The so-called "Railroad" at Rakaia Gorge.

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Plates 65, 66.

ON pages 388–90 of Haast's *Geology of Canterbury and Westland* (with plate), (Christchurch, 1879), there is a description of a peculiar landscape feature near Rakaia Gorge, locally known as the "Railroad." Haast describes this in some detail, and ascribes its formation to glacier-action, an explanation which presents serious difficulties—some of which Haast, no doubt, clearly recognized—so that the joint authors of this paper have thought that the problem might very well be restated. The conclusions they have arrived at are the result of observations made separately on various occasions, and jointly during three recent visits to the locality.

The feature referred to may be briefly described as resembling a broad railway-cutting, hence its name (see Plates 65 and 66). It is three miles long, about five chains wide at its upper end, six chains in its middle portion, and between six and seven—perhaps more—at its termination. It runs in a south-easterly direction from the top of the high bank of the Rakaia near the Bayfield Homestead, where the river has excavated its bed to a depth of some 600 ft. in gravels and old lake-silts, to the northern slopes of Bryant's Hill, a rhyolite *roche moutonnée* near the lower end of the gorge. In this distance it climbs four old river-terraces, but ends at a slightly lower level as compared with that at which it starts. The first terrace is only about eight chains wide, but the features of the "Railroad" are not marked at this point. They begin to be distinct on the top of the next terrace, where the depression may really be said to commence (see Plate 66), and from this to the end the ground falls about 40 ft. according to aneroid readings; but it must be remembered that as each successive terrace is encountered there is a marked rise in the bed (Plate 65, fig. 2), and this is also the case near the end as Bryant's Hill is approached, in the vicinity of which the terraces disappear.

The depth of the depression below the level of the adjoining land-surface varies from about 20 ft. at a maximum on the top of the third terrace —it is 15 ft. on the top of the second terrace—to nothing on Bryant's Hill; but it must not be assumed that the decrease is regular, since in one section the difference in level may be pronounced, while in any adjacent section it may be slight or absent. In general, the greatest depth appears to be just on the edge of a terrace, with a progressive diminution in depth as the depression is followed to the bottom of the next terrace, where its boundaries may become quite indistinct. This peculiarity should be noted in connection with the features attributable to wind-action. Also, the depth on opposite sides of the same section is not uniform. In general, it is greater on the side where the neighbouring land is at a slighter higher level than it is on the other side of the "Railroad." Thus there is no marked difference on the top of the second terrace, which is somewhat flat, and which

is met by the line of the depression nearly at right angles; but in the case of the next terrace the circumstances are entirely different (see Plate 65, fig. 2). Here the angle between the line of the depression and that of the edge of the terrace is considerably less than a right angle, and on the north-eastern side the bank is much higher than on the south-western side; whereas on the ridge leading up to Bryant's Hill, where the slope of the ground is to the north-east, the bank is decidely higher on the south-western side. A distinctive feature is the presence of a raised bank on either side, somewhat like a natural or artifical river levee, with a height above the level of neighbouring land-surface ranging usually from 0 to 4 ft., but occasionally as much as 6 ft. Where it could be examined it proved to be formed of wind-blown material similar to the soil covering large areas of the Canterbury Plains. The accumulation of loose material is most marked at the upper end nearest the river, whence plentiful supplies are derived, partly from the present river-bed, and partly from the glacial silts of the old Rakaia lake, which occupied a depression behind the rock bar near the gorge immediately after the retreat of the ice. The fine material is swept from this area by the powerful north-west winds which are a notable meteorological feature of the district (note such names as "Windwhistle Point" and "Windwhistle House"). In none of the loose material did we see any angular blocks, although Haast says that they do occur sparingly. There is no doubt whatsoever that the formation of the levee must be credited almost wholly to wind-action.

The floor of the depression is covered with rounded and subangular blocks with an admixture of soil similar to that composing the bank. The soil is in places somewhat scanty, but occasionally it forms rough irregular mounds. These were considered by Haast to be morainic heaps, but those examined by us were rather of the nature of dunes, such as occur now in places near the edge of the high terraces. There are similar banks of wind-blown material off the line of the "Railroad" to the west, where there is a considerable area of land from which the soil has been swept and deposited in irregular heaps at the bottom of an adjacent terrace. At this spot, too, as well as near the tops of gullies reaching up from the river-bed, there are long trailing mounds of loose material formed parallel to the direction of the wind, as well as irregular mounds lying across its path. The irregular ridges lying on the first terrace practically opposite the end of the depression may quite well be attributed to this cause, their alignment with the edges of the depression being perhaps a coincidence.

However, in view of the widespread occurrence of morainic blocks in the neighbourhood, it is quite possible that some of the heaps in the floor of the depression may be morainic or may have a core of morainic material. In places, usually along the base of a terrace, the floor of the depression is swampy, the water which accumulates being due either to the formation of pond-like hollows in the dune-complex, or to the presence of a small stream which has followed along the bottom of an old river-terrace, where the ground is, as a rule, somewhat lower.

Perhaps the most remarkable feature of the "Railroad" is the way it climbs the old river-terraces, and specially the third terrace, about three-quarters of a mile below the Bayfield Homestead. The terrace is here about 20 ft. in height, and the line of the "Railroad" turns off at an angle of 15°, ascends the rise obliquely, and then reverts to its former direction (see Plate 65, fig. 2). Whatever the cause of this landscape feature, it is certainly of a date posterior to the formation of this terrace and the others

FIG. 1.—View looking north-west up the Rakaia Valley, taken from the top of the third terrace, showing general features of the "Railroad." Faceted slopes of Mount Hutt on the left.

FIG. 2.—View looking south-east from the base of the third terrace, showing the "Railroad" rising over the terrace, with higher bank on the left; a patch of dunes almost in alignment with this bank.

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View looking south-east near top of the second terrace, close to the Bayfield Homestead. The banks of the "Railroad" are near the margins of the picture, the floor of the depression being planted with *Pinus radiata;* the depth of the depression may be inferred by comparison with the height of the wire fence. The slight rise in the foreground on the left is merely an irregular heap on the floor of the main depression, and of no special importance, being quite an accidental feature.

which it crosses. The rise from the river over the first terrace noted by Haast is, in our opinion, somewhat delusive, and is due to the accidental formation of dunes in an approximate line with the edges of the depression. Finally, there is a point which must be noted as to variations in width—viz., the presence of a number of contractions due to reductions arranged in rectangular steps. These are excellently shown where the line of the depression edges away on climbing the terrace just referred to.

The possible explanations of the origin of this landscape feature which should be considered are as follows :—

1. It is an old stream-bed. This is ruled out of consideration on account of the rising grade on meeting old river-terraces (see Plate 65, fig. 2), and also on reaching the slopes of Bryant's Hill.

2. It is the bed of a glacier. If this is so the phenomenon is unique; but there are insuperable objections against this explanation. The side levees are, according to Haast, old lateral moraines, but they are composed almost entirely, even according to his own showing, of fine material, and are not formed of the angular blocks usually constituting moraine. Then, again, it is difficult to imagine the precise method by which a glacier eroded such a hollow, climbed terraces without appreciably disturbing the material of which they are formed, and finally occupied the crest of a ridge leading up to Bryant's Hill. The most decided piece of evidence against a glacier origin is based on the fact that the phenomenon dates from a time posterior to the formation of the whole terrace-system of the locality. These terraces are formed by stream-action in an area from which the ice had disappeared; and they are to be attributed entirely to the work of streams issuing from the ice-front as it retreated up the valley. Had they been pre-glacial they could not have survived in their entirety the erosive action of the great glacier which passed over the ground between Mount Hutt and the Rockwood Range, where the ice must have been from 1,000 ft. to 1,500 ft. deep (note the height of the faceted slopes of Mount Hutt in Plate 65, fig. 1). It is certain however, that there were at least two, probably several, periods of glacier advance and retreat, but these have not yet been definitely determined, and, in any case, the objections made to the glacier explanation will hold good even if the advance was of minor importance. If, then, the terraces are post-glacial, the phenomena must be post-glacial and cannot be credited to ice-action.

3. It is due to wind-action. While admitting that wind is responsible for certain features, one cannot credit wind with forming an excavation with subparallel sides, three miles in length, and cut out of terrace-gravels, and perhaps out of underlying rhyolite. Although this rock is not visible in the floor, yet it certainly lies at a shallow depth, judging from the neighbouring exposures, and it may be covered by a thin veneer of loose material in the track of the excavation.

4. It is due to faulting. According to this explanation it may represent an earthquake-rent, such as can be seen near Glen Wye, on the upper Waiau River (see McKay, *Report of Geological Explorations for 1890–91*, p. 16). If this explanation is correct, the depression can be attributed to trough-faulting. This will explain the long subparallel margins, and the rectangular modifications of width can be regarded as due to fault splinters of the main fault-line. Although we think this explanation the most satisfactory, we have arrived at it largely by the method of exclusion, and not because there is positive evidence of faulting along the line. Evidence of dislocation was looked for where the upper end terminates on a high cliff-like bank facing

the river, but the absence of any distinct bed which could be used as a reference level made investigation unsatisfactory. The only bed which promised anything of value was a layer of large subangular boulders near the top of the bank, which no doubt formed the floor of an older river-channel now buried up by fine wind-blown material. There was, however, no sign of any dislocation in this layer, nor in the bands of finer material interstratified in the coarser gravels; but the conditions attending the deposit of gravel and silt in such positions render them extremely unreliable in matters of this kind, and especially so where the exposures are not clear and where the slumping of incoherent beds from a high river-terrace is reasonably certain to have occurred. A local difference in level of the bed of large boulders just referred to may be attributed to river-scour when the bed was being laid down; it is also slightly off the line of the depression, which makes a turn of about 10° at its upper end, and as a result no clear exposure on its line occurs. The possibility of any supposed dislocation petering out must also be considered. The raised banks nearly on a line with the depression are perhaps due to trails of wind-blown material which has come up a gully leading from the river-bed, and their alignment as they reach the level of the next terrace has been determined by the position of the margins of the depression, an agreement in line or arrangement which is well shown on the wind-scoured terrace to the westward, and which is connected in some way with the wind-eddies there formed.

There is some faulting in the vicinity, for the rhyolite rocks in the gorge are extensively slickensided (in one place they have been pushed over undoubted glacial deposits); but this implies a movement with a N.E.-S.W. orientation. There is strong evidence that the Rakaia Valley is primarily of tectonic origin (see E. Dobson in his report for the year 1865 on "The Possibility of constructing a Road through the Otira Gorge"; and Speight on "The Orientation of the River-valleys of Canterbury," *Trans. N.Z. Inst.*, vol. 48, pp. 142–43, 1915). If this is so, then the axis of the deformation is oriented in a N.W.-S.E. direction, parallel to the general direction of the "Railroad."

It is thus possible that the movements may have continued down to a very late geological time. There are definite occurrences of recent dislocation on this line—*e.g.*, that recorded from the Waipara Valley by Speight and Wild (*Trans. N.Z. Inst.*, vol. 50, pp. 76–77, 1918), as well as of dislocations on other lines—so it is not improbable that the phenomena may indicate such a movement.

It is possible that the levees may have been formed as a result of lateral squeezing, but judging from the loose nature of the material of which they are composed they must be almost entirely attributed to wind-action. The line of the depression lies right in the direction of powerful winds which would sweep through it with considerable violence, bearing the fine material from the up-stream river-bed, and depositing a proportion of it on the margins where the force of the wind was less and friction greater; and the vigorous tussocks growing in the loamy soil would aid materially, when once they were established, in building up the levees by intercepting an increased amount of the wind-blown material swept through them. The greater height of the levees on the edge of a terrace, and it tailing away somewhat down-stream, so to speak, would easily be accounted for, as the action would be more pronounced just on the edge of the terrace, where local eddies would cause a dropping of the material more readily.