GUATEMALA EARTHQUAKE OF 19TH APRIL, 1902.
Preliminary Tremors.

Milne H.P. Station.	Epicentral Distance along Arc (y).	Epicentral Distance along Chord (y^1).	Time of Arrival of Preliminary Tremors. (Greenwich Mean Civil Time.)	Time taken in Transit (t).
	Kilometers.	Kilometers.	(Time at Origin, 2h. 26m.) H. min.	Secs.
Toronto	3,422	3,381	2 30·5	270
Victoria (British Columbia)	4,800	4,687	2 31·3	318
Bidston (Liverpool) ..	8,578	7,944	2 35·0	540
San Fernando (Spain) ..	8,600	7,961	2 34·8	528
Shide (Isle of Wight) ..	8,744	8,073	2 35·4	564
Kew (England)	8,822	8,133	2 36·2	612
Wellington (New Zealand)	11,189	9,804	2 38·0	720
Tokyo	12,278	10,462	2 38·8	768
Bombay	15,922	12,085	2 43·3	1,038
Perth (Western Australia)	16,667	12,298	2 43·8	1,068
Batavia	17,856	12,552	2 43·7	1,062

ART. XLVII.—*On some Glaciated Stones from Queenstown, Lake Wakatipu.*

By EVELYN G. HOGG, M.A.

[*Read before the Canterbury Philosophical Institute, 30th November,* 1904.]

THE glacial deposits of New Zealand present one feature in a marked degree which serves to differentiate them from the similar deposits of other regions—namely, the extensive accumulations of morainic material with the almost entire absence of boulder-clay or till. The beds of boulder-clay are widely distributed over the recently glaciated parts of western Europe and North America. They are met with in considerable thickness in the Dwyka conglomerate of South Africa of Permo-Carboniferous age, and the glacial beds of the same age in south and south-eastern Australia may be traced almost continuously from Hallett's Cove, west of Adelaide, to Bacchus Marsh, in Victoria, by the accumulations of boulder-clay nearly always rich in striated stones. Boulder-clays of Permo-Carboniferous age occur on the west, north-west, and south-east coasts of Tasmania. On the other hand, these glacial beds of Australia and Tasmania are strikingly deficient in terminal moraines such as those which constitute a marked characteristic of the New Zealand beds. The nearest parallel, perhaps, to the New Zealand glaciation is that of Switzerland and North Italy, but in this

region the occurrence of striated stones in the glacial deposits, as for instance in the neighbourhood of the Lake of Zurich, is by no means rare.

Soon after my arrival in New Zealand my attention was drawn to the apparent absence of striated stones from the ice-formations of the country. Such literature on the geology of New Zealand as came under my notice was destitute of any mention of striated stones, and an examination of the striated stones in the Christchurch Museum showed that none were of local origin. Under these circumstances the discovery by my wife and myself of striated stones at two localities near Queenstown, Lake Wakatipu, seems of sufficient interest to be placed on record.

To the east of Queenstown lies a hill, locally known as Queenstown Hill, which rises to a height of about 1,000 ft. above the level of the lake. It is separated from the south-east spurs of Ben Lomond by a narrow gorge running north, through which passes the road to Arrowtown. On the south side it slopes gradually down to the narrow arm through which the lake-waters issue towards the Kawarau Falls. The hill is composed of schists and clay slates dipping in a westerly direction. At the foot of the hill is a thick deposit of coarse river-gravel, well exposed near the Roman Catholic Church. The lower part of the hill is covered with small scrub; higher up it is well grassed, though as the top is reached the bed-rock shows itself in increasing amount. A zigzag path has been cut recently up the west and south-west faces of the hill, and in making this path a considerable quantity of loose rounded stones has been exposed either on the path or on both sides of it. On ascending the hill by this path with my wife in January last our attention was attracted by the occurrence of rounded stones at a point about 400 ft. above the level of the lake. A close examination showed us that they were not river or lake gravel, but genuine striated stones, presenting all the typical signs in general shape and markings. They were met with at intervals as high as about the 600 ft. level, but above that we did not find them. Two of the specimens from this locality have been placed by Captain Hutton in the Christchurch Museum.

The other place at which we found the striated stones is about a mile and a half from Queenstown on the new carriage-road which is being made westward along the margin of the lake. The road in places has been cut through the surface-soil, and here the striated stones lie exposed in the bed of the road at a height of not more than 50 ft. above the level of the lake. They are not such good specimens as those obtained from the hill-track, but of their mode of origin there can be no doubt.

Such, briefly, are the conditions under which the striated stones occur, lying loose on the ground only where the grass or vegetation has been removed to a depth of a foot or more. Careful search failed to find any exposure of a matrix of clay or other material of glacial origin in which the stones were imbedded. If a boulder-clay exists at either of the localities in which the stones have been met with it will probably only be found by removing the soil to some depth. The occurrence of striated stones thus lying loose in the surface-soil is somewhat similar to the case of the glacial beds of Coleraine, Victoria, where there are large areas in which almost every stone lying loose on the ground is striated, while the matrix of boulder-clay is found only slightly exposed in two localities at a considerable distance from the areas in question.

The striated stones were all coarse- or fine-grained sandstone, often indurated. There is nothing to show that they may not be of purely local origin. There was no trace of granite or other rock quite foreign to the district. The stones were of moderate size, the longest dimension of the largest one seen not being more than 10 in. Nothing of the nature of a smoothed or striated surface of the bed-rock was to be seen, nor anything which could with certainty be described as a *roche moutonnée*.

Apart from the discovery of the stones themselves, the feature of greatest interest is the height above the lake-level at which they occur on the hill-track; but before dealing with this point it is necessary to refer very briefly to the general question of glaciation in the Lake Wakatipu basin.

There seems little reason to doubt that through the midst of the region now occupied by the waters of Lake Wakatipu originally flowed a river of large dimensions, whose course was continued through the area now occupied by the terminal moraine at Kingston. At a subsequent stage a submergence of the land sufficient to admit the waters of the ocean took place, and during a prolonged period of time beds of shale, sandstone, and limestone were being deposited in what is now the lake-basin. These beds attained a thickness of 600 ft., and are found on both sides of the lake, and it is therefore highly probable that they extended continuously right across the lake-basin. As they rest unconformably on the eroded edges of the underlying schists, and at Twelve-mile Creek dip in towards the lake at an angle of 15°, it is clear that considerable denudation had already taken place over the area of the lake-basin before the formation of these later beds. The scooping-out of the trough in which the limestone and its associated beds rest has been attributed to ice-action, but no sufficient evidence is forthcoming to support this view. Later on there was a re-elevation of the land, and again the work of

excavation took place. The limestone was cut through, and then the subjacent rocks, until a well-defined valley once more existed. Then came the great Glacier age, and down this valley moved a glacier formed by the junction of glaciers from the Rees and Dart. This glacier continued the work of excavation started by the ancient river. It is, of course, difficult to apportion to the river and the glacier the amount of excavation due to each. By some geologists it is held that while glaciers have considerable powers of abrasion they have little or no powers of excavation. The present bottom of Lake Wakatipu is between 300 ft. and 400 ft. below the sea-level, and if the main work of excavation was done by the river it is of course necessary to postulate that the bed of the river was considerably more than 300 ft. higher than the deepest part of the present bottom of the lake, as a large amount of filling-in may have taken place since the ice-front retreated and Lake Wakatipu was formed.

The existence of the sounds on the west coast of New Zealand seems to point to a widespread submergence of this region, as there is little reason to doubt that these arms of the sea were originally valleys eroded first by water and then by ice-action. On the other hand, if the excavation has been for the most part performed by a glacier, it is extremely difficult to explain away the marked absence of the graving-tools by which such excavation was done. The rock *débris* by which the bed of the glacier had been worn deeper and deeper would itself present evidence of the grinding and eroding processes in which it had taken part, and rounded, smoothed, and striated stones and boulders should exist in an abundance somewhat proportional to the erosion which had been effected through them.

Leaving this debatable point, we know that the glacier must have filled the lake-basin to a height slightly greater than the present level of the water. The main glacier was, in the opinion of Captain Hutton, joined at Frankton by the confluent glaciers of the valleys of the Arrow and Shotover, and the united ice-mass moved south to Kingston, where an extensive terminal moraine marks the stopping-place of the ice-front. During a long period of time accumulations of ice-borne *débris* must have been dumped here, filling the valley and finally erecting across it the dam which now blocks up the south end of the lake. Against this dam, and along the valley-bottom near and for some distance north of Kingston, the retreating glacier must have continued to deposit its burden of fine and coarse material. With the retreat and melting of the ice began the formation of Lake Wakatipu. The waters accumulated, and, their overflow escaping by the lowest available point, the River Kawarau came into existence. The presence of terraces at various points along the

shores of the lake shows that the waters once stood about 100 ft. higher than their present level.

It is well known that the recreation-ground at Queenstown, lying to the south of the town, and projecting as a narrow tongue of land into the lake in a westerly direction, is a moraine: it is important to note that no traces of this moraine are to be seen on the flanks of the Queenstown Hill except near the lake-level.

Two hypotheses may be framed tentatively to account for the presence of the striated stones at the high elevation at which they occur on the hill-track. The glacier flowing down the lake would have from White Point to Queenstown an easterly direction, and at the latter place its northern fringe would have its path directly barred by the Queenstown Hill. If there had existed a moderate slope to the hill on its western face it is possible that the edge of the glacier was impelled up the slope and reached the elevation of 600 ft. above the lake-level at which the striated stones now exist, while the blocking of the edge of the glacier here might be held to explain the presence of the moraine at the recreation-ground.

There are instances on record of a glacier having moved uphill under the action of an enormous *vis a tergo*, but this force is operative to the greatest extent on the deeper-seated parts of a glacier, and to a much less extent on the surface portions and edges of the glacier. It is to be noticed that the morainic material exists now only at and just above the lake-level, and also that there is a large area lying just north of the recreation-ground—what may be called Queenstown Harbour—which appears to be free from the morainic *débris*, when we should have expected it to have accumulated here if there had been any serious blocking of the glacier at the foot of Queenstown Hill—and there are great difficulties in supposing the morainic material to have been there once to the same extent as on the recreation-ground, and to have been subsequently removed by a creek or river which has now ceased to flow from any cause, or has had its course diverted. The terrace formation at Queenstown and the bed of river gravel previously referred to point to the former existence of a river discharging into Lake Wakatipu at Queenstown after its formation as a lake.

The deep gorge running north and separating Queenstown Hill from the south-east spurs of Ben Lomond must have been originally eroded by water or by ice. There is no antecedent improbability in picturing the watershed of the river which flowed through this gorge as having been the collecting-ground for snow which furnished a small tributary glacier which joined the lake at Queenstown, and, depositing its accumulated burden of material on the site of the recreation-ground, has built up the

moraine now existing there. The discovery in this moraine of blocks of greenstone or sandstone which could only have come from the west side of Lake Wakatipu does not disprove the theory just put forward as to the origin of the Queenstown moraine, as at the point where the tributary glacier joined the main glacier there must have been considerable commingling of material. Postulating, therefore, a glacier as once descending the gorge west of Queenstown Hill, we see, from the amount of river gravel and shingle deposited in the terrace at Queenstown, and also from the shallow depth of Lake Wakatipu in Queenstown Harbour, that after the glacier had ceased to flow, a stream of considerable size must have flowed through the gorge and deepened it to its present level, and therefore that when the glacier existed it must have moved at an elevation considerably above that of the present gorge, and this height may have been sufficient to enable the glacier to deposit in their present position the striated stones occuring on the hill-track. What subsequent changes of level have caused the river which once flowed through the gorge to flow no longer I am unable to state, but there can be no doubt that a river did once flow through the gorge.

The striated stones found on the carriage-track west of Queenstown were in all probability deposited there by the Lake Wakatipu glacier: there is no such difficulty of level as exists in the case of the stones on Queenstown Hill to be met in this case.

ART. XLVIII.—*The Artesian-water Basins of the Heretaunga Plain, Hawke's Bay.*

By H. HILL, B.A., F.G.S.

[*Read before the Hawke's Bay Philosophical Institute, 19th September,* 1904]

Plates XXXIV–XLI.

THE Town of Hastings is situated almost in the centre of what is locally known as the Heretaunga Plain. Napier is at the northern end of the plain, and Pakipaki, for our purpose, may be set down as situated at the south end. Few persons, had they known the plain as it was even forty years ago, would have thought so many thriving settlements would have sprung up in what was at that time an area just emerging from the condition of impassable swamp.

At the time of the arrival of the first European settlers in Hawke's Bay the fertile area that is now the pride of the district was an untrodden swamp. Only sixty years have gone by since then, and it must be evident even to those not given to careful observation that the changes mark a period of progress that