

## Discussion.

Sir J. WOLFE BARRY, K.C.B., President, was sure the members would all regret that the Author was not present to further elucidate his interesting description of the careful observations which had led him to important deductions in connection with the great landslides in British Columbia. The slides certainly were on that immense American scale to which engineers were not unaccustomed when hearing of what took place in that great continent. The Paper was an interesting one to engineers, as many of them might, on a small scale, have to deal with disasters somewhat similar to those to which the Canadian Pacific Railway had been exposed. No one could envy the engineer in charge of that length of the railway; but it was very satisfactory to know that by the careful observations of the Author, the cause of the slides seemed to have been tracked by his scientific mode of research. He was sure he was only speaking the sentiments of all present in proposing a hearty vote of thanks to the Author for his interesting contribution to the Proceedings.

Mr. G. R. JEBB thought it would add to the interest and clearness of the Paper if cross-sections could be given, one, for example, across the valley and across the north slide, showing the relative levels of the river, the railway, and the country above; also showing the thickness of the boulder-clay and of the various strata forming the sides of the valley.

Mr. HORACE BELL remarked that the Paper was essentially a geological one, and it indicated clearly the necessity of attention to the geological features of any ground upon which works were proposed to be carried out. The cause of these great slips and the remedy for them appeared to be clear enough. The cause was apparently constant irrigation, and the remedy was that of ceasing it. It would no doubt have appeared to the Author that the remedy would perhaps be worse than the disease, as it would end in stopping the irrigation, and reducing the population and the traffic of the Canadian Pacific Railway. The great slides that had taken place on that railway were paralleled in some measure by the enormous slides with which he had had to deal in the Beluchistan frontier of British India. There they were due not to irrigation but to peculiar geological conditions. The line he

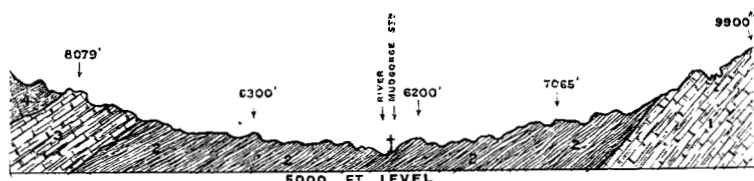
Sir J. Wolfe  
Barry.

Mr. Jebb.

Mr. Bell.

Mr. Bell. referred to connected the Indus Valley with the great military station at Quetta on the Beluchistan frontier; and at an elevation of 6,000 feet above the sea there was a valley which had rightly been called "Mud Gorge," consisting almost entirely of disintegrated shales overlying the lower nummulitic limestone, as shown in *Fig. 5*. The railway, which, perhaps, had been somewhat hastily located over the ground, had proved to be, both at this point and at others, a frequent source of trouble and anxiety to the Government of India. It was a connection between the Port of Kurrachee and the Afghan frontier, and any defect in it could hardly be contemplated with satisfaction either by the Government or by the public. The slides were mainly due to the fact that the shales were permeated by beds of gypsum and anhydrites, which, subject to subaqueous disintegration, forced the whole body of the shales from the upper hills down to the river, which drained the valley, and the result had been that,

*Fig. 5.*



Scale 1 inch =  $1\frac{1}{2}$  mile.

1. Nummulitic limestone; 2. Middle Eocene, black shale and bund; 3. Upper nummulitic limestone; 4. Pliocene sandstones.

#### CROSS-SECTION THROUGH THE "MUD GORGE."

for over 6 miles of line, there had been constant and gigantic movements extending for a mile or more above the railway towards the hills, which were about 10,000 feet above sea-level, thus forcing the railway outwards towards the river. The treacherous nature of such ground was well known to engineers, one of the most prominent cases being that of the tunnel near Heilbronn in Wurtemberg, which had given great trouble many years ago, and resulted in a completely new line being made. The engineers had tried their best to cope with the difficulty; they spent in their zeal between £50,000 and £100,000 in trying to make the railway stable, but they failed, as might have been expected. In 1893, however, the Government of India appointed a small committee, of which he was a member, to determine whether those

operations should be continued, or whether each movement should Mr. Bell. be dealt with as it occurred. The committee carefully investigated the whole matter on the ground, and after considering the many heroic remedies proposed, came to the conclusion, with which probably the Institution would agree, that there was nothing to be done; that the best course was to take each slip or movement as it occurred, slewing over the line, and working with any gradients, or curve up to 300 feet radius, and pushing the traffic through as well as possible. In addition to this, the drainage of the slopes, in order to remove the water from the grounds quickly, was adopted, and since that time there had been comparatively little difficulty. The case, of course, totally differed from that which the Author had described. The one case was entirely a question of water, the other was a case of chemistry and water; but the moral of both was that, before investing large sums of money in public works, an endeavour should be made to test, as far as possible, the geological and chemical conditions of the ground to be dealt with.

Mr. W. R. GALBRAITH thought the Paper set forth the disease Mr. Galbraith. and the remedy. The disease was a large amount of ground moving probably on some stable bed inclined towards the river. In regard to the northern and more serious slip, the Author had said, that directly the irrigation—the supply of water poured in—ceased, the slip was arrested; and he could not see why the same remedy was not applied to the southern slip. It was thought that the purchase of the property now being irrigated would probably involve a large expenditure; but if the northern slip was 155 acres, the land irrigated between the two slips, the southern portion of that which seemed to be causing mischief on the southern slip, could not be much more than 200 acres; and it therefore appeared that the Canadian Pacific Company might long ago, instead of spending £100,000 in continual alterations of the line, have bought the irrigated land and stopped the water. In the case of a railway slip in England the first remedy would be to cut a drain round the back of the slip to take the water off, and the second remedy would be to make two or three drains so as to drain off the water below. The fact that the mere cutting off of the water behind had been effectual in curing the larger and more dangerous slip, seemed to indicate that the same plan ought at once to have been adopted with regard to the southern slip. He did not understand why that had not been tried long ago. If this were the slip of a railway slope a large bank of stone would be erected at the bottom of the dam,

Mr. Galbraith. forming a heavy drystone wall to retain the slope. In the present case this was out of the question, and the only remedy was to drain the slip and stop the water. If that did not cure it he should drive a tunnel through the slip at right angles to the river and draw the water off. He thought that would be much cheaper and better than continually watching and moving the railway, which must be dangerous. A great amount of silt below became impregnated with water, and the heavy mass resting upon it drove the silt into the river, forming a cavity, then the ground settled and broke away into a great number of crevices, causing the railway to be exceedingly dangerous. He thought there was a very simple remedy which might be tried at no great expense—stopping the irrigation in the lower slip, as had been done in the upper. That was what the Paper really seemed to imply; it was a very simple remedy, the amount of ground to be dealt with not being great. If that were effectual on the southern slip the company would be saved considerable danger in working the traffic, and a large amount of money in continual repairs and alterations of the railway.

Mr. Hill. Mr. G. H. HILL had had considerable experience in connection with works constructed for waterworks purposes in different valleys where such slips had taken place. In the case of the Manchester Waterworks there had been, 45 years ago, a very large slip, over which, in the Parliamentary plans, the water-courses were intended to pass. But when the ground came to be examined thoroughly, there was some doubt whether the water-courses could be carried across the slip (the area of which was double that mentioned in the Paper), and Mr. Bateman, the engineer, advised the Corporation to call in the assistance of Mr. Robert Stephenson and Mr. Brunel. Those gentlemen examined the ground, spending the day on the spot, and they came to the conclusion that the proper way to deal with the slip, which measured about  $\frac{1}{2}$  mile across, would be to drive a tunnel underneath it, and then to drive headings in all directions where the water was to be intercepted. The tunnel had been driven, and a great number of adits were put into the hillside from the tunnel; all the water was extracted from the slip, and it became absolutely stable. The water-course was then carried across the slip, conveying about 600 million gallons a day in flood times, and no trouble had since been experienced. It appeared from Plate 1 that, in making the railway up the valley, the cutting away of the old land-slips might have affected the balance, which never had been stable before the railway was made, and that changing of the balance of the

material would probably start the slip again in motion. He had Mr. Hill. himself seen such cases. A slip had occurred in the Ashton water-works of 36 acres; the contractors, in making the embankment, ran a wagon road at the foot of the hill for a distance of 200 yards or 300 yards, and they started 36 acres of land in motion. In the same way, in the making of the railway some of the old slips might have been set in motion. The course he should have adopted would be to begin near the river-level and drive a heading right in, making adits in all directions and tapping the water. If the lower part was stable it would retain the upper part in its position; but there could be no better way of creating a slip than to bring water upon it for irrigation purposes. That would sink through and, coming down to the rock or shale, a movement would take place upon the surface which would be greased by the admission of water. The only way to stop slips was to get the water out; the mere fact of making drains round it would not, he thought, be effectual.

Mr. H. OSBURN considered that if cross-sections of the Thompson Mr. Osburn. river valley had been given, as well as a description of the levels of the land on each side of it, the cause of the slips could be better judged. He had spent two or three days near Ashcroft, at the back of the country where the slips seemed to have commenced. He thought slips had constantly been in progress in that valley, and he was surprised to find that the irrigation above had been given as the cause. One could ride for the whole of a day in that district and only pass one or two ranches, the greater part of the country was entirely uninhabited. He had ridden on a mule up the mountain side, and was able to form an opinion of the country; irrigation was only carried on in a very few places, and it seemed to him very strange that the slides should occur in those places. There were natural streams and reservoirs, and no doubt they sometimes broke bounds, and, rushing down, caused the slips. The whole valley showed, however, that these slides were not unnatural; they were going on constantly.

Mr. L. F. VERNON-HARCOURT had had the opportunity in August Mr. Vernon-Harcourt. and September, 1897, of going to Vancouver by the Canadian Pacific Railway, and though, unfortunately, he did not see the exact places described in the Paper, because the railway train always passed them at night, going and returning, he had seen places alongside the Fraser River, of which the Thompson River was a tributary, where they had been putting the railway further back from the river. The former course of the railway could still be seen; and there had, no doubt, been slips to a certain extent in

Mr. Vernon-Harcourt. that part. If the slides described were really caused by irrigation, he agreed with Mr. Osburn in thinking that in a place like Canada, where there were immense tracts of country perfectly unoccupied in more favourably situated localities, such as the land offered for sale in Manitoba at about 1s. 6d. per acre, and far more fertile than the places described in the Paper, it would be much cheaper to buy out the people who had that small area of land and stop the irrigation than to continue contending with the slides. There were other places on the Canadian Pacific Railway where smaller slips had occurred. He had noticed one especially in the Kicking-horse River Valley, on the western slope of the Rockies, where the sharpest curve upon the Canadian Pacific Railway had to be introduced, where a tunnel had formerly been constructed for the railway through a projecting spur, which, on account of the slides, had to be given up. Apparently some trouble had occurred from slides during its construction; and it was now abandoned, and a sharp curve had been substituted for the railway, running round the spur. That curve was only 262 feet radius. Mr. Cunningham, in his account of that portion of the Canadian Pacific Railway, stated that the spur through which this tunnel had been formed consisted of blue clay interspersed with layers of sand, with an overlying mass of boulder drift.<sup>1</sup> The action of water, he thought, in that treacherous formation had caused the slip. They had, accordingly, been obliged to put in round that spur the sharpest curve on the line of 262 feet radius, the next sharpest being 573 feet radius, or what was known in America as a 10-degree curve. Round that curve the railway went without an elevation of the outer rail, because the curve being so sharp the projecting roofs of the cars, if the rail were super-elevated, would touch one another. A guard-rail had been put in, but it was curious that on most of the other sharp curves a guard-rail was not used. They had put one in, in that case, he supposed, because they were not able to elevate the outer rail. The train went round at a very slow pace, and in that way, with the help of the bogies on which the cars ran, was kept on the line. There were also other places on the line besides the Fraser River where there had evidently been some slips, for example, on the ascending slope of the Selkirks going west, before getting to Rogers' Pass, where they were trying to consolidate some of the fallen portion of a large slip, in a steep ravine above the railway, by directing a stream of water upon it, as in some parts they had consolidated embankments upon the

<sup>1</sup> Minutes of Proceedings Inst. C.E., vol. lxxxv. p. 108.

same principle. The great difficulty with regard to the Canadian Pacific Railway was that, on account of its not being able to follow a regular definite river valley like that of the Columbia River, it had to go through very narrow cañons across the Selkirks and the Gold Range, and therefore there was very little choice of route. Along the Fraser River, moreover, the train ran for some distance in a narrow gorge; and whilst fairly close to the river bank a high cliff rose directly above the railway on the far side. All the way down from the Selkirks, and most of the way from the Rockies, there was very little possibility of changing much of the route of the line. The Columbia River flowed in a very peculiar course, so that although the railway followed along the wide Columbia River Valley for a short distance on leaving the Rocky Mountains, it had to leave the river again soon because it went so far north in order to get round the Selkirks; and the railway crossed the Selkirks by Rogers' Pass. The railway then descended again to the Columbia River Valley where the river flowed south in the opposite direction parallel to itself on the other side of the Selkirks; and as the Columbia River continued its southerly course down to the United States, the railway had to cross it again at Revelstoke, and pass westwards across the Gold Range through the Eagle Pass. There again, though there was but little elevation, the pass was narrow; whilst down the western slope of the Selkirks there was the contracted Albert Cañon, so that there was very little opportunity of modifying the route of the line. How far it would have been possible to have avoided the slides, if the geology of the district had been thoroughly known, by carrying the railway on the other side of the Thompson River he could not say; but it was quite possible that it might have been done, because a little below the confluence of the Thompson River and the Fraser River was crossed by the railway, and the line kept along the western and the northern side of the Fraser River, from thence to Vancouver, and he thought it just possible that though they could not materially change the route of the line, they might have gone on the opposite side of the Thompson River at the site of the slides. The best course now appeared to be to stop the influx of water by buying out the proprietors of the ranches above, and arresting the irrigation where injurious.

Mr. Vernon-Harcourt.

Mr. E. BENEDICT found it difficult to locate the same place on the different maps given in Plate 1. If the degrees of latitude and longitude were given this would be facilitated. Most of the speakers appeared to have overlooked the last paragraph in the Paper; the Author did not mean to stop all the irrigation, but

Mr. Benedict.

Mr. Benedict. to intercept the water just before it reached the railway, thereby making the toe of the slip solid, so that the top would not be inclined to move. It appeared to be a very exceptional place, such as was not likely to be found anywhere else, and the causes of the movement were clearly set forth by the Author. The water in the case described was carried on to the land by small rudely-constructed ditches built almost entirely by the farmers, so that they were not watertight. That was the first step towards the slip. It was seen at Ashcroft that by stopping the irrigation the movement was stopped. It was also said that nearly all the dips were to the westward, and this also tended to start the slips. He thought it was of very little use to discuss the slips that were so exceptional and unlikely to occur elsewhere; besides, the Author himself had pointed out the remedy, and he thought there was no more to be said.

Colonel Pennycuik. Colonel PENNYCUICK, R.E., was, like other speakers, in some difficulty on account of the absence of cross-sections. He imagined there was a deep bluff immediately above the river, with a tableland on the top. In that way the water was distributed over the surface, trying to get down to the river just under the boulder clay, and got to the sand below. In irrigation works in Southern India much the same state of things was often experienced, though on a much smaller scale, and the remedy in every case had been simply drainage. In other words, the water had to be taken out as soon as it got in. In many cases of violent slipping of the rear slopes of embankments, the remedy had been to drive drains into the bank as far as it was safe to go, and to let the water run out freely without passing through the earth. He could not help thinking that something of the same sort was possible in the present case, but without sections it was impossible to say what the proper remedy should be. In the concluding paragraph the Author had stated exactly the remedy he proposed—not to stop irrigation, but to cut off the water, to take it by properly-constructed watertight drains down into the river instead of allowing it to get under the surface of the soil. He knew of one instance, in one of the large tanks of the Madras Presidency, which had an embankment about 40 feet high, where the rear slope slipped so badly that it forced a road which ran along the foot of it 30 feet out of its proper direction, pushing the whole road into the rice-field below. That had been cured by the simple process he described. They cut away the rear slope as far as they dared and drove drains in, running transversely to the bank, and connected by longitudinal drains, which collected all the water that leaked in

and carried it out harmlessly. That was twenty-five years ago, Colonel Pennycuik, and he believed the bank was now as safe as could be desired.

Sir JOHN WOLFE BARRY, President, thought some idea of the cross-section could be formed from a passage of the letter-press in the Paper, which stated that the bluff, where the break-off took place, farthest from the railway appeared to have been about 400 feet in depth, so that it might be imagined a considerable cliff had there been formed to begin with.

### Correspondence.

MR. JAMES R. BELL had had occasion to study the problem dealt with by the Author on a no less gigantic scale at the Mud-Gorge slips in Beluchistan, where in early geologic times a dam of solid limestone rock some 2,000 feet high must have upheld a lake of mud some 10 miles long and 3 miles or 4 miles wide. How far the sides of that lake squeezed together and pressed up the centre of the clay lake hundreds of feet above the dam, or in what other way the clays were upheaved above their original level, their crests on either side of the valley were now far higher than that of the Chappar Mountain which formed the dam. The dam had not failed as a whole, but it had seemingly had a tunnel bored through it by (probably thermal) springs, and the roof of the tunnel falling in while the bed scoured deeper and deeper, the mountain was now cleft in twain by the famous Chappar rift, one of the most remarkable cañons yet encountered by any railway. The present Mud-Gorge Valley had been formed in the clay by the action of a small stream, which had carried away the mud from its bed through the rift. The bed of this stream was alternately raised locally when squeezed up by slips and lowered by cataract-like retrogression of the river-levels. Here and there narrow strips of level "bottom" occurred beside the river, but for the most part its banks conjugated every tense and mood of the verb "to slip" except the past pluperfect. The valley was now about 3,000 feet deep and about 3 miles wide; and beyond the fact that in a recent sequence of drouhty years there had been less trouble than in average rainfall, there was no reliable indication of amelioration. The case might admit of remedies, but such skill as the Government of India had been able to bring to bear on this crux had not yet offered any more promising remedy than to watch the place, and put in deviations of the line as stoppages threatened. It turned