

Interval.	Frequency.	Interval.	Frequency.	Interval.	Frequency.	Interval.	Frequency.
42 <sup>sec.</sup>	0	46 <sup>sec.</sup>	2	58 <sup>sec.</sup>	1	73 <sup>sec.</sup>	1
43	2	47	3	61	1	81	2
44	3	53	2	65	1	82	1
45	1	57	2	70	2		

From the above table, it will be noticed that the interval in question was in the 100 out of the total number of the 135 were included between 11 and 32 sec., while it was specially frequent between 15 and 22 sec. This last feature is similar to the preponderance of the value of about 19 sec. in the cases of the smoke emissions in the ordinary times, before considered.

On July 27th, 1913, the smokes were carried by the strong winds along the south-eastern slope to the mountain base, and constituted in the evening hours a light yellowish misty layer extending over the plains below, which caused some ash-precipitation at Miyoda, Komoro, and neighbouring places. It is evident that the strong explosions send the smokes into a considerable height, thence to be generally carried eastwards by the upper air current, differing in this respect from the small eruptions or the ordinary non-explosive smoke emissions, which cause ash-precipitation in the immediate neighbourhood of the mountain in obedience to the surface winds.

## CHAPTER II. SOUND AREA AND ASH-PRECIPIATION ZONE.

10. The sound areas and the ash-precipitation zones of the 11 typical explosions in the three years 1909 to 1911 have been described in the preceding volume of the *Bulletin*. I now proceed

to consider the cases of the 12 strong outbursts in 1912 and 1913, whose dates and times of occurrence are as follows:—

(1)	Dec.	14th,	1912;	9.	23.	00	a.m.
(2)	May	16th,	1913;	4.	41.	00	p.m.
(3)	„	29th,	„ ;	10.	44.	12	a.m.
(4)	June	17th,	„ ;	10.	47.	41	p.m.
(5)	„	20th,	„ ;	4.	06.	47	a.m.
(6)	„	26th,	„ ;	8.	09.	40	a.m.
(7)	„	26th,	„ ;	11.	41.	59	p.m.
(8)	July	13th,	„ ;	4.	01.	19	p.m.
(9)	„	19th,	„ ;	0.	54.	03	p.m.
(10)	Aug.	12th,	„ ;	11.	20.	33	p.m.
(11)	Sept.	21st,	„ ;	1.	50.	59	p.m.
(12)	Oct.	26th,	„ ;	3.	14.	38	a.m.

The sound areas and ash-precipitation zones of these explosions present, as will be seen from the illustrations in Figs. 29 to 44, many interesting characters, which were not fully exhibited in those of the previous outbursts.

**11. Eruption of Dec. 13th–14th, 1912.** According to the report of Mr. Tsuchiya of the Wakasare Cottage, the volcanic sounds were heard from 8.20 a.m. on the 13th, there being eruptions at 11.40 a.m. and 2.05 p.m. in the same day. After the detonation at 7.06 p.m., the eruptions became stronger and continuous during the night, the mountain top being covered by the red hot rock fragments projected out like fire-works. The force of the eruption was augmented from about 9.25 on the next morning, the intensity of the detonations being such that, from 10 a.m., the doors and shojis began to be thrown down. The smokes were carried by winds toward the NE, causing in the neighbourhood of the Ko-Asama the precipitation of sands, small rock fragments, and pices of light white snow-like pumice stones, about

10 cm. in maximum dimension. The outbursts began to decrease in violence from about the noon and ended at about 3.50 p.m.

At Karuizawa, about 11 km to the ESE, the disturbances began at about 1 p.m. on the 13th, the detonations becoming strong enough to shake the houses and break window panes since about 11 p.m. on the same day. On the morning of the 14th, from about 8 o'clock, the lava pieces thrown out from the crater could be distinctly observed with naked eye, resembling groups of flying birds. That some of the projected masses must have been several metres in dimension may be inferred from the photograph of the eruption (Fig. 2), taken at about 10 o'clock on the morning of the 14th from Komoro, a town situated 13 km to the SW of the crater.

At Iwamrata, 16 km to the S  $17^{\circ}$  W of the mountain, the detonations, which were heard from 7 a.m., became very strong at 11 a.m., when the lava pieces were observed to fall to the NW side of the top, the smokes being thrown eastwards.

On account of the fine quiet weather prevailing at the time of the eruption, the smokes were visible also from Ueda and Nagano, at the radial distances of about 24 and 44 km respectively to the W and the NW of the mountain. Mr. Nishizawa, Director of the Nagano Meteorological Observatory, observed with a hand level the altitude of the smokes at 10 and  $10\frac{1}{2}$  a.m., when the eruption was most intense, to be  $7^{\circ}.0$  to  $7^{\circ}.1$ , giving the height of smoke ascent of about 5.4 km above sea-level or about 3 km above the top of the volcano. At Ueda, Professor Y. Tsukiji, of the Sericultural College, estimated the maximum altitude of the smokes to be about  $2\frac{1}{2}$  km above the mountain. The ash-precipitation zone and the sound area are shown in Fig. 29.

*Ash-precipitation zone.* The ash-precipitation zone was a narrow region, which stretched from the Asama-yama, as the

apex, in an ENE direction to the coast of the Pacific. Its length was about 115 km and its maximum width about 60 km, including Karuizawa and vicinity, and parts of the provinces of Kotsuke, Shimotsuke, Hitachi, Iwaki, and Iwashiro. The ash-precipitation commenced on the 14th at different moments in the various provinces, according to their radial distances, approximately as follows:—In Kotsuke, from 9.50–11.00 a.m.; in Shimotsuke, from 10.45 a.m.–2.00 p.m.; in Hitachi, from 1 p.m.; and in Iwaki, from 0.50–2.50 p.m. The time of commencement and the duration of the ash-precipitation at the different meteorological stations were as follows:

Meteorological Station.	Radial distance = $x$	Time of commencement of ash-precipitation.	Duration of ash- precipitation.
Maebashi.	50 km.	10 <sup>h</sup> 13 <sup>m</sup> a.m.	1 <sup>h</sup> 40 <sup>m</sup>
Utsunomiya.	121.	11 27 „	50
Ōtsu (Hitachi).	204	0 50 p.m.	2 40

Thus the precipitation of ashes at the different stations lasted from about 1 hour to about 2½ hours, the amount being nowhere considerable. The velocity of transportation of the ashes between the above mentioned three places, which are situated on, or approximately on, the axial line of the precipitation zone, is found to be, in the mean, about 16.4 m/s, or 59 km/hour as follows:

Stations.	Utsunomiya-Maebashi.	Ōtsu-Utsunomiya.
Difference of the radial distances.	71 km.	83 km.
Difference of the times of commencement of the precipitation.	74 min.	83 min.
Transportation velocity.	16.0 m/s.	16.7 m/s.

This transportation velocity of the ashes is somewhat smaller than that in the case of the strong explosion of Dec. 7th, 1909, namely, the value of 22 m/s\*, due probably to a comparatively small height of ascent of the smokes on the present occasion. If the rate of transportation of the ashes within the first 50 km of the radial distance had been the same as that for the distances of 50 to 200 km, then the approximate time of commencement of the corresponding ash-ejection at the Asama-yama itself would be about 9.23 a.m.

The sound area extended over the 13 provinces of Shinano, Kotsuke, Shimotsuke, Iwaki, Iwashiro, Hitachi, Musashi, Shimoso, Kazusa, Sagami, Izu, Suruga, and Totomi. Roughly it may be regarded as being made up of the following two parts: (i), A zone of circular arc  $S_1 S_1$ , with a mean internal radius of about 150 km, subtending an angle of about  $156^\circ$ , and extending from the coast of the province of Totomi on the SSW side to the vicinity of the city of Fukushima on the NE side; (ii), A district of an irregular triangle,  $S_2 S_2$ , diverging from the Asama-yama and the surrounding tract to the E approximately. Apart from these general ash-precipitation and sound areas, the explosion effects were perceived at the neighbourhood of the lake of Suwa (Shinano). The province of Kai and the surrounding region, lying between the southern branch of the arc  $S_1 S_1$ , and the neighbourhood of the volcano, where no detonation was perceived, may be regarded as a zone of silence; the radius of the latter being not much different from the values of 120 to 150 km for the strong Asama-yama explosions on Dec. 7th, 1909, and Dec. 2nd, 1910,† and for the violent outburst of the Bandai-san in 1888.

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\* See the *Bulletin*, Vol. VI, No. 1. p. 69.

† The same volume, p. 76.



than in (vi) Kotsuke, where the mean value was about 9.20 a.m., due evidently to the greater radial distance of the former. The time interval, during which the sounds were heard at the different places, varied generally from 1 to  $2\frac{1}{2}$  hours. At the Mount Tsukuba Observatory, the principal sounds were heard at 9.09.40; 10.18.30; and 11.16.30 a.m. The times of occurrence of the strongest detonation heard at the different places in the province of Kotsuke, were mostly from 9.15 to 9.30 a.m., giving the mean value of 9.24 a.m.

The weathers on the 13th and 14th were as follows:—

[13th, 6 a.m.] In the central part of the Main Island there was a high pressure area of 772 mm, the rest of the island and Shikoku and Kyushu being enclosed in the isobar of 770 mm.

[13th, 2 p.m.] Whole of Japan was under the barometric pressure of 768 to 772 mm, the isobars running parallel to the arc formed by the different islands. [13th, 10 p.m.] The isobars were arranged similarly as before, with the difference that a small high

pressure area of 772 mm appeared over the provinces of Shinano and Hida.

[14th, 6 a.m.] The greater part of the Main Island and the NE portion of Shikoku were covered by a high pressure centre of 770 mm, generally with clear or fair weather. At most of the stations there prevailed complete calm or high wind. On

Mount Tsukuba there was at the time *strong* winds in the WSW'ly direction.

[14th, 2 p.m.] The pressure was over Japan 764 to 768 mm, and it became generally cloudy, a low pressure area of 760 mm having made its appearance over Lyukyu.

The wind direction and velocity and the cloud amount observed at the different meteorological observatories at 10 a.m. and 2 p.m. on Dec. 14th are indicated in the following table.

TABLE II. WIND DIRECTION AND VELOCITY, AND CLOUD AMOUNT,  
AT 10 A.M. AND 2 P.M., ON DEC. 14TH, 1912.

Meteorological Observatory.	Wind Direction.		Wind Velocity.		Cloud Amount.	
	10 a.m.	2 p.m.	10 a.m.	2 p.m.	10 a.m.	2 p.m.
Niigata.	SE	SE	4.6 <sup>m/s.</sup>	3.5 <sup>m/s.</sup>	10	9
Fukushima.	W	E	0.5	0.7	2	9
Utsunomiya.	S	S	1.2	1.2	2	10
Maebashi.	NNW	N	5.4	1.6	6	8
Choshi.	NNW	ENE	2.1	4.0	5	10
Kumagai.	—	—	0.2	0.2	0	7
Tokyo.	NW	NNW	4.1	2.0	6	10
Mito.	NNW	N	2.3	2.9	9	10
Yokohama.	N	E	2.8	3.2	0	10
Numazu.	ESE	WNW	1.5	1.8	0	8
Hamamatsu.	NE	SE	1.7	1.2	1	5
Kofu.	SSW	S	0.6	1.6	8	5
Iida.	—	—	0.0	0.4	9	10
Matsumoto.	NW	WNW	1.7	1.2	10	10
Nagano.	N	NW	1.3	0.5	8	10

As will be seen from Table II, at 10 a.m., when the eruption was at its height, the wind velocity was at Niigata, Maebashi and Tokyo from 4.1 to 5.4 m/sec., being much smaller at the other neighbouring stations. The direction of wind was N, NW, or NNW at Nagano, Matsumoto, Maebashi, Tokyo, Yokohama, Mito, and Choshi, namely, within the region extending from the vicinity of the Asama-yama in an ESE direction to the Pacific coast; at other places it was irregular, being S, SSW, SE, ESE, W, or NE. On the whole, at 10 a.m. the wind directions at the different places were, with the exception of Numazu, roughly in

the sense of the extension of the sound area. Again, at 10 a.m., it was clear or fair at the different places within the latter, with the exceptions of Tokyo, Maebashi, and Mito, where the cloud amount was from 6 to 9. At 2 p.m. on the 14th, the wind velocity at the different places within the sound area was under 3.2 m/sec., the direction being in several instances not much different from that at 10 a.m.

The direction and speed of the upper and middle height clouds on Dec. 14th, 1912, at 10 a.m., were as follows:—[Tokyo.] Lower clouds: direction W; speed=7. (There were no upper and middle height clouds.) [Nagano.] Upper clouds: direction SW; speed=1. [Mito.] Upper and middle height clouds: direction W; speed=1. [Numazu.] Upper clouds: direction W; speed=2.

**12. Strong Explosions in 1913.** Of the sound areas of the 11 strong explosions in 1913, Nos. 2 to 12 (§ 10), that of (4) was the most remarkable and extensive, and consisted, as in the 6 other cases of (7), (5), (3), (8), (6), and (11), each of two detached portions, namely, (i) the *eastern branch*, which enclosed the Asama-yama, and, (ii), the *western branch* which was arranged along an arcual zone extending from the provinces of Izu, Suruga, Totomi, and Mikawa on the SW, to Kaga and Noto on the NW, at a mean distance of some 160 km from the volcano. With the explosions (10) and (9), the western branch was further separated into the SW. and N. parts. Again, in each of the cases of the 7 explosions, (4), (7), (5), (3), (8), (6), and (10), there was a more or less distinct indication of the ash-precipitation zone, whose direction was toward the E, the NE, or the ESE. It was only in the two cases of (2) and (12) that the sound area consisted merely of the eastern branch. In the following pages, I describe the

sound areas for the different cases in the order of Nos. 4, 7, 6, 5, 3, 8, 11, 10, 9, 12, and 2.

**13. Explosion of June 17th, 1913, at 10. 47. 41 p.m.** The eastern branch of the sound area (Fig. 30) was roughly an irregular parallelogram, measuring 215 km in the EW and some 170 km in the NNE-SSW direction, whose major diagonal stretched from the locality between the lake of Suwa and the town of Iida in the province of Shinano to the northern part of Hitachi, and whose minor diagonal from the SE part of Echigo to the head of the Tokyo Bay; the approximate distances of its 4 corners from the Asama-yama being as follows:

SW from Asama-yama	.....	100 km.
NNE	„	..... 95
ENE	„	..... 190
ESE	„	..... 155

The ash-precipitation zone was a narrow band about 15 km in width and 150 km in length, which came into existence first at 45 km from the origin of disturbance and extended eastwards from the SE part of Kotsuke to the Pacific coast at the vicinity of the city of Mito in the province of Hitachi. At Maebashi, the detonation was heard at 9.50 p.m., while the smoke cloud arrived at the zenith 22 minutes later, or at 10. 12 p.m., unattended by the precipitation of ashes.

The western branch of the sound area, which extended from the Pacific to the Japan sea coast, was of an irregular lunar form stretching from Suruga, Totomi, Mikawa, and Owari, on the south, to Echizen, Kaga, and Noto, on the north-west, and surrounding a small tract composed of parts of Mino, Omi, and Ise, where the detonation was not perceived. Its distances from the Asama-yama are as follows:—

Furthest distance (outerside) .....	275 km.
Nearest distance (innerside) .....	135
Northern extremity .....	165
South-western extremity .....	190

The areas of the two branches were nearly equal to each other.

Meteorological Condition. At 10 p.m. on the 17th, there existed a high barometric area of 760 mm to the S of the Bonin Islands, at a distance of 1100 km off the coast of Japan; while the central and northern parts of the latter was covered by a pressure ranging from 747 to 750 mm, mostly under northerly or westerly winds, due to the presence of a small centre of low pressure of 746 mm off the SE coast of Hokkaido, and of another also of 746 mm at the SE extremity of the Main Island. In Table III, are given the wind direction and speed, air temperature, and cloud amount, for 10 p.m. on the 17th, at the different meteorological stations, divided into two groups, I and II, or those respectively in or near the eastern and the western branches of the sound area.

TABLE III. WIND DIRECTION AND VELOCITY, AIR TEMPERATURE, AND CLOUD AMOUNT, AT 10 P.M., ON JUNE 17TH, 1913.

Group.	Meteorological Station.	Wind Direction and Velocity (m/s).		Air Temperature.	Cloud Amount.
I	Fukushima.	NW	4.8	19.93 C	10
	Utsunomiya.	ESE	1.3	21.4	10
	Mito.	ENE	2.1	17.7	10
	Niigata.	W	6.5	16.8	10
	Maebashi.	WNW	7.3	20.8	10
	Choshi.	NNE	1.8	19.5	10
	Kumagai.	N	6.1	21.2	10
	Tokyo.	NW	1.8	21.1	10

Group.	Meteorological Station.	Wind Direction and Velocity (m/s).		Air Temperature.	Cloud Amount.
II	Yokohama.	N	3.1	22.4	10
	Kofu.	WNW	0.9	23.9	10
	Nagano.	N	1.2	16.6	10
	Matsumoto.	S	0.6	17.3	9
	Iida.	N	2.6	17.5	10
	Numazu.	SSW	4.7	23.1	10
	Hamamatsu.	W	3.7	20.5	10
	Gifu.	WNW	2.8	19.1	10
	Fushiki.	W	0.8	17.3	10
	Nagoya.	WNW	8.8	19.4	10
	Hikone.	NNW	1.0	18.4	10
	Fukui.	—	0.0	17.7	10
	Kanazawa.	SW	3.3	17.5	10
	Takayama.	—	0.3	16.8	10
	Tsu.	SW	3.1	19.1	10

According to Table III, the sky was at 10 p.m. completely cloudy over Central Japan almost everywhere; the air temperature at the different places varying between  $16^{\circ}.8$  and  $23^{\circ}.9$  C, with the mean of  $19^{\circ}.3$  C. The wind velocity attained the highest values of 8.8 and 7.3 m/s respectively at Nagoya and Maebashi, while it was less than 6.5 m/s at all the remaining places. With regards to the group I stations, the wind directions at Fukushima, Niigata, Maebashi, Kumagai, Yokohama, and Iida, where the velocity had the higher values of 2.6 to 7.3 m/s, were N, W, NW, or WNW; at Mito and Utsunomiya, which were situated on or near the ash-precipitation zone, the winds had the velocity of 2.1 to 1.3 m/s in the contrary or eastern directions, namely, towards ENE and ESE respectively. In the case of the group

II stations the winds were uniformly in westerly directions, namely, W, WNW, NNW, SW, or SSW.

**14. Explosion of June 26th, 1913, at 11. 41. 59 p.m.** The sound area (Fig. 34) in this case was smaller in extension than, but similar to, that in the preceding one. The eastern branch was of an elliptic form, with the major and minor diameters respectively of 126 and 82 km, and included nearly the whole of Kotsuke, a small portion of Shinano at its NE boundary, and the SE corner of Echigo. The greatest radial distance of the direct sound propagation was only 96 km, toward the NE from the Asama-yama. There was a very slight precipitation of ashes in Maebashi, at 0<sup>h</sup> 56<sup>m</sup> a.m. on the 27th, the detonation having been perceived there 1<sup>h</sup> 12<sup>m</sup> before or at 11<sup>h</sup> 44<sup>m</sup> p.m. on the 26th. The western branch was approximately a flat triangle in form, with the apex at Hikone on the eastern shore of the lake of Biwa, and with the base stretching from the city of Kanazawa on the Japan sea coast to the neighbourhood of the town of Hamamatsu on the Pacific; the distances of the three corners of the area from the volcano being as follows:—

Furthest distance (W. corner).....	245 km.
Nearest „ (E. side).....	433
NNW extremity .....	174
SE „ .....	200

**Meteorological Condition.** The approximate meteorological conditions at the time of the explosion may be learned from the 10 p.m. values of the wind direction and velocity, air temperature and cloud amount given in Table IV. The air temperature at the different places varied from 15°·0 to 22°·2 C, with the mean of 19° C. Unlike the preceding case, the sky was clear at several of the stations within the western branch of the sound area. The

wind velocity was everywhere low, the highest values of 4.0 to 5.6 m/s having been observed at Maebashi, Tokyo, Nagoya, and Choshi. The winds at Maebashi, as well as at the majority of the places in or near the western branch were westerly, i.e. of W, WNW, or NW direction; while in all the space lying to its east and around the eastern elliptical area, the winds were easterly, i.e. of NE, NNE, N, ENE, or ESE direction.

TABLE IV. WIND DIRECTION AND VELOCITY, AIR TEMPERATURE, AND CLOUD AMOUNT AT 6 A.M., 10 A.M., AND 10 P.M. ON JUNE 26TH, 1913.

Group.	Meteorological Station.	Wind Direction and Velocity (m/s).						Air Temperature, C°.			Cloud Amount.		
		6 a.m.		10 a.m.		10 p.m.		6 a.m.	10 a.m.	10 p.m.	6 a.m.	10 a.m.	10 p.m.
I	Fukushima.	SSE	1.1	NW	4.7	SE	1.0	16.8	23.2	16.2	7	8	0
	Utsunomiya.	—	0.2	S	5.9	NNE	1.2	19.9	25.5	18.9	4	6	10
	Mito.	NW	1.3	ENE	3.7	NNE	3.3	18.6	24.8	18.4	10	4	10
	Niigata.	NW	2.5	NNE	6.1	NE	1.4	16.2	18.2	15.0	10	10	0
	Maebashi.	NW	5.4	WNW	1.7	SW	4.0	19.1	27.2	19.6	1	2	10
	Choshi.	ENE	2.9	NNE	5.8	ESE	5.6	21.3	23.2	21.3	3	3	8
	Kumagai.	WNW	1.9	SSE	1.7	NE	0.5	19.0	26.7	19.6	2	4	10
	Tokyo.	SSE	1.6	SE	3.0	ENE	4.1	20.2	26.3	22.2	1	6	10
	Yokohama.	N	3.0	NE	2.9	NE	3.3	21.6	24.6	22.0	10	0	0
	Kofu.	—	0.1	W	1.2	W	0.7	18.2	26.2	20.6	10	2	2
	Nagano.	SE	0.5	ENE	4.3	—	0.2	17.1	23.0	16.7	1	1	10
	Matsumoto.	SW	0.5	—	0.3	N	2.2	15.0	21.0	16.8	3	4	8
	Iida.	E	1.7	SW	6.2	NE	1.8	16.2	24.7	18.3	1	1	0
	II	Numazu.	ENE	2.9	W	5.2	ENE	0.7	18.4	24.6	20.8	3	1
Hamamatsu.		WNW	3.4	W	6.2	W	2.8	21.0	25.8	22.1	0	0	0
Gifu.		—	0.3	WNW	5.3	WNW	1.4	18.8	23.3	19.8	7	7	0
Fushiki.		W	1.2	E	3.3	NNE	2.9	17.8	19.2	17.3	10	10	10
Nagoya.		NNW	0.6	WNW	4.9	NW	4.1	19.2	26.0	21.2	10	6	4
Hikone.		—	0.3	W	2.5	NNE	1.7	18.4	22.0	19.2	3	10	0
Fukui.		S	0.9	NE	1.2	W	1.1	18.6	20.6	17.6	9	10	0
Kanazawa.		NNW	2.4	WNW	2.6	ENE	2.5	17.6	20.8	17.4	10	6	5
Takayama.		SE	1.2	NW	3.2	E	1.4	14.7	22.2	15.4	10	9	10
Tsu.		WSW	4.7	W	4.9	WNW	3.9	19.1	25.7	21.1	9	6	0

**15. Explosion of June 26th, 1913, at 8. 09. 40 a.m.** The eastern branch of the sound area (Fig. 32) was small, and included the province of Kotsuke, and small portions of Shinano and Echigo, the greatest distance of the direct propagation being about 75 km toward the E and NNE. The ash-precipitation zone extended eastwards for a distance of about 75 km. The western branch was a narrow arc zone, about 173 km in length, extending from the northern part of Mikawa to the northern part of Owari and the western half of Mino, its distances from the Asamayama being as follows:—

N end.....	155 km.	W, or convex, side,.....	212 km.
SE end .....	165	E, or concave, ,, .....	170

**Meteorological Condition.** Assuming the meteorological states at the time of the explosion to be represented by the means of those at 6 and 10 a.m. on the 26th, we see that the sky was more cloudy on the Japan sea coast than on the Pacific; the air temperature varying from 17°2 to 23°4 C, with the mean of 21°0 C. The winds, whose mean velocity was everywhere less than 4.8 m/s, were of westerly directions in the region to the west of the line joining the two peninsulas of Izu and Noto, and including the western branch of the sound area. In the provinces to the east of the above-mentioned line, the wind direction was more or less easterly, with the exception of that at Maebashi, which was westerly and identical with the extension of the ash-precipitation zone.

**16. Explosion of June 20th, 1913, at 4. 06. 47 a.m.** The eastern branch of the sound area (Fig. 31) included the greater portion of Kotsuke and small boundary tracts of the adjacent provinces of Shinano, Musashi, Shimosa, and Echigo; the greatest distance of the radial propagation being 130 km toward ESE.

The ash-precipitation zone, about 92 km in length and 15 km in maximum width, extended also in the same direction. At Maebashi the detonation was heard at 4.08 a.m., while the smoke cloud reached the zenith at 4.26 a.m.; there being, however, no precipitation of ashes. At Kumagai, the detonation was heard at about 4.30 a.m., the ashes beginning to fall already before 6 a.m. The western branch, which was roughly of a rectangular form, about 230 km in length and 74 km in maximum width, extended from the N part of Owari on the south, in the direction of N slightly W, to Kaga and Noto on the north; the extreme distances from the Asama-yama being as follows:—

W, or outer, side . . . . .	188 km.	N end . . . . .	185 km.
E, or inner side . . . . .	138	S end . . . . .	225

Meteorological Condition. Assuming the meteorological states at the time of the explosion, namely, at 4.06 a.m., to be represented by the averages of those at 2 and 6 a.m. given in Table V, we see that the air temperature varied between  $13^{\circ}.3$  and  $20^{\circ}.1$  C, with the mean of  $18^{\circ}.1$  C; the sky being, with a few exceptions, fair or clear. At Maebashi and Kumagai, the winds which had the velocities of about 6.7 and 4.3 m/s were respectively in the NNW and WNW directions, these latter coinciding approximately with the extensions of the ash-precipitation zone. At all the other stations, with the exceptions of Numazu, Nagano, and Fukui, where the velocity was low, the wind directions were W, WSW, WNW, NNW, SSW, N, or S. Again, taking the cases of Niigata, Maebashi, Kumagai, Matsumoto, Kanazawa, Hamamatsu, and Tsu, in which the velocity were comparatively high, namely, from 3.6 to 10.5 m/s, the wind directions were W, WSW, SW, WNW, or NW, giving W for the average.

TABLE V. WIND DIRECTION AND VELOCITY, AIR TEMPERATURE,  
AND CLOUD AMOUNT AT 2 AND 6 A.M. ON JUNE 20TH, 1913.

Group.	Meteorological Station.	Wind Direction and Velocity (m/s).		Air Temperature.		Cloud Amount.	
		2 a.m.	6 a.m.	2 a.m.	6 a.m.	2 a.m.	6 a.m.
I	Utsunomiya.	— 0.2	SSW 3.1	17.4 <sup>o</sup> C	19.7 <sup>o</sup> C	10	0
	Mito.	W 1.6	W 2.0	18.7	18.9	5	0
	Niigata.	WSW 10.8	W 10.1	17.0	17.2	9	2
	Maebashi.	N 6.1	NW 7.3	17.8	18.7	1	0
	Choshi.	SW 5.0	N 3.4	19.2	18.7	0	10
	Kumagai.	NW 2.6	W 6.0	19.2	19.6	4	0
	Tokyo.	SW 1.6	NW 1.6	17.6	18.8	0	0
	Yokohama.	SW 2.3	NW 1.2	18.6	19.4	0	0
	Kofu.	S 0.7	S 0.5	16.2	16.8	1	1
	Nagano.	SE 0.9	E 0.9	16.9	16.2	10	0
	Matsumoto.	SW 8.0	SW 1.7	17.9	14.8	10	1
	Iida.	— 0.2	— 0.4	14.5	18.5	0	0
	Numazu.	E 2.7	ENE 1.9	18.9	19.0	1	0
	Hamamatsu.	W 2.0	W 5.1	19.4	20.7	0	0
II	Gifu.	N 0.9	N 1.1	18.0	17.6	1	0
	Fushiki.	SW 4.3	W 1.1	18.5	19.1	9	0
	Nagoya.	N 1.5	NW 1.7	18.5	18.8	10	0
	Hikone.	— 0.4	NNW 1.6	17.0	19.6	2	0
	Fukui.	ENE 1.5	— 0.2	19.4	18.3	10	10
	Kanazawa.	SSW 4.7	WSW 2.4	18.6	18.2	9	7
	Takayama.	W 0.9	— 0.2	13.7	12.9	10	10
	Tsu.	W 1.3	NW 8.2	19.1	20.2	7	0

17. *Explosion of May 29th, 1913, at 10. 44. 12 a.m.* The eastern branch of the sound area (Fig. 33) was an irregular ellipse extending for a distance of 186 km from the NE corner of

Shinano, through Kotsuke, to the NE part of Musashi. The extreme distances of the direct propagation was 138 km to the SSE, and about 50 km to the NNE and NW from the Asama-yama. The ash-precipitation was reported from 3 places as follows:—(1), Naganohara, slight; (2), Jonai-mura and vicinity, near the town of Itsukamachi in M. Uwonuma county (Echigo), from 11 a.m. to the afternoon; (3), Hirose-mura, in K. Uwonuma county (same province), between 3 and 4 p.m. The dotted line in Fig. 33, connecting these 3 places with the volcano, indicates the course of the ash-precipitation zone, which extended about 105 km towards the NNE. The western branch of the sound area stretched from the province of Mino toward the SE over a distance of about 190 km to the Cape Omaezaki (Totomi) and the SW part of the province of Suruga, evidently with some further extension over the Pacific; the extreme distances from the volcano being as follows:—

N corner .....	160 km.
NW „ .....	230
Cape Omaezaki .....	202

Meteorological Conditions. At 10 a.m. on the 29th, the air temperature varied from 16.°2 to 22.°9 C, with the mean of 20.°0 C; the sky being entirely overcast almost at all the different places in central Japan. The winds, whose velocity was everywhere very low and less than 4.7 m/s, were various in direction. (See Table VI).

TABLE VI. WIND DIRECTION AND VELOCITY, AIR TEMPERATURE,  
AND CLOUD AMOUNT, AT 10 A.M. ON MAY 29th, 1913.

Group.	Meteorological Station.	Wind Direction and Velocity (m/s).	Air Temperature.	Cloud Amount.
I	Fukushima.	NW 2.2	20.7° C	10
	Utsunomiya.	S 1.7	21.3	9
	Mito.	S 1.1	22.9	10
	Niigata.	NNE 1.8	20.6	10
	Maebashi.	ESE 1.1	21.8	10
	Choshi.	NNE 3.0	20.7	10
	Kumagai.	SSE 0.7	22.0	10
	Tokyo.	NE 2.0	22.3	10
	Yokohama.	E 4.7	20.5	10
	Kofu.	— 0.2	21.2	10
	Nagano.	E 1.2	19.4	10
	Matsumoto.	N 2.2	16.6	10
	Iida.	SW 1.5	16.2	10
	II	Numazu.	W 2.8	21.9
Hamamatsu.		E 4.3	20.4	10
Gifu.		N 0.7	19.6	10
Fushiki.		NE 1.7	17.0	10
Nagoya.		S 2.8	21.2	10
Hikone.		W 0.9	17.2	10
Fukui.		S 2.1	20.7	9
Kanazawa.		NW 1.1	19.8	10
Takayama.		W 2.9	16.5	10
Tsu.		NE 2.2	20.4	10

18. *Explosion of July 13th, 1913, at 4. 01. 19 p.m.* The eastern branch of the sound area (Fig. 36) was a small ellipse of the major and minor diameters respectively of 53 and 40 km, with

the Asama-yama nearly at the centre. The ashes were carried about 20 km to the NE, slight precipitation having taken place at Wakasare Cottage and at the town of Naganohara. The western branch area was in the present case much greater than the above mentioned, and included the three provinces of Totomi, Mikawa, and Owari, and parts of Suruga, Mino, Omi, and Ise, forming an arc extending in the EW direction for the length of about 220 km. The extreme distances of its different points from the volcano are as follows:—

W end .....	250 km.
E „ .....	120
SW „ .....	270
S, or convex, side.....	240
N, or concave, side.....	165

The detonation was also perceived in the city of Kanazawa at the radial distance of 169 km to the W slightly N.

Meteorological Condition. Assuming the meteorological states at the time of the explosion to be represented by the means of those at 2 and 6 p.m. given in Table VII, we see that the air temperature varied between 21.°3 and 27.°8 C, with the mean value of 26.°9 C; the sky being generally cloudy at the stations of Group I, but fair at several of Group II. The winds, whose velocity was from 2.2 to 5.6 m/s, were of E, S, or south-easterly directions in the region lying to the E and SE of the Asama-yama, but were mostly of W or north-westerly directions at the places within the western branch area as well as in the provinces situated to its E and N.

TABLE VII. WIND DIRECTION AND VELOCITY, AIR TEMPERATURE,  
AND CLOUD AMOUNT, AT 2 AND 6 P.M. ON JULY 13TH, 1913.

Group.	Meteorological Station.	Wind Direction and Velocity (m/s).				Air Temperature.		Cloud Amount.	
		2 p.m.		6 p.m.		2 p.m.	6 p.m.	2 p.m.	6 p.m.
I	Fukushima.	NE	5.6	ENE	5.3	30.1° C	24.4° C	3	10
	Utsunomiya.	S	3.5	S	2.6	27.9	27.1	7	7
	Mito.	E	3.1	ESE	3.5	26.9	23.5	10	10
	Niigata.	N	6.1	N	2.5	22.4	22.6	8	7
	Maebashi.	ESE	6.4	ENE	5.8	28.3	26.5	4	10
	Choshi.	SSE	3.5	SSE	3.6	26.1	23.5	10	10
	Kumagai.	SE	3.2	SE	4.8	29.2	27.3	8	10
	Tokyo.	SE	3.5	S	4.1	28.5	25.4	10	10
	Yokohama.	SSE	3.2	SW	5.4	28.7	25.1	10	10
	Kofu.	SW	2.0	SSW	7.4	32.5	26.6	8	10
	Nagano.	SW	3.2	N	4.3	30.9	24.1	3	10
	Matsumoto.	WNW	2.2	SW	3.4	28.7	27.1	8	9
	Iida.	S	0.9	NE	3.4	30.7	26.1	4	9
	II	Numazu.	W	6.0	WNW	5.1	27.5	25.1	9
Hamamatsu.		WSW	4.2	SW	1.7	28.8	27.6	9	10
Gifu.		W	2.3	S	2.7	31.2	28.3	2	4
Fushiki.		ENE	3.8	N	2.1	21.2	21.3	8	5
Nagoya.		SSW	4.2	S	5.4	30.4	28.2	0	9
Hikone.		NNW	3.4	N	1.9	27.1	26.8	1	4
Fukui.		N	5.1	NW	4.2	26.7	25.3	4	3
Kanazawa.		SSW	4.1	NW	4.7	26.3	25.0	7	6
Takayama.		S	4.9	N	2.9	29.1	25.1	9	10
Tsu.		ESE	4.2	S	5.9	28.5	27.5	1	7

19. *Explosion of Sept. 21st, 1913, at 1. 50. 59 p.m.* The eastern branch of the sound area (Fig. 35) included Kotsuke and

small boundary portions of the two adjacent provinces of Shinano and Musashi; the greatest radial distances being 126 and 90 km respectively to the ESE and ENE. There was no report on the precipitation of ashes. The western branch consisted of the northern and the southern portions; the former being in this case reduced simply to the vicinity of the city of Kanazawa. The southern division was of an elliptic form, extending over a distance of 113 km in the W-E direction from the eastern border of the lake of Biwa to the NW part of Mikawa. The extreme distances of the different points of the western branch area from the Asama-yama are as follows:—

N division (vicinity of Kanazawa) .....	175 km.
W end (S. division) .....	250
E end (S. division).....	165

Meteorological Condition. At 2 p.m., the barometric pressure was highest (762 mm) over North China, thence decreasing eastwards, to 758–754 mm over the Main Island, at whose SE corner, namely, over the Izu peninsula, there existed a small depression centre of 752 mm. The wind was generally W'ly or NW'ly, except at the vicinity of Choshi, where it was E'ly or NE'ly. The wind velocity was highest at Choshi (NE, 12 m/s), Hamamatsu (W, 7.7 m/s), Niigata (NNW, 7.6 m/s), and Kofu (NW, 7.1 m/s). The air temperature varied from 16°·8 to 28°·8 C, with the average of 21°·1 C. The sky was cloudy or rainy over the greater part of Japan.

TABLE VIII. WIND DIRECTION AND VELOCITY, AIR TEMPERATURE, AND CLOUD AMOUNT, ON SEPT. 21ST, 1913, AT 2 P.M.

Meteorological Station. (I)	Wind Direction and Velocity (m/s).	Air Temperature. C.	Cloud Amount.	Meteorological Station. (II).	Wind Direction and Velocity (m/s).	Air Temperature. C.	Cloud Amount.
Fukushima.	ESE 1.5	20.8	10	Numazu.	SSE 3.7	28.8	1
Utsunomiya.	ESE 1.8	18.1	10	Hamamatsu.	W 7.7	27.1	8
Mito.	ENE 2.9	16.8	10	Gifu.	N 0.7	22.7	10
Niigata.	NNW 7.6	19.0	10	Fushiki.	WNW 2.4	20.7	10
Maebashi.	S 4.2	20.8	10	Nagoya.	WNW 5.6	22.9	10
Choshi.	NE 12.0	18.9	10	Hikone.	NW 3.3	21.0	10
Kumagai.	E 0.7	19.1	10	Fukui.	NNW 3.2	21.8	10
Tokyo.	NNE 4.3	17.7	10	Kanazawa.	NW 2.8	20.7	10
Yokohama.	N 5.7	19.0	10	Takayama.	NNE 1.8	18.1	10
Kofu.	NW 7.1	26.9	10	Tsu.	NNW 6.1	23.4	10
Nagano.	— 0.2	19.5	10				
Matsumoto.	E 1.2	18.5	10				
Iida.	N 2.3	22.0	10				

**20. Explosion of Aug. 12th, 1913, at 11. 20. 33. p.m.** The eastern branch of the sound area (Fig. 37) was somewhat rectangular in form, whose two sides were about 150 and 200 km in length, with the mutual distance of 75 km, running in the WNW-ESE direction from the NE part of Shinano, through Kotsuke, to Musashi and the SW corner of Shimotsuke. This explosion was the only instance among the numerous Asama-yama explosions, in which the direct western propagation of the detonation reached to the locality some miles NW of the city of Matsumoto; with the exception of the outburst of May 31st, 1909, in which, however, the sound area was nearly a circle with the volcano for centre. The extreme radial distances were as follows:—

W corner.....	62 km.	E corner.....	118 km.
NW „ .....	40	SE „ .....	150

The ash-precipitation zone extended, with the maximum width of 17 km, toward the E slightly S, through a distance of 148 km, to Mount Tsukuba. At Maebashi, the detonation was heard for about 1 min. from 11<sup>h</sup> 23<sup>m</sup> p.m., and the ashes fell there on the next day from 0<sup>h</sup> 28<sup>m</sup> till 1<sup>h</sup> 20<sup>m</sup> a.m., a rain precipitation having thereafter taken place. The amount of the ashes collected on a piece of paper, 80 × 56 cm in area, was 22 grams. On Mount Tsukuba the ashes continued to fall from 10 (?) p.m. on the 14th till 6 a.m. on the next morning.

The western branch of the sound area was composed of the northern and southern portions, mutually separated at the boundary region of Echizen, Omi, and Mino. The northern division stretched along the Japan sea side, through a distance of about 195 km, including the province of Kaga and parts of Noto and Echizen. The southern division was extensive and stretched in the EW direction for a length of 285 km from the vicinity of Lake Biwa on the W to the Bay of Sagami on the E, including the provinces of Owari and Mikawa, and parts of Omi, Ise, Mino, Totomi, Suruga, and Izu. The distances from the Asama-yama were as follows:—

N end (N division)....	187 km.	W end (S division)....	270 km.
S „ ( „ )....	230	E „ ( „ )....	165

Meteorological Condition. According to the weather map for 10 p.m. on the 12th, the atmospheric pressure was high (758 mm) in the vicinity of the Bonin Islands and low (748 mm) in Karafuto. The barometric gradient over Japan was very gentle, the pressure varying only between 750 and 754 mm. The air temperature was, in Central Japan, from 19°·6 to 28°·4 C, with the

average of 25°2 C, while the sky was entirely overcast, with the exception of the cases of Tokyo, Yokohama, and Numazu. (See Table IX.) The wind velocity was greatest, namely, 6.9 to 8.2 m/s, at Numazu, Tsu, and Nagoya. In the eastern and western branches of the sound area, as well as in the space between them, the wind direction was in the main westerly or southerly; while in the region adjacent on the NE side, it was more or less westerly.

TABLE IX. WIND DIRECTION AND VELOCITY, AIR TEMPERATURE, AND CLOUD AMOUNT, AT 10 P.M. ON AUG. 12TH, 1913.

Group.	Meteorological Station.	Wind Direction and Velocity (m/s).	Air Temperature.	Cloud Amount.
I	Fukushima.	ENE 0.7	23.7 <sup>o</sup>	10
	Utsunomiya.	NNE 3.5	24.1	10
	Mito.	NNE 2.1	27.7	10
	Niigata.	SE 2.2	22.8	10
	Maebashi.	NNW 3.8	25.8	10
	Choshi.	SE 4.3	26.4	9
	Kumagai.	W 2.5	19.6	10
	Tokyo.	S 3.9	28.4	6
	Yokohama.	SSW 2.2	26.8	2
	Kofu.	SW 1.8	25.9	9
	Nagano.	— 0.0	22.3	10
	Matsumoto.	S 0.7	22.8	10
	Iida.	WNW 2.2	25.4	10
	Numazu.	SW 6.9	27.7	7
	Hamamatsu.	W 1.3	27.6	10
	Gifu.	W 2.7	27.5	10
	Fushiki.	S 4.5	25.6	10

Group.	Meteorological Station.	Wind Direction and Velocity (m/s).		Air Temperature.	Cloud Amount.
II	Nagoya.	W	8.2	25.3 <sup>o</sup>	10
	Hikone.	SE	2.0	24.7	10
	Fukui.	S	0.8	25.8	10
	Kanazawa.	SSW	4.2	24.7	10
	Takayama.	E	1.2	22.5	10
	Tsu.	N	7.6	25.6	10

**21. Explosion of July 19th, 1913, at 0. 54. 03 p.m.** The sound area (Fig. 38) was similar to, but a little smaller than, that of the preceding case. The eastern branch was elliptic in form, of the major and minor diameters respectively 110 and 63 km in length; the greatest *radius* being 64 km directed toward the ESE. A slight ash-precipitation was reported from the town of Shimonita at a distance of 31 km to the SE of the volcano. The western branch consisted of the northern and southern portions mutually separated by the boundary districts of Echizen, Omi, and Mino. The northern division included the coast of Kaga and the S. half of Noto, extending for the length of 132 km in the SW-NE direction. The southern division was larger in extension, stretching in the form of a butterfly with wings spread out, through a distance of 210 km and in the WNW-ESE direction from the W. part of Omi to the boundary between the two provinces of Totomi and Suruga; this being, so far, one of the two cases in which the Asama-yama detonation was heard on the W side of the Lake of Biwa. (See also Fig. 30.) The distances of the western branch area from the volcano were as follows:—

N end (N division)....190 km.	W end (S division)....267 km.
S „ ( „ )....210	E „ ( „ )....172

Meteorological Condition. According to the weather map for 2 p.m. on the 19th, there existed an atmospheric depression of 740 mm at the N. part of Formosa, while an anticyclone of 762 mm was found to the NE of Hokkaido; the central part of the Main Island being under the pressure of 756 mm. The air temperature varied from 21°1 to 32°8 C, with the mean of 27°9 C, the sky being mostly cloudy. (See Table X.) The wind velocity was over 5 m/s at several of the places, the maximum values being 9.3 and 8.6 m/s respectively at Fukushima and Choshi. The wind direction was more or less easterly in the tract lying to the E and NE of the line connecting the Asama-yama with Nagano and Izu peninsula, while to the W of the latter it was at several places more or less westerly. Again, the wind was northerly along the Japan sea coast, while it was southerly on the Pacific coast.

TABLE X. WIND DIRECTION AND VELOCITY, AIR TEMPERATURE, AND CLOUD AMOUNT, AT 2 P.M. ON JULY 19TH, 1913.

Group.	Meteorological Station.	Wind Direction and Velocity (m/s).	Air Temperature.	Cloud Amount.
	Fukushima.	NE 9.3	26.6° C	7
	Utsunomiya.	S 3.2	24.9	7
	Mito.	ENE 5.0	23.3	5
	Niigata.	N 5.7	28.6	9
	Maebashi.	ESE 3.5	26.7	10
	Choshi.	SSE 8.6	21.1	10
I	Kumagai.	ESE 5.8	27.6	10
	Tokyo.	ENE 4.3	25.8	10
	Yokohama.	NE 3.5	24.6	10
	Kofu.	SW 1.7	32.8	10

Group.	Meteorological Station.	Wind Direction and Velocity (m/s).	Air Temperature.	Cloud Amount.
II	Nagano.	SE 1.7	30.7-C	3
	Matsumoto.	N 1.2	29.0	2
	Iida.	W 4.1	30.5	7
	Numazu.	S 2.9	28.9	10
	Hamamatsu.	SW 3.4	29.4	7
	Gifu.	SW 0.9	29.0	10
	Fushiki.	N 3.9	26.2	2
	Nagoya.	SSW 5.0	27.9	10
	Hikone.	ENE 2.9	29.0	10
	Fukui.	N 2.8	30.9	9
	Kanazawa.	NW 3.6	30.1	7
	Takayama.	S 1.9	29.5	9
	Tsu.	E 5.7	28.6	6

**22. Explosion of May 16th, 1913, at 4. 41. 00 p.m.** The sound area (Fig. 40) was an oval extending for a length of 140 km in the NW-SE direction, from the boundary tracts of Kotsuke and Shinano to the central part of Musashi; the greatest radial distance of 113 km being directed toward the SE. There was no western branch.

Meteorological Condition. Assuming the state of weather at the time of the explosion to be represented by the means of those at 2 and 6 p.m. given in Table XI, we see that the air temperature varied between 6°7 and 16°0 C, with the mean of 11°8 C; the sky being generally overcast. The wind, whose velocity was generally high and above 10 m/s at a few places, was in the region to the W of the line joining the Asama-yama with the head of the Tokyo Bay, mostly westerly or northerly, such that

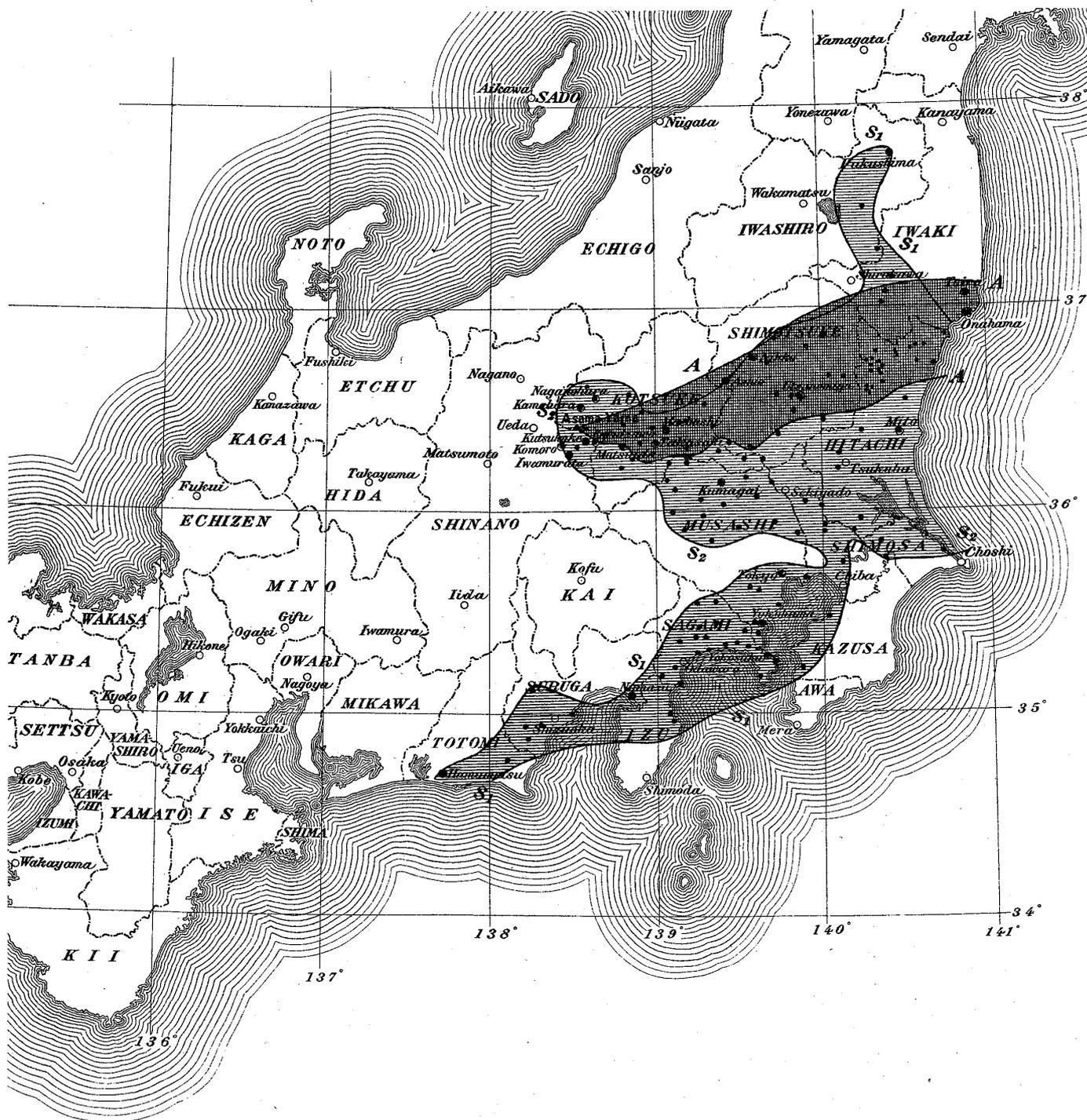
the average direction may be taken to be NW. On the other hand, at the places lying to the NE of the above-mentioned boundary, the wind direction was northerly or easterly.

**TABLE XI. WIND DIRECTION AND VELOCITY, AIR TEMPERATURE, AND CLOUD AMOUNT AT 2 AND 6 P.M. ON MAY 16TH, 1913.**

Group.	Meteorological Station.	Wind Direction and Velocity (m/s).				Air Temperature.		Cloud Amount.	
		2 p.m.		6 p.m.		2 p.m.	6 p.m.	2 p.m.	6 p.m.
I	Fukushima.	NE	4.9	ENE	3.5	7.0 <sup>o</sup> C	6.4 <sup>o</sup> C	10	10
	Utsunomiya.	NE	4.2	NE	7.1	9.0	7.9	10	10
	Mito.	N	4.5	NNW	8.6	9.2	8.2	10	10
	Niigata.	NE	4.7	NNE	1.5	12.1	11.6	10	10
	Maebashi.	S	1.9	WSW	2.9	12.0	11.1	10	10
	Choshi.	N	14.1	N	15.2	12.8	10.9	10	10
	Kumagai.	WNW	3.4	—	0.2	10.9	11.4	10	10
	Tokyo.	NW	5.2	NNW	7.0	10.0	9.4	10	10
	Yokohama.	NNW	5.3	N	6.5	10.6	11.2	10	10
	Kofu.	SSE	0.7	NW	3.6	13.4	12.8	8	8
	Nagano.	W	7.8	E	2.4	10.5	9.0	10	10
	Matsumoto.	NNE	9.3	N	3.9	12.8	8.8	10	10
	Iida.	SE	1.3	NE	2.5	15.6	12.6	5	6
	Numazu.	SE	3.2	SSE	2.5	13.9	13.9	10	10
	Hamamatsu.	W	2.3	W	3.8	15.4	16.6	10	10
	II	Gifu.	W	3.7	NNW	6.9	15.5	14.0	10
Fushiki.		N	5.4	NW	2.6	11.4	10.0	10	10
Nagoya.		SW	3.1	WNW	10.8	16.6	14.4	10	3
Hikone.		NNW	5.1	NW	7.9	13.4	12.5	10	10
Fukui.		NNW	5.0	NNW	4.3	12.9	10.8	10	10
Kanazawa.		NE	3.9	NNE	4.3	11.5	9.8	10	10
Takayama.		N	4.2	NW	6.3	11.1	9.2	10	10
Tsu.		NNW	9.4	NW	11.7	16.6	13.3	10	1

Fig. 29. Sound Area and Ash-Precipitation Zone of the Asama-yama Eruption of Dec. 14th, 1912, at 9.23 a.m.

Sound Area is shaded red (thin). Ash-precipitation Zone is shaded red (deep).  
 Places where Detonation was perceived are indicated by red dots.

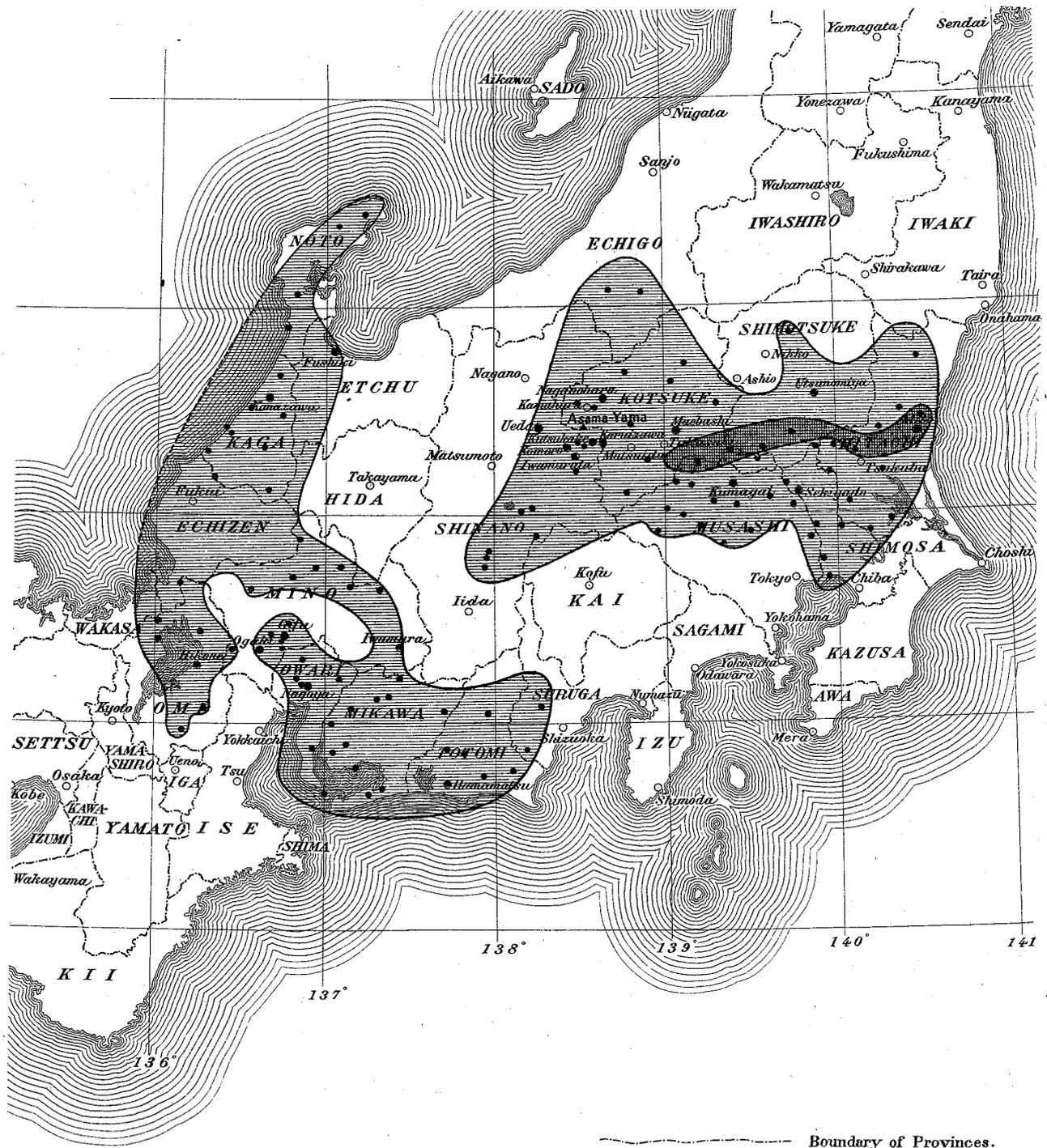


Boundary of Provinces.

Fig. 30. Sound Area and Ash-Precipitation Zone of the Asama-yama Explosion of June 17th, 1913, at 10. 47. 41 p.m.

Sound Area is shaded red (thin). Ash-precipitation Zone is shaded red (deep).

Places where Detonation was perceived are indicated by red dots.

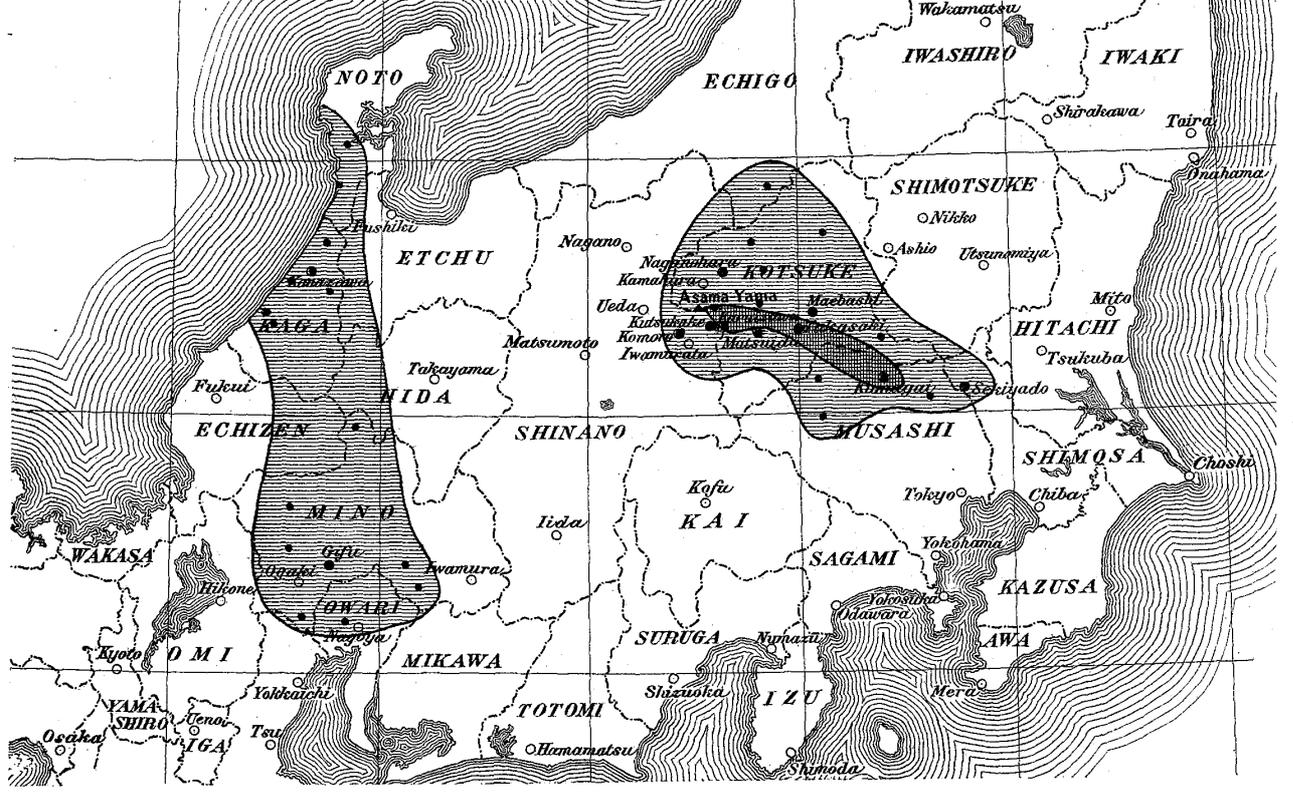


Sound Area and Ash-Precipitation Zone of Asama-yama Explosions.

Sound Area is shaded red (thin). Ash-precipitation Zone is shaded red (deep).

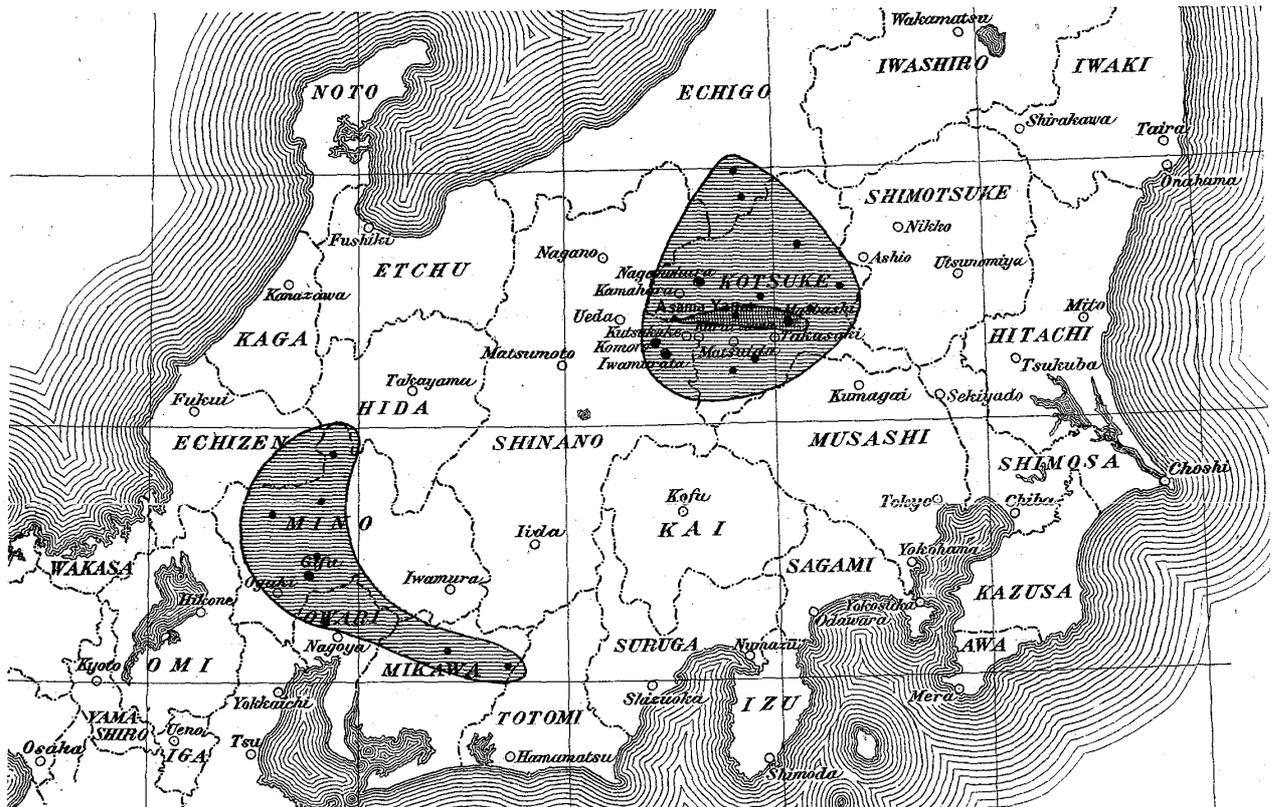
Places where Detonation was perceived are indicated by red dots.

Fig. 31. June 20th, 1913, at 4. 20 a.m.



Boundary of Provinces.

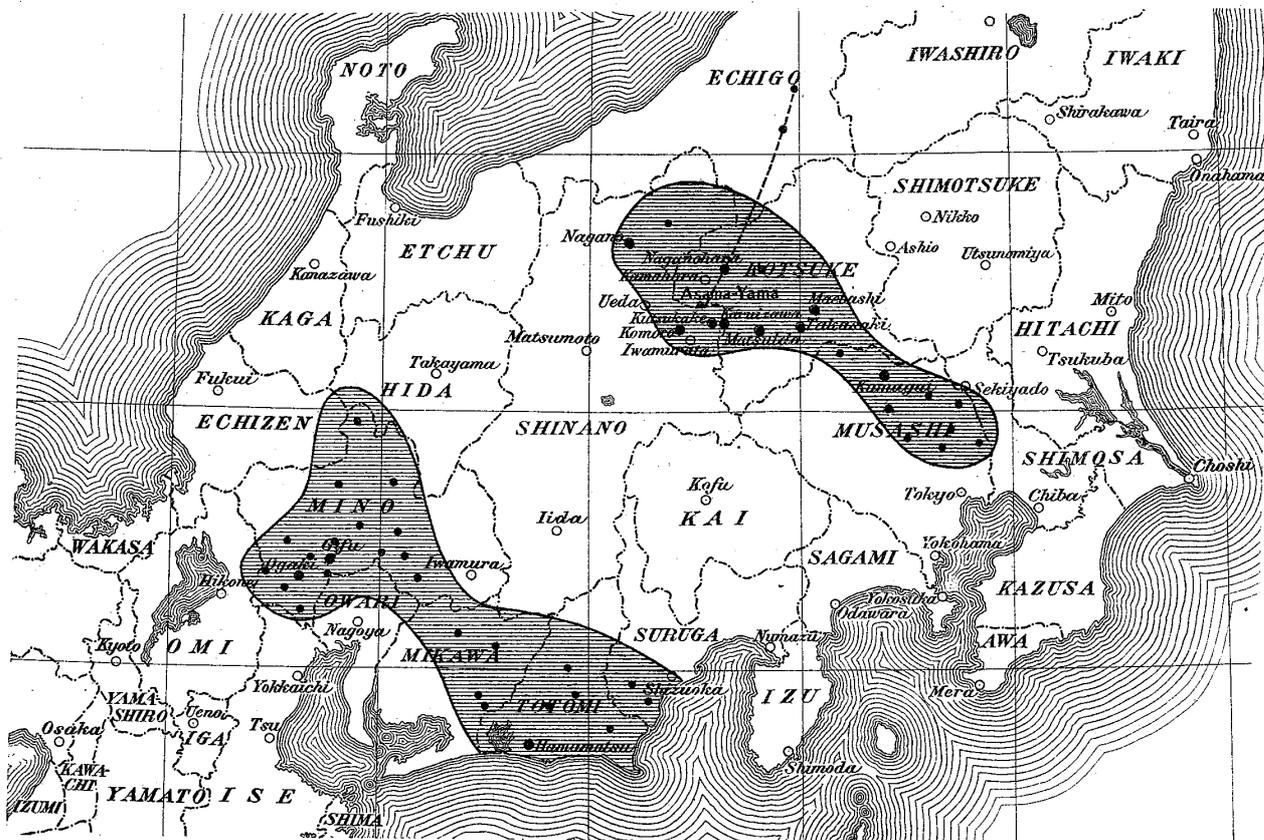
Fig. 32. June 26th, 1913, at 8. 09. 40 a.m.



Sound Area and Ash-Precipitation Zone of Asama-yama Explosions.

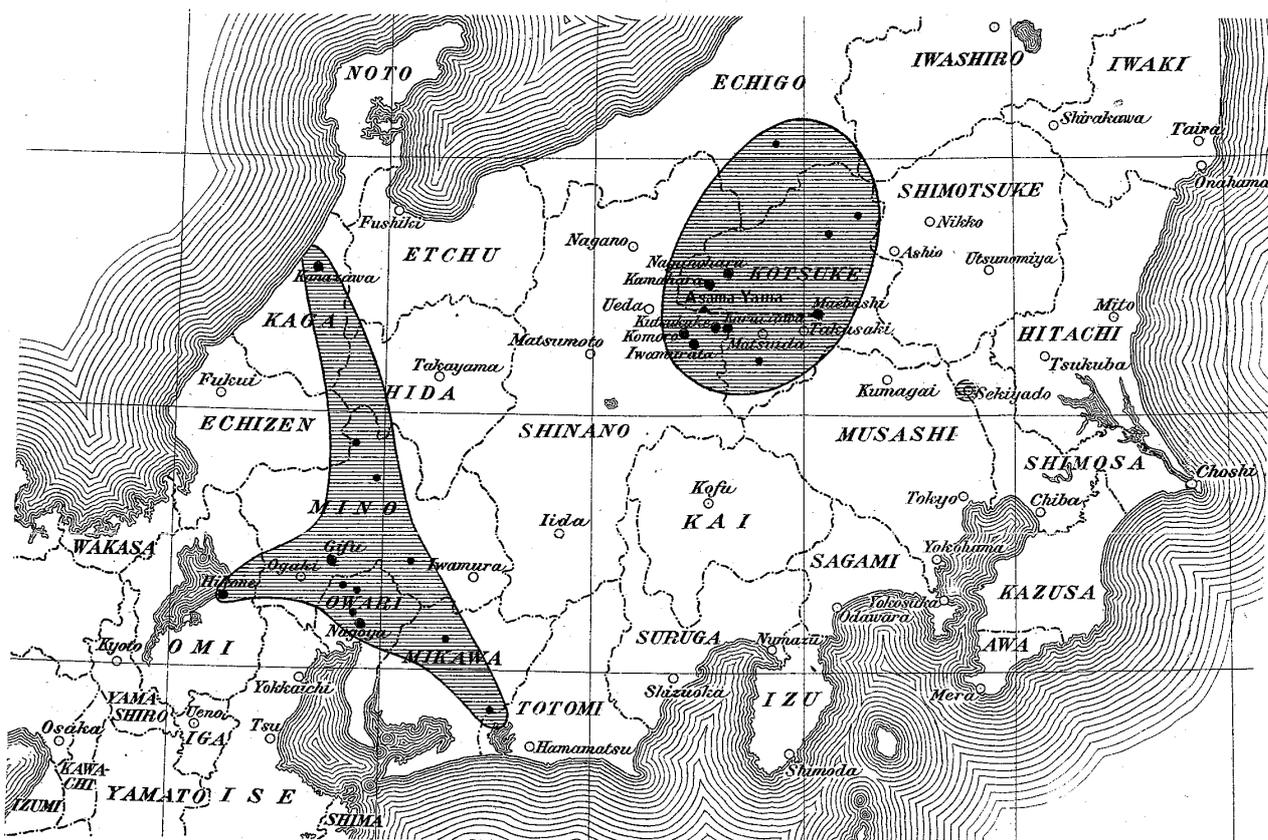
Sound Area is shaded red (thin). Ash-precipitation Zone is indicated by dotted line.

Fig. 33. May 29th, 1913, at 10. 44. 12 a.m.



Boundary of Provinces.

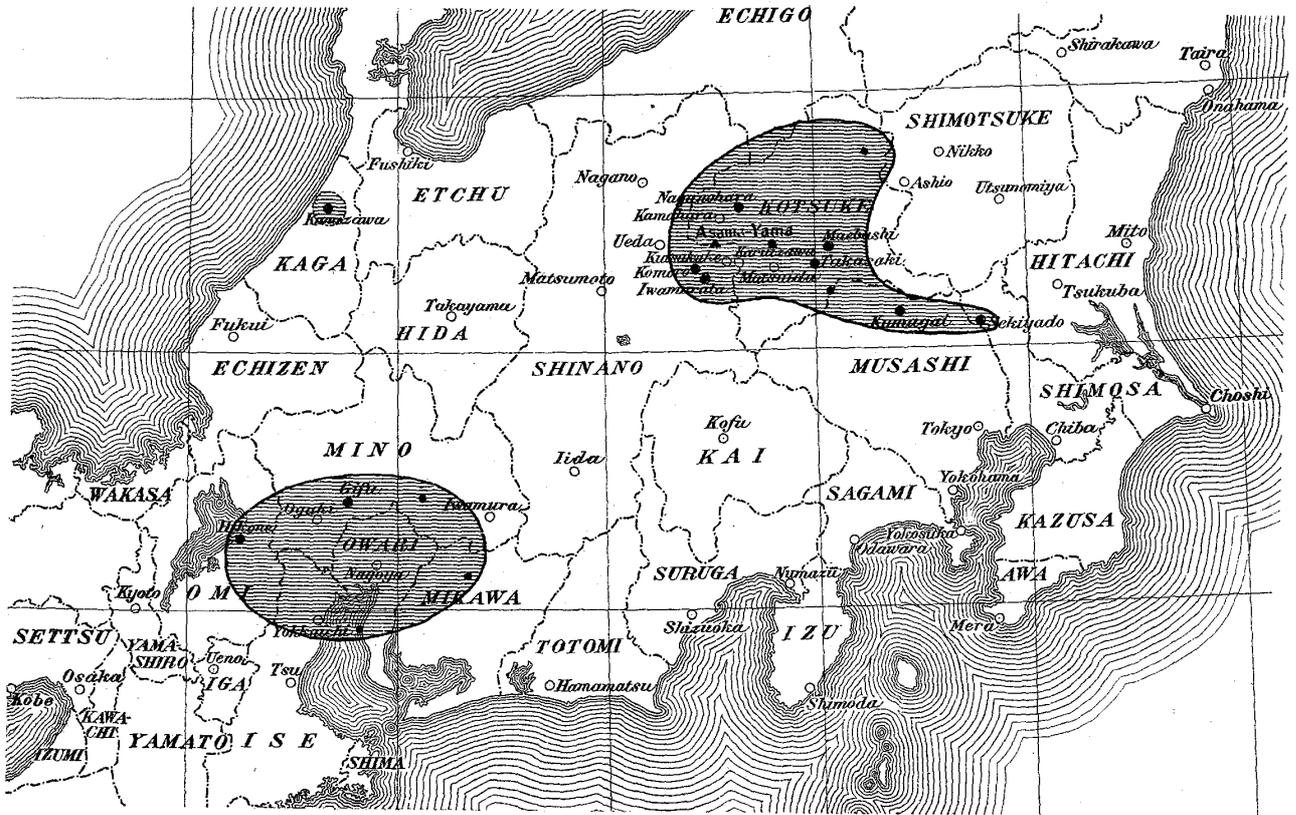
Fig. 34. June 26th, 1913, at 11. 41. 59 p.m.



### Sound Area and Ash-Precipitation Zone of Asama-yama Explosions.

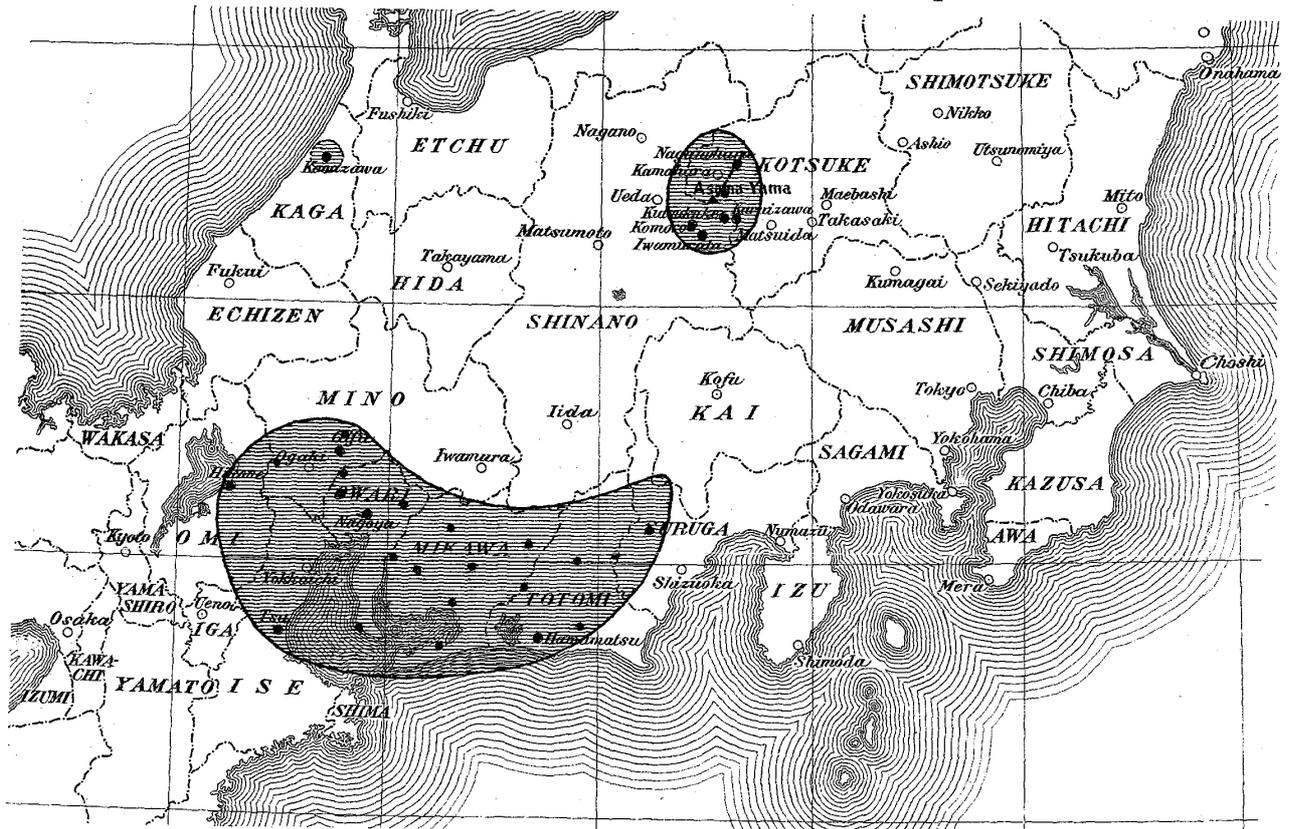
Sound Area is shaded red (thin). Ash-precipitation Zone is indicated by dotted line.

Fig. 35. Sept. 21st, 1913, at 1. 50. 59 p.m.



Boundary of Provinces.

Fig. 36. July 13th, 1913, at 4. 01. 19 p.m.

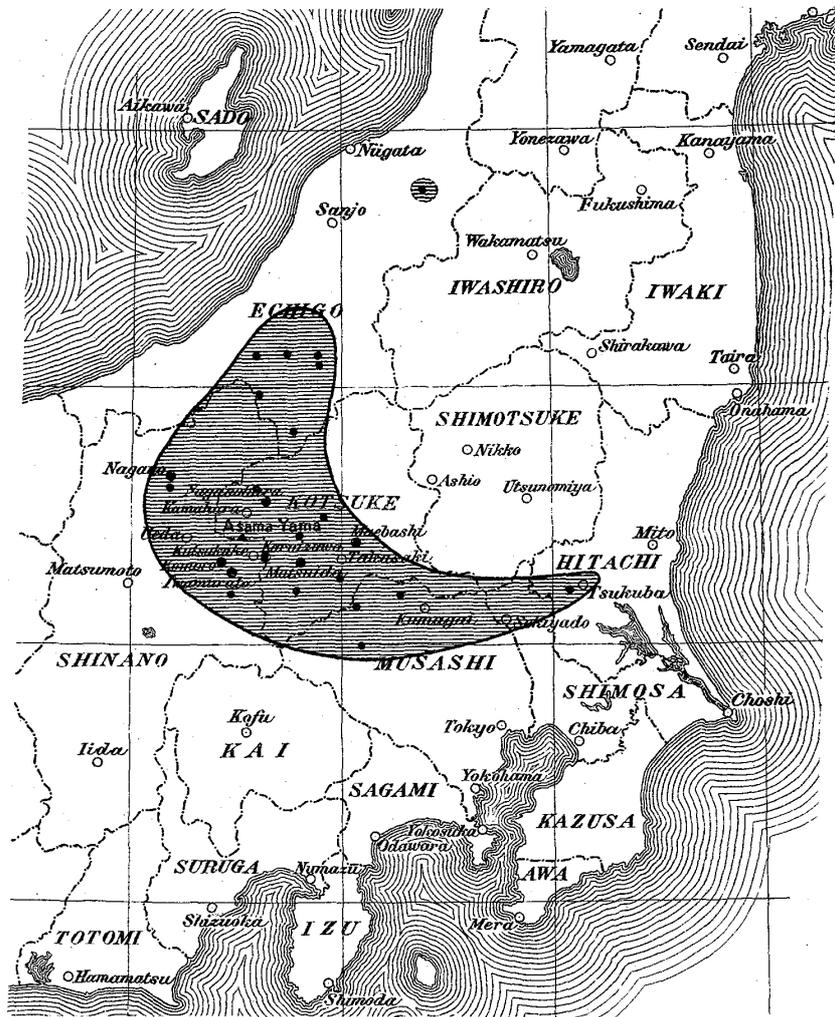




Sound Area of Asama-yama Explosions.

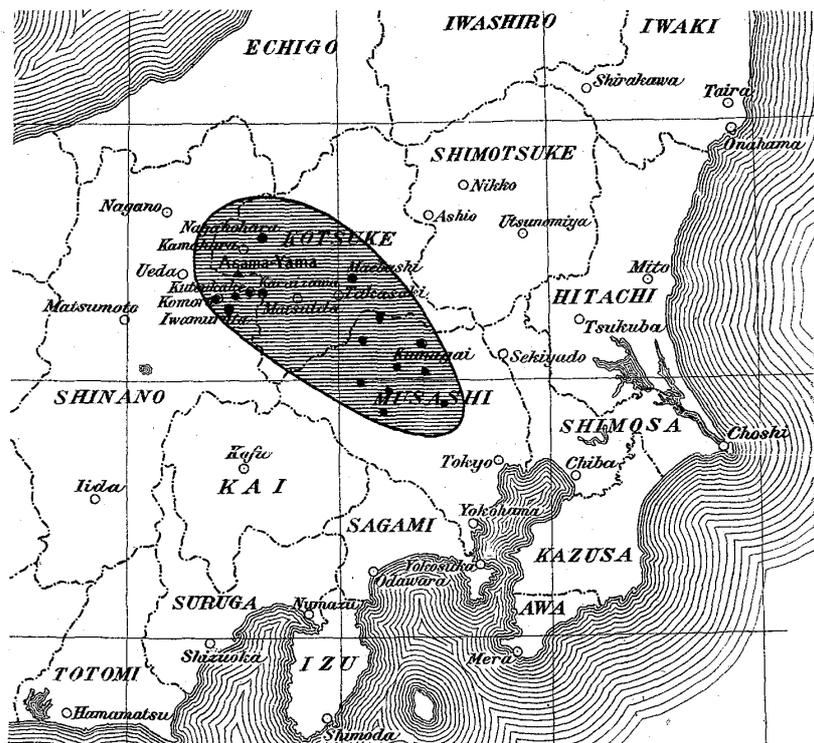
Sound Area is shaded red (thin). Places where Detonation was perceived are indicated by red dots.

Fig. 39.  
Oct. 26th, 1913,  
at 3. 14. 38 a.m.



Boundary of Provinces.

Fig. 40.  
May 16th, 1913,  
at 4. 41. 00 p.m.



**23. Explosion of Oct. 26th, 1913, at 3. 14. 38 a.m.** The sound area (Fig. 39) was roughly of a crescent form, which stretched from Mount Tsukuba on the E to the vicinity of the town of Ojiya (Echigo) in the Shinano-gawa valley, including parts of the provinces of Kotsuke, Shinano, Echigo, Musashi, Shimosa, and Hitachi. The radial distances of the sound propagation were 155 km toward the E slightly S, and 104 km toward the NNE. At Maebashi, there was a slight precipitation of ashes. Outside the above mentioned area, the sound was perceived at a place called Shintani-mura, in the H. Kanbara county, Echigo, at a distance of 170 km to the NNE of the Asama-yama. It will be observed that the propagation of the sound in the present case was similar to that of the strong explosion of Oct. 22nd, 1911.

Meteorological Condition. In the early morning of the 26th, the centre of high barometric pressure (774–776 mm) was over Northern China, thence decreasing to 760–765 mm over the Japanese islands. The isobars were arranged nearly parallel to the extension of the latter, and there prevailed northerly or westerly winds at most places in Central and Northern Japan, with the maximum wind velocity of 14.2–9.7 m/s (NW) at Niigata. The air temperature varied at 6 a.m. from 0°.2 to 13°.8 C, with the mean of 8°.9 C. The weather was clear or fair at several places.

TABLE XII. WIND DIRECTION AND VELOCITY, AIR TEMPERATURE,  
AND CLOUD AMOUNT, AT 2 AND 6 A.M., ON OCT. 26TH, 1913.

Group.	Meteorological Station.	Wind Direction and Velocity (m/s).		Air Temperature.		Cloud Amount.	
		2 a.m.	6 a.m.	2 a.m.	6 a.m.	2 a.m.	6 a.m.
I	Fukushima.	WNW 11.2	NNW 7.2	15.9 <sup>o</sup> C	13.0 <sup>o</sup> C	1	5
	Utsunomiya.	— 0.4	NW 1.6	5.5	4.6	0	0
	Mito.	NNW 2.6	NNW 2.2	7.5	6.0	0	1
	Niigata.	NW 14.2	NW 9.7	13.4	13.5	10	10
	Maebashi.	WNW 7.2	N 4.9	9.5	8.2	0	1
	Choshi.	W 2.0	NW 1.6	12.7	11.7	3	10
	Kumagai.	WNW 3.2	ESE 0.7	8.0	6.8	0	4
	Tokyo.	NNW 2.4	NW 2.0	9.5	8.8	0	10
	Yokohama.	NNE 0.7	NNE 2.7	10.9	9.4	1	10
	Kofu.	NW 0.5	NW 1.0	5.4	5.2	0	10
	Nagano.	E 1.0	NW 1.4	5.6	5.3	10	10
	Matsumoto.	S 0.9	W 1.8	1.6	0.2	0	0
	Iida.	— 0.3	E 1.1	3.8	1.7	0	3
	II	Numazu.	ENE 1.7	ENE 4.5	9.4	9.4	0
Hamamatsu.		WSW 3.6	W 4.5	14.0	13.8	2	9
Gifu.		ENE 1.0	N 3.5	9.8	9.0	2	1
Fushiki.		SSW 2.6	N 5.3	11.6	13.3	10	10
Nagoya.		NNW 2.9	NNW 3.6	10.5	9.8	9	0
Hikone.		S 1.9	S 1.8	9.1	9.1	1	2
Fukui.		ESE 2.3	NE 1.0	10.6	10.1	0	10
Kanazawa.		SSW 5.0	ENE 5.6	13.8	12.7	9	10
Takayama.		— 0.2	— 0.0	1.9	3.0	0	10
Tsu.		W 6.1	WSW 3.3	11.5	10.1	0	0

24. Relation between sound area and ash-precipitation

*zones.\** Among the 12 explosions (§ 10) considered above there were 9 cases, namely, Nos. 3 to 11, in which the sound area was composed of two branches; these having taken place all between May 29th and Sept. 21st, in the year 1913. On the other hand, the three other explosions, 1, 2, and 12, in each of which the detonation was heard only in the eastern branch, occurred respectively on Dec. 14th, 1912, and May 16th and Oct. 26th, in 1913. These facts may indicate the existence in the summer times of the atmospheric conditions over Central Japan favourable for the formation of the western branch of sound area with the zone of silence situated between it and the Asama-yama. It must not, however, be forgotten that the latter phenomenon did also take place in the colder months, as was the case with the explosions of Dec. 16th and 25th, 1910, and of April 3rd, 1911.

From a comparison of the Figs. 29 to 40, we may divide the explosions Nos. 3 to 11 into the following four groups, according to the forms and relative positions of the two branches of the sound area. Group A: Explosions Nos. 4, 7, and 6, or those of June 17th, and of June 26th, at 11 p.m. and at 8 a.m. Group B: Explosion (No. 5) on June 20th. The explosions of Dec. 25th, 1910, and of April 3rd, 1911, also belong to this group. Group C: Explosions Nos. 3, 8, and 11, or those of May 29th, July 13th, and Sept. 21st. The explosion on Dec. 16th, 1910, also belongs to this group. Group D: Explosions Nos. 10 and 9, or those of Aug. 12th and July 19th.

The sound areas of the explosions belonging to each of the

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\* Descriptions of the sound areas of the Asama-yama explosions in 1909 to 1911 are given in the *Bulletin*, Vol. VI, No. 1. For interesting and valuable discussions on the anomalous sound propagation the reader is referred to Prof. v. d. Born's paper, "Ueber die Schallverbreitung bei Explosionskatastrophen," *Physik. Zeitschrift*, 11. Jahrgang, 1910, and to Dr. S. Fujiwara's paper, "On the abnormal propagation of sound wave in the atmosphere," *Bulletin of the Central Meteorological Observatory of Japan*, Vol. II, 1912.

different groups are more or less mutually similar, and the position and form of the western branch seem to depend on that of the eastern branch or the extension of the ash-precipitation zone.

Explosions of Group A. (Figs. 30, 34, and 32.) In the explosion of June 17th, both the general course of the ash-precipitation zone and the longer extension of the eastern branch of the sound area were nearly from W to E, being approximately normal to, and directed away from, the arc of the western branch. In the case of the explosion of June 26th, at 11 p.m., the extension of the western branch of the sound area was nearly in the same direction as that of the preceding case, the ashes being also carried approximately toward the E. In the explosion of June 26th, at 8 a.m., the ashes were carried also nearly toward the E, and the arrangement of the sound area was not much different from that of the outburst in the evening of the same day, except that the western branch was in the present instance smaller in extension.

Explosions of Group B. (Fig. 31.) In the explosion of June 20th, the western branch of the sound area extended from the N. part of Owari into the Japan Sea on the north, being appreciably displaced northward when compared to those of the outbursts of group A. In correspondence to this fact, both the course of the ash-precipitation zone and the greatest radial extension of the eastern branch of sound area were directed toward the ESE. On the occasion of the explosion of Dec. 25th, 1910, the western branch area was limited to the two provinces of Etchu and Hida and did not extend to Mino and Owari southwards; there having been the precipitation of sand at the Wakasare Cottage at the N. foot of the Ko-Asama, which was also the case with the outburst above considered. Again, in the explosion of April 3rd,

1911, the arrangement of the two branch areas was not much different from that for the latter, although there was no report on the falling of ashes. (See Figs. 27 and 28, in No. 1 of the preceding volume.)

Explosions of Group C. (Figs. 33, 36 and 35.) In the two explosions of May 29th and July 13th, the ashes were carried in the NNE direction to the town of Naganohara or further to the SE part of the province of Echigo. Consequently the western branch of the sound area was in each case shifted much south-eastwards and extended from the vicinity of Lake Biwa to the west part of the province of Suruga. The explosion of Dec. 16th, 1910, (Fig. 24, in Vol. VI, No. 1, of the Bulletin), furnished a case analogous to the two outbursts here considered; the ashes having been carried toward the NNE to Naganohara, although the eastern branch sound-area extended eastwards to the Pacific coast. To the S and SW from the Asama-yama, the detonation was, on the occasion in question, heard in the western branch area stretching in the EW direction and composed of the city of Nagoya and the vicinity, the N. part of Mikawa, and the S. extremity of Kai. In the explosion of Sept. 21st there was a precipitation of ashes and small flat lava fragments at the Wakasare Cottage and at the Asama Pasture Ground to the ENE of the volcano. Consequently we find, in the opposite direction, the western branch area extending over parts of Owari, Mino, etc.

Explosions of Group D. (Figs. 37 and 38.) In the explosion of Aug. 12th, both the course of the ash-precipitation zone and the extension of the eastern branch of the sound area were directed toward the ESE, approximately normal to the N. division of the western branch. It may be that the latter was continued for some distance northwards over the Japan Sea and formed,

together with the S. division a great arc similar to, or larger than, the western branch of the explosion of June 17th, which was also very nearly separated into the N and S pieces by the existence of a non-perception tract in Mino. On the occasion of the outburst of July 19th, the ashes were carried south-eastwards from the volcano, in which consequence, probably, the N. and S. divisions of the western branch area were shifted slightly toward the N or NW. It is to be remembered that the two explosions here considered were very violent, being not much inferior to the strong eruption of June 17th.

The facts described above seem to point to the following two conclusions:—(i). The course of the ash-precipitation zone approximately forms a sort of middle axis, about which the eastern branch of the sound area is more or less symmetrical, as is illustrated in the cases of the explosions of June 17th and 20th, and of Aug. 12th, in which the ashes were carried to a sufficiently long distance from the volcano. (ii). The western branch of the sound area, or more strictly its central part, is located in the direction opposite to the course of the ash-precipitation zone\*, such that its position is shifted to different azimuths between the SW and W with respect to the Asama-yama, although the radial distance may not greatly vary.

**25. Eastern branch of sound area and wind direction.** The dependence of the eastern branch of the sound area on the direction of the ash-precipitation zone, which was clearly indicated already by the three strong outbursts of Dec. 7th, 1909; Dec. 2nd, 1910; and May 8th, 1911, is evidently due to the wind prevailing at the higher atmospheric region; the surface winds

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\* This fact seems to have been in a measure anticipated by Dr. S. Fujiwara. In the Bull. Cent. Met. Obs. Japan, Vol. II, p. 59, he says "...the range and the direction of the silent region may vary in every case,...."

having, as will be seen from §§ 11 to 23, no definite relation on the propagation of the sound or the transportation of the ashes. The direction of the latter varied from NW→SE to SSW→NNE, and was on the average toward the E, as follows:—Toward the E, three cases; toward the SE, one case; toward the ESE, three cases; toward the ENE, one case; and toward the NNE, three cases. This conclusion is of course in accordance with the results found from the examination of the former eruptions of the Asama-yama. That the mean direction of the ash-precipitation zone is identical with that of the higher air current is evident from an inspection of Table XIII, which gives the mean direction of motion of the upper cloud observed during the 5 years between 1906 and 1910 at the different meteorological stations in Central Japan.

**TABLE XIII. MEAN RESULTANT DIRECTION OF WIND AND THE MEAN DIRECTION OF UPPER CLOUD.**

Meteorological Station. (I)	Mean Resultant Wind Direction.	Upper Cloud.	Meteorological Station. (II)	Mean Resultant Wind Direction.	Upper Cloud.
Fukushima.	N 25° W	S 86° W	Numazu.	N 86° E	S 85° W
Utsunomiya.	N 77° E	S 86° W	Hamamatsu.	N 55° W	W
Mito.	N 12° E	S 58° W	Gifu.	N 30° W	N 87° W
Niigata.	S 24° W	S 81° W	Fushiki.	S 71° W	S 83° W
Maebashi.	N 14° W	W	Nagoya.	N 45° W	S 88° W
Choshi.	N 14° E	S 83° W	Hikone.	N 31° W	N 86° W
Kumagai.	N 39° W	N 89° W	Fukui.	S 25° W	S 85° W
Tokyo.	N 8° W	S 83° W	Kanazawa.	S 78° E	S 81° W
Yokohama.	N 11° W	N 89° W	Takayama.	N 43° W	N 88° W
Kofu.	S 53° W	S 84° W	Tsu.	N 59° W	S 88° W
Nagano.	N 45° W	S 81° W			
Matsumoto.	S 73° W	S 89° W			
Iida.	S 72° W	S 81° W			

The height of the upper cloud, whose mean direction of motion is, according to the above table, from W to E, varies from a few km probably up to about 10 km above the sea level. The smokes and ashes darted upwards by the strong explosions of the Asama-yama, whose height of ascent varies from about 5 km to 10 km (§§ 4 and 11), will be caught and carried eastwards by the westerly wind in the higher region, whose direction is essentially constant all the year round.

Fig. 41.

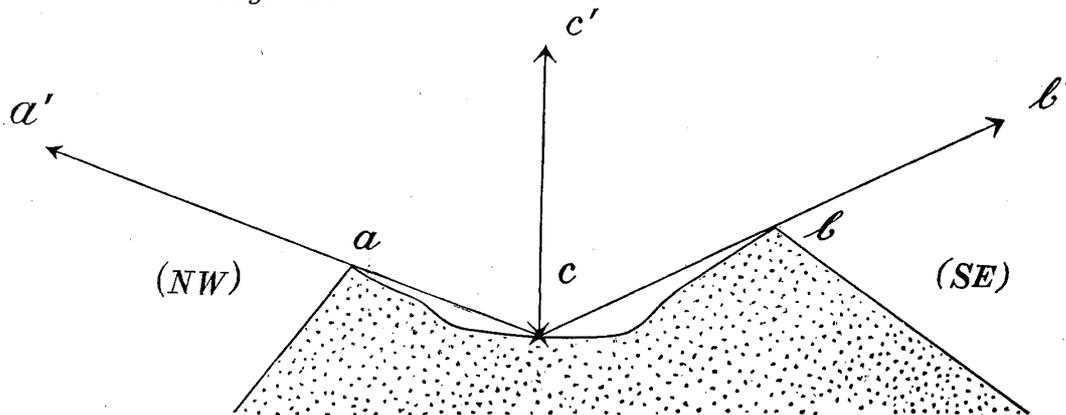


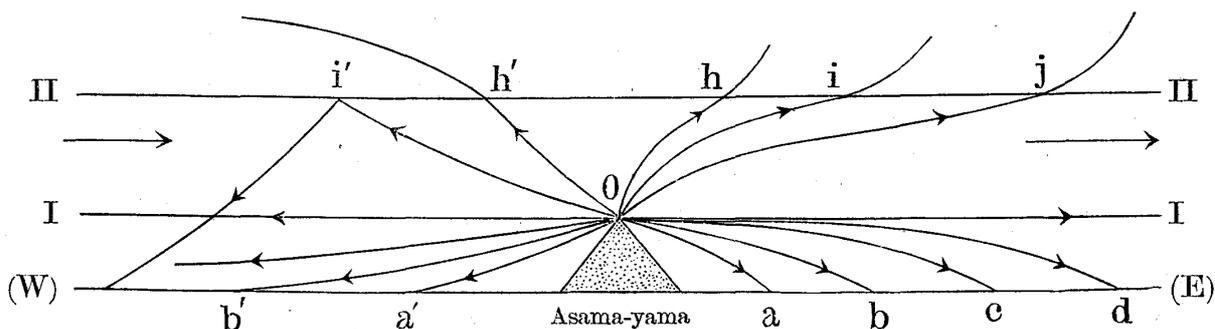
Diagram illustrating the explosive action of the Asama-yama crater.  
 (*acb*)....The present condition of NW-SE section of the crater.  
 (*c*).....The explosive centre at the crater bottom.

In considering the propagation of the detonation or of the sudden change in the atmospheric pressure caused by a strong explosion, it must be remembered that the principal effect will be spent upwards. Thus, in the annexed diagram, the greatest force of the detonation or air concussion must be in the vertical direction  $CC'$ , the boundary of the violent action being approximately formed by the conical surface  $a'c'b'$ , connecting the explosion centre ( $C$ ) of the crater bottom with the rim of the latter. This boundary surface, outside or below which the detonation will be perceived with a comparatively small intensity, may be supposed

for 1912 and 1913 to be represented by the horizontal plane through the top of the Asama-yama, as the actual crater was quite shallow in these two years.

Now to examine the formation of the eastern branch of the sound area, let us suppose I I (Fig. 42) to be the plane last mentioned, namely, that drawn at an altitude of about  $2\frac{1}{2}$  km, the elevation of the volcano. Further let II II be the plane drawn horizontally at a height of some 10 km, such that the space between it and the

Fig. 42. Diagram illustrating the propagation of the Asama-yama Detonation.



- (I I)....Horizontal plane through the top of Asama-yama.
- (II II)....Upper boundary of the layer of the greatest westerly wind.
- (*b'a'....cd*)....Ground level. Arrows indicate the westerly wind.
- O*....crater.

plane I I is approximately the region of the upper cloud, in which prevails the westerly wind whose velocity ( $v$ ) increase with the altitude probably to about 40 or 50 m/s. Below the plane I I, the westerly wind gradually decreases in velocity with the descent. Under these conditions, the detonation will reach the tract to the east of the Asama-yama by the paths below the plane I I, namely, *a*, *b*, *c*, *d*, etc., which are curved downwards, and thus give a condensation in the density of the sound rays. On the other hand, at the western foot of the mountain, there will be also the sound rays below the plane I I, namely, *a'*, *b'*,....which, being

curved upwards, will be smaller in the density than on the eastern side. This, coupled with the decrease of the intensity of sound with the increasing radial distance will cause the detonation to be enfeebled and become soon inaudible in the direction against the wind. Thus the "eastern branch" of the sound area, whose formation is due to the *direct* propagation from the volcano, ought not to extend much toward the W, as is almost invariably the case.

**26. Western branch of sound area and higher air current.**

To account for the formation of the western branch at considerable distance from the Asama-yama in direction contrary to the course of the ash-precipitation zone, let us assume the existence over the upper boundary of the space of the westerly motion of an atmospheric layer of strong easterly wind. Then the sound rays ( $h, i, j, \dots$ ) of the detonation starting upwards or eastwards from the top of the volcano, will be curved eastwards till they meet the plane II II, to be thereafter curved back westwards; the result being that the rays in question will not, under the supposed circumstances, reach down to the ground. This explains why there is no special sound area at a distance to the E (or NE, or SE) of the Asama-yama separated from that enclosing the latter. On the other hand, the sound rays directed westwards ( $h', i', \dots$ ) will be at first curved eastwards or upwards, but curved westwards after crossing the boundary plane II II; those ( $i' \dots$ ) with sufficiently small angle of incidence being, when combined with the influence of the difference in temperature and density, probably reflected back to the ground and giving rise to the western branch sound area. The space between the base of the mountain and the point of incidence of the reflected rays, where no sound is heard, forms the silent zone.

**27. Extensions of two branches of sound area.** From Figs. 30 to 38, it will be observed that the eastern branch of the sound area, or the region of audibility about the Asama-yama itself, was sometimes much smaller than that of the western branch, which is separated by a considerable distance from the latter. In the following table I give the areas measured with a planimeter of the two branches in the cases of the 9 explosions in 1913, and of the 3 explosions in 1910 and 1911.

**TABLE XIV. COMPARISON OF THE EXTENSIONS (LAND AREAS) OF THE TWO BRANCHES OF THE SOUND AREA.**

No. (§ 10)	Date.	Extension (area) of Eastern Branch. (i)	Extension (area) of Western Branch.			Ratio : (ii)/(i).
			N. Division.	S. Division.	Total. (ii)	
4	June 17th, 1913.	sq. km 25,690	sq. km —	sq. km —	sq. km 27,100	1.06
7	„ 26th, „	8,290	—	—	7,460	0.90
6	„ 26th, „	6,840	—	—	5,770	0.84
5	„ 20th, „	9,360	—	—	10,200	1.09
3	May 29th, „	8,130	—	—	11,240	1.39
8	July 13th, „	1,860	—	—	16,390	8.81
11	Sept. 21st, „	7,190	—	—	6,350	0.89
10	Aug. 12th, „	12,330	5,370	18,240	23,610	1.92
9	July 19th, „	6,080	2,720	10,250	12,970	2.13
	Dec. 16th, 1910.	19,000	—	—	5,300	0.28
	„ 25th, „	16,580	—	—	11,020	0.67
	April 3rd, 1911.	4,450	—	—	10,120	2.28
	<i>Mean.</i>	—	—	—	—	1.90

Thus, the land area of the western branch, which had the greatest amounts of 27,100 and 23,610 sq. km respectively in the cases of the explosions of June 17th and Aug. 12th, 1913, was 0.28 to

8.81 times that of the eastern branch, the average ratio being about 2.1. Again the intensity of the detonation perceived at different places in the western branch area seems generally to be well pronounced. Thus, on the occasion of the explosion of July 13th, 1913, whose greatest radius of the direct sound propagation was only about 30 km, the effect was felt, in the city of Nagoya (radial distance=201 km.) as a loud detonation like that of a heavy body fallen on the ground, causing some of the houses to be shaken; while, at the town of Inazawa (radial distance=203 km), the sound was mistaken for an earthquake and some people fled out of doors. The air wave of the explosion of June 26th, 1913, at 11 p.m., was also felt as a loud detonation at the meteorological observatory of Nagoya. The sound of the explosion of July 19th, 1913, was reported to have been violent at the town of Ko-ori (radial distance=193 km) in the province of Owari. Again, in the case of explosion of June 17th, 1913, the sound was perceived at the different places in the province of Hitachi, about 170 km to the E of the Asama-yama, generally as a feeble noise or slight shaking; while, at the meteorological observatory of Gifu, 191 km to the SW of the volcano, there were perceived three successive loud detonations, which shook the doors and *shoji*. On the same occasion, at Mutsumi-mura (radial distance=210 km) in the province of Mikawa, two successive strong sounds were heard, causing some of the people to escape out of doors.

The above-mentioned peculiarities, namely, the large extension of, and the strong intensity of the detonation in, the western branch area admit of an easy explanation, if we remember that the existence of the latter is due to the total reflection of those violent sound rays, which start from the volcano in more or less *upward* directions and become audible at a definite westerly dis-

tance without much loss of energy. On the other hand, the sound perceived in the eastern branch area is due to the air waves of secondary force directly transmitted from the origin below the plane through the mountain top and may be enfeebled at a comparatively short radial distance. The places at the foot of the Asama-yama, where the detonation was often of a terrific violence, causing some such slight damage as the breaking of *shoji*, overthrowing of *karakami* (sliding screens) and *to* (sliding doors), or the falling down of *kamoi* (wooden lintels over doorways) due to the strong shakings communicated to the houses, are Karuizawa on the E, Iwamurata on the S, Oi-mura on the SE, and Naganohara on the N, within the limiting distance of about 20 km from the crater.

**28. Cases of non-existence of western branch.** The extension of the sound areas in the cases of the explosions in 1913 and in the preceding years, in which the western branch did not exist, was as follows:—

Group.	Date.	Extension of Sound Area.
A	Dec. 7th, 1909.	71,800 sq. km.
	Dec. 2nd, 1910.	60,700
	May 8th, 1911.	62,900
B	Dec. 14th, 1912.	32,900
	May 31st, 1909.	7,370
	Dec. 15th, 1910.	12,100
	Jan. 18th, 1911, (5½ p.m.)	6,230
	” ” ” (9½ p.m.)	20,000
	Oct. 22nd, 1911.	28,100
	May 16th, 1913.	7,240
Oct. 16th, ”	14,500	

Group A includes the cases in which the sound area were extensive and greater than 6,000 sq. km, while Group B includes those of smaller extension. Thus, the western branch did not come into existence, amongst the others, when the eastern branch, or area of direct sound propagation was large enough. It would seem that the prevalence of the too strong westerly winds prevents the formation of the western branch sound area, tending to give steeper angle to the sound rays emanating westwards and thereby causing them to proceed on without being reflected back to the ground.

**29. Distribution of sound frequency.** Figs. 43 and 44 indicate the relative frequencies with which the Asama-yama detonations were heard at the different places, each being the results of the superpositions of the sound areas of a number of the strong explosions. Thus Fig. 43 relates to the 11 explosions in 1912 and 1913 (Nos. 2 to 12, § 10) and the 8 in 1909 to 1911, namely, those on May 31st, 1909 ; on Dec. 15th, 16th, and 25th, 1910 ; and on Jan. 18th, (at 5. 20. 58 and 9. 27. 49 p.m.), April 3rd, and Oct. 22nd, 1911. Fig. 44 relates, on the other hand, to the eruption of Dec. 14th, 1912, and the three special outbursts on Dec. 7th, 1909 ; Dec. 2nd, 1910 ; and May 8th, 1911 ; in each of these cases the sound area having notably extended to the NE from the mountain.\*

From Fig. 43 it will be noticed that the sound was heard most frequently, on the E. or around the mountain, in an oval area stretching to the E slightly S ; the approximate mean radius of the sound area at the NW, W, and SW sides being about 50 km. Off in the west the sound was heard most frequently along an arcual zone stretching from the S part of Noto to the

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\* The sound areas of the different explosions in 1909 to 1911 are given in the Bulletin, Vol. VI.

Fig. 43. Sound Areas of the 19 Strong Asama-yama Explosions in 1909-1913.

The curves are the mean lines of equal sound frequency, indicated by the respective numbers.

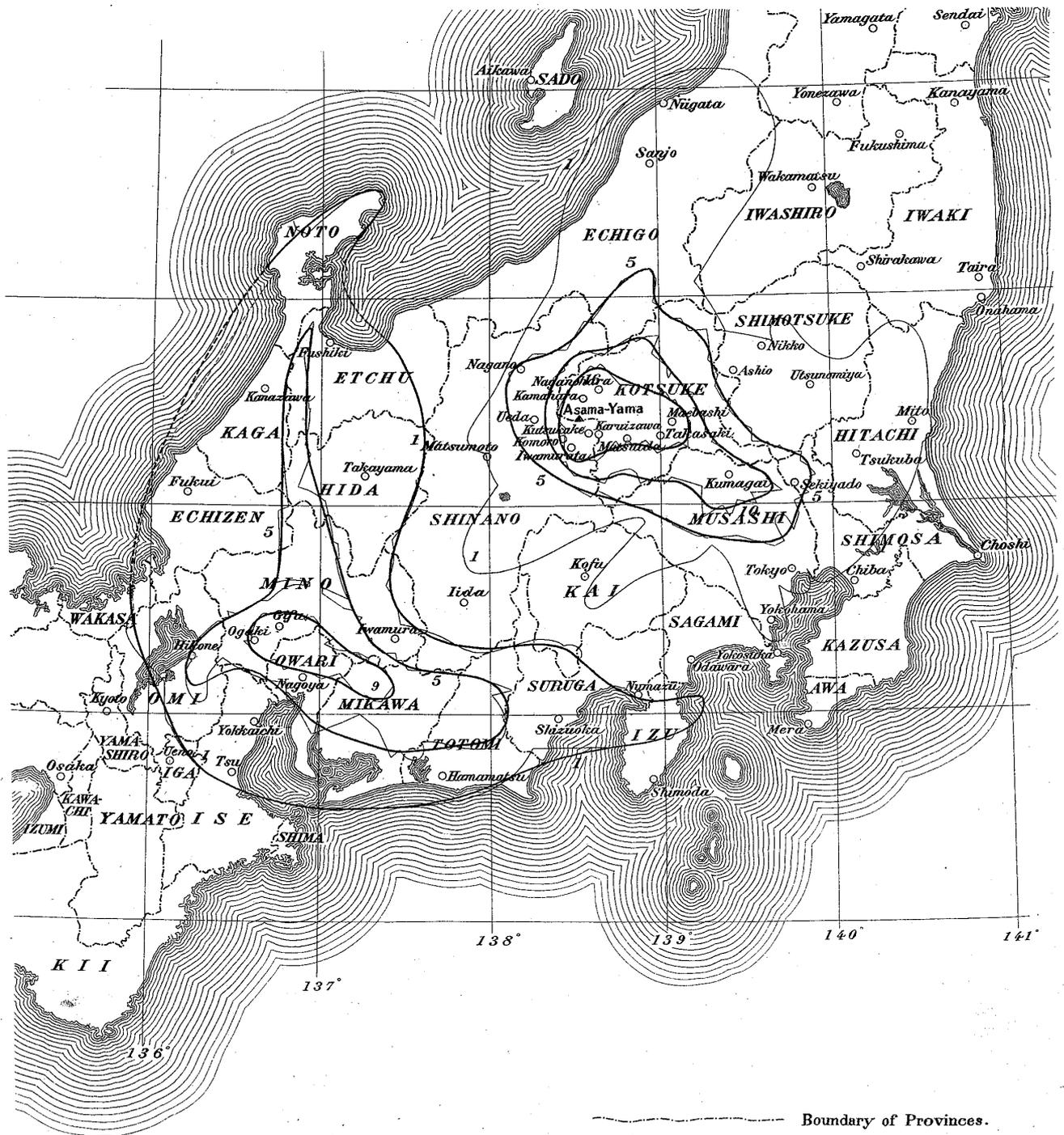
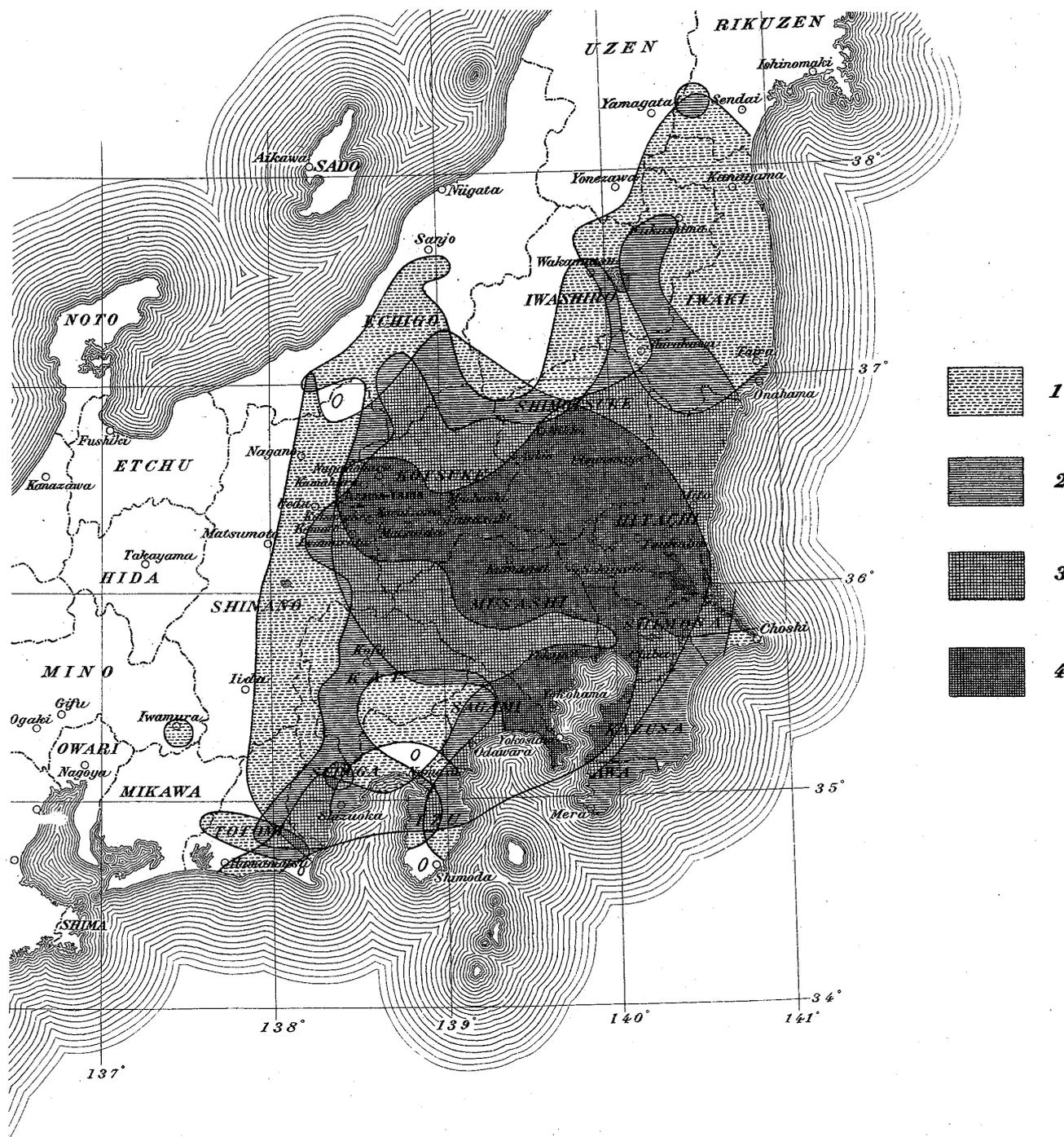


Fig. 44. Sound Areas of the 4 Strong Asama-yama Explosions on Dec 7th, 1909; Dec. 2nd, 1910; May 8th, 1911; and Dec. 14th, 1912.

The four frequencies of 1, 2, 3, 4 are indicated by different red shades. (0)...No sound heard.



Boundary of Provinces.

W. part of Suruga, at an average radial distance of about 170 km, whose central part is to the S 45° W from the Asama-yama. The approximate mean value of the internal (concave side) radius of the western branch sound area, which is of a crescent form, is about 130 km, while its maximum external (convex side) radius is about 270 km.

From what has been said above, it will be seen that the zone of silence is bounded by two nearly concentric arcs at the mean distances respectively of 50 and 130 km from the volcano. This conclusion is to be regarded as applicable to the majority of the Asama-yama explosions, and requires a modification for the cases of the outbursts with specially extensive sound areas, namely, those taken into consideration in the construction of Fig. 44, for which the detonation became audible in a part of the silence zone indicated in Fig. 43.

The greatest distance of propagation of the audible sound of the Asama-yama explosions was about 276 km to the NE and 290 km to the SW.

**30. Repetition of sounds.** In the cases of the strong explosions in 1913, the detonation was each time repeated twice or thrice at several places scattered throughout the western branch area, which is thus to be regarded essentially as a multiple-sound region. This fact is supplementary to the discussion respecting the 2-sounds and 3-sounds propagations given before, (the *Bulletin*, Vol. VI, p. 76), and it is interesting that the mean radius of the inner boundary of the western branch area (=130 km) is approximately equal to the distance (=120 km) of the boundary of the 2 and 3 sounds zones to the east of the Asama-yama. To the E, N, and S from the volcano the repetition of sounds occurred, in 1913, only at a few places in the province of Kotsuke and Echigo.