The (EW component) max. $2a$'s at Nagano of the different earthquakes, which were all unfelt, were thus smaller than 0.2 mm, making the accurate determination of the duration (y) of the preliminary tremor often doubtful. The average value of y, however, comes out to be 5.4 sec., which according to the equation

$$x \text{ km} = 7.48\ y \text{ sec.}$$

gives $x = 40.3$ km for the distance between Nagano and the mean earthquake origin, perfectly identical with the actual value.

CHAPTER X. ELEVATION OF THE CRATER BOTTOM AND THE FUTURE ACTIVITY OF THE ASAMA-YAMA.

65. ***Signs of increasing activity.*** The subjects, whose investigations are of vital importance in connection with the volcanic activity of the Asama-yama, are two-fold, namely, (i), the elevation of the bottom of the crater, and, (ii), the seismic disturbances of the local origin. (i) may be regarded as indicating the rate of increase of the expansive force of the steam and gases accumulating under the volcano, and (ii) as the forerunners of the explosions.

66. ***Depth of crater in*** **1887.** In the years succeeding the great eruption of 1783, the Asama-yama crater was probably very deep, its diameter being appreciably smaller than at present. The first attempt to determine the depth of the crater was made, so far as I am aware, by Dr. John Milne and the former United States Minister, Mr. Edwin Dun, in 1887, or 104 years after the Temmei disaster. The following is an account of their experiment, in which the depth was found to be some 224 metres.

"The crater of this volcano, as it stands today, measures a mile and a quarter in circumference, and never ceases to belch

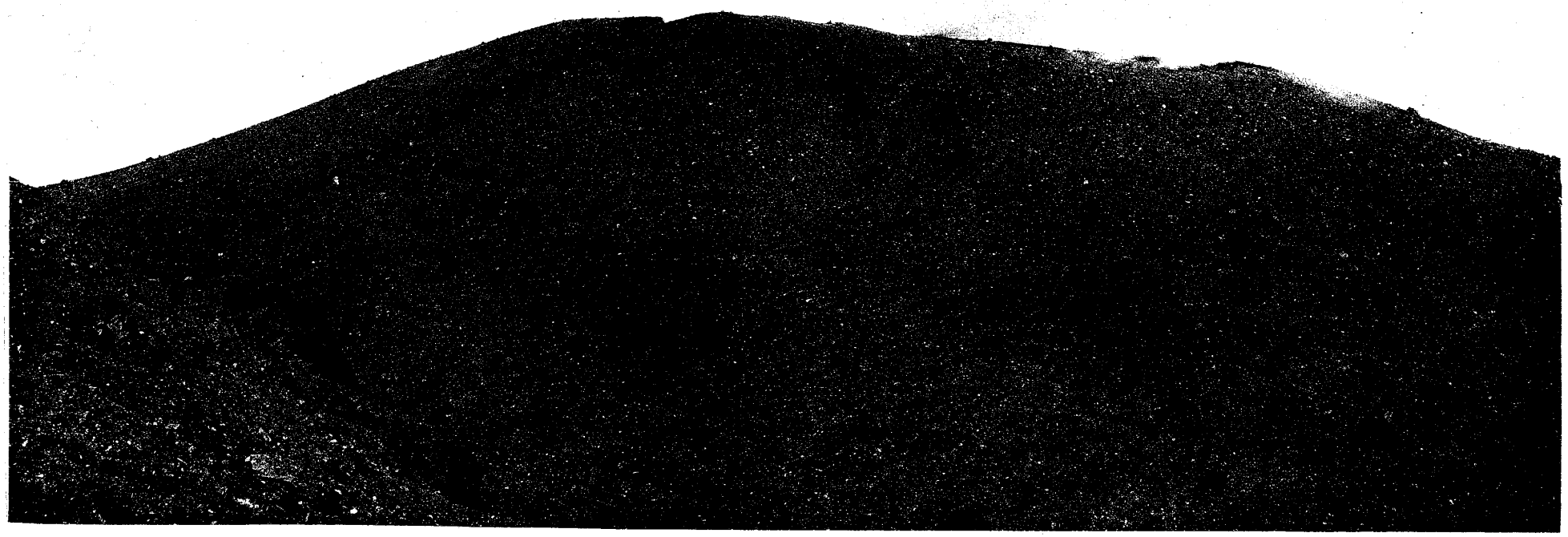


Fig. 52. The W. side of the Central Cone of the Asama-yama,

seen from the top of the Maikake-yama, indicating five radial cracks, of which the greatest was the one at the extreme left-hand, or NW, side.
(F. Omori, photo. Sept. 29th, 1910.)

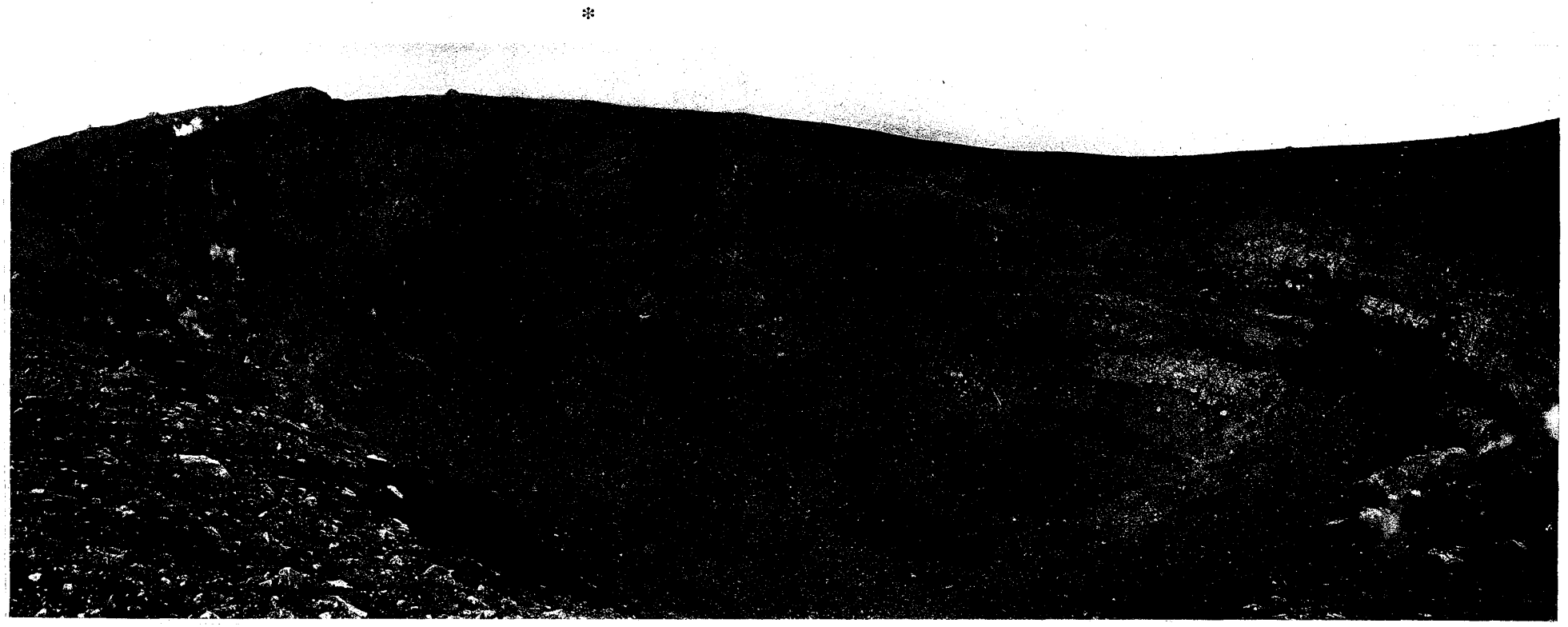


Fig. 53. View of the Inside of the Crater of the Asama-yama,

taken from the south. The lava was red hot at the lowest part of the crater bottom, a little to the right from the middle of the figure. (*) marks the position, where the author found by measurement on June 1st, 1911, the depth of the perpendicular crater wall to be 120 metres. (T. Kato, photo. Oct. 7th, 1911.)

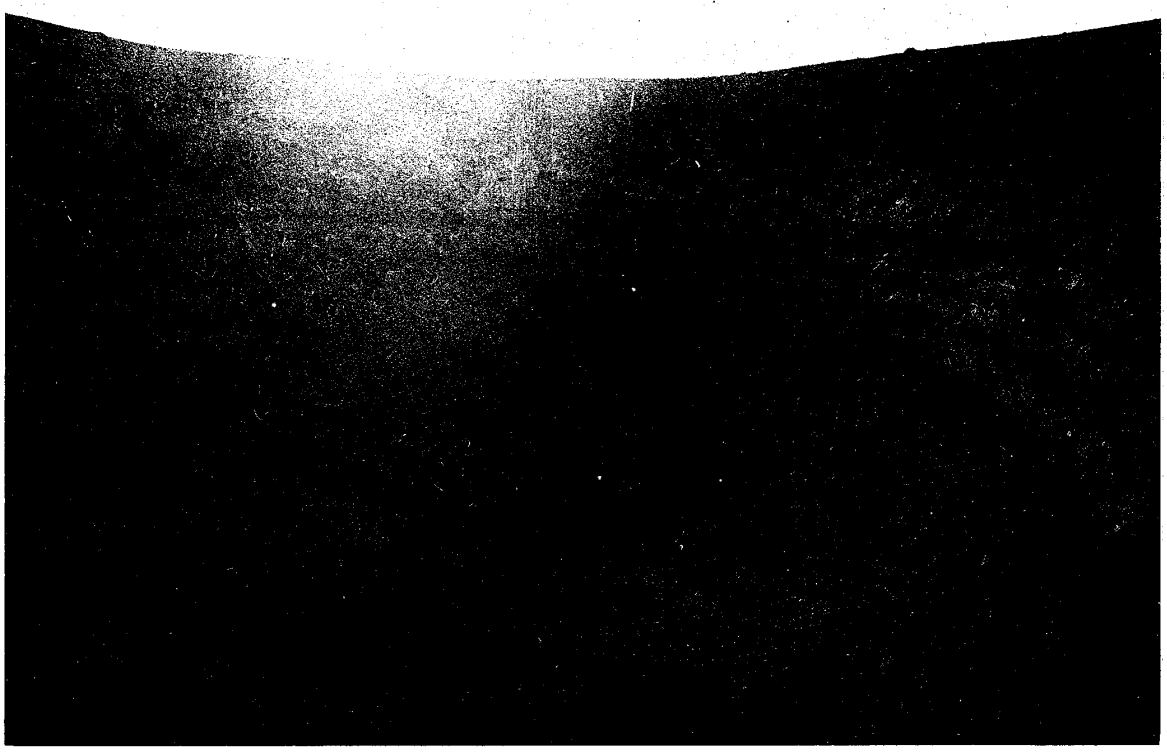


Fig. 54. View of the crater of the Asama-yama, taken from the south. This photograph was taken by T. Kato, on June 26th, 1911, from practically the same position as on Oct. 7th of the same year (Fig. 53). The lowest stratification at the right-hand side in the latter figure is in the present one covered up by sands.

Fig. 55. View of the crater bottom, taken from the NW.
(F. Omori, photo. Sept. 29th, 1910.)

Fig. 56. The SE edge of the crater of the Asama-yama.
(F. Omori, photo. Sept. 29th, 1910.)

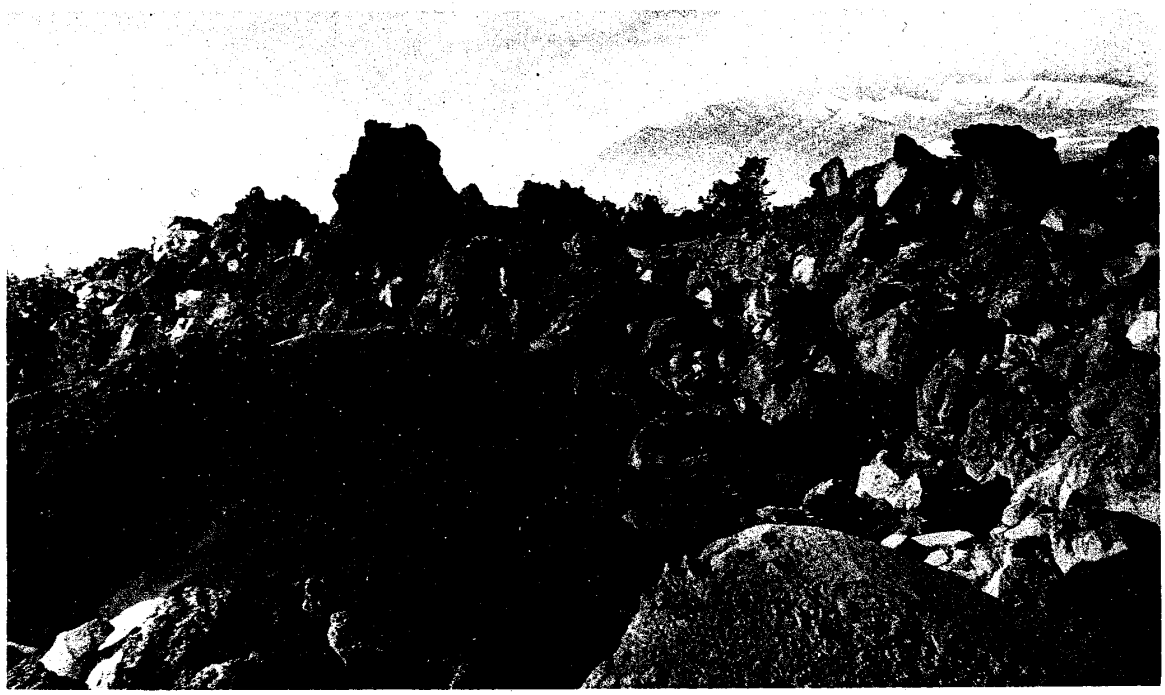


Fig. 57. View of the "Oni Oshidashi" or great Lava Flow of 1783. taken above and near the edge, facing toward the north. (F. Omori, photo. Dec. 24th, 1911.)

Fig. 58. Great Crack through the SW wall of the crater of the Asama-yama. (F. Omori, photo. Sept. 29th, 1910.)

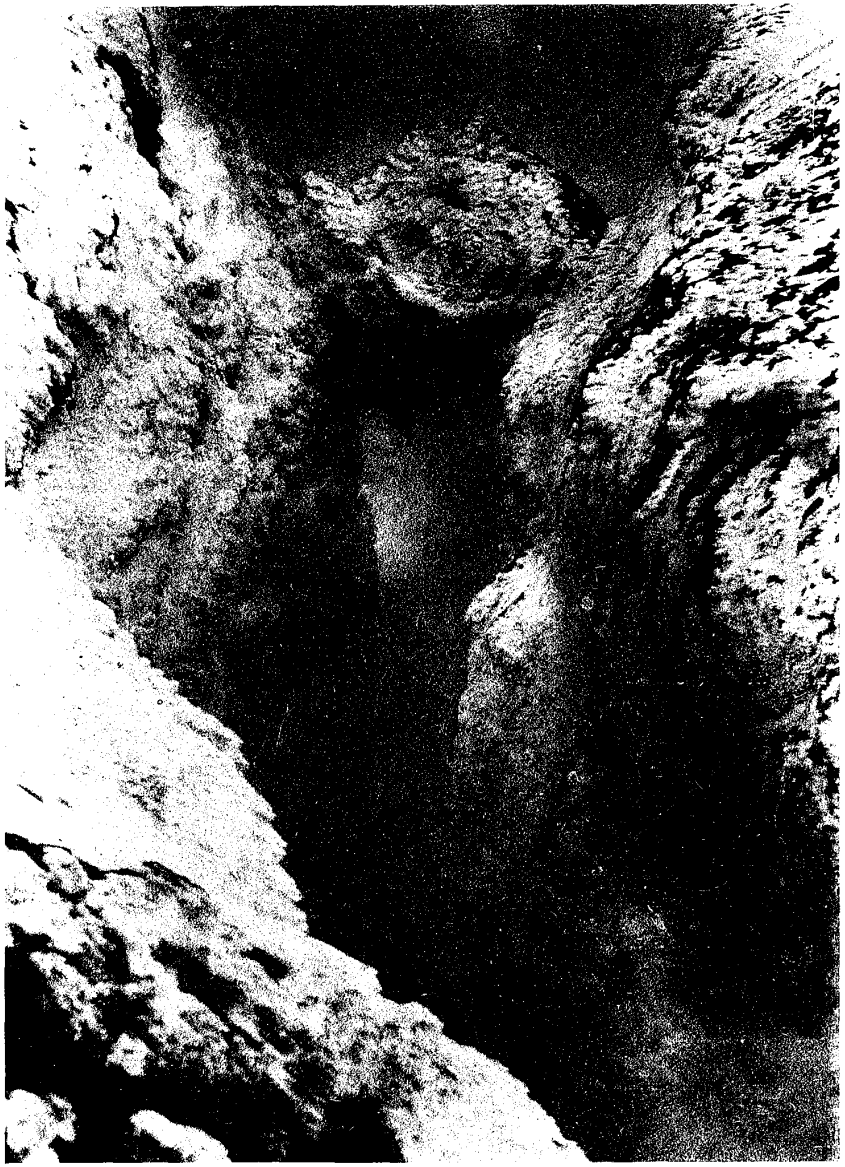


Fig. 59. Same, as seen on Feb. 16th, 1911. (F. Omori, photo.)

forth pungent, strangling vapours of hydrochloric acid and sulphurous anhydride, to breathe which is to die. The depth of the crater has been a subject of endless discussion among the foreign residents of Tokyo, some putting it at 1,000 ft, others at 8,000, and it was to settle this controversy that the experiment just referred to was undertaken. A party set out one day, headed by Prof. Milne and United States Minister Edwin Dun, with no less an object than to sound Asama's crater. They took with them elaborate chemical and physical appliances, a great quantity of rope, and a number of coolies to haul it. When they reached the edge of the crater, keeping carefully to the windward of the vapours, they proceeded to execute an idea of Minister Dun for measuring the depth. First with extreme difficulty, a rope was stretched across the crater, a distance of about 500 yards. Then a pulley was run out on this fixed line with another rope that could be lowered straight down (a thick wire was tried first, but it kinked and broke), and at the end of the vertical rope was made fast what the explorers called their *chemical and physical laboratory*, that is, special thermometers, bits of metal and other substances that would fuse at various temperatures, pieces of red and blue litmus paper, etc. Finally, when all was ready, the coolies were told to lower away, and the rope began to go down in the very thick of the vapour clouds, while all waited expectantly. Everything went well until a depth of 735 feet was reached, and then the experiment came to an abrupt and disconcerting end by the burning up of thermometers, rope, and everything."

Six year later, on July 16th, 1893, Prof. M. Goto, of the Tokyo Higher Normal School, with a party of the students, tried to measure the depth of the crater by a method similar to that used

by Dr. Milne and Mr. Dun. A strong rope, 576 feet in length, was stretched chord-wise across the SW part of the mouth of the crater, where the inside of the latter was formed by perpendicular cliffs; a weight of about $2\frac{3}{4}$ kg being lowerd down to the bottom by means of an iron wire passing through a pulley attached to the middle of length of the rope. As the crater bottom was at the time completely obscured by smokes, the first experiment, which indicated the depth of about 500 feet, much smaller than had been anticipated, was judged unsatisfactory. In the second trial, the rope broke, due to too much pull, and the experiment had to be abandoned on account of the approaching night-fall. According to Prof. N. Yamazaki, who ascended the mountain also in 1893, the crater depth was in that year about 230 metres.

67. *Depth of crater in* 1911. On June 1st, 1911, the present author, in company with Messrs J. Nishizawa and T. Ushiyama, of the Nagano Meteorological Observatory, and Mr. T. Kato, of the Seismological Institute, ascended the Asama-yama, arriving at the summit at 7.30 in the morning. As the weather was fine and the issue of the smokes was small, we had a clear view of the bottom of the crater (§ 69), and were enabled to measure with certainty the depth of the latter. For this purpose was employed a heavy bob, about 3 kg in weight, consisting of a finely nickeled brass cylinder filled with lead, which was to be let down from the cliff edge by means of a rope, whose weight was 0.9 kg per 100 metres of length. The rope being much lighter than the bob, the moment of arrival of the latter at the bottom could easily be ascertained. Besides, the descent of the weight was watched by a man from an opposite site, who gave a signal when it had reached the bottom. The first trial was made at a point on the NNW part of the crater edge, where the wall was perpendicu-

lar, with the result that the bob descended 98 metres and then came to a stop at the head of the sand slope at the foot of the cliff. The measurement was repeated at a point about 30 metres apart on the northern side (marked with an asterisk [*] in Fig. 53); the bob stopping, after a descent of 110 metres, at the middle of the sand foot covering. Thus it is clear that the depth at the NNW part of the crater was a little greater than 110 metres, and probably not much different from 120 metres, counting in the height of the small sand accumulation which covered the inside base of the crater wall at the part under consideration. At the same time, Messrs Nishizawa and Ushiyama made the measurements with a theodolite and found the depth of the central part of the bottom to be about 111 metres below the S. edge of the crater wall.

Three weeks previous to the above date, namely, on May 10th of the same year, Messrs Nishizawa and Ushiyama determined the time taken by a stone piece, projected horizontally from the S. crater edge, in reaching down to the bottom, and found the value of 5 seconds. This indicates that the crater depth was then about 125 metres.

According to the preceding results, the depth of the crater at the NNW part was, in May—June, 1911, very nearly 120 metres.*

68. ***Elevation of crater bottom.*** Comparing the result of the sounding undertaken by Dr. Milne and Mr. Dun and that found by the present author, it will be seen that the bottom of the crater has risen 104 metres in the course of the 24 years be-

* On Feb. 16th, 1911, the present author tried the sounding of the Asama-yama crater at the S. edge, finding the depth to be about 150 metres. The result was, however, not satisfactory, as the crater was completely filled with the smokes, and also as the weight of the bob was small (about 0.7 kg).

tween 1887 and 1911, giving the average yearly amount of the elevation of 4.3 metres. Should the rate of the elevation continue to be the same for the future, then the bottom would come up to the level of the margin of the crater in about 28 years more. The rate of the elevation is, however, likely to become less with the progress of the process. (See the next §)

69. *Recent condition of crater.* On Sept. 30th, 1910, when the weather was fine, the wall of the crater, whose inside was clearly observed, was seen, except on the N. side, to be perpendicularly vertical in the upper part. On the W. side, the base of the cliff, whose height was estimated to be about 50 metres, was continued to a slope which descended to the bottom. The latter was deepest at the N. part, where a portion of the lava surface was glowing red. The crater bottom was, however, far from being flat, but broken into irregular heaps, there being, amongst the others, a conspicuous ridge extending in an E-W direction, from whose middle powerful explosions took place from time to time. (See Fig. 55.) There were, on the higher parts of the NW, N., and NE slopes of the cone, a number of cracks or dislocations running parallel to the crater edge; these being marked by a series of small smoke columns issuing along them. On the W. and S. slopes, the wall of the cone was traversed by four radiating fissures (Fig. 52), the most westerly of which was the greatest and extended from the crater edge across to the top of the Maikake-yama. This fissure, which was probably formed at the time of the great Temmei eruption (1783), was, in the upper part, about 10 feet in width and about 12 feet in depth, its communication with the crater being blocked up by the rock fragments which crumbled into it. (See Fig. 58.)

Since the strong eruption of Dec. 7th, 1909, the Asama-yama

remained for nearly one year comparatively quiet, there having been only a few cases of detonations and projection of ashes in that time interval. This probably favoured the progress of the formation of the crust of the lava surface, the latter being consequently thrown into irregular heaps, as was the case at the time of the above-mentioned ascent. The strong eruption of Dec. 2nd, 1910, and the numerous subsequent outbursts must, however, have stirred up the lava mass in the crater and reduced, so to speak, to a condition of a homogeneous mixture, settling to an equilibrium state with a plane free surface. Thus, according to Prof. N. Yamazaki and Mr. J. Nishizawa, who ascended the mountain on Feb. 10th, 1911, the crater bottom, which then presented an appearance entirely different from that described above, was perfectly flat, and there was at the centre a small aperture about 20 metres in diameter; this, as well as the cracks along the circumference of the bottom plane or the inner base of the wall of the crater forming the channels of active escape of the white smokes. There was at the time no exposure or projection of red hot lava masses.

The present author's second ascent, on Feb. 16th, 1911, proved a toilsome one, the to-and-fro travel between Ashino-taira and the mountain top, a total distance of only about 12 km, taking 12 hours from 7 in the morning till 7 in the evening. A snow storm was raging on the mountain top, and the inside of the crater could not be seen at all, on account of the smokes filling the latter. On this occasion was, however, noticed that the cliff edge on the N., W., and S. sides had broken down, in no insignificant amount, into the crater bottom; one of the consequences being that the great radial fissure had its back wall thrown down and was converted into a channel opening into the crater, keeping be-

tween its two sides a large round stone mass, as shown in Fig. 59. It was a striking spectacle to witness large icicles hunging down from the snow covered rocks at the cliff edge amid the pungent and warm vapours issuing out so abundantly from the huge volcanic crater. Subsequently the above mentioned fissure became, by the removal of the incumbent rock mass, a simple opening (Fig. 48), being thus reduced to the same condition as it was twenty-five years ago.

On the occasion of the third ascent of the author, which was made on June 1st, 1911 (§ 67), or 3 weeks after the strong eruption of May 8th (Fig. 1) in that year, the crater presented a further change in appearance; there was at a little to the north from the centre of the flat lava area a circular portion of red hot molten mass, about 50 metres in diameter, surrounded by 5 concentric rings, into which the surface was solidified and which completely filled the crater bottom in a manner quite similar to the water waves generated by a stone thrown into a pond. At the same time, the cliff edge of the crater suffered considerable break-down on the N., W., and S. sides; the northern part of the wall, in particular, being appreciably reduced in height. It was only at a small portion at the NNW, where the sounding was performed (§ 67), that the inside of the crater made perpendicular cliffs; at all the other points, the lower part of the wall was much covered by sand and stones, which made up a slope of 30° or 40° descending into the bottom area; especially, at the SE side of the crater, the wall was vertical only in the upper 25 metres, the entire remaining part being hidden by the débris. Thus the crater assumed the form approximately of an inverted truncated cone, with the result that the area of the bottom of the crater was considerably reduced, while that of its

mouth was increased. It was very remarkable that there was no escape of steam and gases from the bonndary, or circumference, of the lava area, due doubtless to the falling down of an enormous amount of the sand and stones from the cliff edge of the wall, thereby stopping for a time the escape of the smokes, until the strong explosion of May 8th took place from the centre of the crater bottom. The crater was thus reduced to a condition similar to that observed after the strong eruption of May 31st, 1909, the only difference being in the decrease of the bottom area. After a time, the central part of the latter would be hardened and thrown into a convex surface, leading to explosions from the circumference of the bottom. This would, in turn, weaken the inside of the wall of the crater and cause the gradual falling down of the cliff edge, thereby covering the boundary part of the lava area, until the occurrance of an explosion from the centre. The changes in the condition of the crater would thus go on alternately. The break-down of the cliff edge of the crater wall reduces, of course, the height of the latter and enables the lava face to approach the level of the mouth of the crater more rapidly than when the elevation of the bottom is alone going on.

Fig. 2. represents one of the small eruptions of the Asama-yama which happened very often during the 23rd and 24th of Dec., 1911. On these two days, when the author was engaged in examining the "Oni-oshidashi," the detonations were also very frequent, which were like distant thunders, gun discharges, or beating of drums. During the night, the mountain top glowed red for a dozen seconds or so at the time of each outburst or detonation; during the day time, could be observed with the naked eye from the mid-slope on the northern flank, the rock fragments thrown out like a group of birds from the crater at

frequent intervals and in parabolic paths, sometimes drawing behind them a tail of white steam like a silken thread. These projectiles must naturally prove fatal should the traveller happen to be hit by them, although the explosion itself may be so insignificant as to be perceived nowhere except on the higher part of the mountain.

70. *On future great destructive eruption.* Several of the numerous recent outbursts of the Asama-yama were strong, being accompanied by loud detonations, the precipitation of ashes, and the projection of rock fragments, sometimes of considerable dimensions (Figs. 3 and 4). Such eruptions, though highly dangerous to the travellers ascending the volcano and often injurious to the sericultural industries, are, of course, of far smaller magnitude than the Temmei catastrophe. What may be termed a great destructive outburst of the Asama-yama is one in which the places at the base of the mountain suffer damage other than a mere precipitation of ashes. Thus the special features of the Temmei eruption (1783) consisted, beside the projection of a great amount of ashes, sands, and red hot stones, in the outflow of a large quantity of lava, the "Oni-oshidashi," and in the descent of a huge volcanic avalanch. The "Oni-oshidashi," although a highly remarkable and extroardinary object, stopped at the mountain base and did not prove disastrous to the neighbouring villages, while the volcanic avalanch produced an enormous amount of damage not only at the mountain base, but for a considerable distance along the courses of the Azuma-gawa and the Tone-gawa.

In connection with the past and the possible future disturbances of the Asama-yama, the questions present themselves :—Why did the great volcanic avalanch of 1783 as well as the "Oni-oshidashi" and the old lava flow, the "Butai" (Stage), all find

FIG. 60. DIAGRAM SHOWING THE RELATIVE POSITIONS OF THE PRESENT CRATER OF THE ASAMA-YAMA AND THE WALLS OF THE TWO FORMER CRATERS.

C = Present Crater. *M* = Maikake-yama. *K* = Kurofu-yama.
M' = Continuation of the Maikake-yama. *Ki* = Kiba-yama.
[Dotted arcs indicate the portions of the crater walls broken away.]

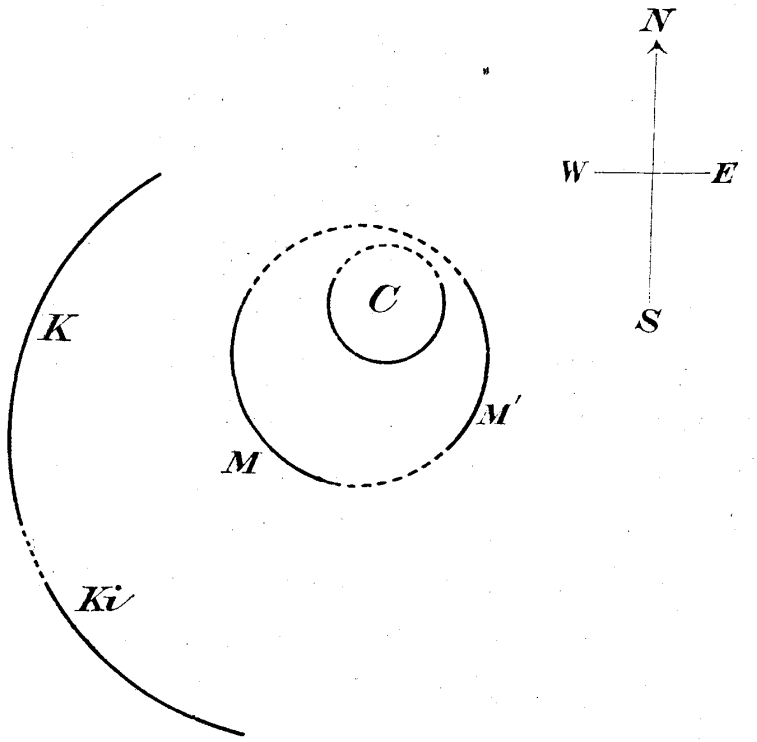
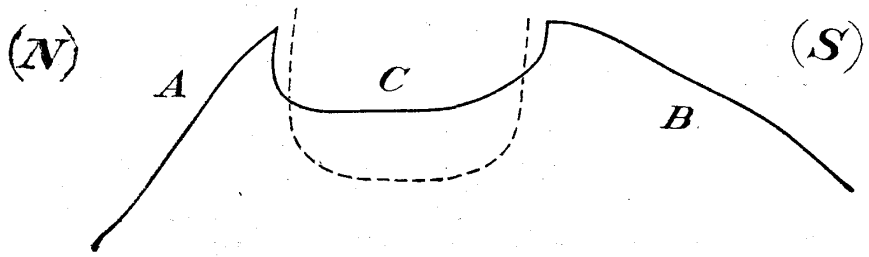


FIG. 61. DIAGRAM SHOWING THE NS SECTION OF THE CRATER OF THE ASAMA-YAMA.



C....Crater at the present day, (1911). (The dotted line indicates the crater in 1887.)
A....N. crater wall, directly and steeply sloping down to the mountain base.
B....S. crater wall, whose inclination is more gradual than that of the opposite side.

their way northwards and not toward other directions? Which would be the probable direction of discharge of the future lava stream and volcanic avalanch from the Asama-yama crater? The answers to these questions are to be found in the peculiarity of the topography of the volcano. As remarked in § 2, the Kurofu-yama and the Kiba-yama (Fig. 6) are the remnants of the wall of the first-epoch crater, while the Maikake-yama (Figs. 9 and 10) is that of the second-epoch one. Now, the position of the present crater is eccentric and shifted northwards (Fig. 60), with respect to those of the two predecessors; in consequence the mountain presents a nearly symmetrical shape when seen north-westwards from the vicinity of Kutsukake (Fig. 7), but it looks markedly unsymmetrical when viewed westwards from the foot of the Ko-Asama (Fig. 8), the crater being adjacent to the northern flank but much removed from the opposite side. The result of this eccentric disposition of the site of the crater is that the wall of the latter is lowest and thinnest on the N. side (Fig. 61), where the steep slope descends uninterruptedly to the Rokuriga-hara below. Thus the N. boundary of the crater forms the point of the least resistance, the height and thickness of the wall being most easily there reduced by the volcanic disturbances and the atmospheric agencies. This was probably the reason why the "Oni-oshidashi" and the Volcanic Avalanch of 1783 found their ways northwards, as was also the case with the "Butai," a lava flow of much older date. The course of lava mass and volcanic avalanch in a future great eruption will likewise be to the north. The inhabitants of the villages and towns situated on the northern base of the Asama-yama need, however, take no alarm at this conclusion, as the crater bottom is still 120 metres in height and prevents the molten lava and hot

stones from overflowing even in cases of very strong eruptions. It would be only after the lapse of some twenty years that the bottom of the crater may come sufficiently near to the level of the top of the wall, in case the process of elevation of the lava surface continues steadily also for the years to come. In the meanwhile it is necessary to study with great attention the volcanic and seismic phenomena of the Asama-yama.

In conclusion I have to express my thanks to my assistants Messrs T. Kato, H. Kurosaka, and T. Toyoda, and to Messrs J. Nishizawa, T. Ushiyama, and C. Koborinai, of the Nagano Meteorological Observatory for the active services rendered in the investigations on the Asama-yama, and especially in the seismographical observations at Ashino-taira and Yuno-taira; Mr. Nishizawa having moreover superintended the construction of the Seismological Observatory near Yuno-taira.

Tokyo. Jan. 1912.