THE ERUPTION OF AZUMA-SAN.

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A full report on the eruption of Azuma-san will soon be published by the Earthquake Investigation Committee. The following preliminary note is in the main a translation of an article by myself published in the *Tōyō Gakuget-Zasshi*, No. 141, with some additions.

The first eruption of Azuma-san took place on May 19th (1893), at about 11.30 a.m. Of the subsequent eruptions, those on June 4th, 4.10 a.m., and on June 7th, 0.36 p.m., were the most violent.

The character of the eruption was similar to that of Bandai-san in 1888. However, the subsequent phenomena were different. In the case of Bandai-san, the whole energy of outburst was practically exhausted by the first great explosion, there being subsequently only gentle issuings of steam. In the case of Azuma-san, the first eruption was not very strong, but was followed by several which were stronger. Again, in the latter case, the falling of ashes occurred very often, which did not occur in the former except on the occasion of the first explosion. The difference probably arose from a dissimilarity in the hardness of the material of the mountains and of the shape of their craters.

TOPOGRAPHICAL FEATURES.

The topographical features of Azuma-san are similar to those of Bandai-san. At the centre, there is likewise a plain, which is about 1,600 m. above sea-level, and of a nearly ellip-

tical shape, whose axes are respectively 600 and 400 meters and whose area is about 0.2 square kilometre (according to the survey by Prof. A. Tanakadate and others). The southern part is called Torinoko-daira, and the northern part Numano-taira, and before the eruption, the ground is said to have been covered with grass and gravel. Near the centre of the plain, there is a small pond 23 metres in diameter, called the Azuma-yu or Doro-yu, in which hot water bubbles up. The Azuma-fuji-san is to the east of the plain, and is separated by a streamlet from another cone called Okenuma. The mountains to the north of the plain are Sannobayashi, Daiten, Issaikio, Shimofuri, and Iwo. Issaikio-san is the highest of the group, and on its top, which is 1,950 metres high, there is a triangulation station. Azuma-Fuji-san is 1,700 metres high, and Okenuma 1,670 metres high, the craters of both these cones are lower towards the South and higher towards the North, so that their form can clearly be seen from halfway up the slope of Iwo-san or Daiten-san. There are two principal streams among these mountains. One runs towards the east along the southern foot of Shimofuri-yama and Mukade-yama (a continuation of the former). The other, called Shiono-gawa, has its source at the Kama-numa (a crater lake at the back of the Daiten), and joining the stream coming from the newly-formed craters, goes between Azuma-fuji and Okenuma and finally flows into the Ara-kawa.

HISTORY.

The name Azuma-san is applied to a big group of volcanic cones, where there must have been several violent eruptions. The Azuma-Fuji, Okenuma, Goshiki-numa, and Kama-numa are cones retaining their perfect shape; whether there were several eruptions within the historic period is not clear. The last eruption took place about 50 years ago, and since that time steam continued to be thrown out more or less till the beginning of the *Meiji* era (1868). This crater, called Ōana, is situated on the southern flank of the Iwo-san. It is nearly

circular in form, being about 100 metres in diameter and 60 metres in depth. Azuma-yu or Doro-yu has ejected hot water since *Meiji* 2nd year (1869), and continued to throw it up to a height of about 5 feet. The temperature was sufficiently high that a person could not put in the hands. Recently, however, the eruption of hot water ceased and there has only been gentle bubbling. After the eruptions, the temperature was found to be only 19°, 30°, and 25°C. (according to the determination of Professor Tanakadate and others). It seems evident that the volcanic energy beneath Azuma-san is always making efforts to find a constant exit from one point or other in the district.

Azuma-san is described in a book entitled Ōu-kanseki-bunroshi, as follows :—"There is a mountain to the south-west of Fukushima called by the natives Azuma-take. This is what is known as the Mono-omoi-yama in Japanese poetry. Yahazu-dake is situated to the east of Azuma-take and to the north-west of Tsuchiu-mura." The name "Mono-omoi" means "burning heart," and was probably applied on account of smoke having been more or less thrown up from the mountain. Yahazu-dake in the above description is the same as Azuma-Fuji-yama, and Mono-omoi-yama the same as Issaikio or Iwo-san.

PREMONITORY SIGNS.

The present eruptions took place at a distance from any habitation, and it not being summer there were no persons at the Yahazu-spa, and so no one had opportanity to note premonitory signs of the eruptions. Some people in the neighbouring villages are said to have heard roaring sounds since noon of the preceding day or for a few days previously. Again, it was afterwards found on examining the daily-journal of the Fukushima Meteorological Station, that sounds like distant thunder or like those caused by the passage of railway trains had been often heard during the night since the 10th of the previous month. These "sounds" might have been fore-

warnings of the eruptions. It is also possible that small earthquakes or tremors might have been often felt in the immediate vicinity of the mountain.

The hot springs of Taka-yu and Nuruyu, which are half way up the mountains, showed no remarkable changes in temperature previous to the eruptions.

THE ERUPTION OF MAY 19TH.

According to the statement of the Director of the Fukushima Meteorological Station, the "sound," on the day of the first eruption, was heard from 11h. 30m. a.m. and became very loud at 11h. 34m. a.m., when people became generally aware of the event. The end of the pointer of the contact-maker of the Seismograph at the Station, when observed at this moment, showed very small vibrations, which did not cease for three minutes. The motion of the ground, however, was not large enough to start the machine. According to this report, it appears that the eruption was not quite sudden, but there had first been small explosions, just as tremors precede proper earthquake motions. But it is probable that the big eruption took place first, and its sound was propagated through the air, which must have taken about one minute to traverse the distance of 20 kilometres between Azuma-san and Fukushima. The preliminary sound might also have been caused by vibrations propagated with great velocity through the ground. When witnessed from Fukushima or Inawashiro, the smoke or steam first ascended straight up to a height equal to about twice or one and one-half times the height of the mountain. This height of ascent would be about 2 kilometres. The lower half of the smoke column was observed to be intensely black, and this is probably owing to a great quantity of rock fragments, mud, and ashes mixed up in the steam. On the day of the eruption, the weather was very fine and calm, with a slight wind whose velocity was not more than 0.5 metre per second. The ashes were thrown chiefly towards S.S.E. and reached a

distance of a few miles. The white snow on Mount Adataro was covered by the falling ashes giving it a grayish colour.

The site of the present eruption was at the middle of the southern slope of Daiten-yama. Here a few large and small craterlets were formed along a fissure or crevice in a ravine called Tsubakuro-sawa, and the pent-up steam broke the mountain flank at this point and threw off rocks and mud.

The ejected earth having been mixed with a great amount of steam, it became muddy in consistency and accumulated around the crater. This in the main must have been projected vertically upwards, and there was no trace of any particular mud avalanches as in the case of Bandai-san, where the *débris* was projected sideways. The depth of the mud was greatest around the crater, and equal to about 3 metres, thence gradually diminishing. About half of the Numano-taira was covered with this mud. Since mud and rock fragments were found projected up to near the top of Issaikio-san, we may infer that the *débris* was partly projected to a vertical height of more than three or four hundred metres. (The top of Issaikio is about 300 metres above the level of Numano-taira.) The ashes covering the ground around the crater, were from 2 to 5 inches thick in Numano-taira, but in places they accumulated to a depth of 2 or 3 feet. At the time of our first visit, three days after the eruption, Numano-taira, owing to previous heavy rainfalls, appeared like a muddy marsh. It was very difficult to cross, the mud being sometimes up to the waist. The ascent to the crater was likewise extremely troublesome.

The volume of mud and ashes accumulated around the crater, we estimate as equal to the volume of a right cone whose height is 3 metres and whose radius of base is half a kilometre. This is equal to 790,000 cubic metres. There is no exact data for estimating the volume of the ashes which were carried to a distance. If we suppose an oblong area, in length 20 kilometres and breadth 10 kilometres to have been

covered with ashes to a thickness of 0.1 millimetre, the total volume is equal to 20,000 cubic metres. If these calculations be not very erroneous, this result is approximately equal to the volume of the crater. As observed a few days after the eruption, the crater cavity was nearly a triangular prism of which the (upper) width was about 60 metres, the depth 50 metres, and the length 400 metres. The volume of such a cavity would be about 600,000 cubic metres. This estimate as well as the preceding one is probably a little too great, and we may therefore put the volume in question to be equal in round numbers to half a million cubic metres.

MAGNITUDE OF THE ERUPTION AND THE EARTHQUAKE.

The eruption of Azuma-san was fortunately not very strong, and indeed far smaller than that of Bandai-san in 1888. The volume of the mud and rock thrown off was, as seen above, only some 500,000 cubic metres, while the volume of the newly opened crater of Bandai-san formed by the disruption of nearly the whole of Ko-bandai was, as estimated by Professors Sekiya and Kikuchi, about 1,700,000,000 cubic metres. Of course, the manner of transportation or projection of the *débris* was very different in the two cases, and the above figures can by no means be taken as a relative measure of the intensity of the eruption. However, we can see a great difference in the intensity between them.

It is well known that earthquakes are caused by the impulse communicated to the ground when an eruption takes place, or when some sudden expansion of subterranen steam produces fissures, etc. These so-called volcanic earthquakes are usually very limited in area. The relative magnitudes of volcanic explosions may most naturally be compared by the magnitudes or areas of disturbance of the earthquakes they occasion. In the case of the eruption of Bandai-san, the shakings reached to the mean distance of 50 kilometres from the mountain and the area of disturbance was about 10,000

square kilometres. In the case of the Azuma-san eruption, the shakings were propagated to different distances in different directions, but we may take the mean radius of propagation to be 20 kilometres, and the area of disturbance about 1,300 square kilometres. Comparing these two areas of disturbance, the eruption of Bandai-san was some ten times greater than that of Azuma-san. When considered in relation to other circumstances, this ratio seems to be rather too small.

In the case of a volcanic eruption, the energy of the pent-up steam is chiefly expended in breaking and scattering the superincumbent material and so the earthquake caused by the eruption cannot be very strong. Thus, on the present occasion, there was on Numano-taira, at a distance of about 5 *cho* and along the Shiwogawa, a small, roughly made house known as the Jinbei Cottage, which had been intended for a bath house, which did not appear to have suffered any particular damage by the shaking. Again, at a locality called Sainokawara, which is at the base of Azuma-Fuji-yama, there were many piles of stone fragments looking like very rough tombstones. None of these seemed to have been disturbed. Judging from other facts, the intensity of the shock at Numano-taira was probably not more than one which would cause ordinary houses to swing and possibly to dislodge articles from shelves.

In earthquakes accompanying volcanic eruptions, the intensity of motion often decreases very quickly with distance from the origin of the shock. In the case under consideration, the earthquake was felt only very feebly at Nuruyu and Takayu, which are 1 or 1½ *ri* distant from the crater. This is probably owing to the origin of the shock having been quite near the surface of the ground.

I myself felt one earthquake at Nuruyu on June 6th at about 11h. 2m. a.m., which was first announced by a loud sound like that caused by the approach of a violent gust of wind. Immediately after this, feeble tremblings of the ground

were perceived and sliding doors slightly rattled. The duration of the shock was about 7 seconds, and its character extremely quick. At the same time black smoke was seen to issue from Azuma-san. This shock was felt at Fukushima Meteorological Station as very weak tremblings, which lasted for 9 seconds. We did not get satisfactory instrumental records of these earthquakes. Their character is very probably like that of artificial earthquakes caused by dynamite explosions.

As noticed before, the earthquake which accompanied the first eruption was propagated differently in different directions, and sometimes was felt more strongly at one place than at another nearer to the origin of the disturbance. Thus, for instance, Fukushima is 4½ *ri* to the E.N.E. of Azuma-san, and Motomiya at 7 *ri* to the S.E. of the same mountain. The earthquake at the time of the first eruption was not distinctly felt at Fukushima, the motion being only strong enough to move slightly the pointer of the contact-maker of the Seismograph at the Meteorological Station, while at Motomiya the shock was distinctly felt and so strong as to cause articles to slightly rattle. Differences like this are no doubt due to some peculiarity in the geological structure of the district. The formations around Azuma-san are very complicated, but are in general arranged parallel in a N.-S. direction. Thus the Abukuma mountain range runs from north to south, and the rock systems composing it form zones parallel to the same direction. The volcanic zone, including Azuma-san, Adataro, etc., called the Nasu Chain, is also nearly in a N.-S. direction. It may be that the vibration of the ground is thus transmitted much easier in a N.-S. than in an E.-W. direction. In the case of the eruption of Bandai-san, the area of earthquake disturbance was slightly more extended in a N.-S. than in an E.-W. direction. Questions of this kind would be important in connection with the study of volcanic chains.

ENERGY OF ERUPTION.

The estimation of the energy of volcanic eruptions may be important in connection with problems relating to earthquakes and volcanoes. And, as the present eruption was simple in character, we may make approximate calculations. It is superfluous to remark that the results to be obtained will be only rough estimates, merely indicating the order of the quantity under discussion.

The energy of volcanic explosion in spent in four principal ways :—(1.) In breaking the material of the mountain, or overcoming the cohesive force of rocks and earth; (2.) In projecting rocks and earth up into the air; (3.) In producing an earthquake; (4.) In producing disturbance in the air. Now, in the case of Azuma-san, the crater was formed among loose piles of rock fragments and earth, and there was no breaking asunder of hard rocky masses as in the case of Bandai-san; so that the energy spent in the first way would not be very great. The energy spent in the fourth way would also be small. It therefore remains for us to consider the expenditure of energy in the second and third ways.

As mentioned above, the mud and ashes seemed to have been projected upwards to a height of about 1 kilometre. We have no means of finding the height to which the centre of gravity of the whole projected mass was raised. Let us assume this height to be 100 metres, which probably would not be much greater than the actual value. Then, since the total volume of rock and mud projected is 500,000 cubic metres, the work done would be

$$100 \times 500{,}000 \times W = 50{,}000{,}000\ W \text{ kilogrammetres,}$$

W being the weight of 1 cubic metre of rock and mud.

Again, the energy of an earthquake vibration is, when the motion is of simple harmonic type, given by the formula

$$\tfrac{1}{2}\, m\, v^2$$

in which v is the maximum velocity of the earth particle, and m is the whole of the disturbed mass. In the case of the earth-

quake caused by the explosion under consideration, we may probably, without much mistake, put the mean amplitude of motion at $\frac{1}{10}$mm. and the period at $\frac{1}{10}$ second. If we further suppose the whole area of disturbance, 1,300 square kilometres n extent, to have been at any instant of time disturbed to a uniform depth of $\frac{1}{4}$ kilometres, the energy of vibration is,

$$\frac{1}{2} \times 1.300,000,000 \times 250 \times \frac{4\pi^2 \left(\frac{1}{10}\right)^2}{\left(\frac{1}{10}\right)^2} \times \frac{1}{(1,000)^2} \times W^1$$

$$= 6,400,000 \times W^1 \text{ kilogrammetres,}$$

W^1 being the mean weight of 1 cubic metre of the surface earth. If we assume $W^1 = W$, the works done in the above two ways are together equal to $56,000,000 \times W$ kilogrammetres. As the energy of explosion has been spent in doing other work, $60,000,000 \times W$ kilogrammetres may be less than the actual amount of the whole work done. If we put W to be equal to 2,300 kilogrammes, *i.e.* assume the mean density of the mountain to be 2.3, (which was adopted by Professors S. Sekiya and Y. Kikuchi for the mean density of Bandai-san), the work done by the energy of the explosion is about 140,000,000,000 kilogrammetres.

FLAMES AND OTHER PHENOMENA.

Some people thought they saw flames among the smoke at the time of the first explosion and also subsequently, and these flames were stated to be like gases burning and not like lightning. The information on this subject is not positive.

When a volcanic explosion takes place, the steam pent up underneath finds itself liberated and consequently the volume is suddenly very much increased. Its temperature is then lowered and the volume again diminishes. Thus it often happens that simultaneous with volcanic eruptions violent gusts of wind are produced directed first from the mountain and then towards it. In the case of the present eruption, there were probably no remarkable phenomena of this kind. Thus, we did not see rushes and reeds at the base of the Azuma-Fuji-san which had been broken by wind. It may be noticed that in this locality

grasses and trees were found covered by ashes, but only on the side facing towards the crater.

Violent rain-falls sometimes accompany these sudden expansions of steam, but at Adzuma-san none was observed. This is probably because the quantity of steam was not sufficiently great.

CONICAL HOLES, ETC.

There were numerous round holes on Numano-taira and also around the crater. These were all small, and very few had their diameters more than 7 or 8 feet. Holes of this kind were also abundant on the occasion of the eruption of Bandai-san, some of them having diameters greater than 30 feet. These holes would most naturally seem to have been formed by falling stones projected to great heights. However, as things of this kind had not hitherto been discussed in reports of foreign volcanic eruptions, various explanations were advanced, the formation having been attributed to the emission of steam or gases, to the effect of the seismic disturbance, to the uprooting of trees, etc. Professors S. Sekiya and Y. Kikuchi attributed them to falling stones. In the case of Bandai-san, all these causes might have been operating, each in different degrees. In the present case, all the holes were doubtless formed by the falling stones. These were indiscriminately formed in the marshy plain and over snow on the mountain flanks, and the presence of stone fragments within these holes could easily be ascertained by searching with sticks. In a few cases, we actually dug up stones. When seen a few days after the eruption, these holes were filled with water and mud, and their exact shapes somewhat obscured. We give here the diameters and depths of a few holes found in Numano-taira.

Diameter of Mouth. metre.	Depth. metre.
1.25	—
1.12	0.63
0.83	0.80
2.70	—
1.32	0.66

The diameters of the conical holes were generally much larger than the dimensions of the stones found within them. The stone found in the last hole of the above list was nearly parallelopipedal in form, its length was 0.65 metre, breadth 0.3 metre, thickness 0.22 metre.

Most of falling stones buried themselves among earth and formed conical holes, and very few were found exposed on the surface. Near the crater, however, many stone blocks were found in the mud, some of which measured more than 6 feet.

The projection of rock fragments was limited within a horizontal distance of half a kilometre from the crater. These showed no sign of having been fused, but were quite like the rocks around the crater.

Near the crater, there were many trees with their lower portions buried in mud which were broken. Some were uprooted. These effects were in the main probably due to falling stones.

CONDITIONS AFTER THE ERUPTION.

When I visited the place a few days after the eruption, steam was being violently ejected, the column ascending to a height of about 1 kilometre in the air. The craters were five in number, besides some small ones. The number and form of these were constantly changing. Each craterlet or mouth gave forth white steam, occasionally mixed with black smoke. The third hole, was inclined towards the east, and its steam was violently thrown against an embankment-like obstacle in the upper part of the crater excavation. This craterlet was most active, and vomited forth puffs of smoke without cessation, though there were some slight periodical changes in the intensity of the explosions. Smoke was also powerfully ejected on the other side of the above-mentioned obstacle. Many smaller columns of smoke rose from the upper and lower portions of the crater cavity. Loose rock fragments fell down occasionally from the walls of these mouths. When this occured, loud explosive sounds were

heard and at the same time black smoke issued forth. Together with smoke, rock fragments were more or less thrown out, and ashes were being scattered without cessation. The latter being mixed up with steam made a sort of mud rain.

The powerful steam ejection from the aforesaid inclined craterlet was accompanied by deafening rumbling sounds, which may be compared to the noise caused by the passage of a railway train, or escape of steam from a huge engine, or the rolling of waves on a sea-beach. These sounds continued without cessation. But as there were some periodical fluctuations in their intensity, it might be imagined that now and then they stopped, especially if heard from a distance. Thus, on the morning of May 22nd, when heard from the Saino-kawara, the durations of successive sounds were 40 seconds, 60 seconds, etc., and the intervals of stoppage 13 seconds, 8 seconds, 4 seconds, 76 seconds, etc. The nature of these sounds was quite different from those underground heard on the occasion of the recent Mino-Owari earthquake in the Neo Valley and other places, which were like those caused by the firing of a heavy piece of artillery or by the falling of a great weight. At Azuma-san there was a peculiar oscillation in intensity, the number of beatings being about 30 in 10 seconds. This was probably due to the orifice of the craterlet being narrow, and consequently the steam confined within it being made too scillate. Professor A. Tanakadate compared this to the vibration of air in an organ pipe, and suggested that the depth of the cavity might be some 100 metres. This peculiar phenomenon was observed only in the inclined mouth or craterlet.

These sounds caused the ground to slightly tremble, which motion was perceived at a good distance. Thus I have heard at Fukushima during a very quiet night feeble sounds and felt tremblings like those caused by the passage of a railway train at a distance.

The smoke ejected from the crater showed no glow when

seen at night. This indicates that at the bottom of the crater there was no red-hot molten matter.

THE EXPLOSION OF JUNE 4TH.

After the first eruption of May 19th, the activity gradually diminished and there was subsequently no explosion of any note till May 31st, when much ash began to be thrown out. Especially violent explosions took place on June 4th at 4.10 a.m. and at 5 p.m.; and on June 5th at 6.3 a.m. The fine ashes borne by the wind reached Fukushima and other places. The explosion of June 4th at 4.10 a.m., was most powerful, and of a magnitude greater than the first explosion. This was perceived at Fukushima, and sounds like distant thunder, which commenced at about 4 a.m., gradually heightened in intensity. Immediately after this, an earthquake was felt, which lasted about 30 seconds, and was sufficiently strong to cause *shoji* and wooden doors to rattle. At Nuruyu, the shock was so strong that houses were violently shaken. On the other hand, at the time of the first explosion of May 19th, there was almost no perceptible tremblings at Fukushima, and only a slight movement at Nuruya.

This time no new craters were formed, but the explosion took place from the old ones; so that the operation consisted, not in rending accumulated rocks and earth and in forcing away mud, but chiefly in projecting rock fragments. The shape of the crater and the manner of steam ejection became by these violent efforts much altered. The embankment-like obstacle which formerly existed in the upper part of the crater cavity disappeared. The former inclined hole became markedly enlarged, and it was no longer inclined, but instead there was a big funnel-shaped cavity, whose mouth was nearly elliptical in form, the longer diameter being about 500 feet. It was almost exclusively from this hole that steam and black smoke were powerfully ejected. From two places at the lower part of the crater cavity, steam was issuing in small quantities, but

from these there was no ejection of black smoke. The lower part of the cavity was filled with water. Above the largest hole before mentioned, there was another which was next in size. This hole had now completely ceased to eject steam, and brownish water filled its bottom. The shape was nearly an exact circle, in diameter 200 feet, and the wall was perpendicular, the depth to the water surface being 130 feet. A third hole situated above the latter also ceased to be active, and its bottom was filled with water. Rock fragments occasionally fell down from the walls of these several craters.

CONDITIONS AFTER THE EXPLOSION.

Immediately following the first eruption of May 9th, peculiar rolling sounds accompanied the steam ejections. These, however, completely stopped after the new explosion of June 4th. This is probably because the mouth of the crater became much enlarged.

The conditions after the new explosion (when visited on June 6th and 7th) were such that although ordinarily white steam was issuing in small quantities, suddenly a large amount of rock fragments would fall down from the walls of the crater and a violent explosion take place, which threw out rock fragments and black smoke and caused ashes to fall at a few miles distances. Following such an explosion, for the next few hours a series of minor explosions at 8 or 10 minutes intervals would take place. Then followed a period of calm, lasting several hours, during which small quantities of steam gently issued. After this another violent explosion would take place, and so the phenomena were repeated. The falling ashes were sometimes wet and formed fine mud rain, but generally they were completely dry. This is probably because the amount of steam ejected was comparatively small. Occasionally fine condensed steam fell not mixed with ashes.

ASHES.

The area covered by ashes was on this occasion wider

and their quantity many times greater than at the time of the first explosion. Shimofuri-yama, which is a continuation of Issaikio-san, so-called on account of its white colour, became entirely grayish. Iwo-san became also thickly covered with ashes appearing as if a snow-fall had occurred. Ashes chiefly fell towards Azuma-fuji-san, and were ½ or 1 centimetre thick at a distance of 1½ kilometre from the crater. The leaves of ash-covered plants withered up, and even in the vicinity of Nuruyu, where ashes fell only in small quantities, there were many cases in which the ends of leaves became charred and black in consequence of acids in the ashes.

THE CONICAL HOLES AGAIN.

This time again there were numerous small conical holes produced by falling stones, being especially abundant to the east, south and west of the crater. The holes furthest away were about 1½ kilometres from the crater, *i.e.* the stones this time reached about double the distance that they did with the first explosion. As now the ground was completely dry, and there were only a few holes filled with water, the form of these latter was clearly seen. The smallest holes had diameters of only 1 or 2 inches and the largest of 7 feet. The greatest depth of those found in the marshy Numano-taira amounted to 9 feet. We here give a list of the dimensions of some of these holes:—

Diameter of Mouth. metre.	Depth. metre.
0.60	0.33

(In this hole a stone block was found of length 0.26 metre, width 0.20 metre, and of thickness 0.19 metre.)

0.65	0.90
0.25	0.23
0.22	0.40
0.08	0.15

(All the above five holes were formed in clay at the base of Azuma-Fuji-san.)

0.40 0.40

(This hole was formed in accumulated frozen snow, and within it was found a stone block, about 0.12 metre square and 0.06 metre thick.)

2.00 2.70

(This was found at the base of Okenuma.)

In most cases, the axes of the holes were not vertical, but more or less inclined to it, the angle with the horizon amounting in some cases to 45 degrees. The inclinations were generally turned towards the crater.

The roof of the Jimbei Cottage was struck in six or seven places by falling stones, some of which made conical holes in the ground after breaking through the roof. In these cases, the inclinations of the orbits of the falling stones were clearly shown to be some 60 degrees. The cottage is at a distance of ½ kilometre to the south-east of the crater.

When we know the distance of a hole from the crater and also the inclination to the horizon of the orbit of the falling stone as it touched the ground (which can be ascertained from the axis of the hole), we can approximately determine the height to which the stone was projected. The result of such calculations show that the greatest vertical height of projection in this new explosion was about 1 kilometre. The height of projection of the stones which fell on the Jimbei Cottage is found to be about 250 metres.

OF THE FALLING STONES.

At the time of our second visit, on June 6th, small steam columns were seen issuing from several points near and around the crater, chiefly towards the south-west, where there was a thick covering of still viscid mud. On examination, it was found that these took place from conical holes, where generally there were fallen stones exposed, whose temperature was so high that it was impossible to touch them for long. (This observation was made on the afternoon of

June 6th.) There were also fragments of stone with high temperatures which had fallen upon dry ashes and stones. These did not give rise to columns of steam. In a few instances, the faces of fragments of hot stones showed traces of having been melted. These projected stones were black basalt-like andesite, which had not been found after the previous explosions. From this it would seem that they came from a greater depth than their predecessors. According to the statement of Mr. T. Suganuma, of Fukushima Prefecture, there were no phenomena of this kind when he visited the same spot on the noon of the 4th (June), so that these hot stones seem to have been thrown out by the explosion at 5 p.m. of the same day, or by later explosions.

The largest ejected stone fragment which we saw was about $4\frac{1}{2}$ metres in length (found at the edge of the crater).

CAUSES OF THE EXPLOSIONS, ETC.

The eruption of Azuma-san is a species of what might be termed intermittent explosions. At first sight it may appear startling that any explosion greater than the first should take place a few days subsequently. This, however, would be a sign that the energy of explosion was gradually diminishing.

As at the time immediately following the first explosion the ejection of steam was very powerful, the rock fragments falling down from the walls of the crater would have been incessantly thrown out again, and thus there could not be any shutting up of the holes. As the steam explosion became gradually weakened, this was no longer the case, and in fact two or three craterlet-holes completely ceased to eject steam. This must have brought about an unusual accumulation of steam underneath, and the great explosion of June 4th was probably the result. It might therefore be expected that occasional explosions would happen for the next few days, and that the mountain would come to a state of complete quietness only when steam had sufficiently escaped.

Of the explosions which happened since June 4th, that on June 7th, 1 p.m., was the most violent and of an equal magnitude to the latter explosion. It was attended by an earthquake, which was felt quite sharply at Fukushima. Recently the disturbance has become much quieter.

When the initial eruption is very great and the whole explosive energy is spent at a single blow, as in the case of Bandai-san, there is probably little risk of subsequent great eruptions. But when, as in the present case, the initial eruption is not very great, intermittent eruptions may follow, and the degree of violence of the subsequent disturbances will depend on the rate of decrease in the escape of steam and on the magnitude of the operations tending to stop the mouth of the crater. It seems probable that there will be no very great further explosion at Azuma-san.

The present volcanic disturbance fortunately took place at a distance from inhabited portions of the country and consequently the damage was only slight. Two things produced a temporary surprise; the first was that the water of the Sugawa (which flows by Fukushima) became turbid with ashes and in consequence deprived people living near the river for a time of means of watering their fields and in some instances of their drinking water; and the second was that ashes fell (though only thinly) on mulberry trees which are largely cultivated in the Iwashiro province, and it was feared that bad effects might be produced on the silk industry. Both of these events, however, produced no very serious consequences, and the eruption is by no means among the most notable in this country.

Lastly, I must mention a very lamentable event—the death of Mr. Sojiro Miura, Rigakushi, Geologist to the Agricultural and Commercial Department, and of Mr. Sokichi Nishiyama, his assistant. Both of these gentlemen were killed by falling stones on June 7th, which occurred while they were making observations near the edge of the crater. They have,

indeed, fallen victims to their zeal for scientific investigation and should never be forgotten amongst us. It is with a feeling of deep reverence and regret that the writer records their death. He himself visited the scene of eruption the day previous (June 6th) in their company, and only escaped sharing their fate by returning in consequence of indisposition.

The above was written in the beginning of June (1893). The subsequent condition of the volcano is as follows:—

(Based on the Reports of the Fukushima Meteorological Station.)—June 8th, 5.36.20 a.m. An earthquake felt, of very short duration, which was sharp at first and afterwards became gentle. The motion was attended with sounds. The volcano seems indeed to have been in a very active state since the great explosion at 0.36.12 p.m. of the preceding day, and the pendulum of the contact-make of the Seismograph at the Station was making minute vibrations almost without cessation till 4 p.m. of the same afternoon, when the ground was for a time at rest. The same apparatus showed similar vibrations when examined at 11 p.m. and 12 p.m. that night and at 2 a.m. the next day (8th). For a few following hours, the ground was again at rest, till there occurred the earthquake we have here mentioned. (From the Report of the Fukushima Meteorological Station June 17th-20th.) The volcano had been for several preceding days in a quiet state, and only white steam has been issuing in small quantities. On June 17th, at 11½ p.m., rolling sounds were heard, which continued for about 10 minutes, and at the same time steam was ejected in large quantities. After this, black smoke continued to be occasionally ejected, and on the 19th ashes fell abundantly at Fukushima. On the 20th there was also some falling of ashes. No particular damage took place.

The volcano was for many succeeding days again quiet, there being only occasional rolling sounds and falling of ashes, till July 8th, when at 6.37.20 a.m. a small explosion took place. This explosion was observed from Issaikio-san by Mr. Y.

Wada of the Central Meteorological Observatary and his party, who had been stationed there since July 1st on meteorological observations. The height of projection of stones was estimated at about 400 metres.

Since the beginning of September there were only slight ejections of steam from the mountain, till October 19th, when at 10 a.m. rolling sounds were heard, and the quantity of steam given off continued since then to be great. Since 22nd, 9 a.m., much grayish smoke began to ascend, and since 23rd, 8 a.m., the smoke became black and increased much in quantity, there being sounds heard at 9¼ a.m. From 1 p.m. of the last day, the mountain became surrounded by clouds, and further observation was impossible. The increase of steam ejection might be due to the falling inwards of the crater walls in consequence of the previous long continued rainfalls. When observed again on 25th-31st, the steam column of grayish colour was issuing gently in a normal state. (Report of the Fukushima Meteorological Station.)

November 9th-10th. At about 11.20-30 a.m., sounds like distant thunder were heard towards the West. The pointer of the contact-maker of the Seismograph showed, however, no tremblings. At 4.9.25 p.m. there was a loud rolling sound, and about 2 minutes after black smoke was seen issuing abundantly from the mountain. Another small rolling sound was heard at 4.27 p.m. At 6.34.50 p.m., there was a violent sound heard, and simultaneously weak tremblings of the ground were perceived, about 3 minutes after which very black smoke ascended from the mountain. Then followed several sounds, as tabulated below :—

November 10th.

Time of occurrence.	Duration of Sound.
2.18.10 a.m.	120 seconds
3.4.30 a.m.	120 seconds
3.12.30 a.m.	90 seconds
3.16. a.m.	60 seconds
3.28.30 a.m.	80 seconds

These were all of small intensity, and not accompanied by perceptible tremblings of the ground. At 9.52 p.m. there was a strong sound, and after 6 seconds black smoke was observed to ascend in rolls. On the afternoon of the same day the following record was taken :—

Time of occurrence.	
2.25.50 p.m.	(sound, followed 5 seconds after by the ejection of black smoke.)
3.3.11 p.m.	(sound only.)
4.31.1 p.m.	(sound and smoke.)
10.12 p.m.	(very loud sound, continued for about 4 minutes.)
11.6.13 p.m.	(sound only.)
11.14.40 p.m.	(sound only.)

At noon of the 11th matters returned to their normal state.

ON THE PERIODICITY OF THE EXPLOSIONS.

From what has been said above, it is seen that the mountain makes occasional efforts at violent explosions, all other times steam is given off quietly. Each time the period of activity lasted a few days. The beginning of these epochs was as follows :—

1893.

	Successive Intervals.
May 19th (beginning)	16 days.
June 4th (beginning)	13 days.
June 17th (beginning)	21 days.
July 8th	103 days.
October 19th	21 days.
November 9th	