The Eruption of Bandai-san.

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With Plates XV–XXIV.

When the news of the eruption of Bandai-san in the Province of Iwashiro, which took place on the morning of July 15th, 1888, was received in Tōkyō, the President of the Imperial University directed us to proceed at once to the spot and to fully investigate that terrible subterranean convulsion and its attendant phenomena. We started from the capital on the 18th and arrived at the scene of the disaster on the 19th. During the next ten days we made several ascents and descents by different routes, travelled over the devastated lands, and collected all the information that we could by examination and inquiry on the spot. In order, however, to perfect our investigations, we determined to camp for some days on the volcano, and at the same time to survey the dimensions of the newly opened crater and therefrom to estimate the cubic content of the mass that had been blown away. At our request, the President despatched Mr. I. Toya, C.E., a graduate of the University, to take charge of the surveying work. Equipped with provisions, theodolite, levels, and other instru-

ments, we ascended on July 31st and remained on the summit till the 8th of October. It was mainly owing to Mr. Toya's patient labour that we were enabled to arrive at the valuable conclusions deducible from the survey. The spot selected for our camp was Nakanoyu, a spa almost on the very edge of the crater, that is to say, not more than one hundred metres from it—a position admirably suited for our purposes. Though so close to the volcanic focus, the spa had escaped total destruction, being situated at the back of the crater, and screened by a hillbrow from the direct effects of the explosion. As might be expected, our surveying and other works on the summit, the fruits of which are embodied in this paper, were not unattended by discomforts and difficulties—such, for example, as indifferent food, breakneck ascents and descents, foul vapours, chilly nights, and long sultry summer days spent in scrambling over a scorched and barren crater.

Soon after the eruption we sent letters of inquiry to a large number of schoolmasters and local officers in the neighbouring provinces ; accounts given by other observers, as well as those published in newspapers, were also duly considered. The information embodied in the answers to our letters was very valuable for the purposes of this paper, especially in preparing Plate XXIV, and we take this opportunity of expressing our sincerest acknowledgment to all who thus helped us. We also tender our best thanks to the colleagues and friends who have since assisted us, by suggestions and otherwise, especially to Major-General Palmer, R. E., for kindly helping us with our English and for many valuable hints.

The questions we asked in our letters were mainly as follows : The names and addresses of the observers. The times at which they first noticed the eruption. Did they hear the sound of the explosion? Its nature, duration, loudness, etc. Did they see steam (com-

monly called smoke) rising up in the air? Its colour, height, form, etc. Did they see lightning in the steam, or fire on the volcano? How did the lightning or fire look? Did volcanic dust fall? Its thickness, colour, consistency, structure, etc. Were there any earthquakes either before or after the eruption? Their times of occurrence, intensity, duration, nature, etc. The state of lakes, rivers, and springs before and after the explosion. The meteorological conditions, especially the force and direction of the wind. Any other information bearing on, or which might seem to bear on, the eruption was also asked for. The answers to these questions are given in a tabular form at the end of this paper.

Bandai-san, considered topographically and geologically.

In Northern Japan, there run along the Pacific seaboard two principal masses of mountains, chiefly composed of crystalline and older rocks. The more northerly of the two, on the eastern side of the Kitakami River, has been named by Dr. E. Naumann the Kitakami Mountain-land, and the other, situated to the east of the Abukuma River, the Abukuma Mountain-land. These two mountain-masses are remarkably similar in their geological structure, and the principal direction of strike is north and south. They are very old formations, consisting of granite, granite-gneiss, gneiss, and other crystalline schists, together with thick accumulations of Palæozoic strata, much folded and faulted, and some patches of Mesozoic strata not less disturbed. We have, in fact, the relics of old land, the principal features of which must have been determined at the end of the Mesozoic Era, and much of which has, no doubt, been subsequently denuded away.

On their western sides, the two mountain-lands face broad valleys, in which the rivers already mentioned run in a meridional

direction—the Kitakami from north to south, and the Abukuma from south to north—and along which passes the chief highway of Japan. The valleys separate the Abukuma and Kitakami ranges from a high ridge which, traversing the middle of Northern Japan, forms structurally the backbone of the region, and constitutes the main watershed between the Pacific Ocean and the Japan Sea. This central ridge owes its origin to volcanic effusions of comparatively younger date, and consequently the natural barrier thus created is made up mostly of prominent volcanic peaks, and differs in its features from the neighbouring old land. The more important of the volcanic peaks are, Osore-yama and Yake-yama on the extreme north of the main island, and thereafter Ganju-san, Komaga-take (Province of Rikuchū), Zoō-zan, Azuma-san, Bandai-san, Nasu-dake, Shirane-san (Province of Shimotsuke), Akagi-san, &c. These mark the course of the line of weakness along which terrestrial disturbances of varying degree have manifested themselves, in times past, attaining their climax during the Tertiary Era, and thereafter declining into their present state of comparative quiescence.

Bandai-san (Lat. 37° 36′ N., Long. 140° 6′ E.) is situated in the Yama District (*kōri*) in the Province of Iwashiro, immediately adjacent to the Abukuma mountain region, a part of which, formed of granite and gneiss, borders the east bank of the river Nagase that runs immediately past the foot of the volcano. Besides Bandai-san, there are in this part of the country several other volcanoes, both active and extinct, as shown in Pl. XXIV; the line of principal volcanoes belonging to the central ridge of Northern Japan, already referred to, is shown in the same Plate by a broken line. On the north-east of Bandai-san are Dake-yama and the Azuma-san group, the latter consisting of three principal peaks called the Eastern, Western and Middle Azuma; while on the south are Nasu-dake, Takahara-yama, &c.

Immediately north-west of Bandai-san there is a small lake called Okuni-numa, at an elevation of 1065 m. above the sea-level, and surrounded on all sides by ridges, the highest of which is called Nekoma-yama, and rises 305 m. above the lake. Judging from its features, Okuni-numa is unquestionably an old crater. Between it and Bandai-san there stands a round-topped hill, till lately overgrown with forest, and known as Marumori-yama, which is apparently a small volcanic cone. The few naked tree-trunks, stripped of branches and leaves, that are now to be seen on this hill-top vividly attest the severity of the recent eruption.

From the fact that the older rocks of the Abukuma mountain-land underlie the volcanic groups in the vicinity of Bandai, it seems reasonable to infer that the volcanoes originated on the fractured edges of the old formation.

Though all of the volcanoes that have been in eruption in recent times are shown as active on Plate XXIV, it is to be understood that such activity never exceeded intensified solfataric explosions, disturbing the upper crust alone. The late explosions of Nasu-dake and Azuma-san were of this class only, neither lava nor pumice having been ejected. The extreme volcanic energy which once raged in the district of Bandai seems to have gradually waned down to the present time. Denuding action has evidently played a more prominent part than plutonic agency in changing the forms of the mountains, and the decomposition of the rocks has produced a thick layer of soil, supporting a dense forest-growth, and concealing the old lava-flows and scoriaceous ejections which attest the volcanic origin of the hill-masses. Peasants worked daily among the green forests of Bandai, to collect fuel and to fell trees, wholly unsuspicious of the calamity that hung over them.

The district about Bandai-san is made up principally of tufa-

ceous deposits and sheets of volcanic rock, forming the basis of an elevated area known as the Aizu Plateau, which includes the districts of Yama, Aizu, Kawanuma and Ōnuma, in Iwashiro, its average height exceeding 500 m. above the sea-level. This plateau is surrounded on all sides by mountains of volcanic origin. On its southwest border stand the extinct volcanic peaks of Hakase-yama, Mikagura-dake &c., and on the south the conspicuosly flat-topped Nunobiki-yama, formed of volcanic sheets. Among these mountains are found numerous hotsprings, more than 30 of which have been counted.

The streams which rise in the surrounding mountains discharge into a depression on the south side of Bandai, there forming the Lake Inawashiro, which is one of the largest in Japan. This lake, the surface of which is 496 m. above the sea-level, is not a true crater-lake as is sometimes supposed. Its principal feeder was the river Nagase, flowing from the northern part of Bandai. The upper course of this river was, however, entirely stopped by the falling *débris* during the recent eruption, and the lake is now supplied mainly by its tributary, Sukawa, flowing from Azuma-san. The lake discharges northwestward, at the village of Tonokuchi, by a stream which flows through the Aizu Plateau under the name of Nippashi-gawa for about 19 kilometres, then joining the Aka-gawa. The latter stream collects all the waters of the Aizu Plateau, and finally runs into the Japan Sea near the port of Niigata. Recently another outlet was made on the eastern side of the lake, by means of a canal for irrigation.

It seems probable that the Inawashiro Lake fills up a depression formed by evisceration of the ground, resulting from the copious outpourings of volcanic products in its vicinity, notably those of Bandai. The origin of the lake, according to current tradition, is ascribed to a great terrestrial disturbance which took place in the

ninth century. The districts known as Tsukinowa and Sarashina, consisting of 49 villages, are said to have been submerged on that occasion.

The name Bandai-san is usually given to a group of peaks, consisting of Ōbandai, Kobandai (lately destroyed), Kushiga-mine, and Akahani-yama, surrounding an elevated plain called Numano-taira. (Pl. XV). This group, standing on the northern side of Lake Inawashiro, forms a very conspicuous object in the landscape, and displays the characteristic outlines of a volcanic mountain. When seen from the southwest side, from the town of Wakamatsu, it appears as a single pointed peak. It has sometimes been called the "Fuji of Aizu," from its resemblance to the well known Fuji-yama. Ōbandai, or Great Bandai, is the most prominent of the peaks, its summit being 1840 m. above the sea-level. It presents a highly rugged and precipitous escarp toward the Numano-taira, exposing volcanic strata which are the results of accumulations of augite-andesitic lava and scoriæ during its period of activity. Viewed at a distance from the east, Ōbandai has a highly characteristic appearance, descending by a very steep slope toward the central plain and by a gentle one in the opposite direction. Kobandai, or Little Bandai, was less known, on account of its being situated far away from the inhabited portions of the Aizu Plateau, and being also partly screened by its more prominent sister peak. From the latter fact it appeared to be lower than Ōbandai, and was therefore so regarded; and hence its name. But careful examination has shown that they were probably of almost identical height, as will appear farther on.

It is probable that the plain Numano-taira is the remains of the original crater—Atrio—and that the several peaks above mentioned are parts of the Somma-wall which encircled it. But gradual denudation during long periods of quiescence, together with occa-

sional rendings of the crater-wall when explosions took place, have brought about the present form, namely, that of separate masses presenting more or less conical shapes. In the Numano-taira, or "plains with ponds," there were several small lakes or pools, as is usual in craters of this nature. Nearly in its centre, there existed before the eruption a solfatara on a small hillock called Iwō-yama, or "sulphur mount," from which sulphur was collected by the neighbouring villagers. The plain was also covered with dense forests, which were destroyed on the 15th of July.

The flanks of Bandai are cut into numerous channels called "sawa." The largest of them is that known as Biwa-sawa, which opens eastward from the Numano-taira. It was down this ravine that the smaller stream of mud and rock descended in the late eruption. Seen from the east, it presents a very conspicuous appearance. Fig. 2, Pl. XVII, is a sketch made of this part of the mountain immediately after the eruption. From our point of view we had a magnificent prospect of Ōbandai, with its rugged and precipitous wall on the northern side. The plain of Numano-taira is seen to terminate in a very steep cliff, known as Futatsu-iwa, at which place the water of the lakes in the above plain made a sudden leap, forming a high waterfall. Immediately below this is a small depression called Hikage, which has been regarded by some as a secondary crater of the late eruption. Another large ravine is that lying between Ōbandai and Akahani-yama, opening southward, and named Katsura-sawa. There is also a bare glen on the southern flank of Ōbandai, known as Kara-sawa. These ravines or valleys may be considered to have been chiefly modelled by the paroxysmal explosions which, as the history of the mountain tells us, took place at intervals in past times. Denudation, however, has doubtless modified their original forms. The same remarks may be held to apply to the topographical features of the

whole mass. For, not only must the original form of the mountain have suffered by the sucessive eruptions, but the *débris* thus produced, obstructing the water-courses, must have gradually brought the surface to its present form. Some of the outbursts would seem from the history of Bandai-san to have been very similar in character to that of the 15th of July last.

The hot springs on the north-western side of Bandai, known as Bandai-no-yu, were latterly the principal remnants of the volcanic forces which once raged with so much vigour. There were three of these springs, all celebrated for their curing effects upon various diseases. They were known as Kami-no-yu, Naka-no-yu, and Shimo-no-yu, respectively meaning the upper, middle, and lower bath, where small huts had been constructed for the accommodation of bathers, who flocked thither in summer from various parts of the neighbouring district. They were sulphur springs originating in solfatara formed by the issuing of steam and sulphuretted hydrogen from numerous rock-fissures.

Several years before the eruption Prof. J. Milne,* of the Imperial University, ascended Bandai-san, when he took a sketch and described it, classifying it as an active volcano.

Traditions and History.

According to tradition, Bandai-san was originally a single massive peak, the summit of which was burst open in olden times by a volcanic eruption, and split into several peaks, the event being productive of a terrible catastrophe. The *débris* of the explosion descended on all sides of the mountain, and the two districts Tsukinowa and Sarashina, containing some fifty villages, were engulfed beneath

* The Volcanoes of Japan—Transactions of the Seismological Society of Japan, Vol. IX. Part II.

the area thereafter occupied by Lake Inawashiro. This account of the splitting of one large mountain into several minor peaks is interesting, as it agrees with the suppositions suggested by the structure of the volcano. For, as has been previously explained, the several ridges together constituting the Bandai group surround an elevated plateau which has all the appearance of an old crater.

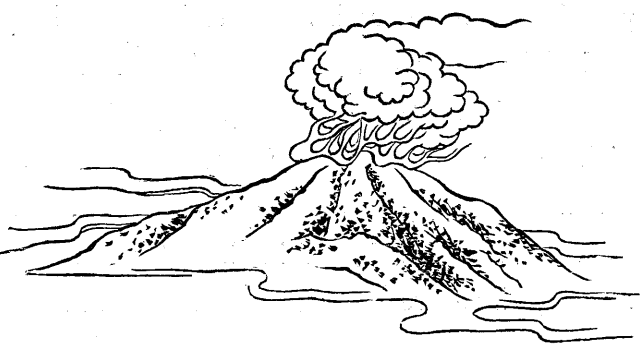
Another tradition, apparently referring to the same event, says that in the first year of Daidō (806 A. D.) Lake Inawashiro was suddenly formed, and in it a small island, now called Okina-shima, appeared.

Religious traditions, on the other hand, not unnaturally connect the catastrophe with demoniacal agencies. A Buddhist temple in a village near Bandai-san contains a document, said to chronicle its founding, which runs thus: "In olden times there used to dwell about Bandai devils who did much harm to the inhabitants; in the year of Daidō numbers of people living at the foot of the mountain were swallowed beneath the earth, and there was left a great lake (Inawashiro). The reigning Emperor, in order to subjugate the evil spirits which were probably the cause of all these terrestrial mysteries, despatched the famous priest Kūkai, who, on arrival at the spot, performed ten days' secret prayer to Buddha, when the devils were compelled to vacate Bandai and to flee to the neighouring mountains. In commemoration whereof, Kūkai caused this temple of Dainichi-ji to be built."

Several ancient records describe the mountain as having at various times smoked and ejected fire and poisonous vapours. Such accounts are highly interesting, especially when we consider the volcano's apparent quiescence for ten centuries. We give below translations of some of the records published by the Geographical Bureau, with remarks on them.

The *Koden* (古傳, Old Tradition) says: "This mountain vomited fire; and sulphur was spread over the country for 10 *ri* around, its vapour being injurious to health. After Lake Inawashiro was formed, the fire ceased and the vapour was dispersed."

The *Tōgoku Ryokōdan* (東國旅行談, Travelling Tales in Eastern Provinces) says: "To the east of Lake Inawashiro there stands a steep peak called Bandai-san; from its high summit ascend blazing fire and smoke, as if to burn the firmament." This account is followed by an illustrative sketch, as in the accompanying wood-cut, of the volcano belching forth fire and smoke.



In the *Ōu Benranshi* (奥羽便覽誌, Handbook on Ōu Provinces) the following account is given: "Aizu-yama, commonly called Bandai-san, lies to the east of Lake Inawashiro; from its top ascends burning smoke."

It sounds strange to hear of flame and fire; but we ought not to put much confidence in the tales of travellers, which are too often exaggerated and grossly inaccurate. Though the phenomena caused by streams of molten lava in volcanic eruptions are commonly spoken of as presenting the appearance of flames and fire, we do not find in Bandai-san any indication of lava-flows that can have taken place within historical times. It may be added, however, that there are cases on record in which flames caused by the combustion of gases have been a feature of volcanic outbursts.

The *Shinpen Aizu Fūdoki* (新編會津風土記, Accounts of Aizu)

says: "In olden times the destruction of a part of Bandai-san gave rise to Akahani-yama. The effects were very violent and extensive; earth and stones falling down dammed the stream of Sugawa and inundated Hibara." To the north-west of Oda village there are places respectively called Ōnamiyose (large wave beach) and Konamiyose (small wave beach). These localities, it appears, were formerly washed by the waters of lakes formed on the occasion above referred to, which, however, subsequently disappeared. As to the cause of this destruction of Bandai-san, it is not clear from the description whether it was volcanic or otherwise, but the phenomena exhibited seem to have been similar in character to those of the late eruption. Besides, there are authentic records of other terrestrial disturbances of much younger date, though perhaps of less magnitude, which have occasionally troubled this part of the country. These accounts seem to attest successive outbreaks of the same store of energy that wrought such havoc on the 15th of last July.

In the 8th month of the 16th year of Keichō (1611), a violent earthquake occurred at Bandai, and the fall of earth and rocks that was produced by this convulsion dammed up the river Nippashi, the outlet of Lake Inawashiro, and resulted in the formation of three new lakes. Water issued in great quantities from fissures opened in the ground. Accumulations of water, caused by the stoppage of streams, formed several other lakes, and in one place a waterfall of considerable height. In the villages of Matsuno and Terauchi some temples were overthrown; and there were innumerable damages of other kinds. In spite of the efforts of Gamō, the ruling Daimyō, who employed large numbers of men to cut an outlet for the accumulated waters, inundation spread over the districts Yama and Kawanuma, producing a lake at Yamazaki; and it was not until after several engineering attempts that a passage was effected, by the aid of which

about one-half of the inundated area was at length reclaimed.

During the period Hōreki (1751-1783), another convulsion took place in Mount Hanzawa, and created the present lake of that name.

The last recorded disturbance, although its particulars are not known, is said to have taken place about 80 years ago, when several lakes in Numano-taira were filled up, and great quantities of *débris* descended by the Biwa-sawa. Traditions and tales relating to this event were cherished with superstitious fear by the peasantry of the region, and listened to with wondering awe by the children, until there fell upon them the yet more terrible catastrophe of last July, which we now proceed to describe.

Eruption and Attendant Phenomena.

On the morning of July 15th, 1888, the weather in the Bandai district was fine, there being scarcely a cloud; and a gentle breeze was blowing from the W.N.W. Soon after 7 o'clock, curious rumbling noises were heard, which the people thought to be the sound of distant thunder, often heard among the mountain-tops. At about half-past 7, there occurred a tolerably severe earthquake, which lasted more than 20 seconds. This was followed soon after by a most violent shaking of the ground. At 7.45, while the ground was still heaving, the eruption of Kobandai-san took place. A dense column of steam and dust shot into the air, making a tremendous noise. Explosions followed one after another, in all to the number of 15 or 20, the steam on each occasion except the last being described as having attained a height above the peaks about equivalent to that of Ōbandai as seen from Inawashiro, that is to say, some 1,280 m, or 4,200 feet.

The last explosion, however, is said to have projected its discharge almost horizontally, towards the valley on the north. And, considering the topography of the mountain and the form of the crater,

it is probable that previous discharges were also more or less inclined to the vertical, in a northerly direction. The main eruptions lasted for a minute or more, and were accompanied by thundering sounds which, though rapidly lessening in intensity, continued for nearly two hours. Meanwhile the dust and steam rapidly ascended, and spread into a great cloud like an open umbrella in shape, at a height equal to at least three or four times that of Ōbandai. This cloud was gradually wafted away by the wind in a southeasterly direction. At the immediate foot of the mountain there was a rain of hot scalding ashes, accompanied by pitchy darkness. A little later, darkness was still great, a smart shower of rain fell, lasting for about five minutes. The rain was quite warm. These phenomena, as well as the terror and bewilderment which they caused among the peasantry, were described in thrilling terms by the newspapers of the day. While darkness as aforesaid still shrouded the region, a mighty avalanche of earth and rock rushed at terrific speed down the mountain slopes, buried the Nagase valley with its villages and people, and devastated an area of more than 70 square kilométres, or 27 square miles.

Account of an eye-witness.

Mr. Tsurumaki, a priest of Echigo, who was staying at the Nakanoyu spa on the edge of the crater at the time of the eruption, and who escaped death almost miraculously, sent us soon afterwards the following interesting and minute account of his terrifying experiences: "I started from my native village on the 8th of July, in company with four of my friends, for Bandai-san, and arrived there on the 12th, *i. e.* three days before the catastrophe. I had been there before, in July, 1885, when I stayed three weeks. On the day of my recent arrival (the 8th) the fog was unusually dense, and the volume of steam at Kaminoyu seemed to have lessened. On the 13th the fog was denser still, and remained so till the evening. The 14th was a bright day, the fogs of the previous days having cleared up. From

about 10 o'clock in the morning of this date the flow of the spring began to diminish. But the fact that the amount of discharge is smaller in fine weather and larger in cloudy days is well-known among bathers, so that we gave no heed to it. The morning of the 15th, which was the fatal day, dawned with a bright and pleasant sky, and the flow of the spring was as usual. At about 8 o'clock, however, there was a fierce convulsion of the ground, and we all rushed out of the house. In about 10 minutes (seconds?), while we were fearfully wondering what was the matter, a terrible explosion suddenly burst out from the slope of Kobandai, about one *chō* * above a place at which steam has been issuing from time unknown. This was followed by a dense mass of black smoke, which ascended into the air and immediately covered the sky. At this time, showers of large and small stones were falling all about us. To these horrors were added thundering sounds, and the tearing of mountains and forests presented a most unearthly sight, which I shall never forget while I live. We fled in all directions, but before we had gone many metres we were all thrown prostrate on the ground. It was pitchy dark; the earth was still heaving beneath us; our mouths, noses, eyes and ears were all stuffed with mud and ashes. We could neither cry out nor move. I hardly knew whether I was dead or in a dream. Presently a stone fell on my hand, and I knew I was wounded. Imagining, however, that death was at hand, I prayed to Buddha. Later, I received wounds on my loin, right foot, and back. After the lapse of an hour the stones ceased to rain and the atmosphere had cleared from darkness to a light like moonlight. Thinking this a fine opportunity to escape, I got up and cried, 'Friends, follow me!'; but nobody was there. When I had descended about two *chō*, there was a second, and after another *chō*, a third explosion. In these sand

* One *chō* is nearly equal to 109 mètres.

and ashes were ejected, but no stones. I reached Ōdera at noon, and there I received surgical treatment, etc."

Deluge of rock and earth.

The most striking feature in the whole of this eruption was the deluge of rock and earth. Notwithstanding the violence of the phenomena, and the completeness with which the mountain was destroyed, the nature of the eruption was comparatively simple. The destructive agency was merely the sudden expansion of imprisoned steam, unaccompanied by lava flows or pumice ejection. When the explosion took place, a considerable amount of rocks and earth was projected into the air, and a part diffused in the form of dust, but by far the greater part of the bulk of Kobandai was just split into mighty fragments, which were thrown down much after the manner of a land-slip. Descending the mountain sides with ever accelerating velocity, the components of these avalanches were dashed against obstacles in their way and against each other, and were thus rapidly reduced to confused masses of earth and rocks. The loose and friable *débris* thus produced ultimately lost its adhesive power, and may have been compared with a little exaggeration to sand. If we suppose a mass of some 1.21 cubic kilométres, or 1,587 millions of cubic yards (which was the actual volume of the mountain destroyed), of sand to be suddenly precipitated from a lofty summit, it would flow down the sides in a torrent not very unlike that of water. That the earth and rock *débris* did flow down in this way we were convinced by examining the actual state of things on the spot, and more particularly by witnessing afterwards with our own eyes a very similar phenomenon, though on a vastly smaller scale.

One day, while we were at work in the crater, a huge slice of the precipitous wall of rock that had been bared by the explosion fell suddenly and crashed with a tremendous uproar down the steep incline beneath. This slab fell from a place about 300 métres high. The

great masses of earth and rocks were shattered as they fell, and broken up into pieces, ever growing smaller as they descended. The behaviour of this pulverized mass resembled the rush of a headlong torrent. Although boulders measuring 10 métres or more in diameter were mixed up with finer matter, as a whole the movement approximated to that of a fluid. No words can describe the fierceness and force of that impetuous downpour—its mad surgings this way and that, and the bold leaps with which it would now and then bound over low ridges that hindered its progress, and shoot onward down the neighbouring depression. It was a magnificent but somewhat awful sight to witness during an afternoon's ramble.

In a like manner probably, but on a vastly more gigantic scale, the stream of materials on the 15th of July ran down the slopes of Bandai-san, dividing as it went into two principal branches.

The main branch flowed northward. Kobandai, it must be explained, sloped on the north towards the Nagase valley, in an unbroken descent; and, as the mountain burst on this side, the *débris* dashed with great violence down this northern slope in the direction of Hibara, 9 kilométres away. One part of the torrent actually ran *up* the valley, toward the source of the River Nagase, burying on its way the three hamlets of Akimoto, Hosono, and Osuzawa. A part, however, of the pulverized earth ran *down* the valley; reaching Kawakami spa and submerging it to a depth of probably more than 40 métres, it proceeded southward to Hinokuchi, 3 kilométres farther down.

The other and much smaller branch took quite a different route, making an angle of nearly 120° with the main stream. It came down by way of Numano-taira, through Biwa-sawa, rapidly spreading as it descended, and dividing into three minor ramifications. The southernmost of these just reached the village of Miné, overwhelming

nearly one-half of the houses, with their inmates. Fig. 1 of Pl. XVII. is a view taken from the outskirt of Inawashiro, at a distance of nearly one kilométre from the mud field, showing the village of Miné in front, and the avalanche (d) of rock and earth descending upon its prey. Fig. 1 of Pl. XVIII. is another and nearer view of this mud-field.

The combined volume of these two great streams entirely covered an area of 27 square miles, or 70 square kilométres, with a solid sea of mud and rock, beneath which were buried all the features of the landscape, together with people, cattle, and other living things. The grey tint on Pl. XV. marks the area thus devastated.

Velocity of the descending materials.

The descending matter must have moved with great velocity. By some survivors it was described as having reached their vicinity almost instantly after the eruption. From several calculations, made by comparing the time of the explosion with the times at which the streams of *débris* arrived at different points, we roughly estimated the average speed to have been 77 kilométres or 48 milés per hour. On its course the mud-stream must have swelled into great waves, as in a surging current. This is attested by eye-witnesses. The wave-like traces left on the sides of the hill (Pl. XX) show how the torrent surged upwards when it met any obstacle either obliquely or at right angles. In one case near Kawakami, the earth reached a height of at least 40 métres above the general level on a hill facing the direction of flow and at other 40 métres places a spur of the hill which the current struck obliquely caused an uprush of from 30 to 60 métres. The general appearance of the present surface is one of extraordinary havoc and confusion, irregular lumps of earth being mixed up with torn-off trunks and branches of trees, fragments of timber, and stray boulders of huge size. In some places the matter has been largely admixed with water, and is treacherous to walk on.

In describing the phenomena of the earth and rock *débris*, the word *mud* has been frequently used by several observers, who speak of 'mud-stream,' 'mud-field' etc. We also have used the term above, but it must be explained, to avoid misconception, that we have done so for convenience only. Some commentators, indeed, have erroneously classed the phenomena with those of the 'mud volcanoes' of which we read in geological text-books that, while some have been known to throw up mud to a great height, in others liquid earth only oozes out quietly, and gradually forms an earth-ring round the crater. Such outbursts, however, are no more than moderate manifestations of subterranean energy, and are almost insignificant in comparison with the tremendous forces that destroyed Kobandai-san. Moreover, as far as our prolonged examinations went, there was no evidence of any discharge of mud from beneath. It is true that in the Nagase valley and other places there are now immense quantities of mud, but these became mud only after the eruption. During its descent, for example, a part of the *débris*, mingling with the waters of ponds and lakes in its course, doubtless acquired a muddy character and was thus assisted in its flow; and, again, that which reached the stream of the Nagase-gawa became admixed with sufficient water to thin it to the consistency of a paste. But by far the greater volume was comparatively in a dry state, being moistened only by condensing steam, and must have derived its fluid or semi-fluid properties from a rapid process of pulverization after the manner already described.

With regard to the secondary mud-stream that ran down to Miné, there has been a diversity of opinion. Some visitors imagined that there must have been more than one crater—that, in fact, the materials which destroyed Miné had a separate origin from the rest; and a cleft or depression at Hikage in Biwasawa, which, as viewed

from below, bore some resemblance to a broken crater-wall, was not unnaturally regarded as a proof of this assumption. But the spot, when examined by us, was found to be wanting as well in the characteristic features of a crater as in any appearance of its having been the origin of a violent volcanic outburst. If there had been such an outburst as to produce the vast quantity of matter that descended towards Miné we must have seen the crater or cavity from which the matter issued, unless indeed it were supposed to have oozed forth gradually after the manner of some of the mud-volcanoes already spoken of—a supposition, however, which is absolutely at variance with the observed facts.

The matter which descended toward Miné was really found, upon close examination, to be the loose red loamy soil that had formed the superficial covering of the flanks of Bandai, largely admixed with ash or dust, and boulders. The red colour of the soil was however concealed from view by the coating of grey-coloured "ashes," 10-30 cm. in thickness, that fell especially abundantly down Biwa-sawa, the wind having been directed straight into that ravine during the eruption. At Numano-taira the accumulation of ashes was especially thick, and from thence it gradually lessened toward the lower part of Biwa-sawa. The mud field of Miné examined some time after was found to have been cut by the action of running water into numerous deep chasms often forming perpendicular walls and exposing the red loam underneath.

Conical Hills.

Among the various phenomena that constantly bewilder the eyes of visitors to the scene of the eruption, not the least striking are the numerous big boulders, some of them measuring from 5 metres to 10 metres each way, that are to be seen resting on the surface of the *débris* far away from the crater. These have evidently been carried along as part of the mud current, and not hurled through the air. Not less curious

are the quantities of small cones, varying from a few metres up to 15 metres in height, which are scattered here and there over the surface, standing out of the *débris* like so many miniature Fujiyamas. Fig. 1, Pl. XXI. and Pl. XXII will give some idea of these objects, as seen respectively from the northern and eastern side of Bandai. When closely examined, they are found to be disintegrated crumbling rocks, so affected by the agency of heated steam and corroding gases as to have lost their compactness. They are similar in character to the disintegrated rock commonly found near the crater-walls of active volcanoes. During and after their swift descent down the mountain sides, these rock masses have crumbled away, and the *débris*, falling around their bases, has assumed a conical shape by forming *taluses* around them. Fig. 2, Pl. XVIII, is a representation of one of the smaller of these hills found near the former site of the Kawakami spa.

On reaching the outposts of the mud field, no one could help being struck by the singular way in which the advancing stream of rock and earth seemed to have suddenly stopped, showing a vertical or nearly vertical face, a few metres high. It is apparent that the *débris* of rock and earth in their swift descent behaved like a fluid, but on nearing to the plain below they gradually lost speed and were ultimately brought to rest; the materials that followed, on account of their great friction and adhesion could not pass the limit set by their predecessors, and were piled layer on layer, thus forming a steep edge.

Volcanic dust.

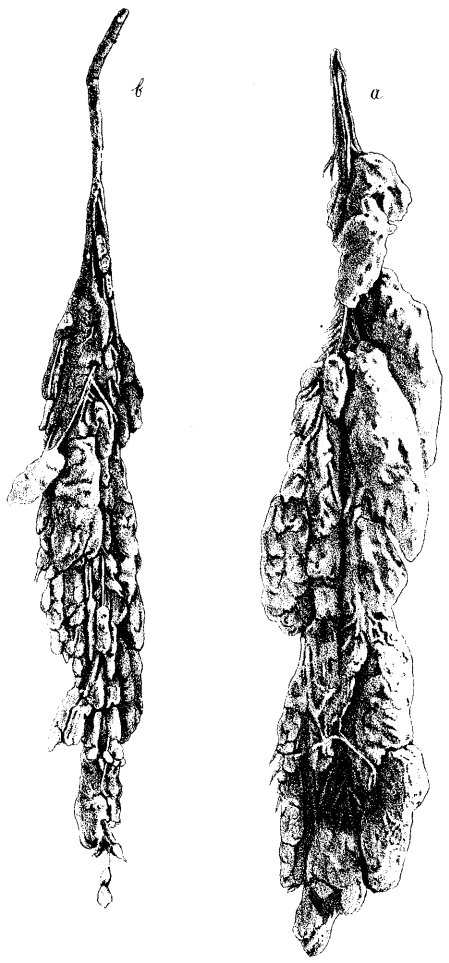
As is usual in all volcanic outbursts, large quantities of greyish-blue dust, or so-called ashes, fell during the eruption in the form of showers. Evidently much of this dust was produced by the mechanical trituration, during their flight through the air, of the rocks ejected by the explosions, which rocks, as already explained, had been rendered highly friable by the action of steam and gases. We found, in fact, that the dust was allied in character to the pulverulent matters com-

posing the conical heaps of *débris* above described, and that both were derived from the andesitic rock which composed the mass of Bandai-san. Hence it is apparent that this dust or ash is quite different in character from the ashes that are usually ejected from craters in other volcanic eruptions, *e. g.*, that of Krakatoa in 1883. In such cases, the ashes are chiefly derived from molten magma, expelled by steam and mixed with fragments of the pre-existing rocks. They contain, therefore, more or less glassy matter, and are in fact pumiceous.

On the morning of the 15th, the wind blew from the W.N.W., so that the dust was carried towards the E.S.E., gradually spreading as it receded from the mountain. On the coast of the Pacific Ocean, which is 100 kilometres or 62 miles from the volcano, the width of the dust fall was 50 kilometres or 31 miles. In shape the dust-strewn area resembled that of partly opened fan, as shown by the dotted space on Pl. XXIV. On the land it covered a space of about 2,050 square kilometres or 790 square miles. How much farther it spread over the ocean we had no means of ascertaining.

At the immediate foot of the mountain, especially toward the S.E., the dense cloud of dust produced pitchy darkness, which, however, did not last long; in the course of an hour the gloom had diminished to about that of the twilight of a rainy evening. But it was nearly 4 o'clock in the afternoon, or 8 hours after the eruption, before the dust wholly ceased to fall. The thickness of the deposite was about 0·3 metre on the south and east flanks of Biwasawa. In part the fall was in the form of a sticky, scalding mud-rain, produced by commingling of the dust with condensing steam. It inflicted terrible burns upon people exposed to it, and was the cause of many deaths. The ground also became so hot from this rain and the later dust that people had great diffculty in walking upon it. Every object was covered with a thick grey coating. Foliage, especially, that of the

sugi (Cryptomeria japonica), presented a very curious appearance, the leaves, branches, &c, being clothed with a thick, pasty and highly tenacious deposit resulting from a mixture of dust with condensing vapour. A bunch of *sugi* (*a*), and a branch of Pine (*Pinus massoniana*), (*b*), thus covered are shown in the annexed illustration. In Shibutani and its neighbourhood, which experienced the full effect of the dust-fall, not a green thing could afterwards be seen. Houses, paths, trees, fields, in fact all visible objects—wore a greyish hue. At Miharu a town 38 kilometres (24 miles) east of the volcano, the dust began to fall at about 9 a.m. and lasted till 2 p.m. During this period the sky had a dim and cloudy appearance, as on a misty day. The ashes hardly covered the ground, but all the leaves of trees and vegetables were tinted grey. At the coast a very slight film only was perceivable on the house-roofs and foliage. Damage to plants and crops by the fall of dust extended as far as 10 kilometres from Bandaisan.



Hurricane.

The explosions were accompanied by terrible wind blasts, or *coups de vent*. In the parts most exposed to the fury of these blasts, houses were levelled to the ground and trees torn up by their roots. Everywhere, however, as might be expected, the fall was in a direction radially away from the forces of explosion, which was also the origin of these destructive and fearful gusts. In Pl. XV the area swept by the windblasts is shown by arrows, their heads pointing in the directions in which the trees and other objects fell. It was curious to see the manner in which one particular field of growing rice, on the southeast of the volcano, had been thus levelled by the wind. The slender stalks were laid flat upon the ground as evenly and regularly as if they had been combed down in parallel lines. Not a stalk lay across its neighbours. The heads of rice in one furrow covered the roots in the next furrow, and the entire field looked like the warp of some huge loom ready for the weaver's hands.

It would appear that the tremendous explosions of steam at quick intervals, lasting for about a minute, produced violent disturbances of the air, consequent upon the sudden radial expansion of the liberated volumes of steam. When a large piece of ordnance is fired grasses, shrubs and objects in the vicinity are overthrown by the sudden expansion of the gaseous products escaping at the muzzle, which, displacing the air, imparts to it a forward impulse and violent vibratory motion. The eruption of Bandai-san may be aptly compared to the firing of a tremendous gun—such an one, however, as can only be forged by Nature.

Places screened by hills and mountain sides escaped. Marumori-yama, situated near the mouth of the crater, and fully exposed, received the severest damage. This hill, which was formerly covered with a thick forest, now presents a most melancholy appearance, the few trees left standing being as naked as telegraphic poles. The

levelling of houses and shattering of forests are of common occurrence in great storms. But on this occasion the destroying tempests especially near the crater were something more than atmospheric, consisting besides of heated blasts of steam and air, thickly mixed with dust and rock-fragments fierce enough to crush the trees and to strip them not only of branches but even of their bark, and withering, scoring, and scorching everything in their course.

Some of the most terrible effets of these tornadoes were wrought in the Biwa-sawa and its vicinity. Originating at the old crater, Numano-taira, this glen, the deepest and widest in Bandai-san, descends directly and in an unbroken line to the villages Shibutani and Shirakijō. Notwithstanding the comparatively great distance of these two villages from the crater, the wind-blasts were impelled towards them, down the Biwa-sawa, with prodigious force, and wrought havoc from which places a little out of the direct course of the wind were happily exempt. In the woods on the S.E. slope of Akahani-yama and on the west side of Biwa-sawa, the effects of the storm were especially striking; trees with a diameter of more than a metre had been laid prostrate on the ground in thousands; and a forest was thickly encumbered with fallen trees. Estimating the probable velocity of the wind from the effects produced in this localtiy, Mr. Y. Wada, of the Imperial Meteorological Observatory, thinks it can hardly have been less than 40 metres per second, or about 90 miles per hour. Here as everywhere else, the trees fell with their heads pointing away from the crater, showing clearly that the wind radiated in straight lines from its origin. There is no evidence of whirlwinds or eddy movements of any kind. The cause and effect of the wind in this locality deserve special attention, for which a brief topographical examination is first needed. South-south-west of the former site of Kobandai stands the massive peak of Ōbandai rising to a

height of 1,840 metres (6,035 ft.) above the sea, and east of it, Kushiga-mine, the third peak of the Bandai group, with an altitude of 1,622 metres above the sea. Between them is Numano-taira, the large flat basin of the old crater, with 1,311 metres above the sea-level. At the base of the huge U shaped aperture formed by the slopes of the two mountains the Biwa-sawa begins to descend. Fig. 1 on the wood-cut shows roughly the relative positions of the peaks and the old crater in plan, and Fig. 2 shows a vertical section through A B.

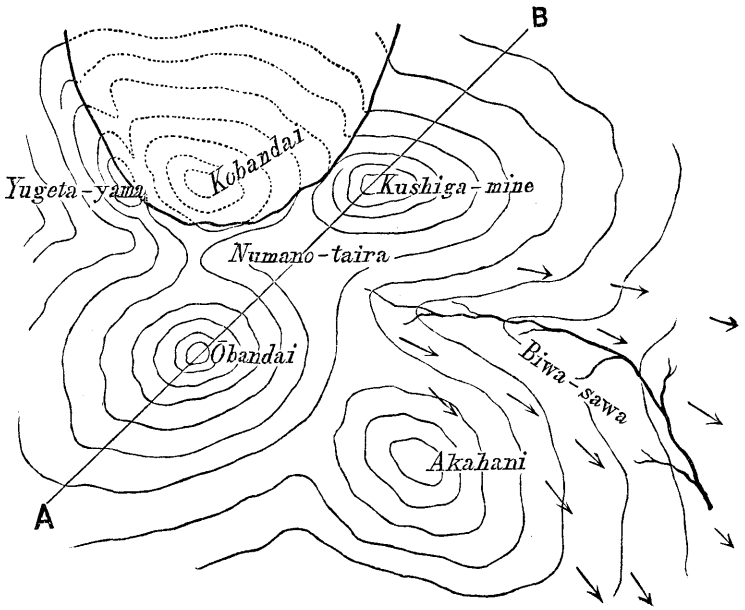


Fig. 1.

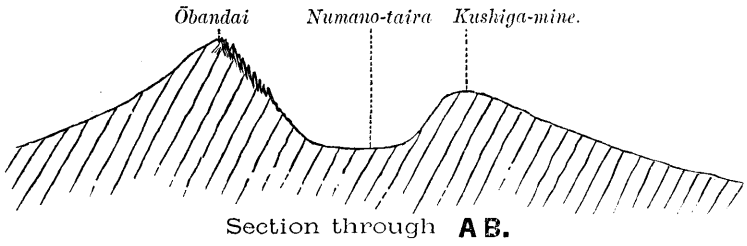


Fig. 2.

Now, when the steam emancipated by the eruption suddenly expanded and drove before it the surrounding air, a portion of this air

and steam must have been forced through the U shaped aperture aforesaid. Emerging therefrom at a very high velocity, it swept the whole Biwa ravine which preserved more or less the U shape downward, and ravaged the eastern half of the inferior peak Akahani. The evidences of this were clearly apparent on the ground itself, the dividing lines between the wind-swept area and the comparative calm which prevailed on either hand having been so sharply defined that the belt of levelled forests and ruined houses was separated by a few metres only from the unharmed areas to the right and left of it. Nothing new can be claimed for this phenomnon, which is a well-known characteristic of certain storms, especially of whirlwinds having their apex near the earth's surface. But its definition on this occasion was interesting and well-marked.

Attempts have been made to associate these particular *coups de vent* with the moderate northwesterly breeze that prevailed at the time. But it is obvious that, though this wind determined the direction of the dust-cloud in the higher regions of the atmosphere, it must have been powerless to contribute sensibly to those intense blasts which descended the Biwa-sawa and swept over the region at the base of the mountain.

Next let us examine how the wind behaved on the other sides of the volcano. On the east, as before described, Kushiga-mine formed a screening wall which deflected the course of the hurricane; on the west, Yugeta-yama, the part of Kobandai that remained undestroyed, and other ranges of hills arrested the expanding steam and the rush of air, and saved the forests behind. But on the north, there being no obstruction in that quarter, to which moreover the discharges were directed at an inclination to the vertical, the effects were probably tremendous, as was evidenced by the condition of Marumori-yama. Indeed, every spot of the ground to the north of the crater, for several

kilometres, was utterly turned 'topsy-turvy' and every land-mark obliterated. For this reason it was impossible to tell the real state of things in that quarter.

It is well known that at volcanic outbursts the immense volumes of steam, suddenly expanding occupy a much larger space than that of the original bulk. This sudden expansion cools the temperature of the surrounding atmosphere and lowers its pressure. Moreover, the steam in part condenses. To fill the partial vacuum thus produced, and to equilibrate the reduced pressure, there follows an inward rush of air towards the crater. The strong winds commonly described as a feature of volcanic eruptions, are probably due to this cause, and the same thing doubtless happened to a certain extent in the case under discussion. But the fearful blasts that wrought such havoc in the forests and villages on 15th of July certainly were not counter currents of this class, however strong these may have been. It was the gusts *from* the volcano that in this instance wrought the real havoc.

A whirlwind is described as having occurred during the volcanic eruption* in the Island of Sumbawa, in Java, on the 5th of April, 1815, when, soon after the ashes began to fall, a violent whirlwind ensued, which blew down nearly every house of Sangir; it tore up by the roots the largest trees, carrying them into the air, together with men, horses, cattle, and whatsoever came within its influence. The whirlwind lasted about an hour. It is not stated in this account, however, how the whirlwind was caused.

Conical holes. Several visitors to Bandai, ascending from the south sides and approaching the summit, had their attention attracted by numbers of curious conical basin-like holes, evidently the fruits of the late eruption. Their size varied from ·2 to 3 metres in diameter and from

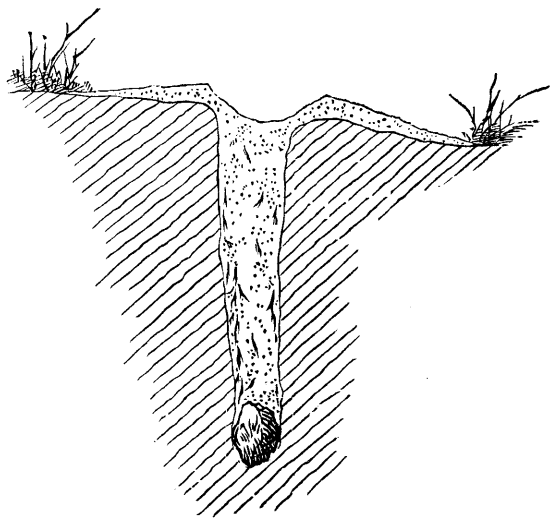
* Lyell's Principles of Geology, 12th Ed. Vol. II, p. 104.

a few decimetres to more than a metre in depth; and they were generally wider at the mouth than at the bottom. They were found in thousands in the neighbourhood of the crater, as well as on the extensive slopes of Ōbandai and Akahani, a few kilometres away.

As to the origin of these holes, though they were not perhaps a very important phenomenon of the eruption, it calls for a brief discussion, because it has been the subject which has caused a good deal of diversity of opinion and some lively controversy. First of all, they were regarded by some witnesses as miniature craters, each formed by a small explosion of steam. This supposition arose from the facts that several of the holes had the appearance of having been formed by ejections from below the surface, and that in some cases steam had been seen issuing from the holes. But the latter phenomenon was only to be seen near the solfatara adjoining the new crater, from which steam had been issuing for ages; and the appearance of fresh steam-jets in that locality would not be surprising after the convulsions caused by the catastrophe of the 15th of July. Even, however, if it be allowed that there were a few slight steam explosions in this immediate vicinity, it is, in our opinion, impossible to extend any such hypothesis to the innumerable holes of like appearance that were scattered over the extensive and distant slopes of Ōbandai, Akahani &c. Prof. J. Milne on the other hand, regarded the cause of the holes as seismic, but not volcanic, that is to say, he concluded that earthquake-waves produced at the time of the eruptions, and passing through the soil, caused sub-surface compression and distortion and thereby ejected earthy matter from below, by the spouting action of water. We shall show farther on that the above theory can hardly be applied to any but a few marshy spots in Numano-taira, to be presently described.

Others, again, contend that the holes were caused by the fall

of stones projected into the air from the crater. This we take to be the true explanation. Puzzled at first as to the origin of the holes, but determined to investigate it fully, we dug a number of them open. Thereby our doubts were soon cleared up. We found imbedded in the ground brittle and freshly fractured stones that had apparently been shot forth by the volcanic outburst. Where the soil was rocky, fragments of similar stones were scattered all about. In one case we obtained very decisive evidence. A stone was discovered in the soft loamy soil formed by the decomposition of andesitic rocks, at a depth of nearly 2·5 metres below the surface. The stone was angular in shape, measuring nearly 0·5 metres each way, and showed a freshly broken surface. Leaves of bamboo, dwarf pine, and creeping surface plants had been carried with it into the soil. These were much packed and crushed, but were still fresh and green when dug out. On closely examining the hole we found that, although more or less funnel shaped near the surface, it had been sharply cut through in a tubular form, by the passage of the stone which lay at its bottom. The original tubular passage was, however, filled up by loose detritus mixed up with ashes, and here and there with shrubs and bamboo twigs, while the surrounding soil was a compact native red loam. The main features of this hole are shown in the accompanying diagram.



It was stated before that the steam ascended perhaps 1,280

metres (4,200 ft.) above the crater. If stones were thrown up to the same height as the steam column, their initial velocity must have been 158 metres per second, and this may be roughly taken as the final velocity with which, on falling down, they would reach the ground. But if we suppose that the steam and stones reached to double or treble the above height, which is not improbable, the initial velocity becomes 224 and 274 metres per second respectively. The velocity needed for penetrating a soft loamy soil to a depth of 2·5 metres would be between 300 metres and 600 metres per second, according to the values of coefficients we take, but in these calculations, as we are using several more or less arbitrary assumptions we cannot take them as a sound basis for discussion.

It seems not strange, however, to find that the basin-like holes wearing those appearances of having been blown out from below have led to the theory of their formation by internal explosion. Stones striking the ground with great force would make holes of larger diameters than their own by throwing the surrounding earth outward. Again, if the fall of any stone take place at a spot where there are rocks on or near the surface of the ground, the concussion will shatter the falling stone and at the same time blow up the adjoiningd soil, thus producing the appearance of an eruption. We have witnessed great number of those cases on Ōbandai and Marumori-yama.

The inhabitants at the base of the mountain noticed among the rising steam small and large white objects ascending and descending like shooting stars. At one time, they were so numerous that they almost looked like white rain. It seems very probable that these objects were stones ejected from the crater.

That large fragments of rocks are hurled into the air during volcanic eruptions is a matter of common experience. But that they have left their traces upon mountain sides in the form of conical holes

has not, as far as we know, been recorded; perhaps it has never been observed. It must not be forgotten, however, that there would have been no such holes on Bandai-san if there had not been the thick layer of soft loamy soil to receive the falling rocks.

Mr. E. Odlum, of the Toyō Eiwa Gakko (Oriental English school), Tokyō, made a thorough investigation of the origin of the conical holes. He went twice to Bandai, the second time for the sole purpose of examining the holes, and his observations on the spot were very complete. Indeed, we consider that the facts and proofs brought forward by this observer must be held to settle the question. In a paper read last autumn before the Seismological Society of Japan, Mr. Odlum showed that hundreds of thousand of stones have been hurled into the air from the crater. People were wounded and forests were shattered by them. Sometimes fragments of rocks of considerable size were imprisoned on broken trunks of trees. Native mountain rocks had on their upper surface marks and scars made by the stone projectiles. On excavating some of the holes, Mr. Odlum found in them imbedded stones, some of which weighed 4,000 lbs, or 1,814 kilogrammes. Under these stones grasses, weeds, leaves, branches, and other kinds of vegetable materials were sometimes discovered, often bruised and shattered till they had the appearance of having passed between rollers. Many of the stones fell in a slanting direction ; they were not lodged in the centres of holes, but almost always to one side, that is, the side away from the crater. The earth round the imbedded stones was solid and native—no sign of their having been disturbed by explosive action or the like was found. The whole mountain, the top as well as valleys, was covered with these pits as if it had had a heavy attack of smallpox. To suppose, continues Mr. Odlum, that the holes were formed by the spouting action of subterranean water, as is held by some authorities, we must assume

that the whole mountain was literally made up of water, and inundation must certainly have resulted from the creation of such immense number of water jets in a short space of time. Mr. Odlum made numerous measurements of the pits; they vary from a few feet in diameter to over thirty feet, and from 2 to 10 feet in depth.

Lieut. Y. Nakashima, of the Army Department, who surveyed the volcano after the eruption, and who, from the nature of his work, acquired an intimate knowledge of the whole area is in entire accord with our opinion as to the origin of the pits.

Notwithstanding these evidences, however, the conclusions arrived at by us and other workers have been freely criticized, and doubts have been thrown upon them. Prof. J. Milne of the Imperial University, dissenting from our views and those of Mr. Odlum, believes that the cause producing the holes was seismic in character—to wit, the severe earthquake that accompanied the eruption. He quotes Robert Mallet in support of the hypothesis that they were produced by the spouting action of water from beneath, resulting from seismic compression of the substance of the ground. Similar pits, he says, were made in the great Calabrian earthquake of 1783, and they were specially investigated by a committee sent from the Royal Academy of Naples. These gentlemen also dug into holes, Prof. Milne continued to say, but we do not hear of their having found any boulders. We (the authors of the paper) think that the Neapolitan scientists did not strike into boulders, simply because the pits in the Calabrian plain were not formed by falling stones, which was the case on the slopes of Bandai. It was also argued that like phenomena were observed in the Charleston earthquake of 1886, when sand and muddy water were ejected, making more or less conical holes. But, as far as we understand the matter, the formation of holes during destructive earthquakes by the spouting of water or sand is limited to plains and

watery places. In the case of Bandai, such formation might have occurred in the marshy plateau of Numano-taira and perhaps in other limited areas among the valleys. But we regard it as impossible that ejections of water or soil, produced by seismic action, could have occurred over the great area covered by the pits under discussion on the rocky summits and steep slopes of Bandai and Akahani. It is true that in Numano-taira large round or elliptical holes were made, some of them having diameters of over 7 metres and being left partly filled with water. But, though it is not impossible that these particular holes were produced by seismic action, the more probable explanation is that the falling *débris* from Kobandai covered the ground to a great thickness, burying under it forests and ponds; and it is natural to expect that in this great field of loose *débris* depressions would be formed here and there by the falling in of the superincumbent layers. We ourselves observed some of the holes gradually increasing in size by the falling in of their margins.

In their paper read before the Seismological Society of Japan, Professors C. G. Knott (Tōkyō) and C. Michie Smith (Madras) contend that by far the great majority of holes are due simply to the uprooting of trees caused by the hurricane. This they regard as especially true of the region to the south-east of Ōbandai. They argue that if the countless numbers of holes were due to falling stones a great many other stones must surely have fallen on the same ground with velocities too small to make holes. But of these other stones there is no evidence. Besides they doubt if it is dynamically possible for a falling stone to make conical holes of the size and form described so fully by Mr. Odlum. For a stone to bury itself several feet in the ground and at the same time make a violent "splutter" is not, they think, at all credible. After the undoubted effects of uprooting of trees, and of landslips in a volcanic soil violently shaken

by an earthquake, are given their full weight, they consider that a very limited number of holes will be left to be explained by falling stones; and that these holes will be either flat basin-shaped bruises or tubular cavities of comparatively small diameter.

We shall not stop to answer all the points criticized by Professors Knott and Smith as we think we have already spoken enough on the subject. It is quite true, we admit, that conical holes were produced by uprooting of trees in forests; indeed we saw numbers of such holes near the upturned roots, especially on Miné-yama. As the origin of these there could be no doubt. But by far the greatest numbers of holes were found on bushy hills, on grassy slopes, in rocky glens, or in regions that were not occupied by forests, and on ground where the trees still stand uninjured. Such are the holes which we believe to have been formed by falling stones, and to which we have been referring throughout.

The fact that the bamboo leaves which we discovered under the stones, and which we brought back to Tōkyō, were comparatively uninjured was much criticized by saying that, if they had been forced into the ground by the bouders, they must have been more severely damaged. Those which we discovered were, however, originally much folded and packed, while the specimens collected by Mr. Odlum were crushed to a much greater extent.

Earthquakes.

Mr. Ōtsuka, a school-master in Hibara, who kept a diary of the weather and other matters, told us that there were slight shocks of earthquake on the 8th, 9th, and 10th of July. At about 3 o'clock on the afternoon of the 13th there were occasional shakings of the ground which were also felt at Inawashiro. Between 3 and 4 o'clock on the afternoon of the 14, i. e., the day preceeding the eruption, quite an extensive earthquake occurred in the neighbouring provinces, but although it was felt in the Bandai-san district its origin was far away

to the west near the coast of the Japan Sea.

On the morning of the 15th, at a little after 7, a feeble earthquake occurred, but it was so slight that many failed to notice it. After half-past seven a severer shock ensued, lasting nearly 20 seconds. This was followed soon after by very violent convulsions of the ground; houses rocked and swayed, furniture fell down, and the frightened people felt the ground heaving beneath their feet. It was reported that the nature of this earthquake differed from that usually experienced, in that vertical motions greatly predominated. The shock was a long one, lasting, according to some accounts, for fully a minute. While it was still in progress the eruption took place. Considering the fierceness with which this earthquake shook the immediate vicinity of the mountain, it is remarkable that the intensity was very rapidly decreased as the seismic waves were propaged into the surrounding region, and the shaken area was limited to a radius of, roughly speaking, about 48 kilometres, or 30 miles. This may be accounted for by the fact that the origin of the shock was rather near the surface. On Pl. XXIV the boundary of the area shaken by the earthquake is shown by a thick elliptical line.

Volcanic eruptions are generally accompanied by earthquakes, and the shocks on this occasion prove that sudden expansion of steam and breaking up of the earth's crust may produce seismic vibrations. The efforts of the pent-up steam, struggling to force its way through the superincumbent masses, at last succeeded in bursting through a weak point, the explosion being accompanied by violent convulsions of the ground, that were propagated as seismic waves.

On the 20th of July, at 11.50 a.m., a feeble shock was experienced. Other minor shocks are said to have subsequently occurred.

To see whether the ground in the crater was perfectly quiet after the eruption, we took with us a delicate though somewhat

roughly made pendulum tromometer, which had a magnifying power of 27. We first set it near a fissure from which powerful jets of steam were issuing with hissing sounds. In that position the instrument indicated very feeble vibrations of the ground, which were doubtless caused by the issuing jets. We next set it in Nakanoyu, near our camp, and made daily observations. As far, however, as the magnifying power of the instrument enabled us to judge, there was no evidence of lingering earth-tremors. And it would seem from this that the forces which produced the explosion had been completely expended in blowing away the mountain, and that the region had already become seismically quiescent.

Sound.

Near the volcano the detonations in the earlier part of the eruption were described as deafening. Though rapidly lessening in intensity, the thundering noises lasted for nearly an hour, and did not entirely cease for several hours. The area over which the sound extended was very much smaller than might have been expected From the tabulated reports at the end of this paper, and from other sources, it appears that the sounds of the explosions were not heard distinctly at a greater distance than 48 kilometres or 30 miles to windward of Bandai-san, though to leeward they were audible at the Pacific coast, a distance of 100 kilometres or 62 miles. How much farther they reached, over the sea, we had no means of ascertaining. Mr. K. Nakashima, of the Geological Survey, told us that, while he was ascending Kinboku-san in the island of Sado, on the morning of July 15th, he heard dull rumblings which were supposed at the time to proceed from the firing of heavy guns in the neighbouring harbour (Report 21). Sado is in the Japan Sea, nearly 161 kilometres or 100 miles west from Bandai-san, and therefore to windward of it. Possibly, however, the sounds heard by Mr. Nakashima came from the volcano. It was also reported that peculiar detonating

sounds were heard on the same morning in Takai-kori, in the Province of Shinano, distant about 164 kilometres or 102 miles southwest from Bandai-san. The barograph in the Imperial Meteorological Observatory in Tōkyō, which is 212 kilometres or 132 miles south of Bandai, was not affected. The magnetometer in the same Observatory also gave no record that could be regarded as an effect of the eruption.

While we were staying on the mountain we often witnessed the fall of large masses of the perpendicular crater wall, which, coming down from great heights with stupendous force, were smashed into thousands of fragments and descended with whirlpool-like movements to the lower levels. These slips produced terrible rumblings, which resounded throughout the crater, and were also heard far away. By the already panic-stricken inhabitants of the neighbouring villages these repeated noises were regarded with consternation as tokens of a further volcanic outbreak, and it was weeks before they became pacified and assured as to the real cause.

Lightning. From the ascending columns of steam and ashes vivid zig-zag flashes of lightning were seen to dart forth, and were accompanied by loud roars of thunder. These phenomena, observed from several points around the mountain, may be regarded as resulting from the discharges of frictional electricity which, as is well known, are liable to be brought about in volcanic explosions when steam at high tension escapes through a narrow orifice, and collides with the surrounding air and the more solid ejectamenta.

Sparks. While the main eruptions were going on, the people in Inawashiro and the neighbouring villages saw through the densely falling ashes innumerable vivid sparks of fire on the slopes of Ōbandai and Akahani, at considerable distances from the crater. These sparks were quite different in nature from lightning, presenting rather an appearance as of the firing of a vast number of guns. The probable

explanation of the phenomenon is that sparks of fire were produced by stones and rocks striking against each other in the air or falling on a rocky bed. Fragments of rocks are scattered in abundance on the slopes of Ōbandai, but we could discover nothing to lead us to believe that there had been combustion or any other heat manifestations. Sensational newspapers in their accounts of the eruption spoke of lurid flames, of a blazing crater and other terrors all probably founded on the peasants' reports of the sparks above mentioned. It very rarely occurs, however, in volcanic eruptions that flames are produced by the burning of gases issuing from craters. Sir W. Hamilton, in describing the Vesuvian eruption of 1779, noted that large vitrified masses (bombs), falling upon the ground, broke into many pieces, and set fire to combustible objects. In this case, however, the fire was produced mainly by the heat of the fused masses, whereas at Bandai the sparks were caused by impact. On the other hand, at the time of the great volcanic eruption of Tarawera, New Zealand, in 1886, the falling sand was said to have been hot and to have set the trees on fire.*

Optical phenomena.

As regards unusual optical phenomena, we have heard of one or two only that seem to have been connected with the eruption. Anything like the twilight-glows, haze, etc, which were such important features after the Krakatoa explosion, could hardly be looked for in this case, which, though exceedingly remarkable in many respects and interesting in the highest degree, was very much inferior in magnitude to the gigantic eruption of 1883 in the Sunda Strait. However, an observer at a place about 87 kilometres or 54 miles E. S. E. from Bandai noticed towards evening on the day of the eruption sparkling rays of red light issuing from the clouds (Report

* Nature, Vol. 34, 1888, p. 392.

15). Another, living in a village S. S. E of the mountain, saw with mixed fear and delight how the rising columns of steam from Bandai-san, refracting and decomposing the light that fell upon them, produced a most beautiful display of variegated colours (Report 8).

Premonitory signs.

It has been often asked whether there were any premonitory signs of the explosion. It is certain that slight shocks were felt on previous days, as well as half an hour before the outburst. But beyond this the evidence is vague. Some persons vouch to having heard mysterious rumbling sounds in the mountain prior to the eruption. Again, some animals are said to have shown alarm. No doubt before an explosion of such magnitude as that of Bandai-san, earth must have been in a seismically sensitive condition, and certain animals which are known to be highly susceptible to even minute earth-tremors may very well have been frightened on this occasion. Some well-waters are also said to have diminished in flow. None of these alleged facts, however, have been clearly established on the evidence of trustworthy persons. On the other hand, Mr. Tsurumaki says in his letter (page 105) that the bathers at Nakanoyu did not observe any abnormal changes in that spring, though it is situated on the very edge of the new crater. It would be interesting to know exactly how Lake Inawashiro behaved before the eruption. The water level of that lake is systematically recorded at two places on the shore, for purposes of irrigation. But we were unable to learn, either from conversation with Mr. Akiyama, who keeps the record, or from the entries in his books, that there had been any sudden fluctuations of level during the two months preceding the catastrophe. In reports lodged at the Fukushima Prefecture it is stated that the river Nagase, the Lake's chief feeder, decreased its flow from April or May, and that the water level of the Lake on the 1st of July was one foot lower than on the corresponding day of the previous year. A captain

of a steamboat running on the lake told us that his vessel, anchored close to the shore, was moved outwards nearly 0·6 metres by the disturbance of the water. Though this disturbance occurred almost simultaneously with the eruption, we are disposed to agree with the captain in believing that it was a result of the earthquake immediately preceding it.

On the whole, the only premonitory signs that were really trustworthy were the slight shocks which occurred on previous days and half an hour before the eruption, and no implicit faith can be placed on the slight testimony in favour of other warning symptoms.

Change of topographical features.

Volcanoes have often been described as one of the principal restorative agents in counteracting the denuding action of water that tends to bring the surface of the earth to a level. In the late eruption of Bandai, however, the effect was destructive and not constructive. The materials which had accumulated in past ages gave way, and were thrown down from a higher to a lower level in less than an hour; the effect of this being analogous to a gigantic land-slip. In this way, considerable changes have been wrought in the topography and contour of the adjoining districts. How the torrent of earth and rocks devastated an area of some 70 square kilometres (27 square miles) has already been described in the preceeding pages. The general effect of this spreading out of *débris* was to effect the levelling of the general contour; all the surface ravines and gorges, being entirely filled up. The northern side of Bandai was before the eruption, an undulating grassy plain—the 'Hara' so characteristic of volcanic districts in Japan—drained by the river Nagase, and dotted here and there with some straggling hamlets. Professor J. Milne who visited this part of the country several years ago described it as consisting of grassy slopes without any exposure of rocks. The descending deluge of *débris* pouring across Ōbudaira, as the northern

slopes of Kobandai are called, engulfed all the familiar land-marks, and converted the district into a desert waste. Thousands of conical mounds, large and small, have been formed on this vast sea of mud,—giving a quite unique appearance. Not only have the depressions been filled up, but the higher ridges have been reduced in height. The deluge of earth *débris* in its quick descent, impinging on the prominences that were lying in its way, have actually leaped over them, scraping off the outer-crust of the soil, and exposing the native rocks beneath, as a glacier might have done. In other places the torrent of rocks dashed against the hill-sides and scoured them away. Large quantities of mud carried along with rock, *débris*, and boulders, have penetrated deep into every recess of the valley. The largest and longest of the mud streams is that which flowed down the slope of the river Nagase to the Kawakami spa. Near the village of Hibara, and the former site of the little hamlet of Hosono, the peaty deposits which had accumulated in the marshy ground have been ploughed up. Large clumps of red loamy soil mixed up with half carbonized wood and grasses are found turned up or standing in an irregular state of contortion.* Nowhere could the scouring action of the mud torrent be better realized than in these parts.

The official reports relating to the area of land buried under mud are given in the following figures. The loss of property involved is said to have been immensely great. There is absolutely no hope of recovering or reclaiming the buried land.

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*Among this turned up peaty deposit, an interesting occurrence of *vivianite* may here be noticed. The formation of this mineral seems to have been brought about through the agency of organic matter. It is found in the form of a beautiful azure-blue coloured, fine powder, filling up the spaces especially of the rind and core of the fragmentary branches of half carbonized wood belonging to some Coniferous tree. The spot, however, where we have witnessed this phenomenon, being situated just on the sourthern front of Hibara lake, must have now been submerged under water.

	Square kilometres.	Square miles.
Cultivated land	0·82	0·32
Plains	22·60	8·73
Mountains and forests	41·93	16·19
Rocky slopes and glens	5·36	2·07
Total	70·71	27·31

It is highly probable that, though at present the new land appears like a desert waste, the growth of vegetation will take place in a comparatively short time favoured by the admixture of the fertile volcanic products.

One of the most striking secondary effects of the eruption is the formation of new lakes, due to the damming up of the river Nagase and its tributaries by the *débris* of the shattered mountain. These lakes are four in number, and are shown on Plate XV. They may be conveniently called Osuzawa, Hibara, Onogawa, and Nakatsu (or Akimoto) lakes, after the tributaries of the Nagase to which they are respectively due. The largest of them is Hibara lake, measuring nearly 4 kilometres or 2.5 miles from north to south, the breadth being nearly $^1/_3$ of the length. These lakes continued for many months to increase in size, through the gradual accumulation of water within the newly formed barriers of *débris*. Thus it was not till fifteen days after the eruption that the village of Onogawa became coverd with water. The inhabitants then fled to Hibara; but were subsequently driven out from that village also as the waters gradually rose.

Beside these four large lakes, there are scattered among the mud-field smaller patches of water caused by the accumulation of rain water, or formed by the smaller streams on the mountain-sides. These lakes will continue to increase in size until the water comes to the level of the lowest possible outlet from the hemmed-in basin. The

issuing stream will soon cut deep passages through the loosely cohering *débris*; and it is to be expected that sudden yieldings of some of the barriers will take place. Hence will result a rush of escaping water accompanied by violent floodings in the lower courses of the stream. It was thus that certain villages and cultivated field were flooded when the Nagase-gawa burst its lowest barrier, which immediately after the eruption quite stopped the flow of that river into Lake Inawashiro. Because of the loosely compact character of the *débris*, the configuration, size, and number of these lakes will alter greatly as time goes on.*

On the 13th of April of this year (1889) about 6 p.m., a large portion of Onogawa lake was suddenly drained, and the torrent of water rushed through the mud-field, carrying mud, pebbles, and boulders to the lower levels. The embankment newly erected at Nagasaka and other places to protect from inundation, was destroyed, and the water spread out into the cultivated fields adjoining the district of Inawashiro. Considerable damage was done to bridges, and roads, but fortunately the houses and inhabitants escaped.

New lakes or ponds are also being formed within the crater, by the condensing steam and the rain water. The waters of these lakes contain much soluble matters and some of them are hot. But as the crater-bottom is set in a sloping position, an accumulation of water to any considerable extent cannot take place.

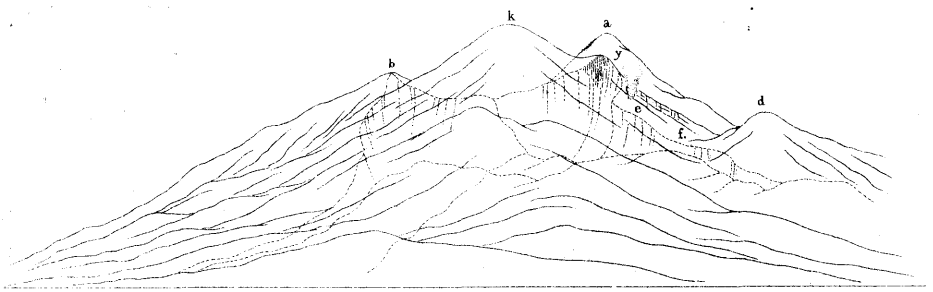
* As this is passing through the press, we are able through the kindness of Professors C. G. Knott and C. Michie Smith to call attention to the remarkable changes in the region under consideration. These gentlemen visited Bandai towards the end of May, 1889. They report that Hibara and Ōsawa lakes have united into one huge lake which forms the most prominent feature in the landscape. The other lakes are comparatively small. Of particular interest, also, are their observations on the erosion of the new earth by the action of running water. Thus the comparatively small stream that ran down Biwa-sawa has cut out of the new earth a deep V-shaped gorge, in many places attaining a depth of 40 or 60 meters. At these places the stream has not yet cut down to the original surface. Their observations are to be published in full in the Transactions of the Seismological Society of Japan.

The distant view of Bandai as seen from certain directions has been altered by the destruction of Kobandai. When viewed from its south side, however, e.g., from the town of Wakamatsu, the mountain apparently does not show any sign of great change; the prominent peak of Ōbandai entirely screening from view the place of devastation. Before the time of the explosion, the top of Kobandai, when seen from this side, was presented as a small prominence on the left side of Ōbandai. Fig. 3, Pl. XXI, is a sketch taken soon after the catastrophe. The dotted outline in this figure is the original form of Kobandai, which has now entirely vanished, and in its place columns of steam are seen rising.

The most magnificent sight is presented to view when the mountain is seen from the northern side, where the full force of the explosion may be best realized. The newly opened explosion-crater (Fig. 1, Pl. XVI, Fig. 1, Pl. XXI) is fully disclosed; the wreath of steam rising from its central linear fissures like a cumulus cloud. The sound of the evolving steam is distinctly heard from the village of Hibara fully 9 kilometres distant, evidently due to the fact that the crater opens unobstructed on this side, and is backed by perpendicular walls. On the right side we see a jagged rocky precipice, the remains of Yugeta-yama which formed a small prominence on the flank of Kobandai. The extensive waste of mud and rocks, gradually sloping from the crater toward the plain below with its curious conical rock-hills and bared mountain sides, gives a most vivid and awful impression to the mind of the vastness of the devastation.

It would have been very interesting to compare the original form of the mountain as seen from the north with its present form. But as we have already stated this part of Bandai was very scantily peopled, and hardly ever visited by scientists so that there seems to

exist no sketch or photograph showing an accurate outline of Kobandai before the explosion.



The accompanying figure shows the probable appearance of the mountain previous to the eruption ; this reconstruction of the original scenery being made from the sayings of the people who knew the mountain well, and from general topographical considerations. The dotted line in the figure is the present outline of the mountain, viz., the reproduction of the outline as shown in Fig. 1., Pl. XXI., reduced to one half.

The prominent peak (*k*) is intended to be the restored form of Kobandai or Little Bandai, which when seen from this side must have looked more massive and prominent than Ōbandai, or Great Bandai (*a*). To the west of Kobandai immediately over Kamino-yu (*e*), is seen a small prominence known as Yugeta-yama (*y*), which was half destroyed, forming now a very rugged precipice as already mentioned. It is to be observed that the fumarole of Kamino-yu is situated within a small ravine having a very steep side-wall, probably itself a small explosion-crater formed at some former period.

Loss of life and other damage.

Four hamlets—Osuzawa, Hosono, Akimoto and Kawakami—have been completely buried beneath the rock and mud along with their

inhabitants and cattle, leaving no visible trace of their former existence. Even the few survivors who escaped death by their timely absence from home could not tell where their villages had been, as every land mark was entirely obliterated. Seven villages—Miné, Nagasaka, Shibutani, Shirakijō, Hinokuchi, Myōke and Ojigakura—were partially destroyed either by the avalanche of earth or by the storm of wind and rubbish, and were thickly covered by ashes. The loss of life and cattle was also considerable. The destruction of the three spas in Bandai-san, viz., Kaminoyu, Nakanoyu and Shimonoyu, has already been mentioned. In all, 166 houses were either totally or partially destroyed.

The total number of lives lost amounted to 461. The principal cause of the death was the deluge of rock and mud *débris*. In some instances people were buried under their roofs, having no time to escape; but in the majority of cases they were caught in the swift torrent of mud while endeavouring to reach some safe place. Many were also battered by falling stones. A most remarkable incident occurred in the village of Nagasaka which had 168 inhabitants, and was attended with a serious loss of life. This village being situated behind Kushigamine was effectually screened from the direct attack of the mud current. On the morning of the eruption when stones and earth began to fall upon their roofs, accompanied by appalling noises and earthquakes, men and women rushed out of their houses leaving the old and young behind, and attempted to cross the valley of Nagase in order to reach the opposite hill which they thought to be a safer situation. They had only to travel not more than 500 metres across, but of ninety-two who thus fled, not even one reached the other side safely.

Out of the total of 461, only 117 corpses were recovered, all the remaining bodies being entirely buried under the mud. The

number of wounded was 70 in all. They were mostly burnt and scarred by the hurricane of hot ashes and falling stones. The wounds in several cases were very peculiar. Fragments of rock projected violently from the mountain, impinged upon the unfortunate people like grape-shot. The sufferers were tossed about and often felt as if they were lifted up bodily into the air; at the same time their clothing was torn off, even to the under-garments. In many cases bits of stones were found sticking in the skin and flesh of the victims, and were with difficulty extracted. In one case the skin was completely peeled off from a woman's skull, probably torn off through entanglement with trees or other objects which were being violently hurled along. The mere contemplation of such experiences is horrifying.

Bandai-san after eruption.

The winter climate of this part of the country is very severe. Snow begins to fall in the middle of autumn, so that in winter travellers are rarely seen, and the peasantry hardly ever venture far abroad. The result is that very little knowledge can be obtained about the behavior of the volcano during the cold months. Mr. S. Kobayashi, a schoolmaster at Inawashiro, who helped us in various ways during our stay in Bandai-san, has, at our request, very kindly given us the following information :

Letter dated Nov. 7th, 1888.—Since the eruption, even in bright and calm days clouds have been almost always seen round the summit. This has not been so in former years.

This is very probable. The steam that issues from the crater, in ascending and dispersing in the higher region, would produce clouds.

Nov. 8th.—The volume of steam has abnormally increased since yesterday. It is nearly the same as it was three weeks after the eruption. This morning the amount is still greater. Although its height is perhaps not greater than that observed

within ten days after the eruption, its volume does not seem to be less.

Oct 7th.—The new lake Akimoto rushed out cutting through the mud-field, after a heavy rain-storm. In the lower course of the river Nagase, the water level suddenly rose 9 ft. above the ground, causing great uneasiness among the people.

Oct. 20th, 6h. 32 min. 3 sec. a.m.— A slight shock was experienced.

Nov. 19th, 0h. 25 min. a.m.—A slight shock was felt; motion horizontal, direction N. S., duration 1 min. 30 sec. On this day snowfall was first observed on the summits of Ōbandai and Kushigamine.

Nov. 30th.—Thunder-claps were heard toward Bandai-san and Azuma-san, lasting about 20 minutes; have seen lightning twice.

Dec. 1st.—First snow-fall on the ground.

Dec. 5th.—Sound of distant thunder heard.

Dec. 30th.—Great storm swept the accumulating snow over Bandai, and with it the ashes on the mountain-flank. Peculiar rumbling noises heard in the mountain. People believing this to be a sign of a fresh outburst of Bandai were very much frightened.

Jan. 1st, (1889).—A slight shock was experienced at 7h. 10 min. p.m., lasting 2 seconds.

Jan. 23rd.—A *halo* observed, probably due to the refrigeration of the vapours of the steam from Bandai.

Feb. 8th.—Rumbling sound heard in Bandai, probably due to the falling of the crater-wall.

Feb. 17th,—Hibara-village was deserted on account of the encroachment of the new lake.

Feb. 18th, 5h. 30 min. a.m.—A slight shock.

In his last communication Mr. Kobayashi says that during the winter the action of rain, water, and snow, has greatly eroded and smoothed down the rugged points, the vertical walls and the precipitous hills in and round the crater, reducing them to much gentler inclines, and thus the grandeur and picturesqueness of the scenes have been considerably lost. This fact was confirmed by recent visitors to Bandai-san. From this it may be expected that such a bold scene as that shown in fig. 2, Pl. XXI, which is a sketch taken from the western edge of the crater just above Kaminoyu, about 20 days after the eruption, would not be long preserved.

The Character of the Eruption.

The explosion of Bandai has furnished us with an example of a volcano, long dormant, bursting with terrific force. So far as we know the last great explosion took place more than ten centuries ago. Some minor eruptions are said to have occurred in subsequent years, but seem to have been of a local character. During the long period of rest, the original crater now known as Numano-taira, has in large measure lost its crater-like form by the disintegration of the surrounding walls. In such cases it often happens that subsequent eruptions take place at other parts of the mountain, breaking open new chasms along other lines of weakness. Such has indeed been the case with this last eruption of Bandai; the line of weakness lying to the north of the old crater so that the mass of the mountain was thrown toward the north into the Nagase Valley. There is now seen in the new crater a great fissure running N. 20° W. from the bottom of the horseshoe nearly to its mouth. Along this fissure runs a long row of steam jets, large and small, puffing and hissing and emitting immense volumes of white watery vapour. Pl. XXII

is a distant view of the mountain from a photograph taken by Prof. W. K. Burton, nearly a week after the eruption, showing the linear arrangement of the steam-fissures. It was along this line that the eruptive power of steam rent Ko-bandai into pieces.

It is manifest that the immediate cause of the eruption was the sudden expansion of steam pent up within the mountain. Of lava or pumice there is no trace. The grey coloured ashes which form a chief product of the explosion are evidently the powder of pre-existing rocks decomposed by the action of fumaroles, and have not been derived from fused magma.

The character of the explosion was thus comparatively simple, being to all appearance a sudden shattering of part of the mountain flank. The work of the explosion has been practically to tear off a portion of the side-wall of the old crater.

It has often been observed that the first action of some volcanic outbursts is characterized by extreme violence, large masses of superincumbent materials which have accumulated in the crater being thrown out, or the side-wall being blown away, by the expansive force of steam. This first stage of the eruption is usually followed by minor ones accompanied either by lava flows or pumice ejections. Thus the finer particles or ashes ascending into the air are different in character in the successive outbursts; those which are ejected during the first stage of the eruption consisting largely of fragmentary materials, while those of the later eruptions are found to be more or less pumiceous, a fact showing that the latter are derived from the fused matter. The explosion of Bandai, characterized by its suddenness and violence, and effected in a very short time, may be likened to the first stage of eruption. But no subsequent discharge took place, nor were any signs of further disturbance discernible.

We have already indicated that the volcanoes in the vicinity of

Bandai, though classified as active, have never, within historic times, shown a true lava eruption. And this may be said to hold good for most of the active volcanoes on the Main Island. In fact, most of them, which had their climax of activity during Tertiary times, are now verging to extinction. This is due to the general and gradual abatement of volcanic force since the end of the Tertiary Era. Any great geologic changes which have taken place since then, have had to do with the general rise of the land surface above the sea-level. At present the Tertiary strata, some three or four hundred metres above the sea-level, cover a large part of the whole area of Japan. They consist principally of tufaceous deposits, are mostly of marine origin, and are often found surrounding or even underlying the volcanoes. These volcanoes would thus seem to have attained their maximum intensity at a time when proximity to the sea greatly favoured their activity. But the subsequent gradual rising of the land surface has had the effect of shifting the volcanoes further and further from the sea-board, thus greatly mitigating their action.

The eruptions which are usually experienced in these volcanoes in modern times seem to be essentially superficial. The recent catastrophe of Bandai may indeed be taken as a grand example of this kind of volcanic manifestation and may well be called an *explosive eruption.* The great horse-shoe-like chasm opened toward the north may be called an *explosion-crater.* Its appearance from the north side (fig. 1, Pl. XVI, and fig. 1, Pl. XXI) presents a striking resemblance to the deep chasms which are often characteristic of certain volcanoes, e.g., the 'Val del Bove' of Etna, the Caldera of Palma, &c., and at the same time suggests similarity of origin.

Perhaps it may be of interest here to refer to a volcanic outburst which occurred in Japan early last century and which seems to have strongly resembled the present Bandai eruption. It is the great lateral

eruption, which took place on the south-eastern flank of Fuji-yama in the 4th year of Hōyei (1707 A.D.). By this outburst a great chasm very similar in its character to that of Bandai, was opened on the mountain side. It is an explosion-crater not inferior in magnitude to the latter. Hōyei-zan is really a prominence on the outer rim of this great chasm. It has, however, hitherto been regarded as an example of a 'parasitic cone.' It is to be observed that, in case of the Fuji explosion, there were produced numerous volcanic bombs, which are now found scattered all around the crater, showing that there was ascent of lava. Another striking phenomenon is the presence of a magnificent series of numerous vertical dykes which traverse the side-wall of the crater. On the other hand there may be seen on the perpendicular walls of the newly opened crater of Bandai, bands of volcanic strata exposed, consisting of an alternation of old lava-streams, and of agglomerates of fragmentary materials, a singular feature of these strata being the absence of any noteworthy dykes passing through them. This fact would show that since the formation of the Bandai group, the mountain has been very little attacked by the intrusion of molten magma from the interior.

Again, as we have already seen, among the products of the late eruption there is no lava. There are, however, among the *débris*, especially near to the spot where the steam-jets are issuing within the crater, some greenish coloured rock-specimens with disseminated patches of iron-pyrites, and a white coloured sintery rock having a bleached appearance, almost wholly consisting of silica as shown by the analysis given in the sequel. These materials indicate the action of fumaroles and hot springs in altering the rocks in the interior of the volcano, and in depositing mineral matter while percolating through the crevices. Among the *débris* that ran down to the north, are often found porous or scoriaceous rocks of a reddish

or black colour, which some observers have referred to a molten origin. It is more than probable, however, that these rocks are the fragmentary materials which, having been ejected during the previous periods of activity in the history of the volcano, had accumulated in the form of volcanic strata, and taken their share in the building-up of the mountain. The destruction of Kobandai, which was itself a part of the side-wall of the volcano, reduced these strata to a powdery state, and scattered the scoriaceous materials imbedded in them abroad on the mud-field.

Survey of the Crater and the Volume and Weight of the Mountain destroyed.

After great volcanic eruptions, surveys have sometimes been made with the view of estimating the dimensions of the parts blown away, or the amount of material ejected during the outbreak. The difficulties attending these attempts are obvious, for it happens very often that the seat of the outburst is inaccessible on account of lava flows or other dangerous obstacles that beset the way.

In estimating the dimensions of the newly opened explosion-crater which was formed by the destruction of Kobandai, and in deducing therefrom the volume and the weight of the mass that was thus removed, we encountered one serious difficulty, viz., ignorance of the original topography and former contour of the mountain. An unexpected advantage was however derived from the fact that, since in the case of Bandai the explosion lasted a very short time and no subsequent outbreaks took place, we could walk into nearly every nook and corner of the newly formed crater, and thus with comparative ease complete a survey which might otherwise have been almost impossible. The inaccessible or dangerous parts were the

fissure lines whence steam issued with great violence, the gorges filled with water (new lakes), and the regions at the base of vertical cliffs down which earth and rocks, and even slabs measuring one or two hundred metres, were constantly thundering. Otherwise the conditions were as favourable as could reasonably be expected in the circumstances. Not that the inside of the crater was anything like a level plain. Far from it; it was cut up by precipitous hills, deep chasms, wild depressions of all imaginable shapes and sizes. Pl. XIX shows a prominent rock-hill inside the crater, on which was located one of our stations. The crater-bed was full of these boulder-mounds, and was so irregular that we spent nearly two days in fixing upon a suitable base-line. We were, however, fortunate in finding a nearly straight narrow band in the bottom of a valley in which to locate the base-line.

For five successive days Mr. I. Toya laboured indefatigably, until all the important points were measured from prominent heights in and round the crater. When this was done, we removed to Ottate, a spa on the south flank of Ōbandai, and mapped the results of the triangulation.

The form of the crater, as deduced from the plan, is semi-elliptical, or like a horse-shoe. It opens toward the north, its bed gently inclining outwards. The plan in Pl. XXIII shows the general outline. It is surrounded by precipitous walls and steep cliffs of great height especially on the southern side, where a part of Kobandai still remains with rugged edges, and where Kushigamine exposes a clean section. The heights of the wall as may be seen from the numbers indicated on the plan gradually become smaller as we approach toward the mouth, at last reaching to the same level as the crater-bed. The heights in and round the crater were measured by taking altitude angles and were afterward referred to sea-level. The

position of the steam fissure running N. 20° W. is marked with star-like signs ; prominent hills, depressions, valleys, ponds, etc., are also indicated.

Roughly speaking the crater measures 2,463 metres or 8,080 feet across its mouth, which is the widest part from east to west. From the bottom of the horse-shoe to its mouth it is 2,274 metres or 7,460 ft. The total area of the crater-bed is 3·83 square kilometres or 946 acres, or nearly 1·5 square miles.

In the estimation of the volume and the weight of the mass blown away the chief difficulty encountered was our ignorance of the original contour. The original height of Kobandai, or Little Bandai, was assumed to be equal to that of Ōbandai, or Great Bandai, (1,840* metres or 6,037 ft.). It was generally believed that Kobandai was a little lower than Ōbandai, probably owing to the fact that the former was situated further away from the more populous districts in the vicinity and was partly screened by the latter. We were told, however, by those who knew the district well that although Kobandai looked smaller in bulk than its sister peak, there was no appreciable difference in height, and that snow used to fall on the former earlier. This perhaps might be due to its more northern position. Lieut. Y. Nakashima of the Surveying Bureau of the Army, who subsequently surveyed Bandai-san, confirmed this view ; and after a thorough examination of the topography of the district and the forms of the various peaks, he concluded that Kobandai had been equal to, if not a little higher than, Ōbandai. On the sound judgment of this specialist we can safely place our confidence. We obtained permission to see the map he constructed. It was made with characteristic painstaking care, and every detail was ad-

* The barometric measurements by Messrs Y. Wada and N. Ōtsuka, of the Imperial Meteorological Observatory.

mirably carried out. We are glad to say that our measurements and those of Lieut. Nakashima agree well; some difference existed in regard to the heights of crater-walls, but this was more reasonable than otherwise, as they were daily being reduced in altitude by the falling in of the perpendicular edges and steep prominences.

The height of the crater-bed above the sea level was 1,170* metres or 3,839 ft. The south-western part of Kobandai which was left undestroyed, exposed an almost perpendicular wall of 505 metres or 1,658 ft. overlooking the crater. From these and from the other data already mentioned, it was found that the part of the mountain that broke away had an altitude of 670 metres or 2,198 ft. above the crater, and that 164·6 metres or 540 ft. had been sheared off from its top. On Pl. XXIII is given a rough vertical section through the line AB, that is the section passing through the original summit and the highest fractured edge of Kobandai. The dotted line shows the parts blown off. It will be seen that the vertical line passing through the summit of the mountain was situated about 442 metres or 1,450 ft. N.E., from the fractured edge, its position being indicated on the plan by a cross. The main body of Kobandai and the north-eastern side were completely blown away, leaving a portion of the south western flank. The flank of Kushigamine sloping S.W. met that of Kobandai sloping N.E., practically forming one connected mass, and the consequence was that the latter's destruction was shared by the former in parts where they were so united. Kushigamine now stands overlooking the crater with a bared perpendicular wall 452 metres high.

It is also to be observed that the great fissure-line along which the mountain was rent nearly passed through the summit vertical,

* Also from Messrs. Wada and Ōtsuka's measurements.

or in other words, the fissure-line lay under the summit of Ko-bandai.

For ease of calculation the shape of the mountain was assumed to be conical, a near enough approximation. Then, subtracting the parts left undestroyed and making other allowances, we found the total volume of the mountain blown away to be 1·213 cubic kilometres or 1,587 millions cubic yards. This is equivalent to say that if the devastated area extending over 70 square kilometres or 27 square miles had been evenly covered with a stratum of earth, rocks and boulders, this stratum would have had an average thickness of 17·4 metres or 57 ft. The cubic content above given represents the gross total of the volume of the mountain destroyed, including not only the *débris* of earth and rock that descended the mountain-sides, but also the dust, ashes and boulders which were hurled into the air.

To calculate the weight of the material corresponding to this cubic content, we determined the specific gravity of different kinds of rocks and earth obtained from Bandai-san. The specific gravity of the pyroxene-andesite composing the mass of the mountain differed more or less with the different varieties met with, ranging from 2·58 to 2·71. On the average it may be taken as 2·65. But as the mountain consisted of much looser materials than these rocks such as pumice, scoriæ, &c., the density of the mountain would be much lower than this value. The mean specific gravity of the earthy materials thrown down by the eruption, as determined by Prof. J. Sakurai, was 2·172.

We may suppose without much error, that the mountain mass of Bandai consisted of rock and earthy materials in the proportion 1 : 2, and then we obtain from the foregoing numbers, as the density of

the mountain, 2·33.* From this number and from the already estimated volume, the weight of the mountain destroyed was found to be 2,826,290 million kilogrammes or 2,782 million tons.

Volcanic products of Bandai-san.

Volcanic rocks.

The volcanic rocks that compose the mass of Bandai-san, are comparatively of uniform character, and belong to that class of andesite which is of wide occurrence in Japan, viz., the Pyroxene-andesite which is now to be briefly described. This rock under its various modifications, may be seen piled up in layers in the side-wall of the newly opened crater, alternating with accumulations of loose products ejected from the volcanic vent in former times, such as pumice, scoriæ, fragments of obsidian, &c. Prof. B. Kotō considers that there are six of these principal layers. The rock-layers which doubtless consolidated from lava-flows, are divisible into two main types; the one being lighter coloured, and the other darker coloured, evidently more basic than the former. The first kind is well observed as a great band on the eastern side-wall down Kushiga-mine, more than 10 metres thick, overlaid by reddish coloured loose layers. Lower in position and separated by layers of agglomerate, is found the darker variety. The fragments that compose the agglomerate are also usually of the latter kind. These rocks have, however, essentially of identical mineral composition, and are probably to be considered

* Prof. J. Milne in calculating the weight of Japanese volcanoes has assumed the average density to be 2·5. (The Volcanoes of Japan—Trans: Seism. Soc: Japan Vol. IX, part II 1886). Prof. T. C. Mendenhall, formerly of the University of Tōkyō, in determining the force of gravity at the summit of Fujiyama, took the density of that mountain as 2·12, which was the mean of the densities of pulverized and porous rocks. (On pendulum experiments on the summit of Fujiyama for the purpose of ascertaining the force of gravity at that point—Trans: Seism. Soc. Vol. II, 1880). In the authors' Preliminary Report of the Bandai-san Eruption published in the Official Gazette of September 27th, 1888, the value of the density was taken a little higher, but it was since altered to the present figure.

the different facies of the same magma that supplied the materials for their formation.

The microscopical examination of these rocks shows that the ground-mass is microcrystalline, with a very little of colourless glass-basis in the lighter coloured variety between the microlithic plagioclase, while in the darker variety a brown coloured glass is found more abundantly. Numerous magnetite crystals and grains are in both cases always scattered within the general mass, and as enclosures.

The micro-porphyritic mineral components are Plagioclase, and Pyroxenes, which are represented by the monoclinic and the rhombic. The most frequent accessory component is Apatite. Among secondary minerals of less frequent occurrence may be mentioned Tridymite and Iron-pyrites.

The principal characteristics of the porphyritic components are here given :—

Plagioclase.—The porphyritic crystals are found generally in lathe-shaped outline, having characteristic twin-lamellæ of the albite-type. The extinction-angle of the plagioclase examined in the sections exhibiting these twin-lamellæ varies to a considerable extent; the range being from 20° to 30°. In general character the plagioclase is quite fresh and transparent, often with numerous glass-enclosures, which sometimes fill up the entire space of the crystal and are arranged in distinct zones. In polarized light, the phenomenon of zonal structure is often very typical; the extinction angles differing in the inner and the outer zones, thus showing a difference in the chemical composition of these layers.

The specific gravity of the plagioclase as determined by Thoulet's solution gave as a mean 2·686. These characteristics indicate that the chemical composition should approximate to that of Labradorite.

Sanidine.—Although this mineral under the microscope is so difficult of detection, we are justified in claiming its existence, since we observed cases in which the basal cleavage face of a glassy felspar devoid of twin-lamellæ, exhibited straight extinction.

The following chemical analysis of the 'feldspathic' components isolated from a

rock of Ōbandai, has been made in the laboratory of the Geological Survey Department. Somehow or other, the amount of foreign ingredients is so large that we cannot tell from it the true nature of its composition.

SiO_2	61·26 %
Al_2O_3	19·55
Fe_2O_3	3·36
FeO	4·06
CaO	3·20
MgO	2·54
Na_2O	3·42
K_2O	1·22
H_2O	1·77
	100·38

Augite.—This mineral is found in well-defined forms or sometimes in grains. The common type of a twin with the face $\infty P\bar{\infty}$ as a twinning face, is frequently met with. It is usually greenish-yellow in colour, showing a feeble dichroism. It is usually fresh, with glass enclosures, and occasionally small needles of apatite.

Hypersthene.—The occurrence of the rhombic form of Pyroxene has received considerable attention in recent years. This mineral which has hitherto been regarded as rare, was found to be of wider occurrence than we had expected.*

The rhombic pyroxene generally appears in more slender sections than the augite; breadth to length being as 1:3 to 1:5. Under polarized light the interference-colour is weak, and always shows a straight extinction. The pleochroism is very marked; $\parallel \gamma$ = light green, $\perp \gamma$ = greenish brown.

On examining the macropinacoidal section, under a convergent polarized ray, we can often very distinctly observe a biaxial interference-figure, which, however, on account of the thinness of the section appears elliptical. The dark cross which traverses the middle of the figure under crossed nicols, passes into an hyperbola as we rotate the section.

The rhombic pyroxene is often found in a cross shaped twin, the vertical axes of the two individuals making an angle of 60° with each other. This twin is there-

*An interesting Japanese occurrence of this mineral is in the Bonin Islands. See the preceding article in this Volume.—Y. K.

fore that which has often been met with in other localities, the twinning plane being $P\bar{\infty}$. Parallel-intergrowth of the rhombic pyroxene with augite is also found. This has been dwelt on at length in the description of the Bonin specimens.* Though in specimens from Bandai this is not so clearly defined, yet we have found some cases in which this phenomenon was very characteristically developed, the crystal of the rhombic pyroxene being surrounded on both sides, or flanked on one side, by an augite band.

The rhombic pyroxene isolated from the rock by means of Thoulet's solution and then lightly washed with hydrofluoric acid, was analyzed by Mr. T. Shimizu. It was impossible to separate the rhombic pyroxene from the augite. The following analysis is therefore that of a mixture.

SiO_2	51·80 %
Al_2O_3	trace
Fe_2O_3	1·89
FeO	18·86
Mn_3O_4	1·03
CaO	7·96
MgO	18·84
	100·38

This leads to the composition nearly equivalent to $2\,Fe\,SiO_3 + 3\,Mg\,SiO_3 + Ca\,SiO_3$.

Magnetite.—It is very abundant in grains, and as enclosures, especially in the pyroxenes.

Apatite.—The crystals of this mineral sometimes occurs in a very characteristic form. It is dichroic; $\parallel \dot{c}$ = brownish, and $\perp \dot{c}$ = yellowish. The crystals usually with fine longitudinal striæ, and with transversal cleavage-fissures. This kind of apatite is very abundant in the lighter coloured rock which was found in the bottom of the conical hole at Mine-yama.

Tridymite.—This mineral is seldom found in the fissures in microscopic form. In the rock imbedded within the hole at Mine-yama just referred to, it was found in well-defined crystals visible to the naked eye, nearly ·5—1 mm. in size, lining the cavity of the rock in the manner of a druse. Some of them were found in

* l. c. p. 78.

characteristic twins. When taken out of the cavity and examined closely the crystals were found in hexagonal plates, in combination with the faces (when referred to the *hexagonal* axes) oP, ∞P, P, ∞P_2, flattened along the base. Under crossed nicols, however, the plate was seen to consist of innumerable patches crossing at an angle of nearly 120°, and showing oblique directions of extinction. The specific gravity of the mineral determined by swimming it in the Thoulet's solution was 2·272.

For the chemical analyses, given below, of the Bandai rocks and ashes we are indebted to Prof. T. Wada, the Director of the Geological Survey. They are the result of a very careful analysis by Mr. T. Shimizu.

	I.	II.	III.
SiO_2	59·66 %	59·56 %	59·47 %
Al_2O_3	15·51	16·10	17·12
Fe_2O_3	3·76	6·28	2·33
FeO	5·40	3·02	5·69
Mn_3O_4	1·40	1·80	——
CaO	6·56	6·32	7·24
MgO	3·67	3·08	4·04
Na_2O	2·50	3·09	2·23
K_2O	1·08	·80	·30
S	·59	——	——
P_2O_5	·18	·18	——
Loss by ignition—		·44	1·35
	100·31	100·67	99·77
	Insoluble portion in HCl. = 75·34 %	Insoluble portion in HCl. = 85·34 %	

I. is a greenish-black rock taken from the rugged cliff of the partially destroyed wall of Yugeta-yama, containing a small quantity of iron-pyrites.

II. is a reddish coloured rock, very frequently met with within the *débris*, especially in the conical mounds, somewhat powdery at the surface, due to the fumarolic action to which it was subjected within the volcano. There is more sesquioxide of iron in this rock than in the others. The sample for the analysis was obtained from the ejected masses near Tokoro-sawa, a ravine on the eastern side of Bandai.

III. is the analysis of a rock from Bandai given by S. Nishiyama in his report to the Geological Survey, in 1887. The exact locality of this rock is not mentioned.

From these results it will be seen that the rocks of Bandai are nearly identical in their composition. We may, nevertheless, distinguish two types as we have already stated. One is a lighter coloured rock, the structure being usually porphyritic; the porphyritic components being pyroxenes and microtine plagioclase within a greyish coloured ground-mass. A typical example of the first type may be seen exposed on the side-wall of the new crater, as an extensive sheet in the great cliff forming now the western side of Kushigamine. A similar kind of rock was also found near the summit of Ōbandai. Microscopically examined the greyish white groundmass is microfelspathic in character, with a small amount of colourless glass-basis. All the mineral components are quite fresh. The plagioclase of this rock was found to have a specific gravity of 2·682.

The other type of the pyroxene-andesite is a darker coloured rock evidently more basic than the first and resembling Basalt in its outer appearance; the glassy plagioclase being interspersed within the

dark, often compact, and resinous ground-mass, thus presenting a marked porphyritic structure.

Besides occurring in the form of a sheet of solid rock, it is also abundant among the fragments which compose the agglomerate, being, in this case, often scoriaceous in appearance. Under the microscope, the ground-mass is micro-crystalline, with a more or less brownish coloured glass-basis. In the scoriaceous rock just referred to, the hypersthene crystal is often highly pleochroic. The specific gravity of the plagioclase determined with Thoulet's solution is found to be little higher than that contained in the first type, being on an average 2·691.

To this type also belongs the rock which is exposed in a rugged cliff of the half destroyed Yugeta-yama, on the western edge of the new crater, and the analysis of which is given above (I). In this rock there is a very light brownish coloured glass-basis among the microlithic ground-mass. The black colour of the rock is, however, in this case, also due to another cause, viz., to the alteration which the crystals of pyroxenes have undergone. These crystals are seen to have altered into a peculiar dirty green coloured fibrous substance like viridite, the alteration proceeding from the fissures or from the periphery and often forming a pseudomorph. The altered product, diffusing itself into the surrounding ground-mass, imparts a peculiar dark greenish hue to the appearance of the rock. The alteration also often results in the formation of a reddish coloured iron-oxide. Sometimes the crevices of the rock are filled with iron-pyrites. It is highly probable that these phenomena have been greatly due to the action of fumaroles and hotsprings, the rock being found in close proximity to the Kaminoyu spa.

The following analysis of the white coloured rock, already referred to (p. 143), found near to the steam-fissures, together with that

of the water which has accumulated within the crater-basin from the condensing vapours, appears to show that corrosive gases have been active within the volcano, decomposing and altering the rocks. These acid gases have no doubt affected the rocks, by combining with bases to form soluble salts, which are now dissolved in the waters of the new lake within the crater, leaving as residue the white coloured sintery material, which consists almost wholly of silica.

Microscopically examined this white rock is seen to have been entirely altered in substance, but the original form of the porphyritic crystals is more or less preserved. A completely isotropic colourless substance is found filling up the spaces of all the crystal-sections, which nevertheless exhibit the characteristics of the original minerals. The decomposition of the andesitic rock by the action of acid gases had doubtless the effect of decomposing the mineral matters; the silica first separating out in a gelatinous form, and then consolidating to a porodine-amorphous state. Thus the isotropic substance mentioned above seems to be silica in the form of opal.

The fissures of these crystals are often filled with crystals of sulphur which may frequently be detected by the naked eye as well as under the microscope. Under crossed nicols it may be recognised by the fact that certain faint yellow coloured portions within the section exhibit vivid interference-colours, while the general ground is entirely dark. The crystals of plagioclase sometimes retain their original substance, which the pyroxene crystals never do. In the latter case it is interesting to observe that the alteration of the original substance into a fibrous viridite-like product had began before it was completely decomposed into its present state, as we can still detect in it the characteristic trace of this alteration in the manner already described.

The analysis of this white rock found within the crater gave:—

SiO_2	91·66 %
Al_2O_3	2·88
Fe_2O_3	1·20
CaO	·36
MgO	·10
S	·50
Loss by ignition	3·00
	99·70

The following is the analysis of the water of the lake at the crater-basin, by Mr. M. Hida, 1,000,000 parts of water containing these substances:—

NaCl	154·07
Na_2SO_4	34·46
K_2SO_4	30·00
$CaSO_4$	1136·57
$MgSO_4$	286·09
$MgCO_3$	178·58
SiO_2	86·40
$Al_2O_3 + Fe_2O_3$	trace
H_2S	,,
	1906·17

Total evaporation-residue = 1947·40

Volcanic ash.

The general description of the volcanic ash or dust that fell during the eruption has already been given (p. 111). It has a bluish-

grey colour, is usually very fine grained, but sometimes mixed with coarser rock-fragments. The microscopic examination of the dust shows that it is essentially made up of the same mineral components as the Pyroxene-andesite already described, proving that it was derived by the mechanical trituration of this rock. It consists of minute particles of the microfelsitic groundmass, mixed with crystal-fragments of Plagioclase, Sanidine, Augite, Hypersthene, Magnetite and Apatite needles with a very small amount of glass.

A specimen of the dust was brought from the town of Miharu, 38 kilometres to the east of Bandai-san. It is essentially the same as that which fell in the immediate neighbourhood of the volcano, only that it is somewhat finer grained. In mineralogical composition also, it is almost exactly similar, being chiefly made up of the finer particles of the rock, the crystal-fragments of plagioclase, the pyroxenes, and magnetite. These ashes, being comparatively heavy, do not seem to have fallen to any very great distance, thus differing from the fleecy pumiceous materials produced from molten lava at the time of other volcanic eruptions.

The following chemical analysis (I.) of the ash obtained by Mr. S. Ōtsuka of the Geological Survey, from Hikage in Biwa-sawa, when compared with those of the andesite rocks already given, will show how close is the agreement.

This ash, when treated with a mixture of hydrochloric acid, mixed with nitric acid in order to dissolve out the sulphur, gave a residue amounting to 52·92 %. This, when analyzed, gave the result as in column II.

	I.	II. Insoluble portion.	III. Soluble portion. (by difference.)
SiO_2	59·70 %	40·11	19·59
Al_2O_3	16·68	6·75	9·93
Fe_2O_3	5·43	1·44	3·99
FeO	2·05	——	2·05
Mn_3O_4	·98	trace	·98
CaO	5·20	1·75	3·45
MgO	2·35	1·08	1·27
Na_2O	2·67	1·25	1·42
K_2O	·99	·71	·28
S	2·25	——	2·25
SO_3	·95	——	·95
P_2O_5	·15	——	·15
Loss by ignition	·90	——	·90
	100·30	53·09	

The ash contained some soluble matters which on being extracted with cold water gave traces of lime, chloride, and sulphate.

The analysis of another, and a somewhat more stony sample of the ash was made by Mr. H. Yoshida of the Imperial University, with the following result :—

SiO_2	61·82 %
$Fe_2O_3 + Al_2O_3$	28·10
CaO	5·73
MgO	·79
K_2O	1·10
Na_2O	2·42
	99·96

Reports.

Under this heading, we arrange in tabular form the answers to inquiries made to school-masters and others living in the provinces near Bandai-san. We have already referred to the particulars obtained in this way, and the great help we derived in the preparation of our paper from the answers so received.

In the Table when the phenomena under consideration were reported not to have been observed, the space is marked with a dash; when it was not known whether certain phenomena occurred or not the corresponding space is left blank.

Unless otherwise stated, the date refers to the 15th of July, 1888 —the day of the eruption.

1 *Shaku* is nearly equivalent to 0·303 metres or one foot.
1 *Sun* = $^1/_{10}$ of 1 *Shaku*.
1 *Bu* = $^1/_{100}$ of 1 *Shaku*.
1 *Ri* = 3·93 kilometres or 2·44 miles.

REPORTS.

Name & Address of Observers.	Direction and Distance from Bandai-san.	Sound.	Ashes.
No. 1. T. Uda, Kokai village, Yama-kōri, Prov. Iwashiro.	E. S. E. 5 kilometres. 3·2 miles.	A black column of smoke ascended high into the air; the sound of the explosion was something terrific, lasting for about 30 minutes.	Ashes fell in abundance in the neighbourhood of the mountain for about an hour and it was not until about 4 o'clock p.m. that it entirely ceased. I was bathed by ashes. The thickness was 1 *shaku* near Shirakijō, and 6 *sun* near Hinokuchi. The ashes were powdery, but occasionally mixed with rocky fragments which struck upon our bodies.
No. 2. U. Hayakawa, Sasakawa village, Yama-kōri, Prov. Iwashiro.	W. 30 kilometres. 18 miles.	A rumbling sound was heard by some.	———
No. 3. S. Yamamoto Kitagata, Yama-kōri, Prov. Iwashiro.	W. N. W. 15·7 kilometres. 9·8 miles.	Sound like distant thunder.	No ashes fell.

Earthquakes.	Meteorological Conditions.	Miscellaneous Notes.
No earthquakes on previous days. A few minutes before the eruption curious rumblings were heard, and while we were wondering what was the matter, a violent shaking of the earth occurred about 3 times. At the end of the 3rd shock, a black column of smoke ascended from Bandai-san. The character of this earthquake was different from that usually experienced, heavy up and down movements predominating.	Very fine. No cloud streaked the heaven. It was however somewhat hotter than usual. No wind before the eruption. Soon after the eruption, a great whirling wind suddenly swept over the eastern part of the mountain with great violence, destroying Shibutani, Shirokijō, Ojigakura, etc.	Some people say that they have seen fire on the mountain; I saw two flashes of lightning from the rising steam. At Oda village more than 2 *ri* away on the eastern side of the mountain, a spring became as warm as hot bathing water while the ashes were still falling; but at about 4 o'clock p.m. it became cold again. This is evidently due to the effect of heat imparted by falling ashes, which often scalded the naked parts of the body. The ashes also had the smell of sulphurous acid. Thunder claps were heard, followed by heavy rain continuing 3 or 4 minutes, which was also warm having the temperature of at least 70-80° Fah.
No earthquake on previous days. On the 15th a slight shock of very short duration was felt. It passed unheeded by most people.	Very fine. Thermometer 88° F.; atmosphere calm. At the time of the eruption a gentle breeze blew from the west.	Two travellers who were at the time of the outburst, resting at a pass of a neighbouring ridge, observed a black cloud rising from behind Bandai, among which were occasionally seen reddish coloured objects. The phenomena lasted for a few minutes; after this a white column of steam was seen ascending from these places; at the same time Kobandai entirely vanished from view.
A slight shock at 4 p.m. on the 12th.	Very fine; calm in the morning; it was little hotter in the afternoon, when the thermometer stood at 88° F., and the northern wind began to blow.	Black columns of smoke were seen rising to a great height; neither lightning nor fire were seen. There was observed also a light reddish coloured cloud spreading at right angles to the columns of the smoke.

Name & Address of Observers.	Direction and Distance from Bandai-san.	Sound.	Ashes.
No. 4. T. Kamizuma, Tajima, Aizu-kōri, Prov. Iwashiro.	S. W. S. 47·3 kilometres. 29·3 miles.	Rumbling sound heard twice. It was, however, so slight that it was unnoticed by many.	———
No. 5. H. Kotō, Kawaguchi, Ōnuma-kōri, Prov. Iwashiro.	W. S. W. 47·1 kilometres. 29·3 miles.	At 8 h. 40 min., and 9 h. 15 min. a.m., sound was heard.	No ashes.
No. 6. N. Yamasaki and T. Mafune, Fukuyoshi, Asaka-kōri, Prov. Iwashiro.	S. 21·6 kilometres. 13·4 miles.	The detonation of the explosion was very intense, continuing for nearly 5 minutes. It was also heard for several hours afterwards. People regarded the rumbling as a premonitory sign of the earthquake.	No ashes.
No. 7. S. Sugeno, Harimichi, Adachi-kōri, Prov. Iwashiro.	E. 45·2 kilometres. 28 miles.	People inside the houses did not notice the sound. Peasants who were working in the field heard it. It continued for nearly 5 minutes. The screech of the pheasant which is generally heard during an earthquake, was also noticed.	No ashes.
No. 8. T. Katō, Naganuma, Iwase-kōri, Prov. Iwashiro.	S. E. S. 35·3 kilometres. 22 miles.	Low rumblings noticed.	———

Earthquakes.	Meteorological Conditions.	Miscellaneous Notes.
About 5 days before the eruption somewhat strong earthquakes occurred twice. A slight shock at about 7 a.m. on the day of the explosion.		
At about 0 h. 30 m. a.m. on the 11th of this month, an earthquake was felt.	Very fine; some patches of cloud seen in the eastern sky. Western breeze at the time of the eruption.	No lightning or smoke seen; no change in rivers, springs, wells, etc.
No earthquake on previous days. At about 8 a.m. a very severe shaking experienced continuing for 5 minutes. It was very violent and the people felt as if the ground was suddenly upheaved.	Very fine before the eruption; the wind was northerly; after the eruption it appeared as if it had changed to N.W.	From the ascending columns lightning was emitted. The smoke soon covered the top of Bandai. N.W. wind blowing at the time; ashes fell at the village of Yokohama, nearly 2 *ri* N.E. from this place, coating the vegetation with greyish powder.
Nobody felt any shock.	Very fine, and no cloud, calm, temperature reaching to 90° F. in sunshine. N.W. wind at the time of the outburst.	While the heaven was clear, a very peculiar cloud (which I afterwards learned to have been steam) appeared near Adatara-san. There was neither lightning nor fire.
At 7 a.m. a slight shock, before we heard the rumbling noises.	Very fine; calm. Weather somewhat changed in the afternoon.	A black streak of cloud appeared, with beautiful stripes of purple, red, yellow, and green, probably caused by the reflection and refraction of sunlight falling upon steam.

Name & Address of Observers.	Direction and Distance from Bandai-san.	Sound.	Ashes.
No. 9. Motomiya, Adachi-kōri, Prov. Iwashiro.	E. S. E. 29·5 kilometres. 18·3 miles.	At about 7 h 30 minutes a.m., a roaring sound.	On the north-western mountains, a peculiar cloud of sharply defined form appeared, which gradually spread out in a circular form, like an umbrella, at the same time becoming lighter in colour. As the cloud spread wider, grey coloured ashes of the size of millet grains began to fall at about 8 a.m. This was followed by the fall of powdery ashes; all the vegetation wore a grey colour.
No. 10. Wakamatsu, Aizu-kōri, Prov. Iwashiro.	S. W. 15·7 kilometres. 9·8 miles.	Thundering noises were heard accompanied by the ascent of black smoke.	No ashes.
No. 11. Fukushima, Shinobu-kōri, Prov. Iwashiro.	E. N. E. 37·3 kilometres. 23·2 miles.	Distant sound was heard.	———
No. 12. K. Mita, Onoshinmachi, Tamura-kōri, Prov. Iwaki.	E. S. E. 74·8 kilometres. 40·2 miles.	At about 8 a.m., the sound was heard thrice at short intervals by those who were outside of houses.	The fall of ashes began at about 9 a.m. and continued till about 12.

Earthquakes.	Meteorological Conditions.	Miscellaneous Notes.
Strong shock was felt.		Ascent of smoke observed. The umbrella-shaped cloud disappeared at about 10 a.m.
There was a smart shock shortly before the eruption, then it was followed by violent heavings of the ground. The houses were observed to sway.	Fine weather, very gentle breeze.	Smoke ascended very high.
A moderate earthquake.		
A shock of short duration on the day before the eruption.	Very fine; 82° F. at noon; somewhat cool at 7–8 a.m.	On account of ashes the atmosphere became very dim and heavy; in the direction of Bandai a thick cloud appeared.

Name & Address of Observers.	Direction and Distance from Bandai-san.	Sound.	Ashes.
No. 13. M. Murata, Miharu, Tamura-kōri, Prov. Iwaki.	E. S. E. 38 kilometres. 24 miles.	Tolerably loud sound was heard.	Ashes began to fall from about 9 h. 30 min. a.m., and continued until 2 h. 30 min. p.m. During this interval the atmosphere had a misty appearance; the film of the ashes turned vegetable and other objects into greyish hue. Ashes fell at one time so thickly as to fill the eyes and nostrils of the passers-by. The street was almost impassable. [A sample of the ash was sent].
No. 14. Taira, Iwamai-kōri, Prov. Iwaki.	S. E. 86·4 kilometres. 53·7 miles.	Peculiar sounds were heard by some continuing for about 2minutes.	At about 10 a.m. finely powdered ashes fell, coating the vegetation and roofs.
No. 15. N. Ōishi, Kohama village, Naraha-kōri, Prov. Iwaki.	E. S. E. 86·4 kilometres. 53·7 miles.	Noises heard for about 3 minutes.	A greenish white coloured powder or ash fell forming a thin coating over mulberry leaves, &c. In the village of Kawauchi, 5 *ri* west of this place, the ashes fell in the form of lumps about the size of a pea.
No. 16. F. Kurosawa, Shimo-Ishii village, Shirakawa-kōri, Prov. Iwaki.	S. S. E. 78·5 kilometres. 48·8 miles.		

Earthquakes.	Meteorological Conditions.	Miscellaneous Notes.
Earthquake occurred before the eruption, continuing for about 20 seconds. It felt as if something had fallen in the next room. In general character it differed from the shocks usually felt.	Very fine; gentle N.W. breeze, 85° F.; it was a little stronger after the eruption.	A dark coloured cloud seen in the N.W., gradually spreading as it ascended. At about 10 h. 10 min. a.m. that part of the heavens became so thickly covered with misty cloud that we could not see the mountain for 20 min.
Feeble shocks at about 8 a.m. on the 14th, and at about 4 p.m. on the 15th.	Very thick mist in the morning, but gradually began to clear away from about 8 a.m. It was quite fine at noon. Thermometer 75° F., at 6 a.m., 90° F. at 12 a.m. About 8 a.m. W. wind prevailed but afterwards turned to S. At 11 a.m. it became S.E.	The thick smoke rising from Bandai-san, which was generally regarded as cloud, looked black and somewhat reddish. During sun-set sparkling rays of red light were emitted from the cloud.
———	Very fine and calm early in the morning. At about 9 a.m. a black cloud appeared on the west, and became dark, but it cleared again in the evening. Therm. 85° F.	In the direction of Bandai, cloud of an elliptical form was seen.
	Very fine; temp. 95° F. at noon; a gentle north wind.	

Name & Address of Observers.	Direction and Distance from Bandai-san.	Sound.	Ashes.
No. 17. ——— Watari, Watari-kōri, Prov. Iwaki.	N. E. 80·5 kilometres. 50 miles.		
No. 18. S. Chika & R. Ashikawa, Yonesawa, Okitama-kōri, Prov. Uzen.	N. 33·4 kilometres. 20·7 miles.	At about 8 a.m. thundering noises were heard in the southern mountains.	No ashes.
No. 19. T. Kusaka, Shikase village, Higashi-Kanbara-kōri, Prov. Echigo.	W. 53 kilometres. 33·2 miles.		———
No. 20. ——— Takai-kōri, Prov. Shinano.	W. S. W. 164 kilometres. 102 miles.	It was reported that a peculiar detonating sound was heard on the morning of July 15th; it was attributed to the roaring sound sometimes audible from Asama-yama.	———
No. 21. K. Nakashima, Kinboku-san, Island Sado.	W. N. W. 161 kilometres. 100 miles.	While I, in company with others, was ascending Kinboku-san in the island of Sado on the morning of July 15th, we heard curious dull rumblings which we thought to be the firing of heavy guns in the neighbouring harbour.	———

Earthquakes.	Meteorological Conditions.	Miscellaneous Notes.
At 11 h. 50 min. a.m. a slight earthquake lasting for only about 10 seconds was felt; motion horizontal.	Cloudy, a warm wind, 78° F. at noon.	
A feeble shock at 3 p.m. on the 14th; at 7 h. 30 min. a.m. and at 8 h. 20 min.a.m., on the 15th feeble earthquakes; the former was a little stronger than the latter.	Extremely fine. 90° F. at noon. W. wind.	While the weather was extremely fine, we observed the rise of a peculiarly grey coloured cloud-like smoke in the southern sky over Azuma-san.
At about 4 p.m. on the 14th a smart shock was felt and was soon followed by strong shakings of the ground which lasted less than 3 min.	Very fine; 85° F. at noon; gentle E. breeze.	After the eruption, the water of Akagawa diminished and became turbid.

Letters of inquiry were sent to the following places, but we received answers to the effect that nothing which could certainly be referred to the influence of the volcanic eruption was noticed in these districts.

Localities.	Direction from Bandai-san.	Distance from Bandai-san.
Sanjō, Prov. Echigo.	W.	96·2 kilm. / 59·8 miles.
Mizuhara, Prov. Echigo.	W.N.W.	76·6 kilm. / 47·6 miles.
Muramatsu, Prov. Echigo....	W.	76·6 kilm. / 47·6 miles.
Nagaoka, Prov. Echigo.	W.	106·0 kilm. / 65·9 miles.
Mito, Prov. Hidachi.	S.S.E.	135·5 kilm. / 84·2 miles.
Takahagi, Prov. Hidachi.	S.S.E.	106·0 kilm. / 65·9 miles.
Noki, Prov. Shimotsuke.	S.	153·2 kilm. / 95·2 miles.
Nikkō, Prov. Shimotsuke....	S.S.W.	106·0 kilm. / 65·9 miles.
Karasuyama, Prov. Shimotsuke.	S.	104·1 kilm. / 64·7 miles.
Tochigi, Prov. Shimotsuke.	S.S.W.	133·5 kilm. / 83·0 miles.
Shiobara, Prov. Shimotsuke.	S.	70·7 kilm. / 43·9 miles.
Namiye, Prov. Iwaki.	E.	82·5 kilm. / 51·2 miles.
Haranomachi, Prov. Iwaki.	E.	78·5 kilm. / 48·8 miles.
Ishikawa, Prov. Iwaki.	S.E.	62·8 kilm. / 39·0 miles.
Yamagata, Prov. Uzen.	E.N.E.	79 kilm. / 49 miles.
Iwahashi, Prov. Uzen.	N.W.	86·4 kilm. / 53·6 miles.
Sendai, Prov. Rikuzen.	N.E.	103 kilm. / 63·4 miles.

Plate XV.

Map of Bandai-san district. The area devastated by the *débris* of rock and earth caused by the destruction of Kobandai is distinguished by the grey colour. The position and form of the crater are indicated.

 Large and small conical mounds standing out from the surface of the *débris* in immense number.

** Principal steam-fissures in the crater.

♨ Hot springs.

↘ Marks the direction of the hurricane-blast and the area swept by it.

Heights are given in metres.

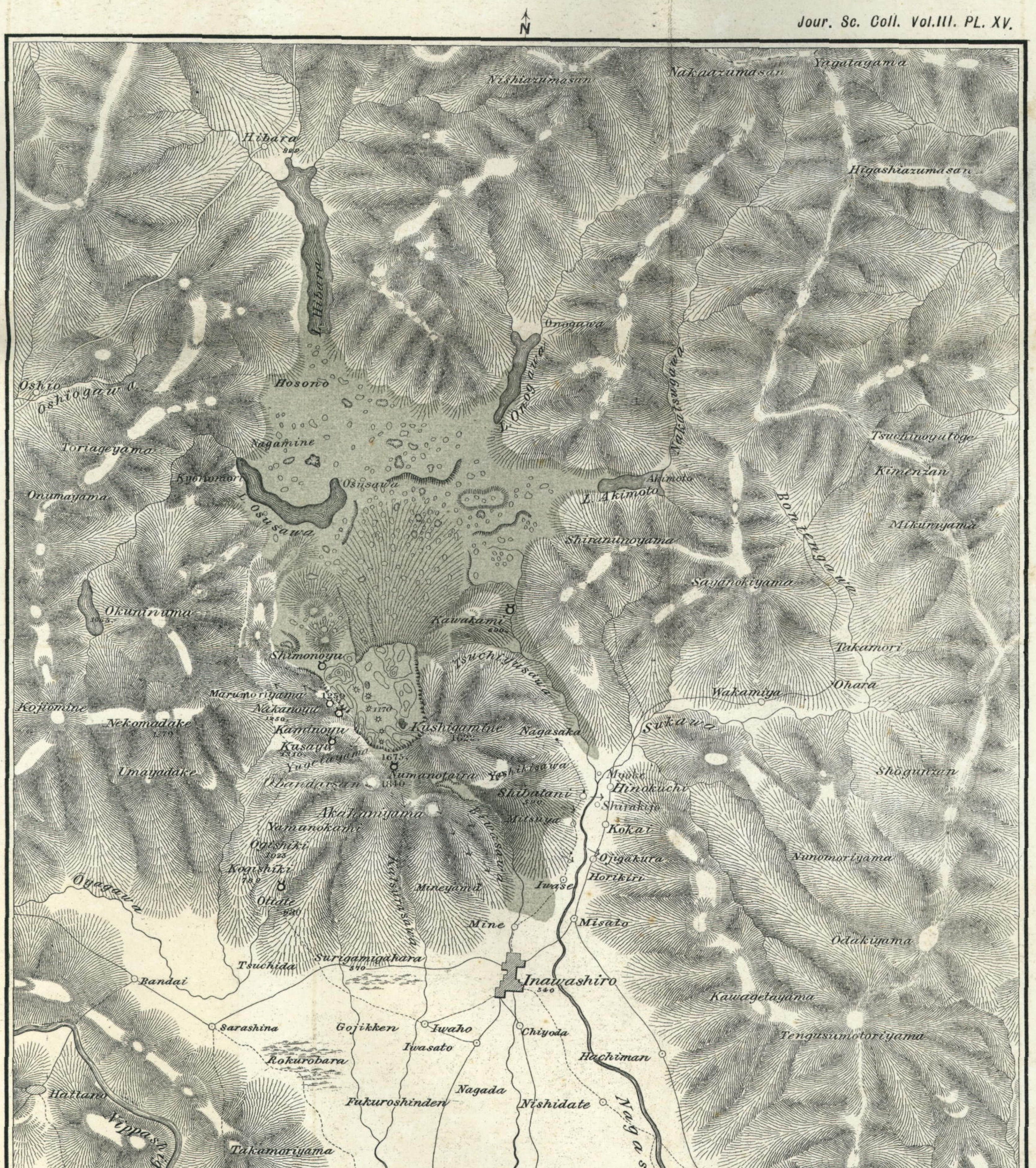

N
Nishiazumasan
Nakaazumasan
Yagatayama
Higashiazumasan
Hibara
L. Hibara
Onogawa
L. Onogawa
Hosono
Oshio
Oshiogawa
Toriageyama
Nagamine
Kyojomori
Osusawa
Onumayama
L. Akimoto
Akimoto
Tsuchinogutoge
Kirinzan
Mikuniyama
Shiranunoyama
Sayanokiyama
Okuninuma
Kawakami
Shimonoyu
Tsuchitagawa
Takamori
Marunoriyama
Nakanoyu
Wakamiya
Ohara
Kushigamine
Nekomadake
Kawanoyu
Nagasaka
Sukawa
Umayadake
Numanotaira
Myoke
Hinokuchi
Shibatani
Shogunzan
Akahaniyama
Yamanokami
Mitsuya
Koka
Ojigakura
Horikiri
Nunomoriyama
Mineyama
Iwase
Oyagawa
Mine
Misato
Odakiyama
Tsuchida
Surigamigahara
Inawashiro
Bandai
Kawagetayama
Sarashina
Gojikken
Iwaho
Chiyoda
Iwasato
Tengusumotoriyama
Rokurobara
Hachiman
Hattaro
Nagada
Fukuroshinden
Nishidate
Nagasegawa
Takamoriyama
Mitsuwa
Katada
Kawageta
Onohara
Okinazawa
Iwane
Tonokuchi
Nakakomatsu
Kaneda
Nakayamatoge
Lake Inawashiro
Okinajima
Sekito
Tsuboyanagi
Nakayama
SCALE 1:10000
Ri
kilm.
Mile.

PLATE XVI.

Plate XVI.

Fig. 1.—Distant view of Bandai-san, from N. W. side as seen from the hill ridge of Nagamine.

a. Ōbandai.	*b*. The rugged and the highest part of the crater-wall.
c. Kushigamine.	*d*. Marumori-yama.
g. Kawageta-yama.	*h*. Mud-field.

The forest in the foreground being situated on a ridge, escaped destruction by the *débris*.

Fig. 2.—View of Numano-taira near the edge of the new crater; the perpendicular cliff of Ōbandai facing this spot. Large hollow depressions (*k*) are found partly filled with water (p. 124.) The ground is covered with grey coloured ashes and smaller rock fragments. For other letters refer to *Fig. 1.*

[*From sketches by Y. Kikuchi.*]

Fig. 1.

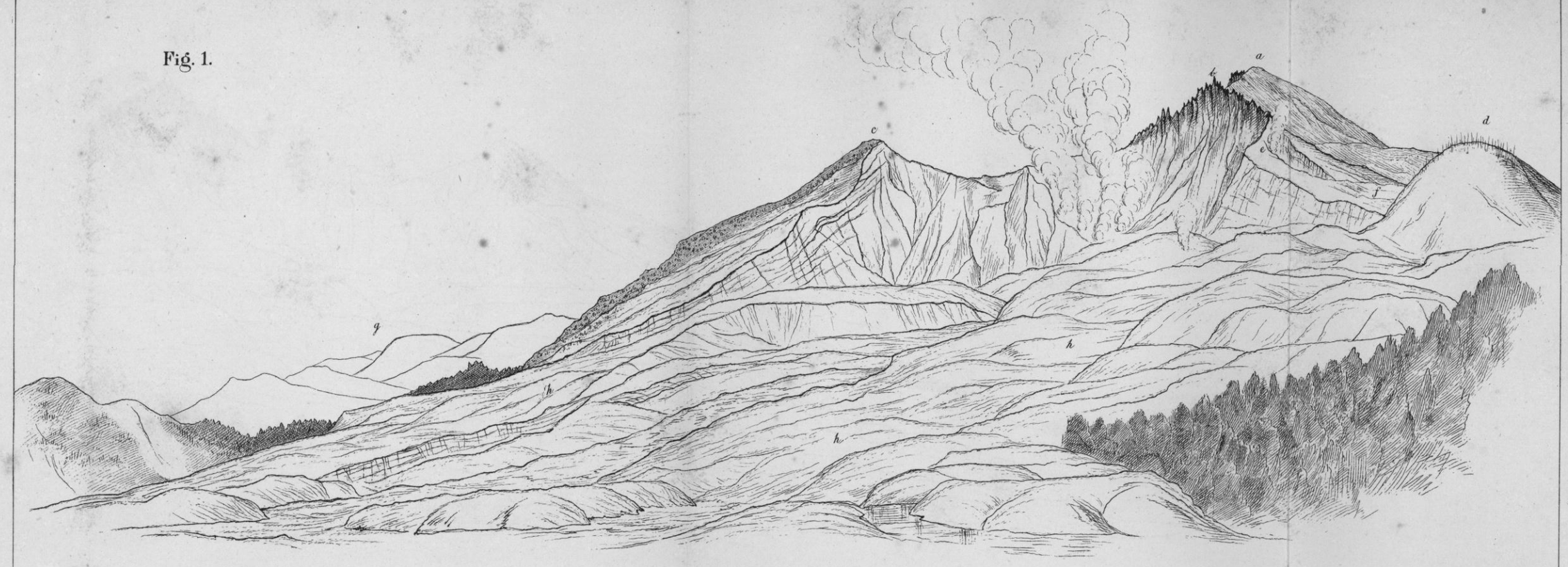


Fig. 2.

PLATE XVII.

Plate XVII.

Fig. 1.—Distant view of Bandai-san as seen from the outskirt of Inawashiro, with the village of Miné in front.

a. Ōbandai.
b. Kushigamine.
c. Akahani-yama.
d. The smaller mud-stream, which ran down through the Biwa-sawa (the ravine between *b* and *c*), descending upon, and burying a part of the village of Miné (p. 107–108).

[*From photograph.*]

Fig. 2.—Sketch taken from Biwa-sawa.

a. Ōbandai with rugged and precipitous wall on the northern side.
b. Kushigamine.
c. Akahani-yama.
d. Upper course of the mud-stream toward Miné.
f. Futatsu-iwa (p. 98).

[*From sketch by Mr. H. Hirauchi.*]

Fig. 1.

Fig. 2.

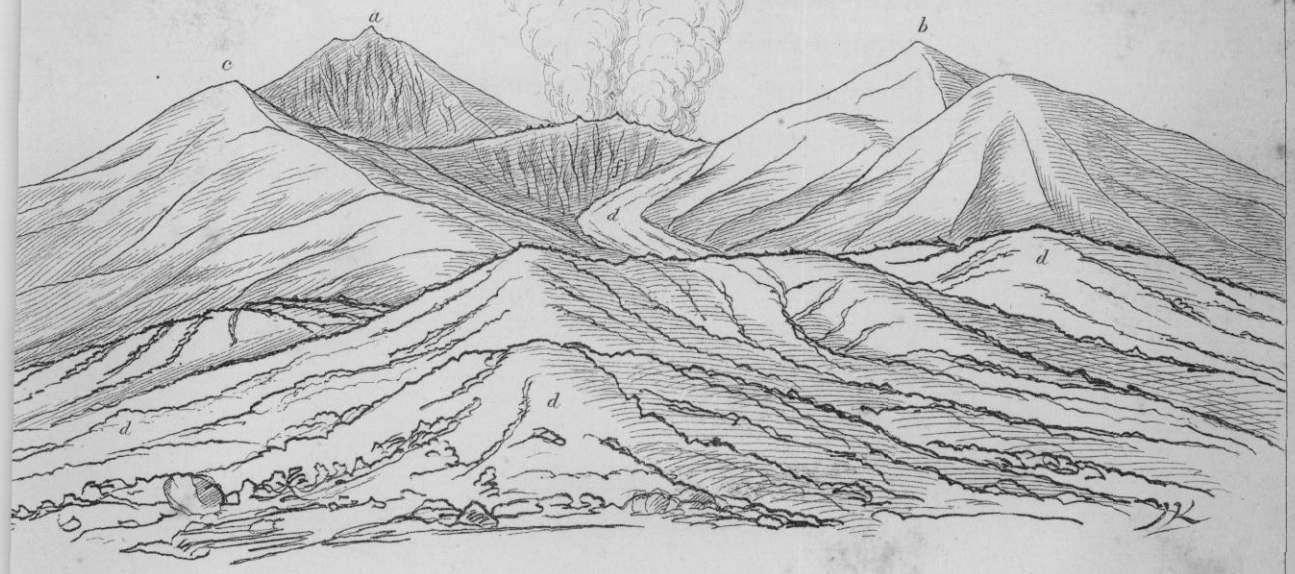


PLATE XVIII.

Plate XVIII.

Fig. 1.—Extensive and nearer view of mud-field of Miné.

Fig. 2.—Example of large boulders carried down along with the mud-current and forming conical mound near Kawakami. Mounds of this kind were formed on the *débris* in great members (p. 110–111).

[*From photographs.*]

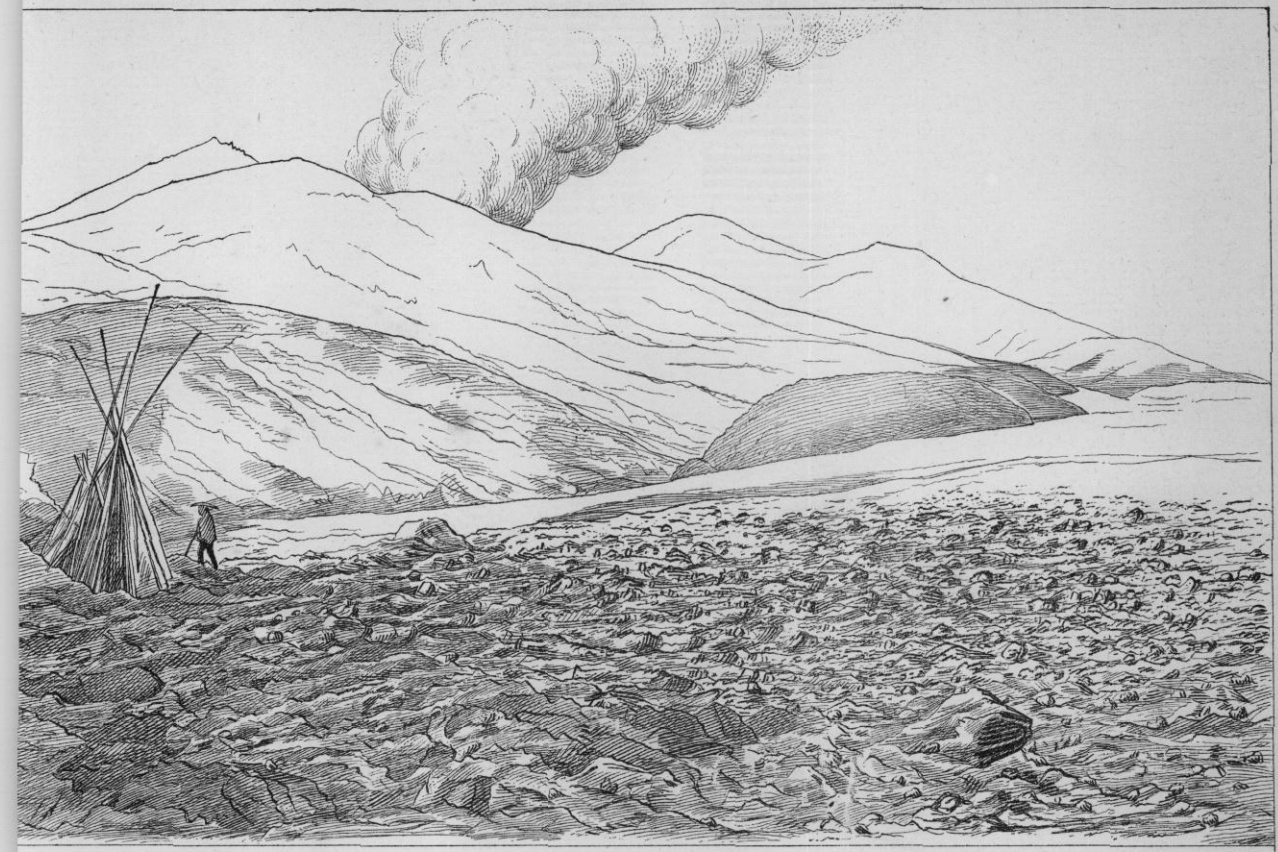


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PLATE XIX.

Plate XIX.

A rock mound prominently standing out in the inside of the crater, that formed one of the stations of the survey.

Encircling crater wall on the background; Kushigamine on the left with its fractured side exposing volcanic strata; on the right a part of the rugged cliff seen through the stream.

The gigantic block on the right foreground is one of the many boulders scattered about in the crater.

From photograph taken by Prof W. K. Burton

PLATE XX.

Plate XX.

Mud stream in Nagase Valley below Kawakami facing S. E. The *débris* of rock and earth descending in a swift torrent left wave-like traces on the side of the hill (p. 108), and filled up the valley perhaps not less than 40 metres deep.

From Photograph by Prof. W. K. Burton.

PLATE XXI.

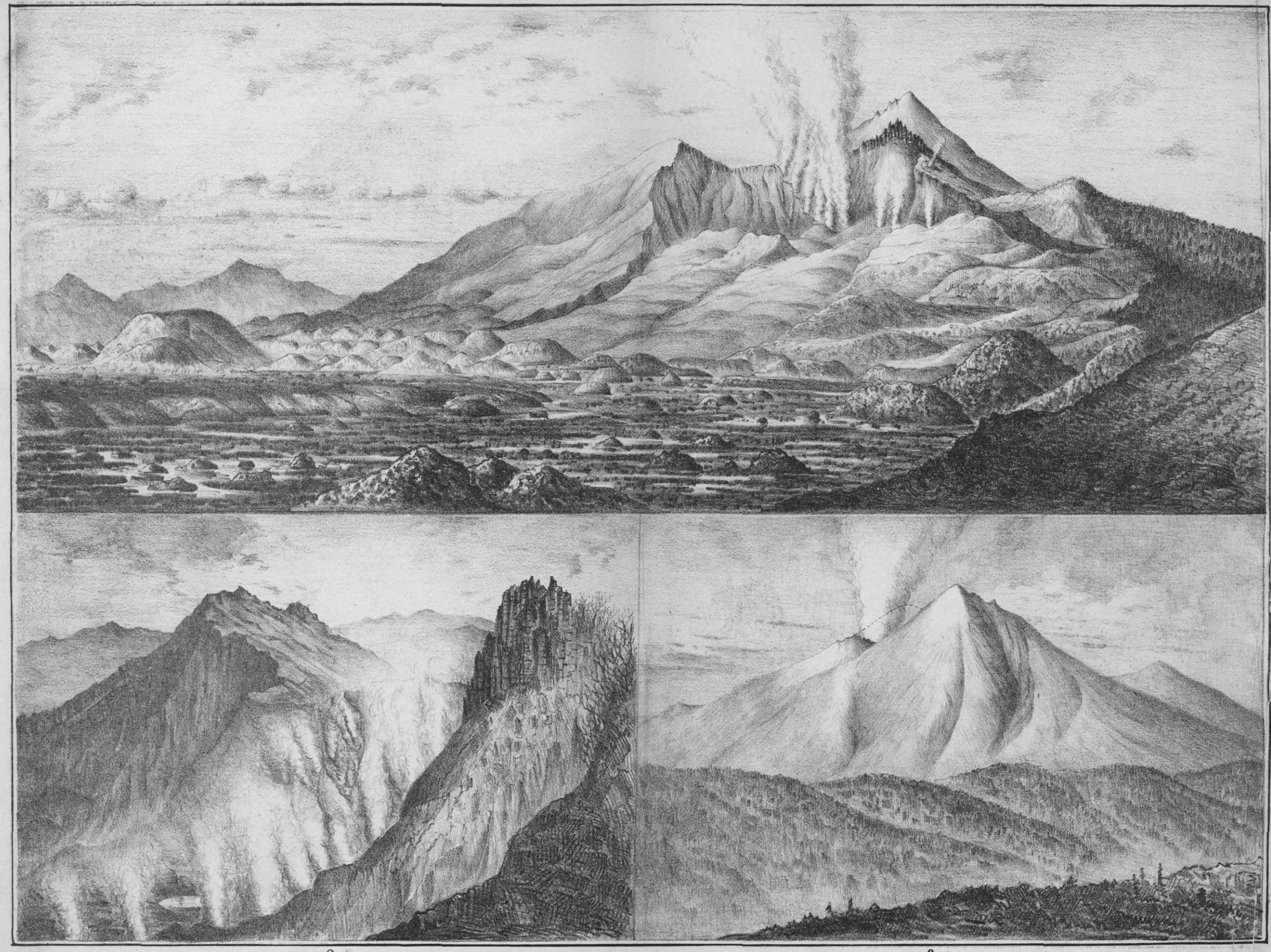
Plate XXI.

Fig. 1.—Crater as seen from the north near the village of Hibara, three weeks after the eruption, and at a distance of 9 kilometres —the position from which the grand view of the devastation could be seen with full effect. Among the *débris* from the crater downward, may be seen innumerable numbers of conical mounds. On the right hand are seen the hillsides bared by the torrent of mud. The main feature of this figure is analogous to *Fig. 1., Pl. XVI.* For the names of the principal peaks refer to that plate.

Fig. 2.—View of the crater twenty days after the eruption, from its edge just over the solfatara of Kaminoyu, looking down the crater, at the bottom of which a small lake or pond may be seen. On the right hand side is the characteristically rugged cliff of Yugeta-yama, on the proximity of which are numerous withered trees stripped of leaves. In the middle of the figure are numerous fissures puffing off steam and behind stands Kushigamine. The distant mountain in the back-ground is the old volcano of Dake-yama.

Fig. 3.—Distant view of Bandai-san from its south side as seen from the town of Wakamatsu, four weeks after the eruption. The most prominent pointed peak is Ōbandai, exposing on its flank a bare valley called Kara-sawa. The dotted line on the left shows the original form of Kobandai previous to the eruption. The prominence immediately below is the remains of Yugeta-yama. Down below is seen Marumori-yama as a small protuberance. The peak to the right is Kushigamine. The hills ridges in the foreground are the part of the Aizu-plateau.

[*From sketches by Y. Kikuchi.*]



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3

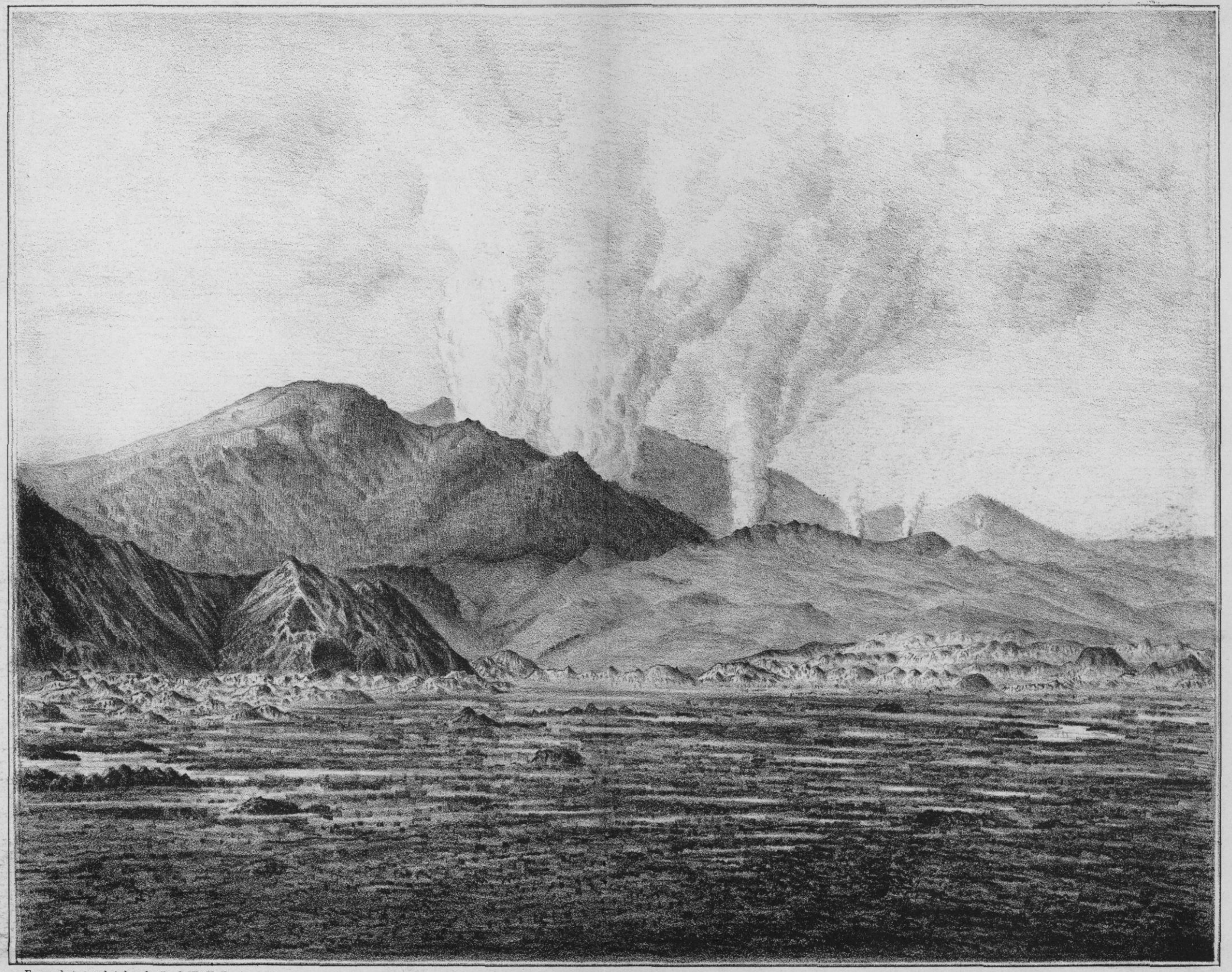
PLATE XXII.

Plate XXII.

View of Bandai-san from its north-eastern side at distance of about six kilometres, from the former site of the hamlet of Akimoto. The linear arrangement of steam-fissures is at once apparent to the eye. The level tract in the foreground shows the levelling effect by the mud stream, in which may be seen accumulations of water. A little farther away we find innumerable conical mounds. Just above the masses of these mounds on the left hand side, is seen the rocky exposure of a ridge which has had its loamy crust completely scraped off. Between this ridge and the prominent tree-covered peak of Kushigamine just behind, stretches the valley of the Nagase-gawa.

On the right hand side behind the group of conical mounds is seen the extensive slope, formerly known as Ōbudaira, converted into waste desert. The prominence at the termination of the steam column is Marumori-yama.

[*From photograph taken by Prof. W. K. Burton one week after the eruption.*]



From photograph taken by Prof. W. K. Burton.

PLATE XXIII.

Plate XXIII.

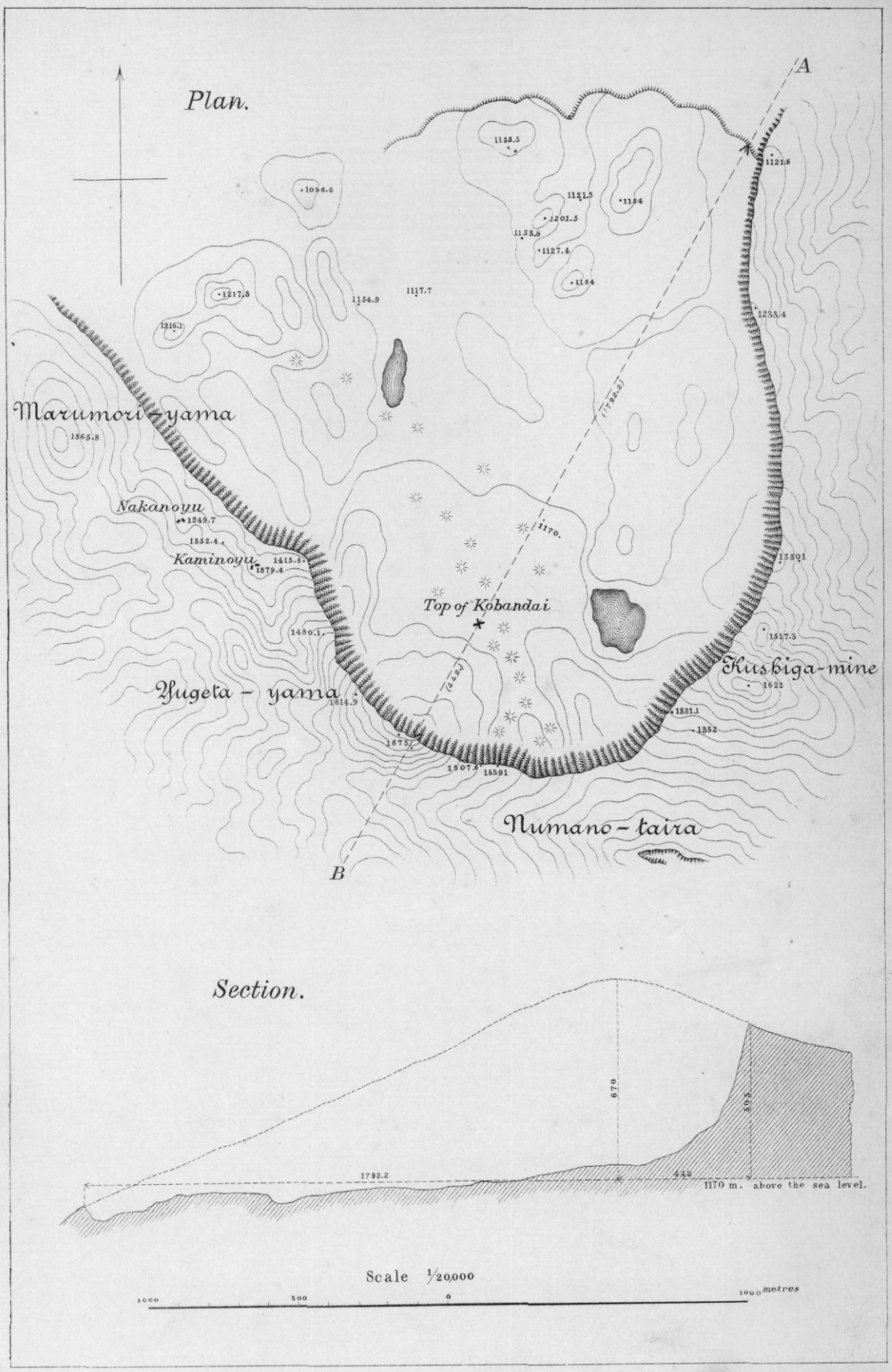
Plan.—Form of the crater as deduced from the triangulation survey. The contour lines in the crater indicate roughly the principal elevations and depressions.

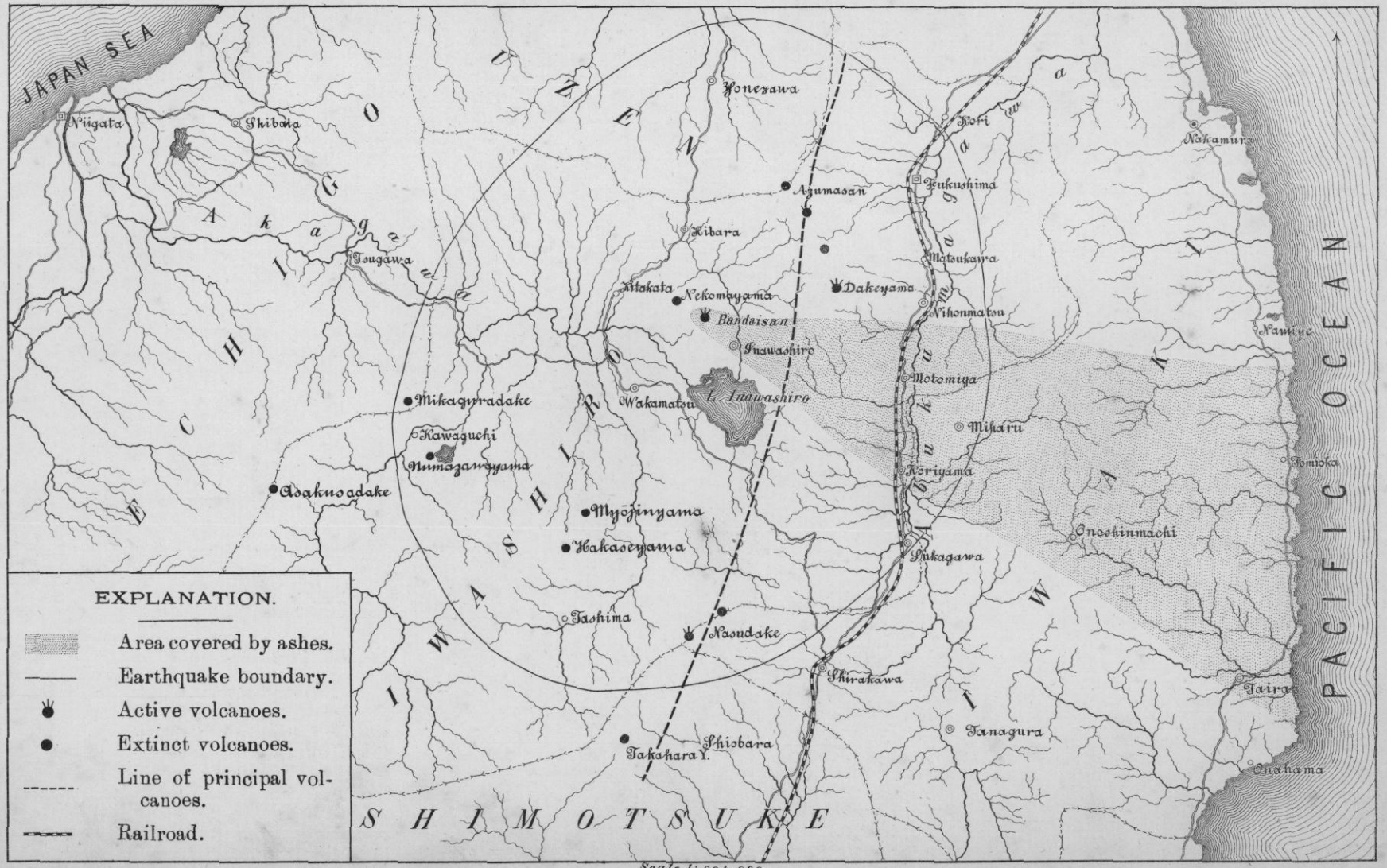
× The original top of Kobandai which is in the line of the steam fissure.

* Principal steam fissures.

Section.—The profile of the crater through the line *A B*, or the line passing through the original top of Kobandai and the highest part of the crater-wall. The dotted line shows the part that was blown away.

The heights are given in metres.


Plan.
A
B
1133.5
1121.6
1096.6
1131.3
1154
1201.3
1133.5
1127.4
1184
1217.3
1154.9
1117.7
1216.1
1233.4
Marumori-yama
1865.8
(1732.2)
Nakanoyu
1249.7
1352.4
Kaminoyu
1415.5
1379.4
1170.
1580.1
Top of Kobandai
1517.3
Kusbiga-mine
1622
Yugeta-yama
1614.9
(1442)
1675
1807.3
1559.1
1331.1
1352
Numano-taira
Section.
670
302
1732.2
442
1170 m. above the sea level.
Scale 1/20,000
1000
500
0
1000 metres



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