Note.—Early in March, 1910, Mr. A. Hamilton reported the occurrence of a great andesitic-boulder deposit between the Waimarino Plain and Raurimu, on the Main Trunk Railway. Later in the same month I examined this area, and found that the western limits of the Waimarino Plain were occupied or fringed by a crescent-shaped chain of morainic hills and ridges rising from 50 ft. to 200 ft. above the level of the plain. This morainic mound stretches from the Maunganui-a-te-ao, on the west side of Ruapehu, to the Upper Wanganui, a distance of over twenty miles. Its breadth varies from two to four miles. On the railway-route it ends near Raurimu, where it is covered with a heavy drift of pumice. The Main Trunk Railway, where it crosses the Waimarino Plain, runs along the foot of the moraine for some miles. Further north the railway traverses an andesitic drift between Oio and Owhango.

North of Waimarino Station the railway passes through the morainic chain for several miles, descending to Raurimu by a series of sharp loops which are known as the "Spiral." In this portion of the line the structure of the moraine is beautifully exposed in miles of deep cuttings. The material is seen to consist of a tumbled mass of large and small angular andesite blocks mingled with reddish-brown clay and rock-rubble.

Water-worn material is absent or rare in the morainic hills traversed by the railway between Waimarino and Raurimu; and it is only when the line passes into the course of the old glacial valley of the Upper Wanganui, south of Oio, that the andesitic-boulder formation as exposed in the road and railway cuttings is found to contain a proportion of water-worn gravel and boulders.

The Waimarino moraine is a typical example of a terminal moraine. It was obviously formed by the confluent glaciers descending from the west side of Ruapehu, Ngauruhoe, and Tongariro.

Art. LIX.—*Further Notes on the Glaciation of the North Island of New Zealand.*

By Professor James Park, F.G.S.

[*Read before the Otago Institute, 7th December*, 1909.]

In the month of November last, accompanied by Mr. A. Hamilton, Director of the Dominion Museum, I made a further examination of the great andesitic glacial drift in the lower Hautapu Valley, already described by me in a paper read before this Society in August of the present year. The primary object of our visit was to obtain photographs of the glacial deposit, and in this we were fairly successful, although the weather-conditions were not as favourable as could be wished for.

A small patch of the andesitic deposit is seen in the railway-cutting a short distance west of Waiouru, and a pile of andesite blocks lies on the coach-road to Taupo, about three miles from Waiouru; but it is only when we reach the edge of the forest-belt, near Turanga-a-rere, that the glacial

deposit becomes so well developed as to attract attention. From Turanga-a-rere southward to a point half a mile or so past Taihape the andesitic material is almost continuous, being particularly conspicuous in many of the deep railway-cuttings, and along the coach-road that follows the Hautapu Valley.

A very fine section of the andesitic till is exposed near the 250-mile post, about a mile south of Turanga-a-rere Railway-station. At this place the railway-cutting passes through the glacial drift for a distance of 15 chains, exposing at one place a face 40 ft. high.

The andesite boulders are mainly angular, semiangular, or partially rounded. They range from a few inches up to over 10 ft. in diameter. And in this cutting there are also seen large angular masses of soft Tertiary sandstone mixed with the andesite blocks. The spaces between the andesite rubble are filled mostly with gritty clays, sandy material, and small pieces of andesite, mixed with a small amount of water-worn pebbles and small boulders. The general appearance of the deposit is well shown in Plates XLV, XLVI, and XLVII.

Many of the harder andesite blocks present smooth polished surfaces on one side. These surfaces are sometimes undulating or rounded, and

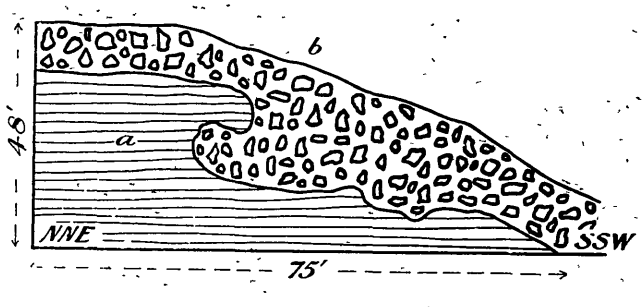

FIG. 1.—SECTION OF RAILWAY-CUTTING AT ONE-QUARTER MILE PAST HAUTAPU FALLS.
a. Pliocene sandy clays. *b*. Glacial drift.

sometimes perfectly flat. The polished surface of one boulder presented very distinct striæ.

At the south end of the big bend, about three miles south of Turanga-a-rere, at a point immediately opposite the Hautapu Falls, the andesite till crowns the hills to a height of 300 ft. above the floor of the valley. Overlooking the falls there is a nest of large andesite blocks, one of which measures 8 ft. by 6 ft. by 6 ft., and another 9 ft. by 7 ft. by 6 ft., the weight of the last being about 27 tons. These blocks are large irregular-shaped masses, with one side well polished. A group of these blocks is shown in Plate XLVIII.

It should be noted that the masses of andesite that lie on or project above the surface often show a tendency to assume a more or less rounded shape, through the process of spheroidal weathering which so commonly affects rocks of a basic or semibasic type.

The surface of the Pliocene clays on which the till rests is generally deeply eroded; and in many places it has been excavated into grotesque

forms, as shown in fig. 1, where the soft clay is undercut, and in Plate XLIX, where a sharp spine-like point of clay projects into the overlying till.

At the north end of the tunnel near the 251¾-mile post there is a fine exposure of the glacial deposit in a cutting about 8 chains long. Here, as at the 250-mile post, the andesite blocks are mingled with many large angular masses of soft Tertiary sandy clay torn from the adjacent bed-rock. These masses of soft sedimentary material are quite angular, and so soft that they could not have withstood even for a few yards the pounding action of running water; hence we are forced to conclude that they now lie in the places where they were dropped by the ice.

At the 252½-mile post there is a deep cutting in which the andesite till is seen to overlie unconformably a series of stratified clays, sandy clays, and loose gritty tuff-like beds composed of andesitic material, the exposed thickness being about 50 ft. This stratified series is obviously of fluvio-glacial origin. At its base it contains a tapering lens of fluviatile drift (*b*),

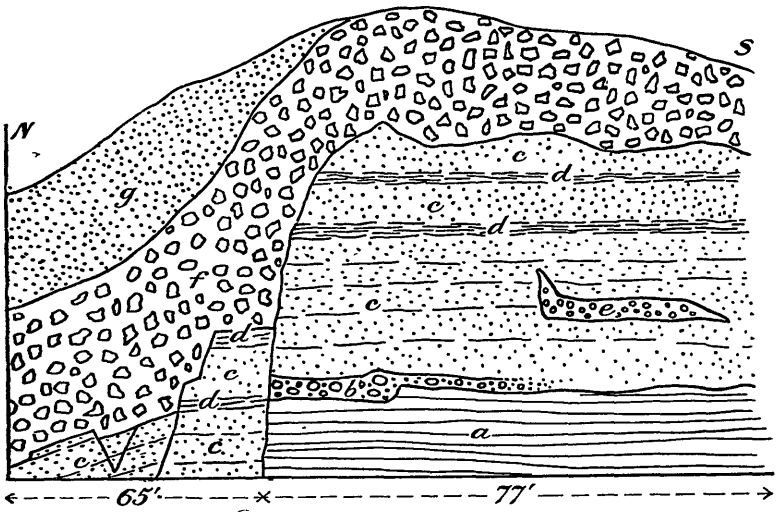

FIG. 2.—SECTION OF RAILWAY-CUTTING (SOUTH SIDE) AT 252½-MILE POST, THREE MILES AND A HALF SOUTH OF TURANGA-A-REERE. (Scale, 1 in. to 60 ft.)

a. Pliocene marine clays (papa). *b*. Andesite gravel. *c*. Sandy clays with tuff-like andesitic beds. *d*. Clayey beds. *e*. Irregular deposit of coarser andesitic grit intercalated in sandy beds. *f*. Glacial boulder rubble or till. *g*. Yellow clays.

the greatest thickness of which is 5 ft. The whole series is intersected by a number of very distinct faults, some of which are shown in fig. 2.

The faulting took place before the deposition of the upper andesite rubble drift or till, as shown by the circumstance that the till rests unconformably against the faulted ends of the stratified beds. Moreover, the faults do not affect the till in any way.

This evidence is of great importance, as it clearly points to the existence of two phases of glaciation in the North Island during the Pleistocene. This section is shown in fig. 2 above and in Plate L.

The glacial till is well exposed in the railway-cuttings between the tunnel at 252½ miles and Ngaurukehu Siding, and between Mataroa and Taihape.

South of Mataroa the glacial till rises on to the summit of the ridges bounding the Hautapu Valley, at many places lying at an elevation of over 2,000 ft. above the sea, or from 800 ft. to 1,000 ft. above the floor of the valley.

Near Mr. W. Shewan's house, about two miles south of Mataroa, there is a perched block of andesite measuring 11 ft. by 6·5 ft. by 6 ft., and weighing over 30 tons.

At Mataroa quarry the andesitic till is seen resting on a fluvio-glacial drift that occupies a gulch in the young Tertiaries. This gulch is obviously the gutter or channel in which the subglacial river ran. In Scotland the boulder-clay is frequently found resting on fluviatile drifts lying in ancient valleys.

The Mataroa drift is mainly andesitic, but there are also present many partially rolled blocks of the harder calcareous sandstone that occurs in nodular form in the blue clays. These blocks are very numerous at the base of the drift; but they also occur scattered throughout the whole mass, which is rudely stratified, and in places shows current bedding.

The andesitic till is strongly developed around Taihape, more especially on the west side of the Hautapu Valley. Plate LI shows the drift lying on the hillside near Taihape Railway-station.

A mile below Taihape, and at many places on both sides of the gulch in which the Hautapu River flows, there are many fine exposures of the re-sorted andesitic gravels formed by the Hautapu River when it ran at the higher flood-level. These gravels can be traced southward almost continuously to the junction of the Rangitikei River. Here and there they form high-level terraces along the course of the river, their upper surface marking the ancient flood-level of the river. They do not rise above the 1,450 ft. contour, and descend by a gentle gradient to the junction of the Rangitikei River. The material is mainly andesitic, and there is no difficulty in distinguishing it from the glacial till, which consists of large masses of andesite set in a clayey and sandy matrix, and forms a sheet on the spurs and ridges above the 1,450 ft. contour.

I have elsewhere described the Hautapu andesitic deposit as a boulder-clay or till of glacial origin, and my more extensive examination in November last, in the company of Mr. Hamilton, has more than confirmed my earlier conclusion.

For the first twenty-five miles nearest Ruapehu the deposit consists almost entirely of clays or sandy material containing blocks of andesite sparsely throughout it. About a mile and a quarter north of Turanga-a-rere andesite boulders are numerous and small in size; but going down the Hautapu—that it is, further from Ruapehu, the source of the andesite—the blocks become more and more abundant, and also of greater size, until we reach the ridges between Mataroa and Taihape, where we find masses ranging up to 30 tons in weight perched at a height exceeding 2,100 ft. above the sea, at a point over thirty miles from their source at Ruapehu. On Mataroa Hill the blocks lie at about the same height as that of the divide between the Wangaehu and Hautapu watersheds.

There is no agency but glacier-ice known to science competent to tear huge masses from their parent rock, transport them over a divide into another watershed, and scatter them in a sheet over an area of several hundred square miles in extent, at their extreme limit over forty miles from their source. And, as previously noted, the greatest development

and largest masses of rock occur at the southern limit, and the least development and smallest blocks nearest the source—the converse of the conditions that pertain with river deposits.

In all its physical characters the Hautapu till resembles the boulder-clay of England and the till of Scotland. Perhaps the only point of difference is that the Hautapu till contains less water-worn material than that of Britain, and only a fraction of that contained in the ancient moraines of Otago.

The great Taieri moraine, which extends along the coastal hills from near Dunedin to the Clutha, contains over 40 per cent. of water-worn material; while the Kingston moraine, at the south end of Lake Wakatipu, the Queenstown, Kawarau, and Clyde moraines, contain over 50 per cent.

The till of Scotland is described by Geikie* as a mere unstratified conglomeration of boulders and gravel in a matrix of stiff clay. This is undoubtedly its prevailing character, but it also contains lenticular stratified beds. In another place he says,† "A boulder-clay is not merely a clay with a greater or less number of boulders scattered through it; it is rather an earth—a mixture of gritty clay, sand, gravel, and boulders heaped together indiscriminately in constantly varying proportions."

EXPLANATION OF PLATES XLV–LI.

PLATE XLV.

On the Main Trunk Railway at the 247¼-mile peg near Turanga-a-rere. Photo by J. Park.

PLATE XLVI.

Near the middle of cutting at the 250-mile peg near Turanga-a-rere. Photo by J. Park.

PLATE XLVII.

Big cutting near the 250-mile peg about a mile south of Turanga-a-rere. Photo by A. Hamilton.

PLATE XLVIII.

Perched erratic rocks near Hautapu Falls, at big bend past Turanga-a-rere.

PLATE XLIX.

Glacial drift lying on eroded surface of Pliocene clays or papa, in big cutting about a quarter of a mile past Hautapu Falls, near big bend south of Turanga-a-rere. Photo by A. Hamilton.

PLATE L.

Showing faulted older glacial deposit overlain unconformably by younger glacial till, in cutting at 252½-mile, about 5 miles south of Turanga-a-rere. Photo by A. Hamilton.

PLATE LI.

Near Taihape Railway-station. Photo by J. Park.

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* A. Geikie: "Glacial Drifts of Scotland," p. 36.
† *L.c.*, p. 35.