of the stretch from the boundary groyne to a point half-way to Rottingdean was entirely stripped of shingle, and there was no possibility of its accumulation, even if groynes were constructed. With regard to the Portslade foreshore, the late Mr. J. B. Paddon, M. Inst. C.E., had given[1] some account of the reclamation work necessary before the construction of the gasworks at Portslade in 1870. Mr. Paddon said :— Mr. Rutter.

"To obtain a deposit of shingle along the sea front as a protection, and to prevent the lighter portions of the waves passing over the shingle bank, two groynes were constructed. In accordance with local custom, one of the three groynes was at a right angle to the shore. With groynes so built there is an invariable scour and waste on the lee side, so that a repetition of such groynes along the coast to be protected becomes a necessity. The second groyne was designed to prevent this destructive action and was projected towards the east at an angle of 45 degrees to the shore. The result has been satisfactory, for, soon after its completion, a large bank of shingle accumulated on the east side, where it has since remained."

The groyne of which Mr. Paddon spoke had not only been carried at an angle of 45 degrees to the shore, but it returned in a south-westerly direction at a similar angle, so that the apex of the groyne was pointing eastwards. That groyne was entirely buried at the present time. Subsequent reclamation work had been carried out with the groynes at right angles to the shore, and that had been entirely satisfactory, the beach being level throughout the stretch where the groynes had been so constructed. On the other hand, the groynes on the Aldrington foreshore, still farther to the east, had been constructed by the harbour-authorities at an angle similar to that indicated by Mr. Grantham in his Paper, and there the difference in level of the beach on the windward and the leeward sides was sometimes very marked, depending to a very considerable extent on the direction of the wind. In putting down any further groynes he would be inclined to build them at right angles to the shore, rather than pointing to the south south-east, as recommended by Mr. Grantham. In constructing a series of groynes it was important not to plank them up to the full ultimate height at the time of building. The planks should be added gradually as the beach made, as by that means a much more regular surface of shingle was obtained. In conclusion, he could have wished that Mr. Grantham's Paper had contained some particulars of the actual

[1] Minutes of Proceedings Inst. C.E., vol. xxxvii, p. 316.

Mr. Rutter. construction of groynes; a Paper by some specialist in groyning construction would be of great interest to many members, especially those connected with any engineering works close to the coast.

Mr. Parkinson. Mr. R. M. PARKINSON remarked that he had had experience of the Norfolk and Suffolk coasts between Blakeney and Bawdsey. The shingle beach at Blakeney died out about Weybourne, but shingle extended as far as Sheringham, which was protected by a sea-wall and by groynes at right angles to it. Sheringham was peculiarly fortunate in having a good supply of shingle, coming from the Blakeney shingle-bank, and a good solid bottom to the sea, which maintained shallow water for a considerable distance out. Between Sheringham and Cromer, where there was no protection, a good deal of waste took place. Cromer was protected, but it was not so fortunate as Sheringham in having a chalky and flinty bottom. In 1917 he made a survey of the coast between Happisburgh and Winterton, and he had been able to compare the coast-line as then existing with the Ordnance Surveys of 1906 and 1886. It showed a considerable loss at Happisburgh, and from there to Eccles; but, curiously enough, although there were no protection-works at all at Palling, which was just to the east of Eccles, there had been no loss in the last 30 years. Beyond Palling again, there was considerable loss as far as Winterton. There it died out, and just beyond Winterton there was a gain. At Yarmouth, for a distance of about 2 miles from the river to the northward, there was no loss at all. Evidently the piers at Yarmouth acted as a big groyne. Whether the river outfall also had an effect, he did not know. A little to the north there had been very considerable loss at Caister—averaging 3 or 4 yards a year for the last 20 years. He thought that was partly caused by some protection-works which the Railway Company had made about a mile to the north. Groyning had been carried out, working from north to south, and every groyne put in had made another groyne necessary to the south. Since the company put those groynes there, there had been very considerable loss to the south of them. There were three groynes opposite the hotel at Caister, and he had tried to induce the directors of the hotel to keep those groynes maintained. They, however, had insisted upon having a breastwork alone. First a timber breastwork had been erected, as recommended by Mr. John Russell in conjunction with the preservation of the groynes. But, as the groynes were neglected, the beach went. A further breastwork which was put up also went, and the first north-westerly gale would destroy the hotel. The same thing had happened at Lowestoft. South of Lowestoft there was wastage, owing to the pier stopping the travel of

the shingle. At Southwold at one time there was considerable wastage; but a number of groynes which had been put at right angles to the beach had thoroughly protected the foreshore. Farther south came Aldeburgh, with a beach 10 miles long, and, curiously, with the exception of Palling and Winterton, Aldeburgh was the only place on the East Coast where he had found no loss on comparing the beach with the original Ordnance Survey. That shingle beach was very similar to the Blakeney beach. Where it came from he did not know. The Blakeney beach was no doubt formed of flints from the front. The trouble experienced at Caister had always been caused by north-westerly gales. A single north-westerly gale would do more damage than years of tidal action and ordinary gales. He imagined that what happened was the following. Beginning, say, with high water at full and change at Penzance at about 4.30 a.m., the tidal wave came up the Channel until it reached the mouth of the Thames at noon. Going round the north of Scotland, the same tidal wave got to Aberdeen at noon. The previous tide round the north of Scotland having reached the Thames also at noon, the two tides combined and formed a high tide in the Thames. But at Yarmouth it would be low water on the one tide and high water on the other, so that instead of getting, as one did at Cromer, a tide of 15 feet, at Colne Point of 15 feet, and at Harwich of 12 feet, the tide at Yarmouth was only 6 feet. When, however, a south-westerly gale which had been blowing for some days chopped round to the north-west, additional water, he took it, being forced down the North Sea, altered the time of high water, so that it was high water on both tides at the same time at Yarmouth, and therefore instead of 6 feet, a range of 12 feet was experienced. He would like to know Mr. Grantham's view as to whether groynes simply stopped the travel of shingle, or whether they caused a deposit by checking the flow of the water? He believed the latter was supposed to be the real effect of a groyne. He would like to see experiments carried out, at the National Physical Laboratory, on a scale-model of a sea-beach in which the conditions with a gale acting from different directions, and with water of various depths in front, and so on, were reproduced. Such experiments might yield very useful results. The cost would be a difficulty; but coast-erosion was a national question, and the nation should pay. There was an interesting case on the coast which he surveyed at Horsea Gap in 1918 or 1919. A very high tide had breached the defences and imperilled 60,000 acres of land. Actually not very much damage had resulted, but he was asked to prepare a scheme of groyning. The estimated cost of it proved to be out of all proportion to the

Mr. Parkinson.

Mr. Parkinson. value of the land which would be protected, and he advised continuance of the existing practice, namely, putting in faggots parallel with the sea, and at right angles. Those faggots caught the blown sand and became buried. When they were buried, more faggots were put in, and the bank was increased. When a north-westerly gale occurred it all went, but it was an elastic front. It got thrown farther back, and a few acres of land were lost, but no real damage was usually done. He had advised the construction of a safety bank $\frac{1}{4}$ mile back, but that had not been done. The protection-work there was carried on by a farmer who knew the coast and had always been successful in the matter—more successful perhaps than some engineers were.

Mr. Martin Mr. A. J. MARTIN considered that Mr. Grantham had given a very practical Paper on questions which appealed to many members, and that he was to be congratulated on the results attained. The profile at groyne No. 6 (Fig. 3, Plate 1) was an achievement with which he had every reason to be satisfied. He would like to ask whether, in any case in which Mr. Grantham had employed groynes under similar circumstances, they had failed to yield any beneficial result. The Paper had been of particular interest to him, because he happened to be dealing with a stretch of coast on the west side of Chichester harbour, close to the portion shown on the key plan of Fig. 3. The Ordnance maps of the last 50 years showed considerable changes in that coast. He had no map going so far back as 1842, and he asked whether the one of that date mentioned by Mr. Grantham was an Ordnance map. [Mr. GRANTHAM said he thought it was not.] He noticed that Mr. Grantham showed one exit only from Chichester harbour. At present there were two. The discharge from the harbour had cut its way to the east of the sandbank shown at the entrance to the harbour, leaving a bank in the centre. He had compared all the Ordnance maps on which he could lay his hands, and they showed that on the south front of his clients' estate the high-water line had receded 230 feet since 1872, and the low-water line about 250 feet. At the extreme south-east corner, at Black Point, there was no change. A little farther to the north the land had gained on the sea to the extent of about 150 feet, at both high and low water. During the storms of 1922 considerable damage was done to the south and east fronts of the estate, and he could not help wondering whether Mr. Grantham's groynes had been robbing his clients of their beach material. During the last few years a great deal of shingle had been removed from the Winner bank (in the outlet from Chichester harbour), and he suspected that the removal

of that shingle had something to do with the erosion of his clients' front, especially if the shingle was removed in a haphazard manner, so as to deflect the currents against his clients' foreshore. In the evidence given before the Royal Commission on Coast Erosion, he had noticed that the South Hayling Parish Council complained of the removal of shingle from banks at the south-west corner of the island. (His clients' land was on the south-east corner.) They attributed to the removal of that shingle the erosion which was going on on the south side of the island. The expense of protecting a shore like that was extremely heavy, and it was to be hoped that Mr. Case was right in stating that groynes, in ordinary cases, need only be carried up to half tide. Mr. Grantham mentioned that in the case of a shingle beach it was advantageous to carry the groyne up to the shingle. Half tide did not mean half length by any means, because the length of groyne above half-tide level, owing to the steepness of the beach, would naturally be much less than the length on the lower and flatter part of the foreshore. The late Mr. A. T. Walmisley, M. Inst. C.E., had remarked, during a discussion some years ago on the same subject, that groynes were of no use on a beach steeper than 1 in 10. He would like to know Mr. Grantham's opinion on that point. It would be interesting also to hear Mr. Grantham's views on the question of the direction of groynes. Most of the witnesses before the Royal Commission on Coast Erosion had been in favour of pointing the groynes to windward. He noticed that Mr. Grantham turned all his groynes in the opposite direction. In view of the effect which a groyne had in holding up beach material, and to a certain extent robbing the beach to leeward of it, it had been suggested that the groyne should be so formed as to let some of the material pass it. Lowering the top of the groyne for this purpose was evidently advantageous in some circumstances; but the alternative plan of leaving gaps in the groyne was, to his mind, suicidal. The current swept with a high velocity through the gaps and scoured out the beach. He had a case of that kind 2 or 3 years ago at the Tendring Level on the East Coast, south of the Frinton beach which had been referred to by Mr. Latham. The coast there was very exposed, the 25-fathom line being nearer the shore than at any other point between the Stour and the Colne. The Level was enclosed by an old sea-wall which had been breached about seven times in the last 22 years. The foreshore had been very much denuded, and the beach in places had been cut down 2 or 3 feet below the toe of the wall. There were groynes at short intervals—every 30 to 50 yards—but they had been neglected. There were many gaps in the groynes,

Mr. Martin.

Mr. Martin. some of them close under the wall. In some cases the planks had gone altogether for a length of 9 or 18 feet. It was not surprising, therefore, that the wall was in a precarious condition. He had recommended that the groynes should be made good. He quite agreed with Mr. Grantham that a sea-wall without groynes was, in the majority of cases, in a parlous state. He thought Mr. Grantham was also right in saying that in ordinary circumstances much good could be done by groynes alone without a wall. He had been rather struck with Mr. Parkinson's suggestion that small-scale experiments should be made to ascertain the effect of groynes. His brother (Mr. G. H. Martin) had made effective use of working models of sand with water and a pair of bellows to illustrate the Gulf Stream and other physiographical effects. A great deal of valuable information could be gained by such experiments; and, provided care were taken to allow for the difference between the conditions of the experiment and those which existed on an actual foreshore, he was sure that valuable results might be obtained at very little cost.

Captain Sir Arthur Clarke

Captain Sir ARTHUR CLARKE wondered what sailors were to do when experts on the tides argued in opposition. The groyne question was important to Trinity House and he had been interested in Mr. Latham's remarks on the matter. He had been particularly struck with his statement that the Port of London Authority was interested in the foreshore. The Port of London Authority was more interested in the channel than in the foreshore, because its duty was to maintain deep water. He was also interested to learn that the saltings at Canvey Island were passing away to the westward. Was that happening to any great extent to the saltings to the eastward? [Mr. LATHAM said he did not know.] Trinity House were seriously concerned on account of the encroachment of the sea between the sets of groynes which had been erected to protect the lighthouse at Bideford. The opinion was strongly held that that was due to removal of shingle. It was all very well to say that the shingle banked itself up again; but, between while, the sea came in and did very considerable damage to the foreshore. Efforts were now being made with a view to reduce in some measure the quantity of shingle taken away. It was one of the curious old duties of Trinity House to advise the Board of Trade with regard to the removal of shingle and banks, and the dumping of material into estuaries, harbours, and rivers. They were not engineers—their opinion was given from the seaman's point of view—and his own motto was "Leave Nature alone, unless it is absolutely necessary to interfere in connection with large engineering works in estuaries and harbours." No material should be deposited in the estuary of a

river. He had had 25 years' experience of the coast, and knew all the places mentioned in the Papers and in the discussion; his opinion was that wherever Nature was interfered with, as a rule, there was trouble. Captain Sir Arthur Clarke.

Mr. W. W. GRIERSON remarked that the Great Western Railway bordered the sea at many parts of its system on the north coast of Somerset, in Devonshire, on the Cambrian Coast, in South Wales, and at other places. The sea-defences consisted of walls with and without groynes, and also slopes formed of big blocks of stone. He would confine his remarks to the South Devon Coast, where the railway skirted the sea for many miles. The railway there was protected by a large and substantial wall built when the railway was constructed, some time in the forties. Groynes were added—whether at that time or later there was no record; but probably, due to the fact that no trouble had occurred, a false sense of security had been engendered, and the groynes had been allowed to fall into disuse. The consequence was that about 14 or 15 years ago a rather alarming interruption to traffic occurred. The wall was uninjured, but it had been undermined by channels formed under it, through the natural strata on which the railway embankment rested. The consequence was a crowning in several feet in width, and extending for a long distance. At that time there was no shingle on the beach; but drawings showed that there had been, many years ago, a bank of shingle ranging from 4 to 8 feet in thickness all along the wall. It was decided, therefore, to renew the groynes, about 70 yards apart, but in the first place to put in alternate groynes only, as the probable effect was uncertain. It was, however, immediate; the gravel and shingle had accumulated since, and there had been no further trouble. The geological formation was the Permian; he thought it was more particularly described by geologists as the lower marlstone and the lower sandstone. It offered considerable resistance to weathering, but it was not weatherproof. He thought that was a case where a wall, however substantial, would not afford adequate protection without the surface of the natural strata being covered by some bank of shingle. In the case of Barmouth, on the Cambrian coast, it had been announced two years ago that the town was about to be swept away. That was an exaggerated statement; but Barmouth was a small place, and they asked for the co-operation of the Company. He found that the beach was quite bare, and that long lengths of a wall somewhat flimsy in construction, which had been put up to form an esplanade, had been entirely swept away, and he did not think the wall would have withstood the battering of the sea under any circumstances. Mr. Grierson.

Mr. Grierson. That, however, was another case where, in his opinion, no wall would be adequate without the added protection of groynes. On the other hand, the Company had numerous walls on the sea-coast which were not protected by groynes in any way, but which had never been damaged and showed no signs of deterioration. In many places groynes without walls were quite effectively protecting the coast against erosion. A type of groyne which railways could build rather advantageously consisted of old rails and sleepers. Pairs of rails about 9 inches apart were erected at intervals of 9 feet, and the sleepers were put in between them. That arrangement avoided the risk of damage to a groyne that resulted when it was built to its full height in the first place and exposed to the full force of the sea before it was assisted by the accumulation of shingle.

Sir Maurice Fitzmaurice. Sir MAURICE FITZMAURICE desired to refer to one point in Mr. Hollingworth's Paper. The following statement occurred on p. 30: "A notable example of material following the direction of the flood-tide is furnished by the slag from the blast-furnaces at Middlesbrough, which can be traced all down the Holderness coast and up the Humber as far as Goole." When he saw that statement he hardly believed that it could be true, because the late Sir William Matthews made a very careful investigation of the whole of the Humber in 1909, taking samples at different places, and came to the conclusion that very little drift from the Spurn entered the Humber. One reason for that was that there was such a vast volume of fresh water coming down. The estuary of the Humber was the outlet for the fresh water from a larger drainage-area—about one-sixth of England—than any other estuary in England. Consequently Sir Maurice Fitzmaurice wondered how that slag had travelled 50 miles from the Spurn to Goole. He had written to Mr. H. Pickard, the engineer of the Aire and Calder Navigation, who were the conservators of the river Ouse from the point where the Trent entered the Humber up to Goole, asking him whether any slag could have been brought to Goole by ship as ballast, or in any other way. Mr. Pickard had replied in the following terms: "When the training-banks were constructed in the river Ouse, we obtained a very large quantity of slag from Middlesbrough, and when this work was proceeding there were often spongy pieces of this material floating about. Probably these drifted on the foreshore of the Ouse above Goole and the upper Humber below Trent falls." He desired to ask Mr. Hollingworth whether that made any difference to the point which he put forward—that the slag had come 50 miles from the Spurn up to Goole.

Mr. GRANTHAM remarked that Mr. Hollingworth stated that the direction of the general movement of the shingle on the South Coast was eastward, and on the East Coast it was southward; and he mentioned a number of places where it varied a little. Those, however, were generally local effects and did not affect the main movement. The reason why west of Selsey Bill the drift was westward was that the Isle of Wight protected that part of the coast from the heavy south-westerly gales, so that the east winds and the easterly gales and south-easterly gales had the greater influence in driving the shingle along. Mr. Hollingworth rather favoured the idea that the movement of shingle and drift was due to tidal currents. As long ago as 1856 Sir John Coode had shown[1] conclusively that the movement of shingle on the Chesil bank, which was 10 miles long, was due to wind-waves and not to tidal currents. In 1896 Mr. W. H. Wheeler revived the question[2] and attempted to show that the movement was due to tidal currents; but in the discussion which followed Mr. Wheeler's Paper, Sir William Matthews, Sir John Wolfe Barry, Admiral Sir George Nares, and Admiral Wharton all expressed the opinion that it was due to wind-waves. Two known facts relative to the South Coast confirmed those views. Part of the flood tide which ran up the English Channel eastward turned round when it struck Beachy Head, so that between Newhaven and Worthing the tidal current was flowing westward for 1½–2 hours before it was high water on the shore. It was known that the ebb tide flowed to the south-west and westward, so that for 15 or 16 hours out of the 24 the tidal current was flowing westward, in a direction contrary to the general movement of the littoral drift. The second fact was that with south-east or east winds the shingle would move westwards. He thought those two facts were the strongest evidence in support of the opinion that movement of drift was due to wind-waves and not to the tidal currents. He did not think Mr. Hollingworth, when considering reclamation, had given sufficient weight to the quantity of material coming down rivers in suspension. He had had occasion to report on the rivers discharging into the Wash, and he had found that large quantities of suspended matter were brought down. At certain stages of the ebb tide that suspended matter drifted down, and when the tide turned on the flood it was spread over the great bay of the Wash, and then was carried up to be deposited against the nearest embankment. Mr. Hollingworth stated that the material was brought up by the

Mr. Grantham.

[1] Minutes of Proceedings Inst. C.E., vol. xii, p. 520. [2] *Ibid.*, vol. cxxv, p. 2.

Mr. Grantham. sea. He did not know whether Mr. Hollingworth referred to the sand, but there was a good deal more in that soil than mere sand, or else the land would not be so fertile as was the case. He had enclosed 550 acres from the sea with a bank about 1½ mile long, and had shut out the tide in July, 1917. Within 12 months fine crops of barley and oats had been grown over 200 acres.

Replying to the discussion on his Paper, he thanked Sir Maurice Fitzmaurice for his correction as to the width of the Spurn, which he had scaled from the map. With regard to Scarborough, Dr. Lapworth's report as to the sea-wall had revealed a very serious state of things. Professor Kendall's statement, however, that the shore in front of the wall had been lowered 6 feet since the construction of the wall, did suggest the question whether, if groynes had been put in when the wall was originally constructed, they would not have stopped the scouring, and, to that extent, have strengthened the front of the wall. He agreed with Sir Maurice Fitzmaurice that thin reinforced-concrete groynes were of little use on a beach where shingle was in motion. Two such groynes put in recently on Shoreham beach were now derelict, owing to the chafing action of the shingle. Timber was much the best material to use in a case like that. It did become worn after a time, but it would last a good many years, it was very easy to replace, and the height of the groyne could be readily altered. He had sometimes found a large surface of the planking exposed, and perhaps the groyne damaged in a south-west gale. By removing planks the risk of damage was avoided. He did not quite follow Sir Maurice Fitzmaurice's remark that the Brighton groynes had intercepted all the shingle. Although Brighton intercepted a great deal, it was his own belief, although it was very difficult to trace it, that there was a large quantity of shingle moving along which passed Brighton and got driven up at various points on the shore during storms. He knew there was a length of beach between Black Rock and Rottingdean where there was practically no shingle. A little shingle had been collected by the new groynes which had been put there, but the reason for the scarcity of shingle was not so much the interception of the shingle by the Brighton groynes, as that no shingle would stop on the flat chalk shore. It had been his experience on other similar flat shores, at Westgate and north of St. Margaret's Bay, that an extensive flat chalk floor, partly covered with seaweed, would retain no shingle at all. That the long groynes at Brighton did not intercept all the shingle was shown by the abundance of shingle at Rottingdean, Newhaven, and Seaford. There was a bank of shingle all the way along the frontage of Eastbourne, the Pevensey Marshes, and at

Bexhill, Hastings, and St. Leonards. A large collection of shingle at the upper end of the Admiralty Pier, Dover, on the west side, was very slowly increasing. Between Kingsdown and Walmer Castle also there was a vast quantity of shingle. All that shingle was not chalk-flints—at any rate so far as he had observed. A great many chalk-flints were eroded from the chalk cliffs, but they could not make up such a quantity of shingle. As far as he was able to judge—although no definite conclusion could be formed—it travelled from the west right round. It could not come from the north of Walmer. There was also the fact that Budleigh Salterton pebbles and Cornish pebbles had actually been picked up at Dungeness. He had found the former himself at Wittering and at Climping on the west side of the River Arun. It was a question which needed to be looked into ; but it was extremely difficult to determine whether shingle did travel in the way he had described. As to groynes alone not being sufficient in all cases, he did not wish it to be supposed that he recommended invariably the use of groynes alone. There were cases where the sea was encroaching on a bank which would be breached after a storm or two. Then some sort of sea-wall was necessary. A cliff with houses on the edge needed something to put an immediate stop to encroachment. But there were in a great many cases long lengths of shore where groynes alone would be efficacious. He knew long lengths of the Lincolnshire and Yorkshire coasts, having sand hills or cliffs at the back, where groynes alone would stop the advance of the tide ; but the important element in connection with those groynes was that of time. Two or three years were required to collect sufficient drift. If there were cliffs behind, the time might be afforded, but in the other cases he had mentioned delay might not be possible. He found difficulty in replying to Mr. Latham's remark about Burnham. It seemed as though groynes would do good, but it was impossible to judge without seeing the place. There were stone groynes on Canvey Island which were put up more than 40 years ago, and he had put up some since. Dry stone groynes were best suited for that part of the shore. They went out a considerable distance, and they held the mud. If there was any scouring by the river they were effective in stopping it. He thought that triangular groynes would prove expensive and not so efficacious as straight groynes. He was very glad to note that in Mr. Paddon's Paper on the Portslade Gasworks it was stated that groynes pointing towards the east had proved effective. Mr. Rutter had also mentioned a right-angle groyne which did good work ; but when a quantity of shingle collected on the one side of a right-angle groyne, there was generally a great drop on the other side,

Mr. Grantham.

Mr. Grantham. Personally he had found that, by placing the groyne in a particular direction, that was avoided, the reason being that in the case of right-angle groynes on the South Coast, as at Eastbourne, although the waves from the south-west came in obliquely to the shore, when the water receded from the lee side—generally the low side—it rushed down at right angles to the shore line and dragged the shingle with it: so that a lower level occurred on the lee side. If the groyne, instead of being at right angles to the shore, was placed across the line of the receding waves, the velocity of the downward rush of water was checked, and the dragging-down of the shingle was intercepted. He had adopted that system not only at Shoreham and Lancing, but also in the Isle of Wight, at Wittering, and on the coast of Lincolnshire, in each case with satisfactory results. The effect of building a groyne was to create an obstruction which stopped and gradually collected the drift carried by the waves—whether it was shingle, sand, or shell. It thus built up a shore, reduced the depth of the water, and so reduced the destructive effect of wave-action. On the east side of Chichester Harbour at Wittering the sea had been encroaching at the rate of about 8 or 10 feet a year before he put down the groynes, which were installed initially to protect the church. At that time it was found, as Mr. Martin had said, that contractors' barges were taking away immense quantities of shingle from the Winner bank, and the Board of Trade was applied to to inquire into the matter. The result of an inquiry was that the Board fixed a line between Wittering Church and a boat-house on the Hayling Island side as the southernmost limit for removal of shingle. It was considered that there was no danger arising from loss of shingle to the north of the line. He did not think Mr. Martin need be apprehensive about the robbing of the shore on the Hayling Island side; there was plenty of shingle on the Winner bank, showing that the supply had not failed. The cost of groyning was no doubt prohibitive in many cases where there was nothing but agricultural land. Tendring sea-wall was an old embankment which was pitched on the face with stone; but what had struck him about it was that it was much too upright. In a big storm the waves ran over it and scoured out the earth backing. The consequence was that a great deal of trouble had been experienced.

Mr. Hollingworth. Mr. HOLLINGWORTH, in reply, regretted that the opinion of so eminent an authority as Commander Warburg should differ so entirely from the views advanced in the Paper; he hoped, however, that the difference might prove to be more in standpoint and expression than in fact. It was evident from Commander Warburg's remarks that the old idea of the tide-wave was dead, but its ghost

walked in the shape of the Southern Ocean tide-wave, and according to the latest theory[1] :— Mr. Hollingworth.

" the tide wave as it exists at all places is formed by the combination of a number of partial waves, some of which are forced waves directly due to the tide raising forces of the moon and sun, others are free secondary waves derived from the forced waves and others again reflected waves."

The practical hydrographer did not attempt to follow this theory, but combined the waves due to any particular component of the tide-raising force, and provided for them all by one harmonic constant, obtained by observations at the place under consideration. Tide-prediction was thus empirical and merely assumed that the tide-raising forces acted in some unspecified way upon the waters of the ocean and that equal forces would produce equal effects. It was difficult to see what objection could be made to the substitution of the simple idea of alternating horizontal motions for the complicated idea of the tidal waves, for Commander Warburg mentioned [2] an oscillatory tide, and Sir G. H. Darwin observed [3] that :—

" The vertical part of the tide-generating force . . . will not be effective in moving the water, since the water must remain in contact with the earth. We want, then, to omit the vertical part of the force and leave behind only the horizontal part. . . The only important part is that along the surface—the horizontal portion."

It should follow that the motion caused directly by the tide-generating force was horizontal. The remark as to the washing of Middlesbrough slag into the Humber was based on the statement of Mr. T. Sheppard [4] in proof of the fact that much of the Humber mud was brought in by the sea :—

" In various parts of the Humber as at Brough, South Ferriby, and even as far as Goole and up the Trent as far as Burton Stather, large pieces of the hard scum from the slag furnaces at Middlesbrough are regularly picked up. . . . They also occur all along the South Yorkshire coast and can be traced point by point, from say Bridlington to Hornsea, Withernsea, Spurn, Sunk Island, Paull, Hessle and on to Goole. They have clearly been washed into the Humber and how could they do this and leave the mud behind ? "

In view of the specific character of this statement, and of the incident of a dead whale repeatedly drifting back into the Humber,

[1] Commander H. D. Warburg, R.N., "Tides and Tidal Streams," p. 16. London, 1922.

[2] *Ibid.*, p. 15.

[3] Sir G. H. Darwin, "The Tides." 3rd ed., p. 107. London, 1911.

[4] "The Lost Towns of the Yorkshire Coast," p. 248.

Mr. Hollingworth. the explanation of the presence of some of the slag given by Mr. Pickard hardly affected the general argument. The opinion of the authorities, cited by Mr. Grantham, that the movement of material along the coast was due to wind-waves, must be accepted so far as the visible travel was concerned. This, however, did not cover the whole action, for if the wind-waves were the sole transporting agency, how could pebbles from Budleigh Salterton and Cornwall travel past the Isle of Wight? The coast to the eastward of it, as stated by Mr. Grantham, was protected from south-west gales, and the drift was to the westward; yet these pebbles were found at West Wittering and Dungeness. The statement that the bulk of new land was formed of material cast up by the sea referred to volume and not to surface, and required to be modified by the statement (p. 33) that the upper layers consisted almost entirely of river-silt. That was in agreement with Mr. Grantham's contention.

Correspondence.

Mr. Reid Bell. Mr. W. Reid Bell remarked, that if Mr. Hollingworth's statement that the effect of the seas during onshore gales was to claw down the beach, thus tending to remove the material out of reach of wave-action and then deposit it ready to be cast up again during offshore winds, was intended as a general statement, he took exception to it. Long observation on sandy coasts had led him to conclude that—at all events, where there was not an oblique wave-travel, such as on the shores of the English Channel —the onshore gales, stirring up the sea-bottom, threw the sand-laden water on the beach. Under such circumstances the on-stroke had more transporting-power than the back-wash, and consequently the sand was soon delivered beyond the reach of the sea. There the force of the wind carried it farther inland, and so the beaches were built up. In milder weather and with wind offshore the tendency was for the sand to be blown into the sea, and to be carried seawards by whatever power of clawing down and transporting the waves possessed under these conditions. This action, which was directly opposite to the case of coast-erosion, was undoubtedly at work in the formation of sand-dunes in many localities.

Dr. Dawson. Dr. W. Bell Dawson considered that Mr. Hollingworth's Paper brought out many points of interest, and there was no doubt that the tides and tidal streams had not been studied sufficiently from