Mr. W. A. Brooks said the Paper contained nothing as to the present state of the River Tyne. Mr. Ure, his successor, had made extensive use of dredging vessels, and there was no doubt the river was improved at the present day. On the bar there was now a depth of 17 feet of water at low water of spring-tides, where in the best times there was formerly only 8 feet; but that had been accomplished by a large expenditure of dredging power,—principally in Shields Harbour and on the bar. So long as this extensive dredging was continued on the bar, and so long as powerful dredging machines were able successfully to combat the operations of nature, so long the public might be congratulated upon having 17 feet of water on the bar instead of the small depth he had stated, although that did not suffice to make the Tyne a bonâ fide refuge habour. He had always held, that it was impossible to bring the Tyne into a state to make it a harbour like the Thames or the Humber, with a depth of 30 feet at low water. It was stated in evidence before the Royal Commission on Harbours of Refuge, that by carrying out the Tyne piers to a depth of 30 feet at low water, that depth at low water would be permanent.

He thought it was desirable that the Institution should possess a true record of the number of tons raised from the bar of the Tyne since the year 1859, when Mr. Ure commenced the dredging operations. If a calculation of the cubical contents on the bar were made, taking it from the inside to the outside below the level of low water of spring tides, and it was contrasted with the same measurement at the present time, it would show a displacement to the extent of about 360,000 tons. That was the entire alteration which had been produced after dredging for so many years. It was only necessary to contrast that quantity with the number of tons raised to form an estimate of the probability of the extent of duration of the present depth on the bar. So long as dredging was vigorously continued this depth would be maintained. The number of tons raised during the last year was about $5\frac{1}{4}$ millons. From 1850 to 1858, only 1,135,000 tons were raised, while his successor, since the latter date, Christmas, 1858, had raised no less than 20,254,000 tons. The result, adding 10 per cent. for the use of the plant, gave an expenditure for the year of £100,835, being at the rate of $4\frac{1}{2}d.$ per ton for each ton raised in 1866, 20 cubic feet being reckoned as one ton. The whole of the material raised was discharged from barges into the sea. Some of the screw-hopper barges cost as much as £6,000 each, and they were able to do the work very cheaply.

Adverting to the subject of bars, a remark was made in the Paper as to the want of proper attention to it on the part of Engineers. The late Mr. James Walker said of the Tyne; "That all the outgoing water, being confined by piers, instead of spreading

over so wide space as at present, would, at the ends of the piers, join the coast tide passing from south to north, with increased velocity or energy. . . . For the position of the bar is by no means fixed; it is at the point where the opposing forces, west to east, and south to north, meet or balance."[1] Mr. Walker's theory was that the cause of the bar was the opposition from the current going from west to east and that of another going from south to north; whereas, instead of opposing each other, it was clear they went all together. There were two forces, and the resultant must be diagonal between the two. His theory of the formation of the bar was this: viz., the real conflict which took place when the flood tide came in and met the as yet undischarged water of the ebb. Very often a rise of nearly 2 feet at sea took place before the tide turned at all into the harbour. The late Mr. Robert Stephenson coincided with him on this point, and he hoped this would elicit the opinions of Engineers on the subject, as nothing was more important than the getting rid of bars in rivers, if it were possible to do so. In a lecture he had delivered at the Royal United Service Institution, "On the Cause of the Formation of Bars at the Mouths of Rivers," he had stated:[2]—

"A very common theory which has long been advanced, is that the primary cause of bars, is "the transverse motion of the wave and current crossing the debouching waters of the river," and the Thames is cited as an example of a river in which there is no bar, because its mouth is freely open to the tidal current, and there no transverse action upon it takes place.

"If this theory were correct, all bars could be removed by simply turning the direction of the seaward reach, to make it freely open to the tidal current, or to insure that the flood current, and that of the ebb, should travel over the same course.

"Nine out of ten who profess to be able to give an opinion on this interesting subject, the bars of rivers, hold this view of the case, and it appears plausible enough, but it is not borne out by reference to facts; thus in the case of the River Tees, of which the Author had charge for many years as engineer, its sea-reach or mouth, between the north and south Gare sands, is usually freely open to the tidal current, yet that river has a bad bar, although it discharges the drainage of a large district, and consists also of a capacious tidal receptacle.

"The direction of the sea-reach of the Tees varies as much as ten points of the compass, and when occasionally open to the east, and then having its debouching waters crossed by the tide, it certainly is not shoaler than when the sea-reach bears from south-south-west to north-north-east, or with its mouth freely open to the current of the flood-tide.

The bar of the Tees is due to the presence of numerous inner shoals of sand, and a ridge of rock in the circuitous channel through the estuary of the Tees, which have the effect of penning back the drainage water of the country, until long after the tide has begun to rise on the sea bar."

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[1] *Vide* "River Tyne Improvement. Piers at Entrance." The Report of James Walker, 15 November, 1853. Westminster. (Tract 8vo., vol. 95.)

[2] *Vide* "Journal of the Royal United Service Institution," vol. vii., p. 190. London, 1864.

He would not trespass longer upon the Meeting; but he wished to draw attention to this subject, believing it to be one of the most interesting that could be brought under the consideration of this Institution.

Mr. GREGORY, V.P., thought most Engineers, instead of adopting the theory of the formation of bars to which Mr. Brooks had alluded as erroneous, took a more simple view, viz., that the material held in suspension by water travelling at a certain velocity would fall to the bottom and form a deposit when that velocity was checked; and this view was consistent with the explanations given of the observations at the mouth of the Tyne. The incoming tide, when it met the water discharged by the river, would check the velocity of this water, and so cause deposit, which formed the bar.

Mr. VIGNOLES thought it unnecessary to travel into recondite experiments and observations as to the causes of the formation of bars. Mr. Brooks had laid down what no doubt might be taken as the general principles. Where the flood waters met the incoming flow of the tide there must necessarily be a deposit. Indeed that rule might be extended considerably farther. It was well known that the same occurred where the Mississippi fell into the Gulf of Mexico, the waters of which were comparatively still, the amount of tide being small. It was so also at the mouths of the Danube, issuing through its delta to the Black Sea, which was tideless. It was sufficient that the outflowing stream of the river should be met by the vis inertiæ or resisting medium of a large body of water, and there inevitably the bar must be formed. He thought Mr. Brooks had shown a great deal of ingenuity, and a great amount of practical knowledge, in the way in which he had operated upon the various points and reaches of the Tyne. He had shown a good example, and had judiciously ceased to endeavour to force, by means of an artificial current given to the river, what nature would not allow to be done. Mr. Brooks' successor had struggled against nature, and, by a large expenditure of money in dredging, had succeeded in obtaining a considerable depth of water on the bar. No doubt where nature had placed a river on which man had brought an artificial traffic, in order to maintain the means of carrying on the trade created, artificial resources must be employed upon it, and therefore it was that Engineers were engaged in the work of fighting, as it were, against nature. Nature had created rivers, and wherever there was a river there was also a bar; and no doubt if harbours could be had where there were no rivers they would be better than where there was a river; but in this and all other civilized countries trade sought for itself shelter within a river, consequently the efforts of man were directed towards overcoming the obstructions of nature. Thereupon arose the employment and the skill of the Engineer. He thought

Mr. Brooks had successfully shown what might be done with the interior of a river; but artificial resources would be necessary at the mouth. He did not know what had been the final results of Sir Charles Hartley's operations in the Danube; but he understood that the bar of that river had been improved at first. He would repeat that wherever the great current of a river met the sea—whether it was with an incoming tidal current or mere dead waters, like those of the Black Sea or the Gulf of Mexico—there the bar must be deposited; and if more than the natural depth of water which the bar afforded were wanted, recourse must be had to the artificial means of dredging, and this could only be kept up at a large annual expenditure. It was a subject of interest to know, to what extent the interior of the River Tyne had been improved, and also to hear that Mr. Brooks' successor continued, *à force d'argent*, to maintain this greatly increased depth of water on the bar.

Mr. Bateman wished to ask whether any effects, independent of the dredging, had been produced upon the bar by reason of the extension of the piers.

Mr. Brooks replied that that was just the point to be proved, and time alone would do so. When there was no more money to spend, then the theory would be tested and the truth found out. His successor had taken away the sand bodily, and when he raised 5 millions of tons a year, it must make a considerable hole. At present, the flood tide came in almost immediately, and the level of low water must have gone down a foot or eighteen inches.

Mr. Bateman had asked this question in order to draw attention to the fact, that the effect of the construction of the North Bull Wall upon the bar at Dublin Harbour had been eminently successful. By the action of the current concentrated on that point, the bar had been deepened from about 6 feet to 14 feet or 15 feet at low water, and that was effected before dredging to any material extent had been carried on. He regarded this as a most successful engineering operation, and he believed that success led very much to the adoption by Mr. Walker of the particular form of entrance of the piers erected in the Tyne, and it would be interesting to know whether the same natural result had followed in that river as was obtained in the case of Dublin Bay.

Mr. Vignoles believed that the success, in the case referred to by Mr. Bateman, was mainly due to its being accompanied by dredging at the same time. The stream of the Liffey, which was weak, had been able to maintain it when executed: although he believed the result was not entirely from natural scour.

Mr. Bateman believed that dredging was carried out to a moderate extent in the upper part of the river, but that the bar itself was operated upon almost entirely by the current, so far as he was in-

formed, without the aid of dredging on the bar. Whether the dredging above had any effect upon the natural scour, he could not say.

Mr. HEMANS remarked that the effect of the North Bull Wall had been very successful in increasing the scour on the bar; but the depth of water could not be kept up without some dredging, which was carried on to a moderate extent. The natural scour did an immense deal, and had been most successful.

Mr. G. F. LYSTER observed that the Paper was so diffuse that he was not prepared to enter upon the discussion of it. With regard to the Mersey, where, as was well known, a bar existed, the depth of water over it had been fully maintained, care being taken to interfere as little as possible with the capacity of the river, so as to admit of its freely receiving and expelling a large body of tidal water; the leading channels of the Mersey had therefore remained in the same condition for the last fourteen or fifteen years. Careful soundings and surveys of the river and the bar were made every year. The natural channel had maintained a depth of 12 feet at low water of spring-tides, and there had been no works lately undertaken within the river which interfered, to any important degree, with its full water capacity and discharge. The abstraction of water by the construction of the Birkenhead Docks had had no effect upon the bar of the Mersey; although at one time it was thought that the loss of so considerable an amount of water as that from Wallasey Creek would affect the condition of the entrance channels to the river, but the depth over the bar remained the same as it was fourteen or fifteen years ago.

Mr. BATEMAN remarked that two excellent surveys of the Mersey had been made—one by Mr. Giles, and another by Mr. Robertson Wright. The former having been made twenty years ago, and the latter since the construction of the Birkenhead Docks, it would be seen on a comparison of the two sections, that the sectional area of the estuary above Liverpool had been increased from 5 to 10 per cent., which would more than compensate for the abstraction of the water of Wallasey Creek, which had been alluded to. By the straightening of the walls on the Liverpool side as well as on the Birkenhead side, and by giving a true run to the current, the scour was so much improved, that the estuary was now larger in capacity than it was before the Birkenhead Docks were constructed.

Mr. G. R. STEPHENSON said, although his acquaintance with the Tyne commenced from his earliest days, having been born on its banks, his avocations had called him for the greater portion of his life away from that locality; still his visits to it had been frequent, and having noticed what was going on, he was tolerably well acquainted with the general character of the works that had been

carried out during many years; though he had no doubt Mr. Harrison, who had constructed the Jarrow Docks, was in possession of details and figures of which he had not command. Having had considerable experience in dealing with the drainage of fen countries in England and abroad, the opinions he would express on this subject were founded upon that experience.

He would remark that the first practical step, towards the question of dealing with the Tyne, was taken when the construction of the Tyne Docks was proposed by Mr. Harrison. Previous to that, he believed, the subject had never been fairly opened out. The question that then arose was, whether the abstraction from the river of the quantity of water which occupied the space of the Jarrow Slake would be detrimental or otherwise to the tidal flow in the Tyne? That was discussed by some of the most eminent practical men of the day, many of whom had now passed away; and he believed, with the exception of the Admiralty authorities, the opinion was almost unanimous, that the walling in of the Jarrow Slake would be of considerable service both to the navigation and to the scour of the Tyne. He maintained that it had been a great advantage; he also thought that if the Jarrow Slake wall were continued further, the effect would be to drive the water higher up the river between Jarrow Slake and Newcastle Bridge, and that, when the old Tyne Bridge was taken away, it would have the effect of giving the water a very rapid communication between the top of high water—at Newcastle, say—and the sea. The object was to get the water to run down to the sea as rapidly as possible; and if the tide were drawn so much higher up the river than at present, it was clear the water must be carried down with greater velocity. He maintained that the taking away of the old bridge would admit of the water being squeezed higher up the river, and would also admit of the same water being thrown back and brought down again with greater velocity, and consequently greater scour. On the Nene Navigation, by taking away a bridge in a similar situation to that on the Tyne, the low-water mark was reduced 6 feet at its site: in other words, the tidal low-water level of the sea was carried 2 miles higher up the river than before. The bridge removed was Sutton Bridge, and it had been a great benefit to the navigation, as well as to the drainage. Having examined the original plans of Mr. Brooks, as well as those of the works now being carried on by Mr. Ure, he felt that great credit was due to the former for what he had done. With regard to the harbour piers, that portion of the work appeared to have been but slightly changed from the designs of Mr. Brooks, who was therefore entitled to credit or otherwise with regard to the disposition of the piers. But at the same time he must say he did not approve of the position of the piers.

He agreed with all that had been done in the Tyne with regard to dredging and walling, but he thought the operations had been begun at the wrong end.

The question that arose with reference to the Tyne was simply this: When the time came—which he thought must arrive sooner or later—when the dredging would have to be discontinued, would the present state of the river at the entrance admit sufficient tidal water to keep the river in the same state as it was now brought to by dredging? He thought not: he believed if the Tyne Commissioners had expended some portion of the money in taking away the Narrows, a great deal of the dredging, which had to be done over and over again on the same spots, would have been saved, because it would have admitted a larger volume of water up the river, to be brought down again and act as a scour on the ebb. He thought that was clear from the fact, that at the entrance of the river there was a difference of level between the inside and outside of the Narrows; the low water in the harbour being above that of the sea. It was therefore evident that there was a stricture at the Narrows, which did not admit the full extent of the tide. It would have been better to have commenced at the bottom, or outlet of the river, and then to have worked upwards, inasmuch as by that means a large amount of dredging would have been saved, which it was now necessary to do over and over again. He would state generally his belief that the ordinary lift of the tide at the outside of any river had little to do with the quantity of water thrown up it. If the actual lift of the tide at the outside of a river was the sole power that filled up a river, it would be impossible to account for the phenomenon which took place at Chepstow, where the tide rose 40 feet or 50 feet above the level of the sea. It was unquestionable that the great tidal wave coming from the south, and entering the Bristol Channel at a velocity of 70 miles or 100 miles an hour, was projected up the Severn, causing the great lift of tide. With a bell-mouthed entrance to a river (and the Bristol Channel was more than 100 miles across), a larger quantity of water must necessarily enter and again recede, and act as scour.

He did not agree with Mr. Brooks' views as to the piers at the mouth of the Tyne. But before leaving the question of the river, he would mention that his experience led him to use entirely different measures than making groynes at right angles to the course of a river. He was satisfied that the proper way of dealing with silt was to form longitudinal walls at once. It would have been useless to have attempted to put piles into the silt of the Nene or the Ouse to make groynes; therefore he adopted longitudinal walls made with fascines, and the result was very successful. With reference to the piers at the entrance, he felt some hesitation in giving an opinion, because so many reports had been written and plans prepared with

regard to them. He would simply deal with the design now being carried out, and he ventured to say in his opinion the design was entirely wrong. That opinion had been entertained by him during the whole progress of the works, and for this reason:—The piers had been in course of construction for some time, and were approaching completion; yet there was no decrease in the number of wrecks that took place at the entrance of the harbour. There had been the most serious mishaps to shipping there, within his own knowledge, during the last year or two, though there certainly ought to be some reliable security to vessels entering the port, but that was far from being the case in the Tyne in anything exceeding a smart breeze. In heavy gales, particularly from the east, the danger to shipping entering the port was very great. A vessel in a heavy gale might have been running 50 or 60 miles trying to get into this port. Owing to the gale, she would carry only the smallest amount of canvas possible—probably reefed topsails, and nothing more: she perhaps could not set anything else outside, as any after canvas would bring her round to the wind, and she would be driven broadside on to the seas, and perhaps be swamped. If the gale were from the north-east, she would have to shave the north pier very closely, and, before she could tack and set her after canvas, she would be nearly to leeward of the inner part of the Herd Sand. If she ported her helm, with no after canvas upon her, she could not fetch to windward of the Herd. He therefore submitted that the north pier for the north-east gales was wrong. Then there was, from the situation of the south pier, a source of danger, in south-east gales, of mishap from the Black Middens. The vessel with little sail upon her had to shave the south pier, which was so far to leeward that with no after canvas she could not weather the Black Middens. There would be no time, especially in heavy broken water, to put on after canvas in that short distance. A clear case of the danger of this was afforded in the instance of the wreck of the 'Stanley.' That vessel was running right in, when, by a slight mishap of the helm, a sea struck her on the starboard quarter, turned her round, and she struck on the Black Middens. In the case of a gale from the east, a sea, striking a vessel on the port quarter, would cause the bow to veer round to the port side, when the vessel would be in great danger of running on to the Herd Sand; but if she were struck on the starboard quarter, her head would be driven starboard, and she would probably go on to the Black Middens. In conclusion, he would remark that a harbour could not be considered as properly designed, in which the greatest danger the mariner met with was after he had got inside the piers.

Mr. T. E. Harrison said, having been asked by the President what effect the enclosure of Jarrow Slake, by the construction of the Tyne docks had had on the river, he did not think he was in

position to give any exact answer, for the simple reason, that since the period at which Mr. Brooks left the office which he so long held on the Tyne, extensive works on the river had been carried out under a totally different system. He would incidentally remark, that during the period Mr. Brooks held the office of Engineer to the River Tyne Commissioners, in all the operations he had to carry out, he was limited by the amount which was placed at his disposal for expenditure. Therefore, anything he had done must be judged of entirely by the amount of the funds at his command. Since that period Mr. Ure, who succeeded Mr. Brooks, had had charge of these works; and under a totally different arrangement of the corporate body who now managed the affairs of the Tyne, they, by sundry Acts of Parliament, had been enabled to raise several hundred thousand pounds for river improvements. That had altered entirely the principle on which the works of the Tyne had been since carried out; and any effect which the enclosure of Jarrow Slake might have had upon the river was so insignificant, compared with the extent of the works which the Commissioners of the Tyne had executed, that it was impossible for any one to say what the relative effect of that enclosure might be. Inasmuch, however, as it was some little period after the enclosure of Jarrow Slake before any of those large works were carried out, he believed, that so far from having had any injurious effect, that enclosure had been decidedly beneficial; but the extent to which any facts could be adduced on the subject was so limited, that he did not think it was safe to base any opinions upon them. In discussing this question at the present moment, the difficulty he felt was simply this—that when he constructed the docks at Jarrow Slake, he thought he was going a long way in laying the cills of the dock gates 6 feet below the level of the best water that then existed up to the entrance of the docks; but at this moment, a vessel could enter the river drawing from 8 feet to 10 feet more water than there was over the dock cills. That had been effected by operations of such magnitude, and so different from those which Mr. Brooks had been able to carry out with the means at his disposal, that Mr. Harrison felt, if they were discussing now the state of the River Tyne, they would be doing so in a most imperfect manner. Therefore, he should much prefer, on the question generally, to wait for the Paper which Mr. Ure had promised to lay before the Institution, describing the operations he had carried out, and the results.

Mr. Longridge, as an old Tyneside man, would offer one or two remarks on this subject. He had known this river intimately from boyhood, when there was not more than 1 foot 10 inches of water at low tide in the channel between Newcastle Bridge and Shields. That was previous to Mr. Brooks entering

upon the works. He remembered the whole of that gentleman's operations, and it was only right to state, that when he left the Tyne, instead of 1 foot 10 inches of water there were 5 feet or 6 feet over the worst places throughout that length. Mr. Brooks' idea—which was no doubt correct—was as much as possible to turn the ebb and flood tides into the same channel, in order that the flood tide should not meet the ebb and cause shoals. He, however, did not agree with the way in which Mr. Brooks attempted to effect this. He thought the groynes at right angles to the shore were not so efficient as longitudinal training walls; but, however that might be, with the small amount of money which Mr. Brooks had at his disposal, much good had been accomplished. The point to which he would more particularly advert, was as to the operations carried on since the period when Mr. Brooks left, more especially the dredging operations. He was surprised to learn the enormous amount of dredging which had been going on within the last seven or eight years; and he had examined the charts to ascertain what the actual effects had been between White Hill Point, which was the first bend of the river, and the bar. He found, taking the state of the river in 1859, that to excavate a deep-water channel from that point through the bar, to give a depth of 20 feet at low water, and a width of 420 feet at the bottom, with slopes of 1 in 12, which was the most the river would admit, the amount of material to be removed would be, from the bar to the Narrows, 2,340,000 tons, and from the Narrows to White Hill Point 3,065,000 tons, or a total of 5,405,000 tons, or just about the amount that was dredged last year. He found that from 1859 to 1866 there had been lifted from that portion of the river something like 19½ millions of tons; consequently, assuming that there was a depth of 20 feet and a bottom width of 420 feet, which however was not the case, there had been from 14 millions to 15 millions of tons raised which had been filled in again. Taking the cost of dredging even at the low figure at which it was done in this case, it amounted to £33,000 a-year. He asked whether it was possible for a port like the Tyne to support anything like that expense? If that quantity of material had been dredged out, no doubt the river must have brought the material down again. It would not do to lose sight of the fact, that, however the course of the river might have been improved, yet that a river was the great leveller of nature, and would bring down a large amount of deposit, which must be got quit of in some way or other, and to bring that to an embouchure like the Tyne, would be a sure means of causing it to deposit there. Therefore, it was quite hopeless to expect to maintain the present depth of water, except at an enormous expenditure in dredging. He did not say there were not circumstances which might justify such an expenditure; but he thought in the case of the Tyne, if the

theory which had been asserted were true, which was, that when the piers were carried out they would keep the river clear from deposit, the dredging should have been delayed. His opinion was, that the piers would not have the effect of maintaining the present depth of water, but that a bar would form outside. He agreed that the most important thing to be done was to open the Narrows; but if that had been done before some inner works had been completed, it would have admitted the run of the sea into the harbour, and have made the shipping places quite untenable in bad weather.

Mr. CUBITT, V.P., remarked, that it seemed to be considered, that the large amount of material, which had been dredged up, had been brought down and deposited by the river. He was not acquainted with the Tyne, but knew other harbours on the east coast—for instance, Yarmouth and Lowestoft—the bars at the mouths of which were evidently composed of sand and shingle, brought by the action of the waves and current of the sea along the coast, in a far larger proportion than of material deposited by the river.

Mr. LONGRIDGE observed that the littoral current of the Tyne was very small, and not more than one knot per hour; so that the bar could not be caused by the littoral current.

Mr. PHIPPS said, the Paper was an excellent record of the condition of the River Tyne during the time that river was under Mr. Brooks' charge, and was no doubt a good illustration of what might be achieved by a moderate annual outlay, when directed by a regular system.

Respecting the Author's favourite theory concerning the formation of the bars of rivers, Mr. Phipps thought that whilst the general notion was correct, that the formation of a bar was due to the fact of the velocity of the ebb tide being stopped wholly or partially over the site of the bar, and hence the deposit of the matter held in suspension by the water, that it was fallacious to attribute this to the extent done by the Author, to the non-emptying from the river at each ebb of a certain quantity of water lying above the level of low water. The argument was, that the conflict of this water with that of the young flood tide caused quiescence, and hence that the deposit took place almost entirely at this time.

Now, if that were so, the time of deposit would be limited to a very short period, and the bar would only in that time receive the deposit of a small portion of the ebbing water; whereas, in his opinion, the whole of the water discharging itself during the ebb tide tended to produce the deposit on the bar. He thought the whole quantity was, more or less, brought to rest by contact with the water outside, according to the state of the ebb tide; and that without this, the quantity of water deposited would be insufficient to produce the effects really experienced.

He had calculated, from the longitudinal section of the flood tide given in the Paper, and on the assumption that 200 yards was the average width of the river,[1] that the volume of water flowing in and

	Cubic Yards.
out of the river in each spring tide amounted to .	13,591,600
and for the portion lying over Jarrow Slake .	2,500,000
Total . . .	16,091,600

Taking the width over the bar as 440 yards, with an average depth of 16 feet during the whole of the ebb tide, the average speed of the ebb tide would be a little under 8 inches per second, or less than half a mile per hour, being a movement sufficiently slow to allow of the deposit of the principal portion of the matter held in suspension by the above enormous quantity of water.

Mr. BEARDMORE said, regarding this Paper as an historical record of the Tyne, he thought its interest would have been enhanced by a more copious introduction of the dates at which the various works had been carried out. The system of works therein described mainly terminated in 1858, and the subsequent efforts involved a vast amount of dredging and other expenditure of capital. On examining a section of the Tyne, and considering the deepening at the mouth, with the rapid slope that would obtain in the fair-way of the river upwards, it appeared inevitable that a permanent deep channel would be effected. Admitting the gigantic amount of dredging, and considering that within the piers a vast extent of the Herd Sand would drift into the cutting, in addition to that which must follow down the river from above Jarrow, it was not surprising that the work should to some extent have to be done over and over again, and prove expensive. But, looking fairly at the section and the form of the new piers, he thought the doubts that had been thrown upon the final success of the operation would be a good deal modified. He considered that 12 to 1 was a far steeper slope than was consistent with a state of rest for sands under these conditions. The strictures on the piers and on the works at the mouth of the Tyne must not be taken as applicable to the complete design, because the heads of the piers were as yet incomplete, and they formed an important element in the design. At all events, a vessel making the harbour without those outer piers must be more exposed to risk. He thought the argument, as to the opening of the Narrows, answered itself. If that had been done without the piers, it would have exposed the most vulnerable part of

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xviii., p. 521.

the Tyne harbour, viz., the Narrows at Shields. The permanency of the new deep-river channel was an interesting question; but it was essentially distinct from the state of the works up to the year 1858, when Mr. Brooks had improved the channel, as a navigation after half tide, in an admirable manner, considering the small funds at his disposal; as might be seen by comparing the original and subsequent survey. But it was to be borne in mind, that vessels since that time had greatly increased in tonnage and in draught of water; then the draught did not exceed 14 feet or 15 feet, and no expedition was made with the freights, and the river was used entirely according to the state of the tide. Now, however, the greater freights were carried in fine ships or steamers of 1,000 or 2,000 tons burthen, which were expected to run in whether the tide was high or low, were unloaded, turned round and reloaded, and started on the return voyage in a few hours. Under these circumstances, he denied that any plan of walls or groynes would be serviceable, unless dredging machines were also used. To show what could be done, by one operation and the other, he would refer to the Clyde, where it had been suggested that a million had been spent in dredging, when groynes would have done the work. In the natural state of the Clyde in 1758, at high water of spring tides, the depth of water was not more than 4 feet as far as Glasgow. Between 1758 and 1824 the river was deepened to from 12 feet to 14 feet, chiefly by the use of groynes and the removal of fords. Up to the latter date not much dredging, if any, had been done by steam; but by means of groynes, and the judicious introduction of connecting walls, so as to turn the groyne system into that of training walls, the vast amount of sand that had been deposited from an early geological period was got rid of. But from the year 1824, when a vessel drawing 12 feet to 14 feet could be taken up to Glasgow at spring tides, dredging machines had to be employed to cut through the boulder clay, and in some cases through solid rock, with the assistance of gunpowder and divers; and the river had been brought to its present depth of 20 feet to 23 feet, at which it was maintained without much trouble, although at the cost of washing down a great deal of Glasgow filth at the lower reaches of the river. He was an advocate for groynes, training walls, and piers, judiciously applied, especially where much sand had to be removed. But where accommodation was required for a large class of ships and steamers, running to staiths or into docks, at all times of the tide, he said—use the dredging machine. In the River Thames there had been a similar application of the dredging machine since 1824; masses of hard gravel and deposits had been removed, and a depth of water had been obtained which it would have been quite out of the power of a current of water alone to effect. The whole of this mass of

sand in the River Tyne had been collected within its own area, so that, geologically speaking, the mass was small, considering the ages during which it had been collecting. The harbour there was not like those of Norfolk, Suffolk, or Dorsetshire, where mountains of chalk and drift had fallen into the sea, and formed the banks of which their bars were a part. But in this case there was a cleft between rocky hills filled up by sand, and the bar was the result of the passing currents, acting on the sand deposited within its own limits. With regard to the bar of the Mersey, the great bulk was the result of the destruction of a large area of land on its own site, and the material was not brought down the country as in this case; and there were several other instances of the same class. There were few rivers whose mouths and bars were precisely of the same character; but observation would generally show whence their bars had been derived. In this case his opinion was, that the sand was merely the deposit from the banks and mountains above for many ages; and considering the time it had been collecting, what rapid changes and improvements had taken place, and the fact that the dredging machine had made in seven years a very sensible reduction, he thought the results must be regarded as satisfactory.

Mr. Brooks said he should be glad to have Mr. Beardmore's opinion, as to the probable effect that would be produced by carrying the piers into 5 fathoms or 6 fathoms of water; whether he expected that would be a permanent depth, or whether continuous dredging would be required to maintain it?

Mr. Beardmore thought when the dredging had been carried on during a period sufficient to bring the slopes of the channel to a state of rest, it would be a perfect operation. But though a channel were now successfully dredged, yet, taking into consideration the immense quantities of moveable and drifting sands that bordered upon this channel, he thought it would take a considerable time to dredge it to such a condition that the sand would no longer drift. But where this was the case the channel would maintain itself; and it would then be reduced to the state of a harbour without a bar, and with a deep entrance of rock, like Dartmouth, where there was plenty of sand in the upper part of the river, but none at the mouth. The number of wrecks in the Tyne had not increased in proportion to the increased number of ships which entered that port.

Mr. Graham said, that when in 1849 the late Mr. Rendel was called upon to make a report on the Tyne, he assisted the late Mr. Comrie in making for Mr. Rendel extensive tidal observations, and repeating the sections made by the former in 1813, when assistant to the late Mr. Giles.

This survey was most carefully carried out, but did not show any

great improvement in the condition of the river; and it was found necessary to call in the aid of Mr. Heppel, to show by figures what could not be shown by plans. Largely engaged as Mr. Comrie had been on the Tyne surveys, the mention of his name ought not to be omitted.

In 1855 a Royal Commission was appointed to inquire into the state of the River Tyne. They sat at Newcastle, heard evidence, and issued, what he thought, a most able and moderate report to the effect, that though there had not been much improvement made between 1813 and 1849, the Commissioners thought no harm had been done, and that the works which were then projected should be carried out, and an opportunity afforded for completing them. The report wound up by expressing a sincere hope, that the differences and disputes which had hitherto prevailed might henceforth cease to interfere with the work of improvement.

He surveyed all that had been done up to 1848, about six years after Mr. Brooks went there, and he surveyed again for Mr. Ure, his successor, in 1859. There had been some difficulty on a portion of the Northumberland shore, in keeping up the navigation to ten or twelve coal shipping places situated at the bend of the river at that place, during the time that the work was being carried out and the course of the river changed; but this was overcome by making, what was now called, the Northumberland Dock. The question throughout was not to make land, but to get a river wall to confine the river; cross jetties or groynes need not therefore have been used. Room would eventually be wanting for the deposit of ballast, as at Cardiff, and the difficulty after a year or two would be to know what to do with the material dredged from the river. His opinion was, that Mr. Brooks ought not to have extended the work over so many years, because everybody was agreed about the course which the river should be brought to. The difficulty was to get the parties to spend more than £5,000 a year. All that had been done was comprised within a distance of 3 miles.

The completion of the Northumberland Dock and the dock and river works on Jarrow Slake had no influence on the river above. The result of the survey of 1860 showed that, since the Jarrow Docks had been completed, no change in the shoaling had taken place for good or bad within the walls.

Mr. J. B. REDMAN said, he did not possess the advantage of some of the previous speakers, in having any great personal knowledge of the Tyne; but he had visited it twice, in 1853 and again in 1855, when he was struck with the enormous trade of that river, ranking as it did, in commercial importance, as the third port of the United Kingdom in respect of tonnage, and as the sixth port as regarded declared value of exports, being only preceded in that

respect by Liverpool, London, Hull, Glasgow, and Southampton. The Author had urged, as a prime objection against the construction of extensive works approximating those which were designed for harbours of refuge, that the Tyne was not, as compared with London or Liverpool, a first-class port. But if reference were made to the Parliamentary Papers annually published of the trade of the country, it would be found that, instead of taking such a position as the Author assumed for it, it was, on the contrary, one of the first ports of the kingdom, coming only after Liverpool and London, the tonnages, export and import, of those ports being respectively as follows:—

	Tons.
London	6,273,951
Liverpool	5,276,648
Newcastle	2,694,657

As regarded geographical condition, the Tyne was a river about 35 miles long, from the junction of the North and South Tyne to the Narrows at North Shields; its two greatest tributaries being the North Tyne, which rose on the borders of, and in the north-west part of, Northumberland, and the South Tyne, which rose 7 miles south from Aldstone, in Cumberland. It was a river which, owing to the elevation of its sources, was subject to sudden and great freshes, and at these times immense quantities of water were brought down. The outfall of the river was discharged from a comparatively narrow mouth, when speaking of it as a port, as compared with London and Liverpool, situated on large tidal estuaries, where there was free range of tide, and that effect was shown in the Tyne in a remarkable manner. The flood tide setting almost north and south along the coast, and the outfall water running east and west direct, the natural result had been the formation of a bar; and the difficulty that the tide had in getting into the river was shown by the fact that outside the bar there was a greater range of tide by 18 inches at spring tides than at the Lighthouse, and the difference of range at neap tides was still more remarkable. An observation had been made by the Author as to the influence of the natural indentation of the Jarrow Slake upon the low water régime of the river. Without attempting to combat the views as to the unimportance of abstracting that quantity of tidal water, the Author argued that that indentation had a bad effect upon the river, inasmuch as it diverted the course of tide that way, and caused the shallowing of the river above; but the same shoaling recurred higher up the river without any attendant indentation like the Jarrow Slake. The Author had also referred to the opinion which had been expressed by the late Mr. James Walker, as to the cause of the bar. On this point Mr. Walker had said, in a report

dated the 26th November, 1858, "The position of the bar is by no means fixed; it is at the point where the opposing forces, west to east, and south to north, meet or balance, and it would be moved out beyond the piers if this balancing point were moved out by increasing the current between them."[1]

Reference had been made, in the course of the discussion, to the effect of the operations carried out in Dublin Bay, upon which there was some difference of opinion, although there ought not to be, and he believed was not, as to the facts of the case. The depth of the water had been increased 6 feet; for whereas, formerly, there were only 6 feet of water over the bar at low water, there were now 12 feet, and 24 feet at high water of spring tides. That had not been accomplished by means of the pier alone, but by reason of a large amount of dredging from the bridge at the end of Sackville Street down to the lighthouse, which had cost about £2,000 a year. In that harbour a result had been produced which had not been previously referred to, viz., that though there was double the depth over the bar, and though the harbour was now available for a class of vessels which it could not accommodate before, yet, attendant upon that greatly increased depth there had been a corresponding shoaling beyond the bar. He had lately visited the Danube and the works at the Sulina mouth, and had passed between Sir Charles Hartley's piers in a steamer at sunset; and though he could not state the results from personal observation, from local evidence the condition of the outfall was good. The Admiralty Survey stated, however, that though a considerable increase of depth had been obtained over the bar, yet that a corresponding shoaling and shifting of the bar beyond the piers might be expected. This was an interesting point in reference to the outfall of the Tyne, and the ultimate effect of the piers at the entrance of that river. He believed one argument in favour of the piers urged by the projectors was the testimony of the North Sea pilots, that the bar was good or bad according as there were one or two channels over it. In other words the bar was always good when there was only one channel, and bad when there were two channels. Mr. Walker, in his report in 1858, alluded to what he termed: "The sympathy between the bar and Sparrowhawk or Herd Sands," *i. e.*, when the bar was good or low, the marginal sands were high, and vice versâ, when bad or high the other sands were low. This had been brought forward as an argument in favour of the piers. That was what the Admiralty Chart stated, viz., that when the stream was divided, the bar was bad; but when it was concentrated upon the bar

[1] *Vide* "Report of the Commissioners on Harbours of Refuge," vol. ii., p. 818. London, 1859.

which was the operation contemplated by the construction of the piers, the condition of the bar was good.

Mr. JAMES BRUNLEES said, as his knowledge of the Tyne was but very general, he would only offer a remark or two on the position of the piers. He understood that the object in placing the piers at an angle to the river was to gain water space behind them, and thus obtain a greater volume to scour the bar. It appeared to him that piers so placed would act as sand-traps, and that in time the whole area inside would silt up, and the river course form a straight line. He was, therefore, of opinion that the piers might as well from the first have been constructed on lines more nearly parallel to the river course.

In his experience of forming half-tide weirs in sandy bays he found, that in attempting to run out such works at an angle to the run of the rivers and tides, he had frequently as much as 22 feet of scour below low water; while wherever the works ran parallel to the rivers and tides the greatest scour was only 9 feet, and this latter depth required only about a fourth of the material to form the weirs.

Mr. ABERNETHY said, having been for many years acquainted with the Tyne, and having paid considerable attention to the subject of the piers at its entrance, as well as to the question of the general improvement of the river, he would remark, first, with regard to the projected piers, it was obvious that in their present state they afforded no adequate protection from the effects of easterly seas, the width between the piers being so much greater than that of the channel within. That accounted for the heavy sea and the number of vessels driven upon the Black Middens or the Herd Sand. But it was equally obvious, that when the piers were carried out to the full extent, as he hoped would be the case, then the width between the pier-heads being so much less than the width within, the wave entering would be depressed, and the water within rendered smooth. He believed one of the objects Mr. Walker had in view in projecting the piers in the direction he did was, that the wave entering between the pier heads would expend itself on the beach within. He altogether objected to the theory that the best way of improving a harbour of this kind was by parallel piers. He knew that in the instance of Aberdeen, where there were partly parallel piers, the consequence was, that in easterly gales there was a heavy sea throughout the whole of the entrance channel, and a range even as far as the dock gates a mile distant. In the case of the Tyne, if the wave was cooped up between parallel piers, there would be a heavy range in Shields Harbour.

With regard to the question of the enclosure of the Jarrow Slake, he had always been of opinion that it was desirable to

remove extensive indents from the banks of a tidal river, and to afford facilities, by dredging, for the passing of the tidal wave up the direct channel of the river. Therefore he quite conceived that by the construction of a parallel wall, and the enclosure of Jarrow Slake, together with the removal of the banks immediately above it, by which the tide flowed sooner into the upper part of the river, a great improvement had been effected. The main object required for the Tyne was the prolongation of the outgoing current. The greater the length of time, and the greater the velocity of the ebb tide as compared with the flood, the more the river, particularly at the entrance, would be improved. He was sanguine as to the good effects of the operations of Mr. Ure, after the piers had been sufficiently extended to permit the dredging away the shoals at the Narrows, and the formation of the bed to a regular inclined plane from Newcastle Bridge to the bar. The bar would probably be removed altogether. He would instance the case of a river somewhat similar in character and circumstances, the Dee, at Aberdeen. Formerly the tide used to flow over the whole of what was called the harbour, and it was only at half ebb that the proper river channel was defined. The greater portion of the area over which the tide formerly flowed was embanked with material chiefly dredged from the river channel. That was a case of facilitating the tidal flow upwards, and the bar, which formerly existed as a distinct ridge of sand, no longer existed. He thought the same result would be obtained in the Tyne by the well-judged operations which were now being carried on by Mr. Ure.

Mr. W. A. Brooks, in reply upon the discussion, said he had listened with great interest to the remarks which had been made, but he could not let them pass without some notice. It had been argued that the cause of the bar in the Tyne was the diminution of the velocity of the water of the river on entering the sea, and consequent deposit of the matter its waters previously held in suspension. That opinion was not satisfactory. No river on the east coast carried more silt and mud than the Humber, but that river had no bar; and many other rivers were in a similar state. The Thames carried down a great amount of silt, but there was no bar. As to the opinion that when the piers were carried out into deep water, the present depth of water on the bar, obtained by constant dredging, would be maintained in the channel, he thought the result would be different. If the dredging were given over, the bar would certainly shoal again directly. There was, however, already a satisfactory proof of that, by the vast quantity of material which had to be lifted by dredging every year, and the small result which was temporarily maintained in the shape of the depression of the bed or bar.

Mr. Stephenson had made some useful remarks, and his opinions

coincided so much with nearly all that had been said in the Paper, that there was no occasion to comment upon them, except with regard to the utility of jetties as contrasted with parallel walls. It would seem that Mr. Stephenson had not had great success with jetties. But Mr. Brooks, by the employment of jetties alone, had been able to carry out works at small cost; and shoals had been removed, and important changes in the navigation had been effected, without the necessity of longitudinal walls, as well in tidal as in tideless streams. The large shoal and tortuous navigation above Bill Point were entirely removed, by the simple use of timber jetties, in one set of spring tides. That shoal had been a great impediment to the navigation; and on the occasion of the Author's closing up the ancient sailing channel, the pilot of the 'City of Hamburgh' steamer refused to take that vessel down. When Mr. Brooks volunteered to take charge of the vessel, the pilot changed his mind, and on the passage down the river said he had never gone down so pleasantly before.

He was satisfied that it was only by the vast dredging operations that had gone on for so many years that the bar was temporarily lowered, though the land-floods, which ran at a velocity of three or four knots an hour, must doubtless have assisted the dredging-machines. He was bound also to notice the shelter given by the north pier to the dredging on the bar. That dredging could not have been carried on if the north pier had not been executed to the extent it had; the bar being now completely under the shelter of the north pier. Every north wind would, previous to the construction of the pier to its present extent, have driven the vessel into the harbour for refuge. It was clear that effectual dredging operations could not be carried out without the protection of a pier. Mr. Redman, who was well acquainted with Mr. Walker's views as regarded the Tyne piers, did not appear to concur in the opinion of Mr. Walker, that the bar was caused by the conflict of the current from west to east with that of the current of the ebb at sea running from south to north, to which Mr. Walker had attributed the formation of the bar, but believed that it resulted from the conflict of the ebb from the river with the current at sea from north to south. That was precisely his own opinion, but with the reservation that the conflict occurred at the early part of the flood tide. With regard to the Mersey, although possessing a tidal range within the harbour of 30 feet, and several feet more range at sea, yet it only had a depth of 12 feet at low water on its bar.

Mr. C. B. Lane stated, through the Secretary, on the authority of Mr. B. B. Stoney, that the deepening of the bar of the Liffey was entirely due to the scour, and not to dredging. Dredging machines could not work on it. The Great North Wall, which projected 9,050 feet from the Clontarf shore, was commenced in 1820. The

result had been the deepening of the bar from $6\frac{1}{2}$ feet to about 14 feet at low water. The Great South Wall alone was inoperative; but as soon as the water was prevented from spreading over the North Bull by the Great North Wall, and directed in a definite channel, by the funnel form of the two walls in conjunction, the deepening of the bar commenced. This was the most successful instance on record of the deepening of an outer bar; and, Mr. Stoney had no doubt, greatly influenced the late Mr. Walker in his designs for the works at the mouth of the Tyne.

April 9, 1867.

JOHN FOWLER, President,

in the Chair.

The discussion upon the Paper, No. 1,152, "Memoir on the River Tyne," was continued throughout the evening, to the exclusion of any other subject.
