Art. XLIV.—Observations on the Eruption of Mount Tarawera, Bay of Plenty, New Zealand, 10th June, 1886.

By J. A. Pond and S. Percy Smith, F.R.G.S.

[Read before the Auckland Institute, 12th July, 1886.]

The 10th of June, 1886, is likely ever to be remembered in the history of New Zealand as that on which the colonists first had practically brought home to them the fact that the volcanic forces for which these islands are so celebrated had still an amount of vitality in them that was unlocked for and unexpected. The eruption of Tarawera Mountain, and the conversion of Rotomahana Lake into a crater, on that date, at about 2.15 a.m. has caused widespread consternation, the loss of several lives, and a feeling of anxiety as to whether this outburst will be confined to the immediate district where it occurred, or whether it will spread to others in which the signs of thermal action have been known for long periods.

Description of Volcanic District.

The volcanic districts of the North Island have been correctly described by Hochstritter as occupying three zones: the first, as that from Tongariro to White Island; the second, as that of the Isthmus of Auckland; the third, as that of the Bay of Islands.

There are many very essential differences in the general character of the results of volcanic action in these three zones, the first-named being that in which any extent of vitality appears to have remained unto the present day; though the Bay of Islands District has still its group of hot springs, whilst that of Auckland, so intimately known to all of us, has ceased to show any sign of life at all, though exhibiting to the observer some of the most perfect examples of extinct volcanic action in its several stages known to the world. Of these essential differences, the most prominent, and those which alone require notice on the present occasion, are the characters of the rock-masses and materials which go to build up the vast accumulation of volcanic remains forming the mountains and ejected matter in the different districts. The rocks of the central or Taupo zone are composed of materials known generally under the name of "acidic" rocks, whilst those of the other two zones are—in their latest manifestation, at all events—entirely formed of basic rocks. We may take, as general names descriptive of these two classes, trachytic rocks for the acidic areas, basaltic rocks for those of the basic areas, the distinction being in the nature of the constituents and their forms of aggregation.

The researches of modern science tend to confirm the idea that there is a regular sequence in the order in which these two
classes of rocks are ejected from volcanoes—the acidic, or trachytic, denoting the earlier; the basic, or basaltic, the later stages of volcanic life. There are well-known exceptions to this general rule, but, taken as a whole, the evidence tends to show that such is the life history of most volcanic districts.

It may be that some volcanoes commence their career by the ejection of acidic matter, and continue throughout the whole course up to their final extinction, terminating in the ejection of basaltic matter, without material interruption of their activity—whilst others, after making a commencement, are quiescent, or only partially active, for ages, remaining in the acidic stages for such lengthened periods, that volcanoes which can be shown to be far younger in actual age have had their day and become extinct.

Such seems to be the case with the Taupo, or central zone. It is still in the acidic stage, whilst the younger volcanoes of this isthmus appear to have run their full course, and have become extinct.

In connection with this subject and the recent eruptions, (which may happen to mark the beginning of a period of greater activity,) it is a matter of very great interest to ascertain whether they show by their action any change in the character of the ejected matter—whether, in fact, the ejecta are still acidic or trachytic, or whether, on the other hand, any basaltic or basic matter has also accompanied the outburst. We shall have something to say on this point further on.

The central volcanic district of this island is of immense extent, far larger, indeed, than is generally known, if we include in it the areas covered by volcanic matter, which spreads over a vast extent of country. Commencing in the far south, the noble mountain of Ruapehu, 8,978 feet high, which until quite recently was believed to be extinct, marks by its lava and consolidated mud streams the most southerly edge of the district. A line drawn thence in a north-east direction will pass along a belt of country celebrated all over the world for its extraordinary development of volcanic and thermal action, until it terminates in the active volcano of White Island. In this belt of country we have types of all the known forms of volcanic action. The active crater on Ngauruhoe has, within quite a recent period, (1869, and possibly 1881,) ejected hot lavas, which were seen rolling down its symmetrical cone; whilst it still constantly emits clouds of steam from the solfataras at the bottom. Tongariro, a few miles north, is still active, but in the solfatara or fumarole stage. This fine mountain, 6,400 feet high, is now but the ruin of what it must have been in former times. Its seven craters, two of which have lakelets within them, and one with steam issuing from a fissure in its side, the powerful emission of steam from Ketetahi and Te Maari—points on its
flanks—and the strong sulphurous stream flowing from the
former, all show that the subterranean forces are still powerful.
One of its craters contains a most beautiful and instructive
example of a lava stream, which has flowed from the crater wall
across the floor, spreading out in fan-shaped form, and having
such a look of freshness about it that it is difficult to believe it
is not still flowing.

A few miles to the north we find, at the southern end of Lake
Taupo, a large number of hot and boiling springs, geysers,
solfataras, and mud volcanoes, all in a very active state; whilst
close by are the innumerable fumaroles of Waihi, and, but
a short distance away, the group of hot springs recently
reported by Mr. Laurence Cusson, which are quite new to
Europeans. These are situated in a recess in the Kakaramea
Mountain.

Stretching along a narrow belt of country from the north
end of Taupo, still in the north-east direction, we find the vast
number of hot springs, fumaroles, and geysers of Tapuaeheuru,
Wairakei, Ohani, and Orakeikorako, with the extinct volcano
of Tauhara, on which is an old crater, now almost hidden by a
growth of tall forest trees. Orakeikorako, on the Waikato
River, a place seldom visited by travellers, has a very large
number of hot springs, some of which are forming terraces, but
greatly inferior in their present aspect to those of Rotomahana.
A little further in the same line northwards rises the Paeroa
Range, the wall-like western face of which is covered at its base
with boiling springs and mud volcanoes, which in one part
(Kopiha) occupy the face of the hill from top to bottom, and the
steam from which appears to have boiled the solid rock materials
into a mass of clay of various colours. It is this part that
Hochstetter refers to in his work, where he points out the
possibility of the clays becoming so loosened, by the thermal
action, that the whole hillside may some time collapse and
deluge the Ratoreka Plain below.

On the northern slope of Paeroa are more hot springs, and
then rises the mountain Maungaongaonga, evidently an old
volcanic hill, though the crater is almost lost to view; and
immediately to the east of it is Kakaramea, or Maunga-
kakaramea, of which we have heard so much lately. It is an
isolated conical hill, of considerable height, whose sides are
seamed by gorges, the sites of former hot springs, and on the
surface of which steam still escapes in a number of places, the
ground occasionally being so hot as to be unpleasant to walk
over. On its southern base, and extending thence to the head
of the Waioetapu River—an affluent of the Waikato—are found a
large number of hot springs, fumaroles, and mud volcanoes,
with some terraces in course of formation, but which, however,
cannot be at all compared to Rotomahana for beauty. Two
Pond and Smith.—On the Eruption of Mt. Tarawera.

little lakes, one of the most lovely blue colour, are also seen here, both of which have been the scene of active hot springs in the past.

We now come, by following in the same direction, to Okaro Lake, situated on the northern base of Kakaramea, and approach the country which is the scene of the late eruption. Passing this over for the moment, merely noting that Rotomahana is directly in the same line of country, we find the Tarawera, Ruawahia, and Wahanga Mountains, all formed of solid trachytic and rhyolitic rocks, and at their northern base come to the hot springs of the Tarawera River, which are continued down its course at intervals for several miles. This part of the volcanic belt is also marked by the old extinct volcano of Mount Edgecumbe, with its double crater and the hot springs. Near Te Teko we find, in Whale Island, situated 6 or 7 miles off Whakatane, another group of hot springs, and close to them the signs of former thermal action on Rurima Rocks, which have been described by Major Mair in vol. v., page 151, of the “Trans. N.Z. Inst.”; and, lastly, marking the most northerly point of activity, White Island, an active volcano, but now in the solfatara stage.

A glance at the map will show that the points of activity just described follow a fairly straight direction—north-east and south-west—and evidently mark a line of weakness in the Earth’s crust, where the heated interior most readily finds a communication with the surface. But, in addition to this line, there are numerous other places on its flanks where hot springs and other indications of activity are found, as at Te Niho-o-te-Kiore on the Waikato, Rotorua, Rotoriti, Rotoma, Rotoehu, Maketu, and Mayor Island, all within a few miles of this central line.

Besides the places where these indications of volcanic action are present in a state of activity, we find that the whole country, for many miles on both sides, is composed of materials which owe their origin to volcanic action. Vast lava streams and sheets are visible, either as forming the hills or lying hidden under immense deposits of pumice, as on the Kaingaroa Plains, which are nearly everywhere underlain by a sheet of lava, or its accompanying mass of tufaceous rock derived from the same source. Isolated hills, built up of trachytic and rhyolitic rocks, denoting old volcanic necks, are common everywhere. The pumice which has been ejected by the ancient volcanoes covers an enormous extent of country, stretching north-easterly from Ruapehu to near Gisborne, where it is found as a thick layer on tops of the highest hills; and to the westwards, following the river valleys for many miles. We know that the plains of the Waikato are formed almost entirely of fine pumice-sand brought down from the central area, either by rivers or by the wind, or
both, and that it has even been carried to within a few miles of New Plymouth. Volcanic mud is of common occurrence all over this country, but now so altered in appearance by decomposition as to be difficult of recognition, were it not for the underlying strata of pumice. It will be seen later on that the recent deposit of mud in the neighbourhood of Wairoa throws a good deal of light on the method of deposition of these beds of mud.

The changes in the central zone of volcanic action since this vast mass of ejecta was scattered all over the country have been, doubtless, very great. It is difficult to believe that all this material has issued from the extinct volcanoes, the remains of which we now see. It is far more reasonable to suppose that, during the ages which have passed since the later Eocene period, other volcanic vents have existed, and added to the immense mass of remains now visible, and that they themselves have disappeared, or been covered up by subsequent outbursts of the present volcanoes. We cannot assign, for instance, to the action of Ruapehu and Tongariro the cliffs of pure pumice on the east of Taupo, which are 400 feet high, nor have the vast lava floes of the west side of the lake come from those same sources. Is it not far more reasonable to suppose that we now see in this long belt of country a great depression, due to the sinking of the whole surface, which carried with it the numbers of points of eruptions whose remains are now all that is left to denote their whereabouts? But to follow out this line of reasoning, and show from the evidence obtainable that this is probable, would occupy more time than is allowable. If this slight notice of some of the principal features of this great volcanic area has shown that changes have occurred in the past on a stupendous scale, it will prepare us for the acceptance of the idea that similar changes may always occur in that locality, and of this we have had recent evidence in the outburst at Tarawera.

Premonitory Signs.

New Zealand has been colonized so short a time, compared with the geologic ages of the past, that observation has not yet been continued sufficiently long to record any great changes in the volcanic region alluded to.

It is true that, from time to time, slight eruptions of Tongariro, (or rather Ngauruhoe,) have been noted; earthquakes have occurred on a larger or smaller scale; the hot springs have been occasionally more or less active; floods and landslips, involving loss of life, and due more or less directly to volcanic agency, have occurred; but no great catastrophe has been recorded, to bring home to us the fact that any great changes are going on. But, nevertheless, a general opinion has been current to the
effect that the forces have been decreasing in activity, rather than the contrary, and Maori tradition lends weight to this impression. They have many stories of the greater activity of the hot springs; indeed, Europeans have seen many fine geysers in play which are now quiet or extinct: but none of their legends speak of any great calamity having befallen their ancestors through volcanic agency, and we may be sure that amongst a people who are so scrupulously careful in handing down their history, any great catastrophe would have certainly been noted. A consideration of some few occurrences in that district during the twelve months, and immediately preceding the eruption, ought at least to have warned us that some changes were impending, a few of which will be noted.

On the 22nd November, 1885, Mr. Josiah Martin, F.G.S., who was then staying at Rotomahana, was lucky enough to witness what may be called an eruption of the basin on top of the White Terraces, a brief description of which he has been good enough to supply us with:—

"Nov. 19 to 21, 1885.—Wind, W., W.S.W. Rain and squalls. Bar. falling.

"Activity of geyser, normal; overflowing and covering the whole of the Terrace.

"Nov. 22.—Wind, S. Clear sky. Bar. rising.

"Visiting the Terrace at daybreak, I found that overflow had ceased, and water was rapidly retiring. At 6 a.m. the great cauldron was empty, and until noon it remained quiet, when activity was resumed by water rising slowly and filling the geyser tube. Very little increase in activity was noticed until 4 o'clock, when furious ebullition commenced, the water rising in wave-like upheavals, with occasional geyser fountains reaching a height of from 50 to 60 feet. By 5 o'clock the basin was half full, and violently agitated. Watching the activity from the upper platform of the Terrace, I was startled by a severe shock, with a deep boom like an underground explosion, when the water in the basin was instantly uplifted into an enormous dome, from the top of which an enormous column of water was projected vertically, with incredible velocity, falling again over the upper Terrace in a heavy shower.

"(The Natives encamped at the foot of Terrace were alarmed at this sudden eruption, which they said was the most violent they had ever seen.)

"By 6 o'clock the crater was full, and no further change was noticed until 8 o'clock, when the water began slowly to retire. On the following morning (23rd) the water was retiring, and by 9 a.m. the basin was left quite empty and dry. No action was noticed until evening, when the water rose a few feet within the basin.
"On the morning of the 24th, the geyser very suddenly resumed its activity, several eruptive explosions following in rapid succession. On two occasions the column of water ejected must have reached a greater altitude than 150 feet, dense ascending clouds of steam accompanying every discharge, and rising to a height of 800 to 1,000 feet before being broken by the wind.

"On Nov. 22nd the movement of the aneroid exhibited a downward tendency, which commenced with the return of activity in the geyser, and continued during its excessive action. During the evening, as the geyser activity ceased, the opposite movement of the barometer was observed. But on three following days a recurrence of similar periods of activity in the geyser was accompanied by reversed conditions of barometric pressure."

A paper which will be read before this Institute by Mr. Laurence Cussen at its next meeting will describe in some detail the crater on top of Ruapehu, which until quite recently was supposed to be extinct. We learn, however, from that gentleman that the crateral lake is filled with hot water, and that on the 16th April and 23rd May last he observed columns of steam rising as much as 300 feet above the mountain; and as nothing of the kind has ever been noticed before, it is a fair inference that the volcanic forces were in a state of greater activity than usual.

Mr. Dinnage, a young officer of the Survey Department, who performed the difficult feat of ascending Ruapehu so lately as the 8th of June last—almost mid-winter, in fact—reports: "The snow was in a favourable condition for climbing, but it was necessary to cut each footstep for the last thousand feet. Large quantities of steam were issuing from the little lake in the centre of the crater, nearly 1,000 feet below us, but was all condensed before reaching the top of the crater. The cold was very severe."

About a fortnight previous to the eruption, one of the fumaroles at Tokaguru, at the south end of Lake Taupo, suddenly burst forth, throwing up showers of mud for several yards round; but it had returned to its usual state on or about the 10th June.

Major Scannell is good enough to inform us that some little time previously to the eruption, a new hot spring broke out at Wairakei, near the north end of Taupo.

About a week prior to the eruption, a wave was noted on Lake Tarawera, causing the waters to rise about 2 feet above the ordinary level, which broke on the shores, washing the boats out of the sheds, and causing some alarm to the Maoris, who, apparently, had never witnessed anything of the kind before. At the same date, some visitors to Rotomahana found
that the Pink Terrace had been in eruption, throwing out mud for several yards round, an occurrence which has never been noted before.

It will be remembered that on the evening previous to the eruption an occultation of Mars by the Moon occurred, at 10.20 p.m., the moon being just then entering her second quarter. It would be high water on the coast near Maketu that evening at about 10 p.m. We do not give much importance to these facts, but it is worthy of note that the well-known theory of the tides assumes that the waters of the ocean are at high water piled up, as it were, on that particular portion of the earth's surface which is just under the moon; but through friction, and the counter attraction of the sun, that the tidal-wave lags after the time of passing of the moon over any particular meridian. It is equally a part of this theory that the solid materials of the earth are at the same moment subject to a wave—much more limited in extent, but still appreciable; and it is well known that an atmospheric wave passes round the earth at 2 o'clock each day. Hence, the crust of the earth being in a state of tension, if there is any predisposing cause tending to a fracture about the period of this earth-wave, it is a natural inference that the conditions are then most favourable for the production of such fractures. The attraction of the planet Mars, added to that of the Moon, may be, and doubtless is, very slight; but the fact remains that, whatever influence the moon may exert at any particular moment, it happened to be greater, by the sum of her own and that of the planet, very shortly before the eruption.

The state of the barometer, as recorded by the self-registering instrument at Rotorua, does not indicate any abnormal depression, either shortly before or during the catastrophe. It is found that on Tuesday, the

<table>
<thead>
<tr>
<th>Time</th>
<th>Reading</th>
<th>Reduced to Sea-Line</th>
</tr>
</thead>
<tbody>
<tr>
<td>8th, at noon</td>
<td>29-40</td>
<td>30-20</td>
</tr>
<tr>
<td>8th, midnight</td>
<td>29-23</td>
<td>30-08</td>
</tr>
<tr>
<td>9th, 6 a.m.</td>
<td>29-23</td>
<td>30-03</td>
</tr>
<tr>
<td>9th, 10 a.m.</td>
<td>29-17</td>
<td>29-97</td>
</tr>
<tr>
<td>9th, noon</td>
<td>29-12</td>
<td>29-90</td>
</tr>
<tr>
<td>9th, 6 p.m.</td>
<td>29-00</td>
<td>29-80</td>
</tr>
<tr>
<td>9th, midnight</td>
<td>29-30</td>
<td>30-01</td>
</tr>
<tr>
<td>10th, 2 a.m.</td>
<td>29-30</td>
<td>30-01</td>
</tr>
</tbody>
</table>

Eruption.

from which time it altered little for the next two days. It will be seen that there was a somewhat sudden fall a little before noon on the Tuesday, but still nothing extraordinary, or such as we learn has occurred at other great outbursts in other parts of the world.
Approaching, now, to the date of the eruption, we find that there was a heavy rain for the great part of the 9th June, which cleared up towards evening. The wind on the night of the 9th was southerly, changing during the eruption to the south-west, from which direction it blew hard until 4 a.m., when it dropped. At Auckland, Gisborne, Waikato, and Lichfield the wind was south-west. Major Scannell, who saw the outburst from Taupo, says that when he first beheld the cloud of ashes, it was moving south and east, but a sharp south wind sprang up about 3 o'clock and carried the cloud westward and northward.

**Phenomena observed at the Outburst.**

The amount of information which has been recorded as to the actual outburst is very considerable, but all through there appears to be a want of exactness as to the times and order of occurrence of the phenomena observed, a very natural result of the excitement and confusion into which people would be thrown by occurrences which threatened their very existence. But the best accounts obtainable seem to place the first signs of anything extraordinary happening, at about 1 a.m. on the 10th June, 1886, when slight earthquake shocks were felt by the people at Wairoa, and atRotorua, (accompanied at the latter place by rumbling noises,) which appear to have been continued as earth-tremors till 2 a.m., or past. At 2.10 or 2.20 the rumbling noise had become a continuous and fearful roar, accompanied by a heavy shock of earthquake; and at this same time, or immediately afterwards, an enormous cloud of smoke and vapour was observed from Wairoa, rising over the hills which shut in that village from a clear view towards Tarawera Mountain, the outside edges and fringes of the different masses of which were outlined by vivid flashes of electricity, darting through the cloud and colouring it most brilliantly and beautifully. This electric display was accompanied by a rustling or crackling noise, which appears to have been heard above the deafening roar, and which is probably the same noise as is heard in electric discharges of an artificial kind, and also probably the same as is heard sometimes at great auroral displays. This heavy shock of earthquake is doubtless the same as that reported at Maketu at 2.30, Tauranga 2 a.m., and Makarerewa at 2.30. It was noted by two observers, (Messrs. Blythe and Greenlees,) that from 2.30 onwards severe shocks occurred at regular ten-minutes' intervals up to 3.30. The latter gentleman had the presence of mind to observe, from the swinging of a ham, that the shocks came from the direction of Tarawera. It is probable that the eruption of Tarawera first took place in any strength at about 1.45 a.m. As described by Mr. McRae, who saw it from the old Mission Station, soon after the outburst, three columns of fire and flame (or probably the glare
reflected on the vapour from lava below) were shooting upward from the flat plateau-like summit of the mountain to an immense height, with flashes of electricity darting forth in all directions, accompanied by balls of fire, some of which fell at great distances, indeed as far off as the Wairoa village, some 8 miles from the seat of eruption. Small stones now began to fall, as the great black cloud which had formed over the mountain worked towards the west, to be quickly followed by a downpour of mud and water and heavy stones, which battered down many of the houses in the village. The mud appears to have fallen in the form of an exceedingly heavy rain, with sometimes large lumps of mud, and this continued up till 6 a.m. All this time, there appears to have been a more or less strong odour of sulphur experienced by the people at Wairoa; and Mr. Blythe describes a hot suffocating blast, which nearly choked himself and Miss Hasard, after their escape from the burning house, and which warmed them through.

Soon after the first outburst, and before the fall of the first stones, a great wind arose, which rushed in the direction of the point of eruption with great force, and was most bitterly cold. It is noticeable that the people who survived, and were nearest to the seat of the eruption, viz., those at the Wairoa, failed to hear the loud detonations which reached Auckland and other places. Probably the loud and continuous roar drowned the louder reports.

These explosions were heard at Hamilton, Cambridge, Lichfield, Coromandel, Te Aroha, Wanganui, Tauranga, Maketu, Taupo, Christchurch, Wellington, Nelson, Blenheim, Whakatane, Opotiki, Auckland, New Plymouth, Whangarei, and Helensville, and sounded like the reports of distant cannon, or—as has been described by a large number of people from different places—like some one hanging an iron tank. The flashes of the electric display were distinctly seen here in Auckland, a distance of 120 miles in a straight line from Tarawera. The immense cloud of ashes, mud, and sand which was shot high up into the air darkened the sky till long after daylight should have appeared. It is stated that it was quite dark at Rotorua till 7.30, (the ashes commenced falling there at 4 a.m.,) and again at 9 a.m.; at Opotiki till 10 a.m., at Tauranga till 9 a.m.; at Te Puke it is said to have been dark as late as 2 p.m. on the 10th; at Maketu till 10 a.m.; the ashes beginning to fall there at 5.30 a.m. The height to which the mass of light ashes was ejected must have been enormous. Professor Verbeek, who was appointed by the Dutch Government to report on and describe the eruption of Krakatoa in May and August, 1883, states that the column of steam arose from that eruption to a height of 50,000 feet, or over 9 miles. The dark cloud of dust and ashes from Tarawera must have been nearly as high as this column of
steam. Mr. R. Arthur, of Mount Eden, who had a distinct view of the cloud illumined by electric flashes on the morning of the 10th, took notice of the height which it appeared as seen behind One Tree Hill; and the angle of elevation, as afterwards measured by Mr. Vickerman, of the Survey Department, gives a height, as computed by him, of 44,700 feet above Ruawahia, or a little over 8 miles. Although this method of observation is not a very accurate one, and may not be quite correct, it gives some approximation to the height.* We know from actual measurement that the column of steam arising from Rotomahana several days after the eruption was 15,400 feet, and even then the top of the column could not be seen, from its proximity to the observer. The ashes and dust ejected fell on the coast line at points 160 miles apart in a straight line—viz., at Tairua and at Anaura, a few miles north of Gisborne, and some of it fell on the s.s. "Southern Cross" off the East Cape, and on the s.s. "Wellington" near Mayor Island. It thus covered an area of land equal to 5,700 square miles with more or less of the deposit; on the edges of which, of course, it is barely visible.

In thus calling attention to the great height to which the dust and ashes were projected by the explosive force of the steam, a distinction must be drawn between this height and that mentioned by Professor Verbeek. In the Tarawera case this refers to the top of the cloud of ashes; in that of Krakatoa to the column of steam seen long after the eruption. Nor must it be inferred that in the New Zealand eruption we shall necessarily see the same extraordinary and beautiful atmospheric effects which followed the Sunda eruption.

The electric phenomena accompanying the outburst must have been on the grandest scale. The vast cloud appears to have been highly charged with lightning, which was flashing and darting across and through it: sometimes shooting upwards in long curved streamers, at others following horizontal or downward directions, the flashes frequently ending in balls of fire, which as often burst into thousands of rocket-like stars. Fire-balls fell at the Wairoa and other places, and doubtless the fires which occurred at Mr. Hazard's house and in the forest near Lake Tarawera were due to these.

**Earthquakes.**

The earthquakes appear to have been almost continuous from 1 a.m. to 3.30 a.m., with heavier shocks at about 4.30 and about 5.30, which were felt over a large district, extending in an east and west direction from Te Aroha, where they were slight, to Opotiki, where 71 separate shocks were felt; and in a north and south direction from the coast to Taupo. Although

---

* Archdeacon Williams, of Gisborne, who saw the flashes of lightning on the 10th, calculates that they were seen at an elevation of 6 miles.
described as severe, (as they no doubt appeared to those who experienced them,) they cannot really be so classed when it is taken into consideration that no chimneys fell, nor were light articles, such as bottles, vases, etc., cast down from shelves, except in one or two instances. No one who experienced the heavy earthquakes of 1848 or 1855, which caused such dismay in the vicinity of Cook Strait, could call those recently occurring severe ones.

It is true, in some places the earth has cracked and opened, but nowhere to any great extent. Nothing occurred like the great cracks at Wanganui and Wairau, in Cook Strait.

It is a very noticeable fact that all of the cracks we saw took the general north-easterly direction of the line of volcanic action, and all of them followed closely along depressions in the surface, which are undoubtedly old cracks, due to much heavier earthquakes in the past.

**Sympathetic Action of other points.**

It has been stated that the eruption is quite local in its action, and goes to prove that the series of hot springs in different places, and other signs of volcanic action in the central zone, are separated, and have no connection or sympathy with one or another. A consideration of the following facts relating to events which occurred at the time of eruption, or soon after, go to prove that such a conclusion has been drawn from insufficient data.

The hot springs in the neighbourhood of Rotorua were greatly affected. A small steam fumarole, (which in its ordinary state was only occasionally visible,) near the Government Agent's house, became a large boiling spring about 10 feet in diameter, from which a good-sized stream of hot water ran away towards the lake. Further north—at the base of the Pukeroa hill, and in the direction of the Maori village of Ohinemutu—steam came forth from innumerable cracks in the earth, sometimes accompanied by hot water, which formed streams running alongside the road from the old to the new township; and in the pah itself a spring burst out in the great meeting-house of Tamate Kapua; another in the path leading down to it; and yet another just behind the building. All of these outbursts occurred on the night of the eruption; they all follow, however, the old deposits of sinter at the base of the Pukeroa hill—the last remaining signs of former great activity in that locality. The activity of the vast number of fumaroles and springs in and around Ohinemutu was certainly greater than usual a few days after the 10th. The level of Lake Rotorua oscillated somewhat on the 10th June, but to no great extent. At 7 a.m. it fell 1 inch, at 9 a.m. it rose 6 inches, and fell again.
at noon 3 inches, and remained so all day, falling on the night of the 10th 5 inches; since when the oscillation has been continuous, but to no very great extent. The temperature of Rachel’s Spring at the Sanatorium on the 11th June was 170°, and from that date to 1st July it gradually rose to 196°, with a greater flow than before. For these exact data we are indebted to Mr. Boscawen, who obtained them from Mr. Hall, the Observer.

In the far north of the central zone, at White Island, it was reported by the s.s. “Jane Douglas” that the crater was showing unusual signs of activity at 9 p.m. on the 13th, whilst the “Hinemoa” reported it to be in its usual state on the 14th. Te Puke settlers saw a “violent eruption of steam on the morning of the 10th.” The “Te Anau” reported that nothing but an unusual amount of steam was rising on the 13th. On the 14th, vast columns of steam were reported as being seen all day from Tauranga, and the same on the 15th. At Waikakei, near Taupo, the springs and geysers are reported to be “in an extraordinary state of activity” on the 10th. We may add that we saw much more steam than usual arising from the large group of springs south of Maungakakaramea on the 14th; but these being in the direct line of the great fissure, it is only natural to expect this.

Taken altogether, then, this group of authenticated facts goes to prove that the disturbance was felt all along the central line of activity of the central zone, from extreme north to south, as well as on its flanks.

Description of the Points of Eruption.

We will commence our description of the effects of the eruption, as seen by ourselves on the 13th, 14th, 15th, 16th of June, by commencing at the southern end, near Lake Okaro, and tracing it thence northwards to the Wahanga Mountain, the most northerly point of eruption. This line, or irregular (and sometimes hidden) fissure, is about 8½ miles long, running in a general north-easterly direction, and along it can be traced a series of craters and points of eruption almost, though not quite, continuous.

Appearance of the District, approaching from the South.

Emerging from the bush called Pareheru, which the track approaching Rotomahana traverses, the scene is wonderfully striking. The whole country is clothed in a pale grey mantle. Hill and dale, level and steep, all is of the same hue. In the far distance, as in the near foreground, nothing has escaped this ashen covering save the Okaro Lake, which lies before us
sombre, silent, and unruffled. Away in the front rises an ever rolling, slow-changing, towering mass of steam, interspersed in the lower portions with sudden bursts of darker material, which prove to be stones, sand, mud, and water, flung up to the height of 400 or 500 feet above the lip of the crater. At times, the bright sun glancing over this wondrous column gives a vivid brightness to it; and again, so brilliantly reflected is the sunlight from the more distant portions of the mantled earth, as to bring vividly to the mind of the onlooker the semblance of a vast field of snow.

On entering this sombre plain, the ashen covering proves to be a fine, dry, powdered material, having throughout small fragments of scoria. Occasionally spherical or ovoid nodules are found, which easily crush between the fingers, and sometimes contain a nucleus in the shape of a rounded fragment of scoria.

Advancing through this material—which closely resembles in colour and appearance Portland cement—the deposit becomes deeper, so that walking was very fatiguing. In many parts each step was knee-deep, while, by leaving the ridges, the soft ash was found to be so deep as to be dangerous, and the effects of the wind stirring the surface made breathing laboured.

Travelling somewhat to the north of Okaro Lake for the distance of about a mile and a half, brought us to the most southern part of the fissure, which has extended from the Rotomakariri Lake in the direction of the Okaro Lake, partly through the Haumi Stream. On the line of the fissure in this direction are five distinct craters, the most northerly of which was decidedly the most active, while the southerly one was nearly dormant.

On reaching the edge of this one, which was ovoid in shape, the bottom was found to be covered with muddy water, evidently hot and probably deep. In the northern part of the crater an occasional uprush of water would take place, rising about 20 feet in height, and slowly falling back into the pool. This would cause a wave to gradually extend, which, reaching the sides, would wash in some of the steep sloping earth, followed occasionally by heavy slips extending to the surface. (Since our visit, Mr. Boscawen and Mr. Main have seen these craters, and have each witnessed the most southern crater, which we have stated as dormant, suddenly, and without warning, send masses of water, mud, and stones high into the air above the edge of the crater, after which, Mr. Main asserts, the activity would be followed by each of the others in succession to the northwards.) At the lip of the crater, and for a considerable distance back from the edge, cracks had formed following the contour of the lip, and from 2 to 6 or 7 feet apart. These cracks made travelling dangerous in the near vicinity of the craters, as the
occasional shocks of earthquake were liable to precipitate the
overhanging portions to the bottom. The depth from the lip to
the water was estimated at about 350 feet, and the length about
200 yards, with a width at the lips of 100 yards.

The second crater to the north was rather more active,
sending up columns of steam, through which occasionally an
uprush of stones and mud was discernible. Owing to a heavy
slip of earth into this crater, a terrace had been formed about
50 feet below the lip, and with a little effort it was possible to
obtain an excellent view from this place, not only of the crater
in question, but of the steam-jets in the third crater. (The
second and third craters here referred to subsequently became
joined in one, called "Echo Lake Crater.") These, to the
number of five, rose in unbroken columns to the height of about
40 feet, sending up stones in large numbers, some of which
reached above the surface. The roar of the escaping steam from
this crater was very great. Passing round to the north, it was
possible to cross the line by a narrow passage between the third
and fourth craters; and from this point an excellent view could
be obtained of the energy displayed by the escaping steam,
which sent up showers of stones to within a few feet of us.

Looking north from the passage on which we stood, the
fourth crater (since called the "Inferno") displayed a very
peculiar form. It had the appearance of an immense cutting
through a long hill, and this was actually the method of its
formation: the disruptive force having been exerted under the
centre of a long spur, had removed the centre of the hill
throughout its entire length, and deposited portions of the
material on its sides. It was noticeable that in each of the
craters already described, the forces had been exerted in the
same manner, the crater having been formed in a hill, the
material of which had been ejected to a considerable distance
on each side. In the most southerly crater the formation was
most distinctly shown, as the surface soil was marked by a
ragged fringe of dead fern and ti-tree, which extended all round
the side from about 10 to 25 feet below the lip of the crater, the
ejected material taking the usual outward slope characteristic
of volcanic cones. The natural contour of all the land covered
in this vicinity, notwithstanding the tremendous forces which
had been at work, was very little altered, and in one instance,
on a steep slope which faced the westward, the fern and ti-tree
was still visible. Still proceeding to the north, the fifth or
Black Crater was reached, and this was certainly the most
active in the line. After a toilsome ascent, a position was
obtained from which the activity could be witnessed with
comparative safety. This cone was the highest of all, and
far above the level of its edges were thrown immense quantities
of stones, mud, and water, the majority of which fell back
into the crater, though large masses were flung with a ter-
rible clatter on to the sides, gradually building them to a
greater height. Some of the stones launched out fell several
hundred yards from the edge, burying themselves in the mud,
and sending up volumes of steam. It was now possible to
witness the manner in which the stones were buried, both in
the mud and in the dry deposit, and to note how greatly reduced
was the activity of the geyser action to what its earlier efforts
had been.

While traversing the ground between the edge of the deposit
and the craters, a large number of circular depressions had
been observed, of various sizes, and having the appearance of
fumaroles. Some of these were not less than half a mile from
the edge of the nearest crater, while as the distance was reduced
the number of these holes increased. Finding a place where
water and mud had been ejected in sufficient quantity to form
a moderate hardness on the surface of the dry deposit, a search
was made at the bottom of some of the holes, resulting, after a
little excavation, in each case in finding a large stone. Some-
times these had only just penetrated the hard wet crust, and at
others had disappeared in the dry deposit which lay below. In
one small valley, where an immense deposit of stones had taken
place, a rhomboid had been thrown which measured about
4 ft. by 2 ft. 6 in.* This had a raised mass of material round it,
showing that it had been thrown, and had not rolled to its
situation. During the whole of the time spent on the sides of
this crater, a constant tremor of the earth was noticeable, and a
heavier discharge than usual of mud and stones was invariably
accompanied by a shock, which gave timely warning before the
effects were seen above the edge of the crater.

Skirting this active geyser, and ascending the hill called
Hape-o-toroa, the former Rotomahana Lake lies before us,
sending up a great volume of steam.

This hill, Te Hape-o-toroa, is situated immediately to the
south of the Rotomahana crater, and, being the highest land
anywhere in the neighbourhood, commands a fine view of all
the points of eruption excepting Tarawera and Ruawahia, the
flanks of which are occasionally visible through the vast mass
of vapour ascending into the upper regions of the air. Its close
proximity to the southern edge of the crater—being distant from
it only 250 yards—enables the beholder to look down on to the
various points of eruption with great advantage, though it must
be acknowledged that the constant shocks of earthquake induce
a wondering expectation as to whether the steep hillside will
not be precipitated into the depths below. Immediately to the

---

* Subsequent explorations show that several rocks, measuring over 1,000
cubic feet in solid contents, have been ejected in this neighbourhood.
right hand, and at the eastern base of the hill, is the course of the Haumi Stream, which formerly wound its way from Okaro Lake to Rotomahana, joining that lake a little to the south-east of the Pink Terraces. But what a change has occurred here! Directly at the base of the hill is a great fissure, from which issues an enormous mass of steam, whilst every now and then, after a loud report like a cannon shot, it is accompanied by large quantities of stones and sand, shooting up into the air and falling generally back again from whence they came. Immediately in front, between us and the crater lip, is a deep dark hole, sending forth a high column of steam. The edges of the crater are covered with fragments of stone ejected from it.

One looks in vain for any sign of the Pink Terrace: all view in that direction is cut off by the column of steam. The edge of Rotomahana Lake is now far within the crater wall, which follows round from our immediate front in a westerly, then north-westerly, northerly, and north-easterly direction to the site of the White Terrace. The crater has clearly eaten its way back from the edge of the lake, a distance of at least a quarter of a mile from the site of the Pink Terrace; and all along the foot of the wall the steam rises from so many points, that it is impossible for the eye to penetrate within its precincts, except on rare occasions when the wind causes a separation of the masses of vapour; and then is disclosed to view for a short time a cavernous-looking aperture, in which can be discerned a picture once seen never to be forgotten. A dismal coffee-coloured light, penetrating the vast mass of vapour from above, enables us indistinctly to see a horrible mass of seething, boiling waters, stained of a black or dirty brown colour, encircled by walls and hillocks of dreadful-looking hot mud, from which the steam curls up in innumerable places. Mud volcanoes scatter their contents around on all sides, whilst every now and then a loud detonation precedes the discharge of a column of water, mud, and stones high into the air, and as they fall splash the black mud right and left. The whole interior surface of the crater, as far as the eye can penetrate, seems to have been boiled and steamed and hurled about to such an extent that the old landmarks are no longer recognizable. Whilst the greatest activity seems to follow the foot of the crater-wall round by the western side, the eastern has also its points of eruption, from which vast columns of steam arise to join the general mass above; but, as yet, no one has been able to obtain a clear view of this eastern side. The size of this crateral hollow is about 1½ miles in a North and South direction, with a width of about 1¼ miles.

From a point which was reached with great difficulty on the west side of the crater, a view is obtained looking north-east, past the site of the White Terraces, and embracing the whole of
Tarawera Mountain. The deep sand in this direction makes progression most slow and fatiguing, and not without danger from the slips of sand on the steep hill sides. We looked in vain for any sign of the White Terraces; and as the eye gradually got to recognize some of the more prominent features of the country near there, under their altered shapes and appearance, the conclusion was forced on us that these beautiful terraces—the most lovely and wonderful of their kind on the whole earth—had disappeared for ever from mortal view. The changes in the general appearance of the country near there are so great, that, even with a familiar knowledge of the locality, which had been impressed on the mind in a visit to the same spot on which we now stood only three short months before, we recognized with great difficulty and uncertainty the main features of the land. But, still, the evidence of the whole contour of the country goes to show that the site of the terraces is now occupied by a horseshoe-shaped recess or bay in the general line of the main crater, from which an enormous column of steam arises high into the air. Nearer to us than this recess could be seen a gentle declivity, forming a very shallow valley, in which once ran the Kaiwaka Stream, the former outlet to Lake Rotomahana. This once deep gully is now nearly filled to its top with ejected matter, to a depth of 80 feet, of stone, sand, and mud. All around this part of the crater edge the ground was cracked and fissured by earthquakes, and by the torrents of water ejected from the crater. Lying immediately to the west of it was a large deposit of mud, which extended some way up the range that divides Rotomahana from the Wairoa Stream, and on its surface were occasional pools of water, the remains of deluges cast out from the crater.

From this same spot a good view of the whole of the south end and top of Tarawera is obtained. The eye is immediately attracted by the altered appearance of the south-west end of the mountain. Here a great rift—an enormous chasm—extends from the plateau-like top to the base of the mountain, ending (apparently) quite close to the site of the former Rotomakariri Lake. Various estimates have been formed of the dimensions of this great rift, and we believe that we are quite within the mark in stating it to be over a mile long, 500 feet wide, and 500 feet deep. No one, up to the present time, has been able to see the actual bottom of it. Out of this chasm rise, at several points, columns of dense black or brown smoke, not continuously, but intermittently; but no sign of any ejection of solid material was visible at the time. The edges were quite sharp and ragged,

* Subsequent exploration proves that this fissure extends right down to Rotomahana, a distance of over two miles; and within it, just at the foot of Tarawera, the new Lake Rotomakariri has been formed.
as if the solid rock had been ripped open by the enormous force of imprisoned steam; and in its upper part the ashes, rocks, and the ground generally for a long distance on either side, were coloured a yellowish-green, due no doubt to some of the products of volcanic action—such as ferric chloride. The slopes of the mountain around were covered deeply by ashes and stones, and near the base of it steam escaped from several cracks. As we sat on the surface of the sand observing the chasm through the glass, frequent shocks of earthquake caused cracks to open near the rift, and steam was seen to escape in little jets, ceasing, however, soon afterwards, as the cracks closed in or the loose materials fell into and stopped the vents. The southern end of the rift seems to be continued as a hollow right into the site of Rotomakanui, which is now occupied by a crater, from which rises a vast column of steam and occasionally smoke; indeed, this part seems to be one of the most active craters of the whole series. Mr. Morgan, who approached this side of the crater from Galatea on the night of the 14th, states that he saw a great glare as of fire, and a large mass of smoke issuing therefrom.

During the time we were in the district the weather was most beautifully clear, with a light south-west wind; and this allowed of a careful study through the glass of the heights of Wahanga, Ruawahia, and Tarawera, as seen from various points. That great changes have taken place in the two latter is obvious to any one who knew their former shapes and appearance. In 1874 we made the ascent of Ruawahia on three occasions, starting from near the outlet of Lake Tarawera, and are thus able to give some description of the range prior to the eruption. All those who have visited the Lake District are familiar with this range, which rises out of the lake on its eastern shore by gradual easy slopes, until near the summit, where a wall-like mass of trachytic or rhyolitic rocks marks the division between its plateau-like top and the gentler slopes below. From the northern end of Wahanga to the southern end of Tarawera is a distance of about three miles, whilst the plateau has a width of perhaps a mile, broken at one mile from the north end by a deep saddle, dividing Wahanga from Ruawahia. The surface of the plateau was covered by immense masses of broken trachytic rocks, which looked as if they had been shivered and fractured by the action of the frost into long angular blocks of various sizes. Running in all directions were depressions or crevices dividing the surface into hummocks, and making travelling very difficult; whilst occasionally a hillock formed of the piled up masses of loose rock rose above the general surface. No sign of any crater was seen, though the rocks are all undoubtedly due to volcanic action. Possibly in this range we see an illustration of one of those great masses of ejected lava described by
Judd, which, issuing from a vent or vents below in a viscid state, swell up in a somewhat rounded mass without forming a crater. Of this description is the well-known Grand Puy of Sarcouci, in France, and numbers of others in various parts of the world. The cracked and fissured surface of these mountains would then be accounted for by cooling from a state of considerable tension.

That a great change has taken place in the mountain top is obvious. The glass shows clearly that Ruawahia and Tarawera (both of these names being on the same plateau—the latter being the name of the southern end,) have been apparently rent along their whole length, and some of the little peaks along this rent appear to be the result of solid materials ejected from below, and built up by stratified layers of scoria or stone having the outward dip common to volcanoes. Smoke was rising from several points for a distance of a mile and a half, but not in any great quantity, though occasionally it increased in volume, sending a dark black cloud high into the air. The surface of the ground on top was coloured a yellowish-green for many acres, denoting the presence probably of ferric chloride, whilst all the original fissures appeared to have been filled up to one general slope by the materials ejected. It is as yet premature to make any definite statement as to whether the mountain is higher than it formerly was—namely, 3,606 feet; but it certainly has that appearance, and the evidence of sketches and photographs tends in the same direction. We believe that when the mountain can be approached sufficiently near it will be found that a true crater has been formed on the north-east side of it.*

In general appearance Wahanga seems to have altered, but not so great a degree as Ruawahia. Smoke issues in smaller quantities from several places on its summit, but principally from the highest point. It also is covered with a mantle of ashes and stone ejected from one of the vents.†

Dr. Hector, in his report‡ on the eruption, has given some slight weight to the significance of these three names as bearing on the question of former activity, of which, however, no tradition exists among the Maoris; but we think no value can be attached to this argument when it is known that each name has another interpretation; and we cannot think that the obvious

* The height of Ruawahia since obtained is 3,770 feet, showing an increase in height of about 170 feet. This is caused by the black and red vesicular scoria piled along the edges of the great fissure.

† The great fissure is found to extend along the eastern face of Wahanga nearly to its northern end, and in it are two deep craters, one of them being the deepest of any along the whole line.

signs of great age in the trachytic lavas of which the mountains are formed will allow of our placing the time of its former (latest) activity within the historical or traditional period, a time extending back for not more than five hundred years.

Many will remember the fine forest that occupied the western slopes of Ruawahia, reaching down nearly to the lake margin. Nothing is left but a number of stumps and branchless trees, many of them burning, and adding by their weird appearance to the general desolate look of the country. The clumps of trees which adorned the south-eastern slope of Tarawera have almost wholly disappeared, being covered up by the deposits which buried the little Maori village in which poor Brown and his Maori friends lie buried. A few charred and blackened stumps are alone left to denote the spot.

The changes in the contour of the country around the base of Tarawera and Rotomahana are most remarkable, and bear witness to the vast amount of matter which has been ejected. Messrs. Harrow and Edwards, who formed part of the boating party which crossed Lake Tarawera to search for Te Ariki village, where it was known a large number of Maoris lay buried, tell us that in many places the shore of the lake near the old landing-place on the route to Rotomahana is so altered by the conversion of part of the lake into dry land that localities cannot be recognized. They furnish an instructive section of the ejecta, as seen in the bed of a torrent cut through it since the 10th June:

<table>
<thead>
<tr>
<th></th>
<th>Ft.</th>
<th>in.</th>
</tr>
</thead>
<tbody>
<tr>
<td>On the bottom</td>
<td></td>
<td></td>
</tr>
<tr>
<td>large stones</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Ashes and mud</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Scommae (still hot on the 15th)</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Ashes and sand</td>
<td></td>
<td>15</td>
</tr>
<tr>
<td>Mud, forming the</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>surface</td>
<td></td>
<td>0</td>
</tr>
</tbody>
</table>

This gives a depth of 23 feet in that particular locality, but it is evidently much deeper in others. On the slopes of Te Hape-o-toroa, we can state positively that in one place 25 feet of matter has been deposited, the topmost layers being fine and coarse sand mixed with small fragments of stone and sinter; and this deposit was quite hot on the sixth day after the eruption at a depth of 4 or 5 feet. The vast number of small fragments of siliceous sinter scattered over the country west and south-west of Rotomahana, points to the destruction of the terraces, of which materials they were mainly formed.

The Steam Cloud.

Riding home, weary and covered with mud, we halted to gaze upon one of the most glorious sights man could view. We stood in a light-timbered grove just outside the belt of the ash-
covered plain, the setting sun at our back. Away and away in our front for miles lay the scene that not long since looked like snow, but now, reflected on it, the rays of the setting sun gave it the aspect of red coral. But, above all, there rose in solemn grandeur the towering mass of steam—thousands upon thousands of feet it ascended, until its crown was lost in the bright, fleecy clouds that came rolling up from the south. Bright, aye bright with the full effulgence of the orb which was still high above the horizon there; but lower, the dazzling brightness waned, and a faint glint of a golden hue was seen, to be rivalled by the richer colours and deeper gold of the nether parts until they deepened and sank through rose to carmine, and deeper hues suffused the base and the far-reaching crimson plain, while the deep greens of the bush in which we stood made up a picture difficult to equal, impossible to excel. And thus from earth to sky rolled the ever-changing mass of steam, rent at the base with the uprush of countless geysers, imparting to it changing and varying tints, beautiful and transient; but above, calm, solemn, and gorgeous, and apparently immovable. Slowly the deeper tints crept up, and left the base white and beautiful in the light of the bright full moon, while the crown still reflected the deep soft tints of a sun which had long since set with us.

Appearance of the Road to the Wairoa.

The appearance of the district, after having entered upon that portion upon which the deposit of mud has fallen, is sombre in the extreme. The view all round is the same: the neutral grey of the wet mud is spread as a pall over the earth. The contour of the ground is not altered, only the steeper angles are rounded off, the smaller gullies and hollows filled up by the all-pervading mud. Locomotion is naturally retarded, the track having from 4 to 6 inches deep of the plastic mass. Proceeding in the direction of the Wairoa, we reach the Tikitapu Bush, so famed for its beauty of tree and fern. Now, all verdure is gone, trees and shrubs are alike stripped of their leaves, and the bark no longer shows its natural and varied hues, but is encased with the all-pervading grey. Only in some hollow of a larger tree on the sheltered side may be seen a few scattered leaves of some close-clinging creeper, or the hardy leaves of the *tataaramoa*, bespattered with mud. Advancing into the bush, we soon came upon more striking effects than that wrought by the fall of the deposit. Trees are lying uprooted, increasing in number as we reach the Tikitapu Lake. Advancing along the road, we find them lying parallel with it in nearly every instance. It runs in a nearly straight line in a S.E. direction, bearing directly to Rotomahana. In one short stretch, near the lake, twenty trees were counted lying near to and on either side of the road, and in only one instance was it necessary to make a detour, on
Transactions.—Geology.

account of a tree which had fallen across the road. This remarkable effect of the storm was only noticeable in the bottom of the valley through which the road ran, as on either side on the hills the trees seemed to have been blown irregularly, and in different directions.

To account for the regular disposition of the trees is not difficult, when we remember that the evidence of the survivors at the Wairoa shows that during the precipitation of the mud a terrible storm was blowing in their direction, from the direction of the valleys which lead down to the village from S.E. of W. This wind would find its easiest passage through the bush up the road which ran in the same direction in which it was travelling, until the pressure became so great that the tall trees abutting on the road, being unable to bear it, were precipitated in the same plane. Further evidence as to this as a cause is the precipitation of the mud on the trunks of the trees still left standing, but only on the S.E. side; while what few leaves of creepers are still left clinging to the trees are only noticeable on the N.W.

Advancing towards the Rotokakahi Lake, the mud deposits on the hill sides appear to be more liquid, and have run together, giving the hills a striped appearance. The steeper angle, and rocky nature of the ground admitting less absorption of the watery matter, is no doubt the cause of this, and will have a serious effect in regard to the future stability of the deposit. In the valley of the Wairoa the deposit is much deeper, and where it has drifted up against fences or trees must be from 5 to 7 feet in depth. At the time of our visit, however, Mr. Macrae's waggon was being dug out from where it had been buried while standing on the road, and there the depth from the surface of the deposit to the top of the old road was 2ft. 6in. Through this deposit were mixed fragments and masses of rock, much of it being scoria; while in some of the roofs of the houses were clearly discernible the holes which had been caused by the force with which these stones had descended. In one instance, we removed a stone which was still imbedded in the hole it had produced. Here, again, the deposit piled on the sides of houses, fences, and trees showed that the material must have been carried with great force in a northerly direction. (On the edge of the deposit in the direction of Ohinemutu it was interesting to note the effect of the mud and stones which had been precipitated on the vegetation, notably on the strong leaves of the tuapaki, growing abundantly on the sides of the road. At first the leaves were only bespattered with mud, further on they were perforated by the small stones, still further on the fleshy portion had been beaten out, leaving only the midrib, while beyond this not a vestige of a leaf had been left on any of the bushes.) The bed of the Wairoa Stream was filled with mud,
and its exit from Rotokakahi so raised as to prevent the outflow of water. The water of all the lakes was grey and turbid, from the semi-liquid mud which had been precipitated into them. On the shore of the Tikitapu Lake was a thin liquid rim of what appeared to be gravel, but which on closer inspection proved to be small fragments of scoria and a few quartz crystals, washed from the mud deposit by the waves caused by the storm. Already the mud had begun to descend the steeper mountain sides in avalanches, with loud rattling noises.

The Material composing the Ejected Matter.

Having viewed the deposition of the material, we will now consider its structure and composition.

We have, first, the dry ash laid in the vicinity of Rotomahana (south side), and extending in a gradually reducing thickness to Galatea. Then the mud precipitated over the Wairoa, Rototiti, Okareka, and Okataina. The dry ash carried in the shape of fine powder over Tauranga, and as coarse sand at Whakatane and Opotiki. Then we have a secondary coating of mud overlying the dry ash in the immediate vicinity of the geysers at Rotomahana, and the varying degrees of fineness of the ash deposited at long distances—notably at Whakatane, where a coarse sand fell for the first few hours, followed by a very fine dust for some hours afterwards. The same circumstance, but in a less conspicuous degree, was noted at Tauranga. In the order as arranged, we find the mud to be chiefly composed of quartz, in the form of fragmentary rock crystal; and as sinter, both white and coloured pink by peroxide of iron; together with a large amount of volcanic scoria in fine fragments, and exceedingly vesicular. This fragmentary scoria we shall find to be in very different proportion as we proceed, and the greatest interest will be felt in this fact, together with its bearing on the future fertility of the soil on which it has fallen, or will itself have replaced. We have not, however, found pumice to any large extent. In some of the older fragmentary rocks isolated patches were attached, but the fine deposits are singularly free from it.*

In addition to these varieties of ash, we have also the solid portions of stone which have fallen, not merely in the vicinity, but also at long distances from the scenes of eruption. The materials thrown out vary considerably. In the immediate neighbourhood of the craters are to be found stones from a few ounces to over a ton in weight.† These vary considerably in

* Some few specimens of newly-formed pumice were afterwards found scattered over the ash-fields, but the quantity is so small as to escape any but the most careful search.

† Some have since been found which would weigh nearly 10 tons.
formation, but are all portions of the rhyolitic rocks adjacent—a fine-grained tuff and coarse-grained brecciated trachytic rocks being plentiful. In the Wairoa, however, we find both scoria and the cross-grained trachyte just alluded to; while on the eastern end the principal solid material is composed of a basic scoria, in the form of lapilli. Returning now to the examination of the mud and ash, we find that the deposits at Okaro, Wairoa, Tikitapu, and Tauranga are very similar in appearance, being composed very largely of silica, both in the glassy solid crystalline form and as sinter; together with a small but varying proportion of scoria. Coming next to the deposit at Matata and Whakatane, we find the silica in the same forms, but the scoria has increased considerably in proportion. Advancing still further eastward to Opotiki, we find the same characteristics, but the scoria has still further increased in its proportion to the uncombined silica.* Now, if we turn to the analysis we have made of the materials obtained from the places mentioned, we find that they bear out the results of our optical examination. Clearly the ash from Okaro, Wairoa, and Tauranga are of the acidic group, while those from Whakatane and Opotiki are more nearly approaching the basic form. Again, the scoria obtained from Wairoa, and also from the southern end of the eruption, are undoubtedly basic, and have been thrown out in exceedingly large quantities, viewed from the amount and composition of the eastern deposits. Now, hitherto we have had the whole of the rocks of this region placed in the acidic group, and certainly no large mountain masses of a basaltic character could well escape the practised eyes of Von Hochstetter, or the members of the Geological Staff of our Colony. We are therefore forced to the conclusion that large quantities of basaltic scoria were ejected from the Tarawera volcano, or mountain, at the earlier stages of the eruption on the morning of the 10th of June. This is fully borne out by the numerous eye-witnesses, who unanimously speak of columns of fire rushing up from the newly-formed craters, and masses of fire bursting and falling back and around the sides of the mountain. That there was no outflow of molten lava actually discernible after the night in question is accountable by the enormous rush of high-pressure steam carrying off the molten mass in a fine state into the air, where it was carried away by the strong south-west wind which had now commenced to blow, or by being covered up by subsequent deposit of ashes.

We see from the foregoing that we have had two distinct eruptions, the one hydrothermal, the other volcanic, throwing

* The deposit found on the shores of Rotoiti contains large quantities of fine scoria, and as the mountains are approached this increases in quantity and the size of particles, until, on the top of Ruawahia, scarcely anything else is found.
out differently rocks, acidic and basic, the physical characters of these rocks being as different as their chemical composition. Thrown to a great height, they were caught by the wind-storm and borne along by it in parallel lines from whence they emanated, the acidic to the westward and the basic to the eastward, more or less admixed in the centre, but slightly commingled on the extreme outer edge of the line. In this order they advanced, and in this order were precipitated on the lands over which they passed. Coarse sand, finer particles, dust: thus it was laid, in the order most to be desired by the agriculturist. So fine, indeed, is a large portion of the deposit, that the elements of nutrition in it are available for vegetation almost as soon as the first rains have carried it into the soil; while the particles not so exceedingly fine are already being attacked by that wonderful disintegrator, carbonic acid. For a moment let us glance at the basaltic lava cones in the vicinity of Auckland; and here we find the richest land, capable of growing extensive crops. The more decomposed, the finer the particles, the greater the amount of disintegration: the richer the ground, the greater the profusion of the elements of fertility. And this is the material which has been so lavishly spread over the land on the eastern portion of the district, and which is so largely intermixed with the acidic matter which has fallen over the western. That this rock in its unbroken, undecomposed form, is nearly valueless for plant life we can learn, by turning to the basaltic floes and cinder deposits of Rangitoto; but even there, in the few gullies where rain has washed the dust, and given depth of friable soil for plants to live in, where will we see a richer profusion of vegetation? The result of this downpour over so large an area need not dismay us, but rather give cause for rejoicing that, in the majority of instances, a richer soil has been added than formerly existed; and so lightly and finely has it fallen, that the winter rains will not have passed before it will have been washed into the soil to invigorate the new vegetation and improve the pastures, except in close proximity to the scene of the eruption. Even here we have shown that these deposits are capable of supporting vegetation.

Probable Cause of the Eruption.

To hazard a theory for so stupendous a cataclysm without first obtaining the most complete data on which to build, would appear reckless and unscientific; but the amount of data already accumulated, and the certainty that many months must elapse before a complete investigation of Tarawera and Rotomahana can be made, prompts us to advance a theory based on known laws, the working of which has been a source of wonder and attraction, and of world-wide interest, centring in Rotomahana. Here, as we are well aware, rose the beautiful terraces of Te
Transactions.—Geology.

Tarata and Otukapuarangi; here also were geysers, ngawhas, mud-springs, steam-holes, solfataras and fumaroles, each and all pouring out in larger or smaller quantities its volume of heated water until the lake itself was fully deserving of its name, "Rotomahana," (warm lake,) and its effluent Kaiwaka was worthy of a similar distinction. Now, the body of water debouching from this lake was large and continuous, and many millions of gallons were daily discharged into the Tarawera Lake. If now we turn to Rotomahana, and witness the effects of these hot springs and geysers, we find an amount of sinter deposited which is surprising, for though we have been used to speak of the two terraces, there were several others in a state of decadence or fragmentary condition, while lavishly around us were the evidences of sinter deposit. Year after year, probably for centuries, had this deposition gone on, though only a tithe of the silica which rose in solution had been arrested. Fortunately these waters have been analysed, the results of Mr. Skey's examination showing the water from the White Terrace to be charged with mineral matter to the extent of 144 grains to the gallon, and from the Pink Terrace 154 grains. Accepting this as equal for all the springs so constantly at work, we shall have in the course of years a very large amount of rock material withdrawn from the earth, most probably leaving cavernous spaces, and a weakening of the earth's crust locally. It required then only some local disturbance of the earth's crust to precipitate the falling-in of these spaces, which would have occurred sooner or later without such disturbance.

There can be no question that the first outbreak came from the Tarawera Mountain, caused probably by some slow-moving earth-wave, evidences of which we have already adduced. This in itself was sufficient to cause a precipitation of the weakened honeycombed rocks through which the waters of the Rotomakariri Lake would make their way into the chasm, and, coming into contact with a large surface of the molten rock, would be followed by a terrible convulsion, the escaping steam ripping up the side of the mountain in the manner already described. Water rushed down on the heated rocks only to be driven back and dissipated into the surrounding space, together with the fragmentary matter and dust resulting from the shock. The water from the Rotomahana Lake would then be driven up, together with the steam and debrisic mass, to fall over long distances in the form of mud, as we now see it, until the water had been repelled from the lake, and with it the solid material of its bed. By this action the bed of the lake has been lowered, and its sides greatly extended, while there can be but little doubt that the whole of the terrace formation has been swept away.

That the long dormant mass of molten lava underlying it extended no further, is very questionable, and the evidences of
the further extension in a S.W. direction are shown by the length of the rift extending to Rotomahana, thence by its entire length, and finally proceeding in the direction of Okaro Lake for a mile and a half. Here we find its effects very violent, the active craters already described not being built up, but blown directly out of the rhyolitic rock.

But all speculations of this kind are premature, in view of the paucity of information with regard to the present state of the interior of the lake crater. We merely bring them forward to incite inquiry, and thereby arrive at the whole truth of the questions involved.

We cannot close without a tribute to the memory of the dead. That this disaster should have had so fatal a result is a matter of great sorrow. Awoke by the roaring of subterranean thunder, by repeated shocks of the moving earth, awed by the fearful scenes of fire and lightning, apparently emitted by a mountain close in their vicinity, with hope of escape cut off, and the despair and uncertainty of unknown and unexperienced terrors, not less than 102 of the poor Natives must have gazed in fear; until with a terrible roar the lake beside them was belched out to cover and obliterate them, their villages and lands, and leave no trace of what had been their homes and cultivations for many years.

Nor can we think without deep regret that some of those Europeans at Wairoa who had viewed the grandeur of this wonderful outburst for hours, from apparently so safe a position, should have succumbed to the storm which raged so soon afterwards. Long, indeed, will it be before the name of Wairoa will be forgotten, or the memory of this beautiful valley, which was transformed into a mournful desert in a few hours.
### Analyses of Volcanic Ash and Lapilli from the Tarawera Eruption

By J. A. Pond, Colonial Analyst, Auckland District

<table>
<thead>
<tr>
<th>Soluble on heating in hydrochloric acid and water, equal quantities</th>
<th>Dust Ash or Mud</th>
<th>Lapilli</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Okaro</td>
<td>Wairoa</td>
</tr>
<tr>
<td>Silica</td>
<td>35</td>
<td>20</td>
</tr>
<tr>
<td>Alumina</td>
<td>3:45</td>
<td>2:80</td>
</tr>
<tr>
<td>Lime</td>
<td>0:95</td>
<td>0:67</td>
</tr>
<tr>
<td>Magnesia</td>
<td>0:20</td>
<td>0:30</td>
</tr>
<tr>
<td>Soda</td>
<td>0:33</td>
<td>0:37</td>
</tr>
<tr>
<td>Potash</td>
<td>1:16</td>
<td>1:19</td>
</tr>
<tr>
<td>Chlorine</td>
<td>0:05</td>
<td>0:07</td>
</tr>
<tr>
<td>Phosphoric Acid</td>
<td>0:09</td>
<td>0:09</td>
</tr>
<tr>
<td>Sulphuric Acid</td>
<td>0:39</td>
<td>0:32</td>
</tr>
<tr>
<td>Carbonic Oxide</td>
<td>Tr.</td>
<td>Tr.</td>
</tr>
<tr>
<td>Organic Matter</td>
<td>1:30</td>
<td>1:30</td>
</tr>
<tr>
<td>Water</td>
<td>0:85</td>
<td>0:90</td>
</tr>
</tbody>
</table>

| Insoluble in acid—                                    |      |        |          |          |        |        |          |        |
|--------------------------------------------------------|      |        |          |          |        |        |          |        |
| Magnesia                                               | Tr.  | Tr.    | 1:60     | 0:90     | 1:40   | 2:10   | 2:65     | 3:95   |

Total: 97.07 97.54 99.74 98.57 97.795 99.415 99.245 100.12
ANALYSES OF VOLCANIC ASH AND LAPILLI FROM THE TARAREWA ERUPTION.

Analysis made by J. A. Pond, Colonial Analyst, Auckland District.

<table>
<thead>
<tr>
<th>Form</th>
<th>Locality</th>
<th>Silica</th>
<th>Iron Oxide</th>
<th>Alumina</th>
<th>Lime</th>
<th>Magnesia</th>
<th>Soda</th>
<th>Potash</th>
<th>Chlorine</th>
<th>Phosphoric Acid</th>
<th>Sulphate Acid</th>
<th>Organic Matter</th>
<th>Water</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ash</td>
<td>1. Okaro</td>
<td>66.85</td>
<td>6.05</td>
<td>17.95</td>
<td>3.85</td>
<td>20</td>
<td>33</td>
<td>16</td>
<td>0.09</td>
<td>0.39</td>
<td>1.30</td>
<td>0.85</td>
<td>97.07</td>
<td></td>
</tr>
<tr>
<td>Mud</td>
<td>2. Wairoa</td>
<td>70.10</td>
<td>5.15</td>
<td>15.95</td>
<td>2.60</td>
<td>3.0</td>
<td>3.7</td>
<td>1.9</td>
<td>0.07</td>
<td>0.32</td>
<td>1.30</td>
<td>0.90</td>
<td>97.34</td>
<td></td>
</tr>
<tr>
<td>Dust</td>
<td>3. Tauranga</td>
<td>64.00</td>
<td>7.20</td>
<td>18.16</td>
<td>5.42</td>
<td>1.90</td>
<td>5.8</td>
<td>1.8</td>
<td>0.14</td>
<td>0.48</td>
<td>0.90</td>
<td>0.75</td>
<td>99.74</td>
<td></td>
</tr>
<tr>
<td>Ash</td>
<td>4. Whakatane</td>
<td>57.15</td>
<td>11.55</td>
<td>18.35</td>
<td>8.36</td>
<td>1.37</td>
<td>6.4</td>
<td>1.7</td>
<td>0.04</td>
<td>0.35</td>
<td>0.20</td>
<td>0.30</td>
<td>98.57</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5. Opotiki</td>
<td>56.30</td>
<td>11.50</td>
<td>17.70</td>
<td>8.45</td>
<td>2.20</td>
<td>5.9</td>
<td>1.7</td>
<td>0.12</td>
<td>0.25</td>
<td>0.15</td>
<td>0.15</td>
<td>97.795</td>
<td></td>
</tr>
<tr>
<td>Lapilli</td>
<td>6. Wairoa</td>
<td>50.30</td>
<td>14.10</td>
<td>20.00</td>
<td>10.38</td>
<td>2.77</td>
<td>7.0</td>
<td>1.4</td>
<td>0.16</td>
<td>0.22</td>
<td>—</td>
<td>—</td>
<td>99.415</td>
<td></td>
</tr>
<tr>
<td></td>
<td>7. Parehu</td>
<td>51.35</td>
<td>14.60</td>
<td>18.20</td>
<td>10.26</td>
<td>3.10</td>
<td>8.4</td>
<td>1.6</td>
<td>0.15</td>
<td>0.41</td>
<td>—</td>
<td>—</td>
<td>99.245</td>
<td></td>
</tr>
<tr>
<td></td>
<td>8. Rotoehu</td>
<td>52.60</td>
<td>12.70</td>
<td>18.30</td>
<td>11.05</td>
<td>4.65</td>
<td>0.9</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>100.12</td>
<td></td>
</tr>
</tbody>
</table>