

Mr. EVAN HOPKINS said, that he was acquainted with New Granada, and the Valley of the Atrato, and that he perfectly agreed with the general description which had been given of that country. He could not speak in favour of the plan proposed, but as the object of the Paper was merely to recommend a survey of this route, he thought it unfair to criticise it, at that stage of the discussion. He had personally examined, as far as was practicable, that part of Central America, between Chiriqui and the River Bayano, with reference to this question, and he did not believe, that any route could be found so economical and so convenient for an inter-oceanic communication, as that of Panama. Between the River Chagres and the Rio Grande, the distance in a straight line, from tide to tide, was not more than about 25 miles, and the highest intervening ridge, only about 260 feet above the level of the sea, and even that, only for a short distance. The route by Chorrera, recommended by M. Garella, was open to the objections urged against it in the Paper; but in making a communication by Panama, that is to say, between the River Chagres and the Rio Grande, he apprehended, that no tunnelling would be required. The summit was not very high, as might be seen by the sections he had already laid before the Institution,¹ and his former observations on the practicability of this route, had been fully confirmed by the survey subsequently made for the construction of the railroad. He believed a strait to connect the two seas, might be made at this place, for a sum not exceeding £10,000,000.

Mr. L. GISBORNE said, that the Paper was ably drawn up, and he believed, that the various routes mentioned, had been correctly described. The only detailed instrumental surveys, with which he was acquainted, were that of the Nicaragua route, made by Colonel Childs, and that across the Isthmus of Darien.

In the account of the Darien route, reference had been made to the survey of Dr. Cullen, and to his own; and he believed, that he was the only European living, who had ever been directly across from Caledonia Bay to the Gulf of San Miguel. The party under Lieutenant Strain was lost in the interior for two or three months, and seven out of the twenty-two persons of which it was composed, died of starvation; the rest eventually succeeded in reaching the gulf, having been saved by a boating expedition up the River Chucunaque, organized, with that view, by Mr. Gisborne. Captain Prevost advanced about 20 miles from the Savannah, and turned back, after meeting with a range of mountains, 1,200 feet high. During the expedition, four of his men were shot by the Indians; their bodies were subsequently discovered by Mr. Gisborne, and buried by him.

¹ *Vide Minutes of Proceedings Inst. C. E., 1849-50, vol. ix., p. 74.*

When at Carthagena, he had seen Captain Kennish, who had just returned in ill health, from his exploration of the Atrato, and he had certainly understood, that the observations had been made without proper instruments. He had also seen Mr. Trautwine, just before he started: that gentleman had no ordinary levels, only two aneroids, which he compared with the standard barometers, taken out by Mr. Gisborne. Now if these were the only instruments used by Mr. Trautwine for ascertaining the levels, he thought their correctness could not be implicitly relied on. He admitted, that with a good standard barometer for each coast, carefully compared with the indications of the mountain barometers, the results might be sufficiently accurate for a general survey; but if no proper instrumental survey was taken, they could not form the basis of calculation, when estimating the enormous number of millions of cubic yards to be excavated, and the equally enormous number of millions of cubic feet of water to be discharged. If, for example, it should hereafter be found, that the junction of the Truando with the Atrato, was 20 feet higher than the level of the sea, instead of 15 feet, and that of the Napipi, 40 feet, instead of 30 feet, then the whole of the calculations would be vitiated. But even assuming the figures to be correct, there was still a summit level of 500 feet between the two oceans, which it was proposed to overcome by means of a tunnel, $3\frac{1}{2}$ miles long, 120 feet high, 200 feet wide, with a depth of water of 30 feet; and it was further stated, that it would occupy twenty-two thousand men during eight years, to complete this immense work. It was impossible to get such a large body of men to work for such a period in that country, without an immense sacrifice of life. So unhealthy was the climate, that out of six hundred Irish workmen, who were employed in the construction of the Panama Railway, four hundred had died at the end of three years. Chagres was only exceeded, in that respect, by Greytown; for he had heard from good authority, that Captain Campbell, commanding the 'Rosamond,' had lost more men in six months, when stationed off that place, than in three years on the West Coast of Africa. He himself had suffered from the effects of the climate. But if the necessity of a tunnel were granted, then he thought, that there were several places in Central America, where inter-oceanic communication could be made more advantageously, than by the Atrato.

The greatest obstacle, in his opinion, to the proposed route, was its great length, which would, of necessity, compel the use of tugs for the 65 miles against stream, and he thought it would be cheaper to transship the goods for California and India, over the Panama Railway, if good harbours were constructed at both ends. But many other points in the narrow part of the Isthmus,

might be found still preferable, if the country was carefully explored; hitherto, this had been rendered impossible from the hostility of the Indians. There was no record, so far as he knew, of any explorer having passed from ocean to ocean, between the Bay of Panama and Humboldt's Bay, with any certitude of his route, except at the Gulf of San Miguel, where he himself had crossed. There was an immense extent of country, which was absolutely unknown, but in which it was possible, that depressions of the mountain range might exist; for it had been ascertained, that opposite the Napipi, the summit level was only between 300 and 400 feet in height. These levels, ascertained merely by barometric observations, were, of course, not to be implicitly relied on, still he believed them to be within 50 feet of the truth. Again, between Chagres and Panama, the summit level was only 287 feet, and the cutting for the railroad being about 24 feet deep, the level of the rail was 263 feet. Between the Gulf of San Miguel and Escosces Bay, however, the lowest level he had discovered was 930 feet, and after walking on the summit of the Cordilleras, for six miles North and South of that point, he had found no place lower than 950 to 1,150 feet. The mountains fell rapidly on the Atlantic side to about 120 feet, and on the Pacific side, to about 400 feet, in a distance of three miles. The summit of the Andes was so narrow at this point, that even if cleared of the underwood and trees, five men could not walk abreast; the crest was nowhere more than from 20 to 50 feet wide, and 'back-bone' was the most appropriate term that could be applied to it. But if the question of tunnels was admissible, he thought, that the Darien route would show greater natural facilities for making a canal from ocean to ocean, than were presented by the Valley of the Atrato, and it had the advantage of being only 45 miles in length; a tunnel of $3\frac{1}{2}$ miles would bring the summit level down to 200 feet, at which height, the Chucunaque would afford a sufficient lock supply. He questioned, however, whether so great an extent of tunnelling through primary rock, would ever prove remunerative.

There was also another point, to which he would call attention: the route by Panama was not, as generally supposed, the shortest from Europe either to China, or India, but it was, actually, 600 miles longer than by Cape Horn; that, of course, was no argument against the importance of the American trade justifying an inter-oceanic canal; and he perfectly admitted, that the passage would really be shorter, on account of the calmer seas and absence of heavy gales. He did not, therefore, object to the principle of a canal; he merely doubted whether the proper place to construct it, had yet been found. It was most desirable, that a good exploration of both coasts of Central America should be made, one of the

first points being to ascertain where there were good harbours, which was a *sine quâ non*, inasmuch as it was next to impossible to create artificial harbours in that country, on account of the absence of mechanical appliances. The Admiralty charts of the coasts were copies of the old Spanish surveys, and were very inaccurate; in the first exploration of the Darien route, relying upon them, he had found himself 25 miles distant from the point he expected to reach. In his subsequent survey, he was more successful; and among the six hundred, or seven hundred men which composed the crews of the five men-of-war attached to that expedition, no loss of life occurred, nor were any ill effects produced. When harbours were found nearly opposite one another, flying observations could be made by means of the mountain barometer; and by establishing observatories on each coast, a line of level might be obtained, which could be relied on within 20 feet; and this, for a preliminary survey, would be quite sufficient.

He would conclude with the mention of some interesting facts relative to barometric observations. On his first survey, he found the variations of the barometers were like a regular tide, assuming their maximum at about 3 P. M., and their minimum, at 9 A. M. On his second survey, he was furnished with the best instruments from the Government Observatory; and he had transmitted the results to Mr. Glashier, who had published them. The variations were so regular, that by a careful comparison of the mountain barometer for every grade within the limits of which they rose and fell, with the standard barometers established on the Atlantic and Pacific coasts, he obtained an equation of errors between the two, so that he was never more than about 10 feet wrong in the height, as was afterwards proved by the levelled sections, calculated by the rule of Professor Forbes.

Dr. BLACK stated, that in 1852, Mr. Kelley and others had employed Mr. Trautwine and two assistants, to make the survey of the Atrato, and that they were abundantly supplied with proper engineering instruments for that purpose. They were also directed to run a line of levels over the Isthmus of San Pablo, with the view of ascertaining the feasibility of opening an inter-oceanic communication at that point. The results of the exploration were, however, so unsatisfactory, that the plan was abandoned by the promoters: and in 1853, Mr. Porter and Mr. Lane were employed by Mr. Kelley alone, to undertake another survey. Mr. Porter was accompanied by two assistants, and Mr. Lane by three assistants, and each party made a separate and distinct survey, which fully corroborated that already given by Mr. Trautwine. Mr. Lane further explored the Pato, and reported on the practicability of effecting a junction with the Baudo. He was again employed

with three assistants, in 1854, to examine the Western affluents of the Atrato, and to ascend the Truando, up to its head-waters. In 1855, Captain Kennish undertook, with three assistants, by Mr. Kelley's directions, the detailed survey given in the Paper. Five distinct surveys had been thus made at different times and by different persons, who were all abundantly supplied with every instrument necessary for the purpose. The spirit-level was used from the Pacific side to the Eastern base of the Andes, but it was impossible, on account of the whole country being under water, to employ it down the Truando. For this portion of the route, therefore, recourse was had to barometric observations, and the ascertained rate of flow of the river. On the Atrato, the spirit-level was used, whenever practicable, on the high grounds between the lagoons, and barometric observations throughout its entire length. The height at the junction of the Atrato and Truando, had thus been fixed by five different parties, one of whom came from the Pacific side, in an opposite direction to the others, and yet the greatest discrepancy between them, was only 1.2 foot. It could not, therefore, be reasonably doubted, that the surveys were, in the main, correct, and afforded sufficiently reliable data on which to base the calculations. Captain Kennish was thoroughly qualified for the task, having passed much of his time in inter-oceanic explorations, and his ability and honesty were so well established, that a provisional agreement was entered into with him by the Atlantic and Pacific Company, in the event of the Darien route proving to be practicable.

How far the proposed plan was feasible, in an engineering point of view, he, of course, could not pretend to say; nor could he speak from personal knowledge of the climate of the Atrato Valley. The Isthmus proper was, he knew, very unhealthy; and in this consisted one of the greatest obstacles to inter-oceanic communication generally, but from various facts, he believed, that the Pacific coast and the Northern part of South America, were less unhealthy than the Isthmus itself. But he submitted, that however important the sanitary question might be, that was not the question at issue, at the present moment, but whether there was a practicable route between the two oceans, by the Valley of the Atrato. The Paper did not assert, that the plan proposed was the best that could be adopted; it merely gave the result of careful explorations, as a reason for an authentic survey of all that portion of the Isthmus which was at present unknown, and a verification of the route by the Atrato, in order to obtain positive information, on which a correct judgment might be formed of the respective facilities for, or obstacles to inter-oceanic communication, presented by each district. Such a demand, he thought, could not but be favourably received in a great commercial country, and he was sure, that

large and enlightened views were entertained upon the subject, by the Governments of Great Britain, of France, and of the United States.

CAPTAIN FITZROY, R.N., said, that this most important question was interesting, not only to England but to the whole world, and the more it was investigated, the deeper that interest became. But before discussing the proposed plan, he thought it desirable to prove to the Institution, that this was no illusory project, got up for the purpose of forming a company by means of British capital, for the benefit of another hemisphere. This was an exception to the general rule: Mr. Kelley was not the agent of others, but a gentleman of independent fortune in New York, who had expended a very considerable sum of money in forwarding the investigation of a subject, in which, for several years, he had taken a great interest,—the exploration of this region of country, with the view of finding out a practicable route for the construction of a canal to connect the two great oceans, the Pacific and the Atlantic; and in the prosecution of this object, he had caused extensive surveys to be made at his sole expense. His present object was to obtain the assistance of the Governments of France and England, in conjunction with that of the United States, in accomplishing an accurate survey of the tract of country between the Gulf of San Miguel, the Gulf of Darien, and Quibdo, in order to ascertain whether any part of it would admit of the construction of a ship canal. If the subject were taken up by those Governments, and a separate district allotted to each party for exploration, the whole might be accomplished in one season, and that *terra incognita* would become known to the world. He believed, that hopes might be entertained of the assistance of the Government of this country; and there would then be little doubt of the co-operation of France and of the United States. In the meantime, Mr. Kelley had submitted his plans to this Institution, as the most competent body that could be selected, for passing an opinion upon its merits. The question now was, not whether this particular line should be adopted, but whether this valley possessed greater advantages than any other point, for the construction of a canal, navigable for large vessels. After a long and careful investigation of the subject, Mr. Kelley had arrived at this conviction, and for the last two, or three years, he had more particularly directed his attention to this district, and had caused repeated and careful surveys to be made of it.

He, at first, turned his attention to the possibility of uniting the head-waters of the Atrato, with those of the San Juan; but on recognising the impracticability of that scheme, and struck with the apparent advantages offered by the Truando and the other Western affluents of the Atrato, he instructed Captain Kennish to

examine the Pacific coast, and if a depression should be found in the mountain range, to level across towards the Atrato: the results were communicated in the Paper. Excepting at the bar, the Atrato was navigable for the largest ships, from the Gulf of Darien, to considerably above the Napipi; and if a canal could be made from the Gulf of San Miguel, across the plain to the foot of the mountain, and thence through to the Atrato, nearer to its mouth, it would, doubtless, be better than going higher up the river: this would be a question of so much cutting for a canal, against so much natural river, but no accurate survey had yet been executed, on which calculation could be made. There were, at present, three routes, which had been proposed at, or near this point:—one, from the Gulf of San Miguel to the Gulf of Darien;—another, from Humboldt's Bay to the Truando;—and a third, from Cupica Bay to the Napipi. An advantage, in favour of the route by the Truando, was, the accessible harbour of Humboldt's Bay, and the equally accessible, although smaller harbour, (Kelley's Inlet,) behind the Isthmus of Paracuchichi, which was some 8 or 10 miles long by 300 yards wide. The entrance to the latter was now barred, but from the quiet nature of the adjoining waters, the entire absence of currents, or gales of wind, and from the vegetation extending down to the water's edge, there could be no doubt, that the entrance to that lagoon-like harbour might be improved. The mountain ridge appeared high, in comparison with that of the Napipi, as the summit was ascertained to be 500 feet above the level of the sea; but those who made the survey, were by no means satisfied, that a still lower level might not be found. Even supposing that to be the lowest, he did not think, that a tunnel of $3\frac{1}{4}$ miles in length, would present insurmountable obstacles to Engineers of the present day. Beyond the tunnel, up to which point there had been a strict trigonometrical and spirit-level survey, a cutting of 12 miles conducted to a level plain abounding in water, and a river of the average depth of 15 feet, and of considerable breadth, flowing slowly, throughout the whole of its extent, down to the Atrato. The level of the Atrato had been ascertained by barometrical observations, and when practicable, by the spirit-level, so that the height of its junction with the Truando, might be depended upon within a few feet; and the mean level of the two oceans, it was well known, was nearly, if not exactly the same. Considering the nature of the country, it was not surprising to find a slight discrepancy: but this was so small as not to affect the opinion of the Engineers, that by cutting through the high ground, and tunnelling under the narrow but high ridge, the current of the Truando might be turned, so that, instead of flowing, as at present, into the Atrato, it would run into the Pacific. This, certainly, was one of those bold conceptions, which, if they failed, were termed chime-

rical, but if they succeeded, (and it did appear, that in this case, there would be a strong probability of success,) immortalised the authors.

An objection had been urged, on the ground that the Atrato would not be able to supply sufficient water for itself and for the Truando. But the Truando was a mere canal, sufficient, it was true, to carry large ships, but still a mere canal, in comparison with the Atrato, which was a river far exceeding anything in this country. Not only had the Atrato its own supply throughout that extent of country, but it was also the main-drainage artery of the whole valley, receiving into its bed numerous other rivers, many of which were as large as the Truando. As it rained for nine or ten months during the year, the workmen must, necessarily, be provided with water-proof clothing and be protected overhead: but when once the works were completed, the very peculiarity of the climate was such, that water could never be deficient. The climate was, perhaps, the wettest in the world; but this very objection was the best argument in its favour. The failure of the Atrato to supply water enough to flow into the Pacific, could not be conceived: and pilots who had examined the Darien coast, reported, that they never found less water in the mouths of that river, in the driest season of the year, than at other times. Its own supply might be greater, or less, but the quantity of water on the bar remained the same, because the Atrato never rose, or fell beyond a few feet. The river was freely navigable, with a depth of from 30 to 60 feet, to above the confluence of the Napipi; but in the wettest season, the greater part of the adjoining country was overflowed, and then the navigation would become difficult, unless the channel of the canal were marked by signals, or beacons.

If this canal were once completed, he had no doubt that, as had been the case with railways, the increased facilities of communication, would give an impetus to commerce, and cause a greater demand for ships. Railways never could carry goods so cheaply across the Isthmus, as ships which could pass through a canal, without breaking bulk. It was also well known, that the route from Europe to Australia, India, China, or California, by the Isthmus, was so favourable, the water so smooth, and the winds so uniform, that a small vessel might carry cargoes more cheaply and expeditiously than by the Capes, where the bad weather and high seas required larger and stronger ships.

With regard to the engineering difficulties of the undertaking, the subject was now before the body most competent to deal with them. Being much interested in the whole question, he knew that Engineers would give their best attention to the proposed plan, and that they would not treat it as a theoretical speculation. The project had been earnestly taken up in the United

States; it had undergone the scrutiny of the Government of that country, and some plan for connecting the two oceans, would, probably, be eventually carried out. A very few years had elapsed, since the project of a railway across the Isthmus of Panama, was treated as chimerical; yet it was now in full operation, and was realising a profit of 12 per cent. upon the cost.

One fact might be mentioned, in addition to what had already been stated, as to the depressions existing at this part of the Cordilleras, which clearly proved, that the range was low and passable at the Napipi. Lieutenant Wood, of the 'Pandora,' had crossed from Cupica Bay to the head-waters of that river, in less than three hours. He did not seek the lowest line, but he took the Indian path, which always followed the ridge, as the most convenient for walking, and for viewing the surrounding scenery; and he reported, that he did not think any part of the ground he walked over, was more than 400 feet above the level of the sea. He would also mention, that in 1821, when the Chilian corvette, the 'Rose,' was upon that part of the coast, her launch, or what would be called in England, a ten-oared cutter, was dragged across the ridge, by the crew and a few Indians, and launched into the Napipi. The party went up to Quibdo in the boat, which was still lying there when Captain Cochrane, R.N., visited that place, coming down the Atrato, and he reported, that so easy was the flow of the river, and so plentiful the supply of water, that the crews of the 'bongos,' (a country craft of about 50 tons,) allowed them to drift down with the stream, during the night. It was evident, that there were, on the whole, greater facilities for crossing the Cordilleras, at this point, than had been supposed: yet Captain Kennish, who had seen them, preferred the route by the Truando. In any case, sufficient reasons, he thought, had been shown for the authorised exploration of the whole valley, demanded by Mr. Kelley, that it might be ascertained, which was the best and most practicable route for effecting this great undertaking.

Mr. WHISHAW said, that for the sake of comparison, he had calculated the dimensions of fifty-four of the principal tunnels in the United Kingdom, and he had found, that one of the proposed tunnels would comprise them all.

Mr. C. H. GREGORY thought it was not correct to compare the cubical contents of a tunnel such as that proposed, with similar works on railways or canals, as the measure of comparative difficulty and cost. In ordinary tunnels, the limited size of the face, and the contracted space in which work could be carried on, greatly increased the cost and time required. Great as the tunnel here proposed would be, and considerable as might be the difficulties attending its construction, there would be much more room for working, and a large face for blasting operations on an extended scale.

Mr. L. GISBORNE was certain that the Meeting would join in the eulogium passed upon Mr. Kelley, for his public spirit and enterprise in exploring the different valleys of the Atrato. In the discussion of this subject, there were many important points to be noticed. First, with regard to the levels of the two oceans. Hitherto, a notion had passed current, that the Pacific was at a higher level than the Atlantic. Nearly thirty years ago, the late Colonel Lloyd examined the country both ways, between Panama and Chagres, and reported the Pacific to be $3\frac{1}{2}$ feet higher than the Atlantic. Colonel Childs subsequently made a detailed survey of the Nicaragua route, and fixed the difference of level at only 19 inches. Colonel Totten, the Engineer of the Panama and Chagres Railway, had, more recently, found the greatest difference to be 14 inches: and in some instances, it was reported to be only 4, or 5 inches. It therefore became a question, whether, in point of fact, the Pacific was at a higher level than the Atlantic. That opinion had been combated by Sir Francis Beaufort, still he believed, with the Author of the Paper, that the mean level of the two oceans, was really the same. The rise in the Pacific being 24 feet, and that in the Atlantic depending altogether on the winds, it was natural to suppose, that the level of the former might occasionally appear higher, on account of the longer time required for the tidal wave to reach shallow water.

It was stated in the Paper, that in consequence of the 24 feet of tide in the Pacific and the small tide in the Atlantic, if a cut were made through the narrow part of the Isthmus, the current would be so great as to impede navigation and injure the works. If that opinion was correct, it would be useless to look further for inter-oceanic communication between the Bay of Panama and the Caribbean sea. But supposing a canal 150 feet wide, with a depth of 30 feet at mean water, and taking the distance for 30 miles only, (which was 10 miles less than any portion of the Isthmus,) there would, of course, be a fall at the bottom of the channel of 12 feet, because the tide flows 12 feet on the Pacific side, and does not flow on the Atlantic;—now this would only give a maximum velocity of 3 miles an hour. It might be urged, that this was not like an ordinary river, but that in consequence of the change, every six hours, of the mean level of the two oceans, the current would be very different. He had consulted Professor Stokes, of Pembroke College, Cambridge, on the subject, who told him, that although he was unable to apply pure analysis to it, yet he did not think, that it need be treated otherwise than a common river question.

It was also stated, that an accurate survey had been taken from the Gulf of Darien to Humboldt's Bay, and that the section showed the mouth of the Truando, to be 15 feet above the mean level of

the two oceans. On referring to Captain Kennish's Report, it would be found, that the only levelling with proper instruments, which had actually taken place, was between the Pacific Ocean and the summit level. That point, therefore, might be assumed, both as to distance and elevation, to be correct. But from the summit level to the Atrato, the distances and heights were calculated by measuring the velocity of the current of the Truando, and the same means were adopted from the Truando to the Gulf of Darien. Now although it was stated, that the same system had been applied to the Nile, the Neva, and other rivers, yet this could not be considered as a survey, according to the common acceptance of the term in this country. The system of taking heights by the velocity of currents, was very uncertain, and he preferred the barometric observations which he had described. Supposing an error of 5 feet, in the calculation of the height of the junction of the Truando, which was not impossible in a distance of 60 miles, the consequence would be, that the Pacific would flow into the Atrato, instead of the Atrato flowing into the Pacific; and if, on the contrary, the level should be 5 feet higher, then the current, instead of being 3 miles an hour, would be 7 or 8 miles an hour. He trusted, he should not be thought as speaking disparagingly of this plan, because the one on which he had been engaged, had proved a failure; he merely wished to advert to certain points which he did not think accurate. It was stated, that the 'Virago,' when in Darien Harbour, in the Gulf of San Miguel, dragged her anchors, and paid out all her cable, owing to the strength of the tidal current: this was true, but it happened several miles up the Savannah River, where the action of the fresh water coming down from the mountains, was added to that of the descending tide. He considered the Gulf of San Miguel and Caledonia Bay, to be two of the finest harbours in Central America.

Mr. GIBBS said, that fifteen years ago, he was engaged, in conjunction with Mr. William Fairbairn, of Manchester, to report upon the feasibility of constructing a canal from Panama to Chagres, for which a concession had been granted by the Government. But from all the information they could collect, and looking dispassionately at the whole question, they came to the conclusion, that the possibility of making that canal was very remote. They certainly did not at that time entertain the idea of making, what was now called, an inter-oceanic communication. All that was then contemplated, was the formation of a ship canal, with summit water. One of the great difficulties to contend with, in canalising within the tropics, was the want of summit water in the dry season, on account of the excessive evaporation. The large amount of flood water, and the bars at the mouths of the rivers, constituted other difficulties, but the greatest of all, was to

obtain workmen, on account of the unhealthiness of the climate, which did not allow of the employment of white labour. As the construction of so extensive a work as a canal must, therefore, depend upon negro labour, they came to the conclusion, that it was better to begin by making a simple paved road across the Isthmus, then to construct a railway by the side, and to leave the question of a canal for after-consideration. But it seemed, that the time for entertaining that question had now arrived. He would, therefore, first of all, draw attention to the rise and fall of the rivers in the tropics. They were all, as far South as the Amazon, bar-rivers, and however wide the rivers might be, the bars were always difficult to cross, on account of the flood waters, which brought down with them a great quantity of mud, and left a deposit of common sand at the mouths. New harbours must therefore be constructed, independent of the rivers. The next point to be considered, was whether it would not be more advisable to make a railway to connect the two harbours, than a canal. It was agreed, on all hands, that the construction of such a canal, would require works of a magnitude, never, hitherto, contemplated, on account of the great depth of the cutting, and the enormous size of the tunnels. It was a question of great difficulty, how to raise centering, which should be able to support arches 120 feet high, in a tunnel; it was not so easy as with an open bridge. It was possible, however, that this difficulty might be got over, by first cutting the space for working the arch, and leaving the mass below to be afterwards taken out; and thus, no centering would be required. Then again, there was the important question of cost; the excavation of the material, after the arch was made, would be, at best, a difficult operation, for the whole of the Cordilleras in that part of the country, consisted of primitive rock, the base of which, no doubt, was granite and clay slate, but it was jointed, at intervals, by what was called elvan rock, or porphyry; and the additional difficulty must be taken into account, in the calculation of cost. He did not make these observations in discouragement of the plan, nor did he say, that it was not practicable; but to show the great caution required, before coming to the conclusion, that it was a work that could be carried out. A double railway, or a three-track railway, with harbours in deep water, away from bars, which would give facilities for transshipment, could be constructed with greater chances of success, and at less cost. But bar-harbours must be avoided, for they penned back the water in the wet season, converting the surrounding country into a swamp, and in the dry season, they deposited such an amount of vegetable and other matter, that they became pestilential to a degree beyond description. A residence of two years and a half on the Isthmus, had seriously injured his health.

Mr. VINCENT said, he had been, during six months, in the district of the Atrato, from its very sources to its mouth. It was a magnificent river with a steady and equable current, but the whole country near the Truando and the Sucio, was such a complete mass of lagoons, or 'cienagas,' that to construct a railway, would be almost impossible. For sixty miles from the mouth of the Atrato, there was, strictly speaking, no shore. From inquiries he had made of the Indians, mulattoes, negroes, and 'patrons' of the river 'champanes,' he believed an eligible point for a ship canal might be found in the vicinity of the Indian pass of Cacarica. In any case, he deemed it highly necessary to effect a thorough survey of the district, in which the Salagui and Truando Rivers were situated. The population was exceedingly quiet and tractable throughout the Province of Choco, and labour to a considerable amount could be cheaply obtained not only there, but also at Cartagena, as in the case of the construction of the Panama Railway. The type of local fever was not in the least dangerous, thus materially differing from the Isthmus fever: his own health had not been at all affected during his stay.

Mr. WEBSTER thought, that justice had scarcely been done to Mr. Kelley, inasmuch as he had not presented this, as a precise scheme, to be adopted in all its details, but as the result of his efforts to obtain the best information, as to the practicability of a junction of the two oceans by the Valley of the Atrato. Two points had been raised in the course of this discussion, which had forcibly struck him: the first was, with regard to the mean level of the two oceans, which was admitted to be the same. But it also appeared, that the elevation of the tide at the upper part of the Bay of Panama, was 24 feet, while at Humboldt's Bay, it was only about 12 feet. If, therefore, a communication was made from Humboldt's Bay to the Atrato, which was nearly at the same level, there could be no danger of a strong current between the two oceans. The objections urged on this point, had proved too much, for if the difference of level at the extreme height, say at Panama, would only amount to a fall of 3 miles an hour, how could a discrepancy of a few feet at the junction of the Truando, cause a velocity so much greater, when the distance was longer? Exceptions had been taken to the Report of Captain Kennish, which was the second point to which he would allude. That Engineer had accurately levelled from the Pacific over the summit to the base of the Andes, but the remainder of the survey was taken by the rate of the current of the rivers, and by the spirit-level, when practicable. He did not conceive, that this course was open to objection: certainly not, as to the Atrato, for it was not intended to alter the state of things in that river. He sincerely hoped, that the Governments interested in the question, would authorise a complete and

accurate survey of the region, so that sufficient data might be obtained, on which to form a practical and definite judgment.

Mr. BEARDMORE, through the SECRETARY, remarked, that considering the subject in an engineering point of view, there were one or two facts and first principles of science, which might be laid down as axioms. He believed it to be a consequence of the law of gravitation, that the mean level of the ocean was substantially the same at all parts of the globe, and would be so, as long as a pound of sea water everywhere occupied the same space, and was composed of the same constituents. He had investigated every available kind of observation on the level of the ocean, including the Ordnance Survey of Great Britain, and the testing levels, taken at the instance of the British Association, between the English and Bristol Channels, and connected with the Admiralty Surveys of the Severn by Admiral Beechey; and he had, in his own professional experience, made numerous minute surveys, all of which confirmed this view. Where surveys showed different results, it was because the mean tide level had not been ascertained with sufficient accuracy.

An investigation into the facts presented by Mr. Kelley, appeared to him to prove incontestably, that the junction of the Atrato and the Truando could not vary materially, from the stated height of 15 feet above the mean sea level. With these facts, combined with the rise of tide of 12 feet in the Pacific, the more important theoretical questions were:—First; whether a free communication between the waters of the Pacific and the Atrato, at the point in question, would be practicable for navigation:—Secondly; whether such a communication would be likely to reduce the level of the Atrato to a serious or injurious extent:—and Thirdly; whether it would cause any tidal action of a prejudicial nature, on that river.

The first question might be answered, without any hesitation, in the affirmative; for the extreme fall could not possibly create a current greater than from 2 to 3 miles per hour, beyond the tidal action; within it, there would be the usual flow and ebb to be found in a somewhat sluggish tidal river, which had no great interior basin to fill or to empty.

The second question might be dealt with in a familiar way, by assuming, for instance, that the Atrato had, at present, as much as 4 inches fall in each mile of its course. Now the river was, evidently, one of very large volume, and liable, from the character of the mountains draining into it, and from the excessive rain-fall of the climate, to heavy floods; its width, therefore, was great, and its depth varied from 40 to 50 feet. Assuming, then, that it were possible to abstract sufficient water to reduce its surface fall to a minimum of 1 inch per mile, (a flatness rarely to be found,) the depth at the junction would only be reduced about 10 feet, and the power of discharging its waters would be reduced fifty per

cent.; or, in other words, one-half its entire volume would be available to fall through the new cut, towards the Pacific. But it must be remembered, that as the height of the Atrato at the point of junction was reduced, so would the velocity down the new cut be decreased; and, therefore, it would not, in reality, carry off any such proportion of the volume of the Atrato. These statements were well-known facts in the science of Hydraulics, being consequences of the law that, *ceteris paribus*, the velocity and the discharge of any river, varied as the square root of the rate of fall.

The third question admitted of a favourable answer; there were many familiar instances in this country, where the tide had been admitted, by new works, into large areas, with great advantage to navigation, and without injury to other interests. No better example existed than that of Peterborough and Wisbeach, at which latter place, the tidal flow had been increased, by the works of Messrs. Rennie, from 8 to 18 feet, without affecting the flow at Peterborough, about 18 miles higher up the same river; and works were now being carried out, which might probably increase the flow at Peterborough, (now about 6 inches at spring tides,) to 3 feet, with every advantage to navigation.

A familiar and grand example of Mr. Kelley's scheme occurred in the Hooghly, or Calcutta River, which branched off from the main body of the Ganges, at about 170 miles above that city, and carried down large floods, with a slope somewhat analogous to that of the proposed canal; the tide was felt for about half its entire length from the Bay of Bengal up to the junction with the Ganges, under circumstances well known to be highly favourable to the development of the tidal wave, and somewhat similar to the case of the Severn.

There were, however, most important engineering questions, touching the especial manner of leading away the new line of navigation from the natural river, which could only be decided by the most careful surveys, and would depend on the amount and rise of flood waters, and on the nature of the soil and valley, at the point which was considered the best adapted to meet the various contingencies of so important an engineering and geographical problem, as the formation of an inter-oceanic ship canal. It was a subject of infinite interest and value, and the very want of data on which to speak more precisely, was the strongest argument for its claiming the attention of the Governments, and its investigation by thoroughly experienced Engineers and Surveyors.

He thought it highly probable, that at the junction of the Truando, corrective engineering works would be necessary, in order to contract the flow from the Atrato, and to prevent the new cut being made a channel for flood waters. How this could be effectually and economically accomplished, was the great problem;

[1855-56. N.S.]

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all others were mere questions of money, and prudent adaptation of the works to the nature of the difficulties to be surmounted.

The foregoing remarks were based on the assumption, that a free river cut was economically desirable, a conclusion which must turn upon more detailed surveys; for it would, of course, be perfectly practicable, to carry out all the more important features of this plan, and yet economize very largely in the works, by a skilful application of locks, in relation, more particularly, to the drainage during the construction of the summit works.

Mr. F. M. KELLEY, through the SECRETARY, said, that as the object he had in view, was to effect a junction of the Atlantic and Pacific Oceans, by that route which should be found the most advantageous for effecting it, he did not wish, that the survey should be limited to the one, which long and careful deliberation had demonstrated to his mind to be the best, but that it should extend to all those regions which offered the possibility of success. Much stress had been laid upon the unhealthiness of Central America, and no doubt, this was an objection of great force: still he thought it had been very much exaggerated. Chagres and Aspinwall were both very unhealthy; yet this fact had not prevented the construction of a railway, nor had it interfered with its success. The mortality during the progress of the works, had been much less than was generally supposed, and it was mainly due to the exposure of the men to the sun and rain, while working in the swamps near the Atlantic coast; but there was very little loss of life among those employed upon the high ground. Mr. David Hoadley, President of the Panama Railway Company, stated:—“The first blow on the work was struck in January 1850. Since then, a strict record has been kept of the deaths which have occurred among the white men, employed by the Company, and up to the time of opening the road on the 28th of January 1855, the number was two hundred and ninety-three, of which many are known to have been caused by diseases, not incident to the climate. How many white men were connected with the work during this period, cannot be accurately determined, but the number was at least six thousand. No record was made of the mortality among other classes of labourers, but the proportion was greater among coolies, and less among Jamaica men and natives.”¹ But the region of the Atrato could not, for a moment, be compared to that part of the Isthmus. The high ground towards the Pacific, was most healthy, and it was there, that the heaviest portion of the works would be required; those on the Atrato and Truando would mainly consist of dredging, and could, therefore, be carried

¹ *Vide* “Communication of the Board of Directors of the Panama Railroad Company.” New York, p. 15.

on in covered machines, which would effectually protect the men, from the danger which had been pointed out. Captain Kennish had, most certainly, returned to New York in good health, and he did not give an unfavourable report of the effects of the climate. Mr. Lane, it was true, and all who accompanied him, were, on his second survey, attacked with fever at Carthagena: but it was caught at Aspinwall, and on their way to, and not from, the Atrato. It had been admitted, that there was no mortality among the six, or seven hundred men, who accompanied Mr. Gisborne on his last expedition, and therefore, it might fairly be concluded, that this region was not so unfavourable as Central America generally. As to Greytown, his information respecting it, did not warrant the very unhealthy character which had been assigned to it. Reference had already been made in the Paper, to the means of obtaining labourers. He did not apprehend, that any difficulty would be found in establishing a system of emigration from the countries there named, sufficient for the construction of the works.

It was very much in favour of the main accuracy of the levels, that in the height of the junction of the Truando, the greatest discrepancy between the five exploring parties, all of which were fully provided with instruments, was only 1.2 foot. But even in the extreme supposition that had been urged, that a much greater difference might actually exist, still even that would only affect the details of the route. The country around being an open plain, one-third of which was under water, and the Atrato receiving at short intervals, other affluents as large as the Truando, the junction could be made, higher up, at the confluence of the Chintado, or at that of the Salaqui, or indeed, at any point, which would not, on the one hand, create too rapid a current towards the Pacific, nor on the other hand, permit the high tides of that ocean to overflow and interfere with the regular navigation of the canal.

It had been stated, that the route from Chagres to Panama would be more favourable than by the Atrato, and require less labour. But supposing the excavation to be made on the finished bed of the railway, it appeared, from a calculation made by Mr. Serrell, the American Engineer, that the quantity of rock which would require to be taken out, was 138,737,345 cubic yards, and of earth, 87,740,400, making together 226,477,745 cubic yards, as against 148,765,484 cubic yards, on the Atrato route; and the great difference in the rise of tide of the two oceans, in the Bay of Panama, and on the opposite coast, would, necessarily, compel the construction of at least two locks, not only at this point, but at every other part of the Isthmus of Panama, or of Darien, which might be selected for a canal. It should be borne in mind, that the summit level opposite the Truando, was the maximum; and that there was not only the possibility, but the probability of a lower

level being hereafter discovered, for Captain Kennish, on account of the extensive growth of underwood, limited his survey, with but few exceptions, to the direct line across the mountains. All this portion of the survey was taken with the spirit-level, down to the base on the Eastern side of the Cordilleras.

The Darien route had been examined, both by Captain Kennish from the Pacific side, and from the Atlantic, by Lieutenant Strain, who told him, that they did not find any indication, that the line of country had ever been crossed over. They both asserted, that it would be impracticable to construct a ship canal in that part of the Isthmus, on account of the great height and width of the dividing range, which would require an enormous amount of excavation, and which entirely precluded any possibility of tunneling. As already stated, after having lost themselves for nearly three months in the interior, Lieutenant Strain and the survivors of his party, eventually succeeded in reaching the Pacific coast.

It had been remarked, that the voyage from England to the East Indies and China, would be 600 miles longer by the Isthmus, than by Cape Horn; such might, possibly, be the fact by the Cape of Good Hope, but he doubted whether it would be so by Cape Horn. With regard to Australia: the distance to Melbourne would be about the same; that to Sydney, however, would be shortened by about 1,000 miles. But the absolute geographical distance was only one of the elements, and that, not the most important, of the question. When the direction of the prevailing winds and currents, and the heavy gales which had to be encountered in the Cape route, were placed in the balance, against the steady breezes, the moderate currents, and the smooth seas of the Pacific, when it was remembered, that in the latter route, the winds were favourable, both outward and homeward, for three-fourths of the entire voyage, it would be evident, that these were advantages which could not fail to be eagerly seized upon by the mercantile marine, since they would insure, what was now become of such great importance, a certain and reliable duration of passage. Time, not distance, was after all, the true measure of the relation between places, and it had been demonstrated, that the route by the Isthmus, would practically save, at the least, ten days in steam communication with Australia. He conceived it would be unnecessary to do more than point out the great economy to ship-owners, which would be effected in the different items, of wages, provisions, wear and tear, and insurance.

He had, while at Berlin, laid the results of the different explorations of the Atrato, before one whom all would acknowledge to be the highest authority, on such a subject,—Baron von Humboldt,—and from him he had received the following letter :—

(*Translation.*)

"It is with the deepest satisfaction, Sir, that I made myself acquainted, during your too short stay in Berlin, with the sound and extensive series of measurements and levels which, by your direction, have been executed, since the beginning of January 1855, upon the course of the great Rio Atrato and its affluents on the West, by an able Engineer, Mr. William Kennish. This survey and those previously undertaken by your orders, and to which my learned friend, Mr. Alexander Bache, Superintendent of the Coast Survey of the United States, had already drawn my attention, are so much the more deserving of regard, since you purpose to have examined with the same precision, the pass from the Port of Cupica to the Rio Naïpi (Napipi), and the points situated above the mouth of the Truando, which are all very important in the solution of the vast problem of an oceanic canal.

"The great number of charts and sections on a large scale, in your possession, furnish all the elements necessary for judging of the possibility of establishing a communication between the two oceans, by the mouths of the Atrato, the Rio Truando and a canal leading to the Pacific Ocean. It was on account of his not having made so thorough an examination of the mountainous country between the Gulf of San Miguel and Calidonia Bay, that Mr. Lionel Gisborne's plan of 1852, could not be carried out. The ignorance he was in as to the localities, and the absence of measurements of altitude, led to the unfortunate issue of the courageous expedition of Lieutenant Isaac Strain.

"The great object to be attained, is, in my opinion, a canal which would unite the two oceans, without locks and without tunnels. When the plans and sections can be placed before the public, a free and open discussion will elucidate the advantages and disadvantages of each locality, and the execution of this important work which interests the civilized nations of the two continents, will be intrusted to Engineers, who have successfully distinguished themselves in similar enterprises. The Junction Company will find subscribers among those Governments and citizens who, yielding to a noble impulse, will take pride in the idea of having contributed towards the execution of a work, worthy of the intellectual progress of the nineteenth century. More than fifty years ago, I earnestly expressed the same opinion, and I have incessantly laboured in the propagation of those geographical views, which tend to prove the practicability of establishing commercial communications, either by canals, (with, or without either stop-gates, or locks), or by means of railroads uniting opposite coasts, and rivers flowing in contrary directions.

"I was the means of obtaining, through Genera. Bolivar, the exact geodesic survey of the Isthmus of Panama, and I was the

first, from information found in the Archives of the Vice-Royalty of Mexico, to lay down in my Mexican Atlas, the course of the two rivers, the Huasacualco and the Chimalapa. I pointed out the proximity of the almost unknown Port of Cupica, to the sources of the Rio Naïpi and to the waters of the Atrato, and also the existence, with which Europe was unacquainted, of a very small navigable canal, 'excavated' in 1788, under the superintendence of a monk, the Priest of Novita, by the Indians of his parish, in order to unite the waters of the Rio de la Raspadura, an affluent of the Rio de Quito (Quibdo), to the waters of the Rio de San Juan de Chirambira.

"I think nothing more dangerous to the extension of commerce and to the freedom of international relations, than to inspire an aversion to all future investigation by an absolute and imperious declaration, that all hope of an oceanic canal must now be abandoned. I expressly described in my 'Political Essay on New Spain,' (compare Vol. I., pp. 202—248, with Vol. II., pp. 95—145, 2nd edition,) the immense work of cutting through the mountains an open channel for the Desague of Huehuetoca, which was executed by the Spanish Government at the beginning of the seventeenth century, and I have too much faith in the powerful means afforded by the present state of civilization, to be yet discouraged.

"The important communications for which I am indebted to the courtesy of Colonel Augustus Codazzi and to the exceeding kindness of M. Pastor Ospina, Minister of the Interior at Bogota, have made me fully aware, that the line from Cupica to the Rio Naïpi presents a series of elevations: in directing this passage to be levelled, you will, therefore, be rendering a further service to Geography. Captain Robert Fitzroy, R.N., whose name is justly renowned among navigators, in his 'Memoir on the Isthmus of Central America,' says:—'Of all the comparatively well-known routes, it has been shown, that the Atrato and Cupica line seems the most suitable for a canal, and the Panama route, for a railway. The officer who recently surveyed Cupica, (Lieut. Wood, R.N.,) states, with respect to the land between it and the Naipi, that he set out one morning from Cupica at eight o'clock, walked with native guides to the Naipi, bathed in the stream, and reached his ship (the 'Pandora') at noon.' The most elevated ground was, in his judgment, 300—400 feet. —Journal of the Royal Geogr. Soc., Vol. XX., 1850, Part II., p. 178.

"Receive, my dear Sir, &c.,
(Signed) ALEXANDRE DE HUMBOLDT."

"Berlin, January 27, 1856."

Mr. R. STEPHENSON, M. P.,—President,—said, the Institution

was much indebted to Mr. Kelley, for his highly-interesting Paper, which had induced the expression of valuable opinions from those who were enabled, from personal examination of the localities, to afford corroborative opinions. Mr. Stephenson had spent some time in Columbia, and during his stay there, the late Colonel Lloyd explored the Isthmus; but the information collected by that gentleman, was insufficient to enable Engineers to form an opinion, whether an inter-oceanic canal, at that point, was practicable. This question had been, more or less, before the public for the last thirty years, and he had watched its progress with the greatest interest. Every successive year had brought with it some new and more accurate information: but there was no Paper, he had ever met with up to this time, which had given him so clear an insight into the difficulties of the problem, and the mode by which, probably, hereafter and at no distant period, they were to be overcome. Although the plan was not brought forward as a specific scheme, yet it presented itself to his mind, as offering less real difficulties than any which had been hitherto proposed.

Nothing could settle this question, but the co-operation of the Governments of Great Britain, France, and the United States, for the purpose of obtaining extensive, accurate, and detailed surveys; and he did not doubt, that they would lend their strenuous aid, in the solution of a problem of such vast importance to the commercial and political interests of the world, as the junction of the Atlantic and Pacific Oceans. A few years longer would, probably, decide whether it was feasible to make an inter-oceanic canal: at all events, it could not fail to be remembered, that Mr. Kelley had produced more intelligible information upon the subject, than had hitherto been given to the world.

April 29, 1856.

ROBERT STEPHENSON, M.P., President,
in the Chair.

The discussion on the Paper, No. 948, "On the Junction of the Atlantic and Pacific Oceans, &c.," by Mr. F. M. KELLEY, having been renewed, was extended to such a length, as to preclude the reading of any other Communication.
