

#### CHAPTER IV. PROPAGATION OF SOUND WAVES WHICH ACCOMPANIED THE SAKURA-JIMA OUTBURSTS OF 1914.

**23. Report of Kagoshima meteorological observatory on the course of eruption.** The following is a summary of the report of the Kagoshima meteorological observatory on the earlier course of the eruption at the Yokoyama, or west, side of Sakura-jima:—

On the 12th (Jan., 1914), at 8 a.m., white smokes like cloud or mist were seen ascending at the W. side of Kita-dake, while at 9.10 a.m. similar white smokes were thrown up from the top of Minami-dake. The first eruption consisted in the projection at 10.05 a.m. of a mass of black smokes from the valley above the village of Akamizu, at an elevation of 350 to 400 m above sea-level; at 10.10 a.m., fires were observed shooting out from the base of the smoke column, and sounds began to be heard. At 11 a.m., the black smokes ascended vertically to a height of about 3000 m, and at 10.30 a.m. the thick projection and falling down of lava fragments became visible, while the doors and shojis began to be rattled by the air shakings. At 2.30 p.m., black and white smokes enveloped the entire island, and the eruptive sounds increased in violence, till the detonations began to be heard at 3.30 p.m. At the severe earthquake shock of 6.30 p.m., the burning of the mountain was further enlarged and the detonations became still more powerful. At 10 p.m., the explosive sounds were further reinforced, reaching their climax about 1 a.m., on the 13th.

On the 13th, the sounds, which gradually decreased from 6 a.m., still occurred incessantly during the day time. At 5 p.m., the wind was southerly, the right-hand side of the island becoming

visible. At 8. 14 p.m., the volcanic fire-outbursts were exhibited in a grand scale and lava streams began to flow down, while red-hot rock fragments covered the mountain slope, from top to base, setting on fire the villages to the north of Hakamagoshi. The detonations occurred in continuous succession, and from the black smokes, which were thrown eastwards, lightnings flashed out in various directions. At 8. 30 p.m., the detonations ceased and the volcanic sounds became intermittent in occurrence; the shakings of the doors and shojis also ceasing.

On the 14th, after 1 a.m., the smokes were still abundant, but the sounds occurred at longer intervals. At 7 a.m., the lava streams, from which some strong explosions took place, approached to about 5 *cho* (5½ km approximately) above Hakamagoshi. The floating lava fragments, which converted the entire sea surface about the Oko-jima into a field of pumice of dark colour, drifted before noon toward the south. At 5 p.m., the fumarole phenomena from the lavas decreased to a certain degree. During the night, the activity was principally exhibited from the craterlets situated to the east of the village of Yokoyama at an elevation of 200 m above sea-level.

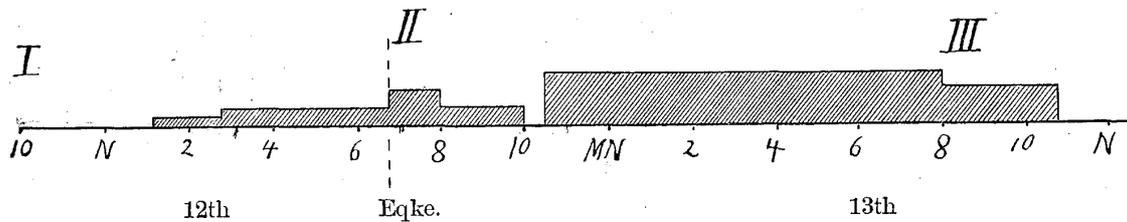
The precipitation of ash took place from 11.10 a.m., 12th, to 8 p.m., 13th, the amount of accumulation being 108 *momme* per *tsubo*, or 123 grams per sq. m.\*

**24. Barogram at Kagoshima.** In fig. 24 is reproduced the barogram for Jan. 10th to 16th, 1914, obtained at the Kagoshima meteorological observatory; its diagrammatic representation being given in fig. 23. The barometric disturbance due to the eruption was very slight from the commencement at 10 a.m. till about 1 p.m., on the 12th, when an increase took place, remaining then in

\* 1 *momme* = 3.76 gram; 1 *tsubo* = 3.30 sq. m.

Fig. 23. Diagrammatic Representation of the Barogram obtained at Kagoshima during the Eruption (Jan. 12th and 13th, 1914).

The greater height or thickness in the diagram is intended to indicate an increased barometric disturbance.



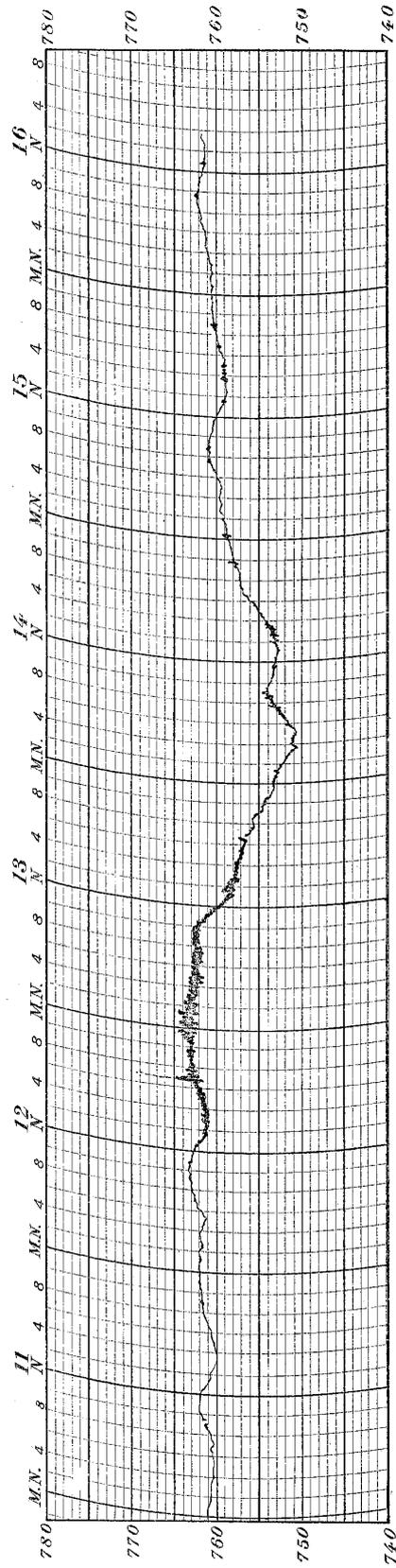
Correspondence to Sound Propagation and Ash-precipitation:

	Sound.	Ash.
I:	Reached to the "strong-sound zone"....	Caused "mists" at distant places.
II:	{ Became louder. Heard in much distant places.....	Precipitated as ash at distant places.
III:	Loud detonations ceased. ....	Became thicker in precipitation.

nearly the same condition for  $9\frac{1}{2}$  hours, till a little before 10 in the night of that day. Then, after nearly an hour of repose the atmospheric quakings became from  $10\frac{2}{3}$  p.m. doubly violent for nearly 12 hours, till  $10\frac{1}{2}$  a.m., on the 13th; the maximum activity being reached at 0 to  $1\frac{1}{2}$  a.m. of the latter day. Thereafter the disturbances became much reduced and smaller than in the afternoon of the preceding day, except that noted maximum groups occurred at 1 to  $2\frac{2}{3}$  p.m., 13th; about 8 to 9 a.m., and 2 to 4 p.m., 14th; and  $3\frac{1}{2}$  to 5 p.m., 15th. There were also single conspicuous disturbances at  $6\frac{1}{2}$  p.m., 13th;  $9\frac{1}{2}$  p.m., 14th;  $0\frac{1}{2}$  a.m., 15th;  $7\frac{1}{2}$  and  $8\frac{1}{2}$  a.m.,  $1\frac{1}{2}$ ,  $6\frac{1}{2}$ , and  $8\frac{2}{3}$  p.m., 15th; and at 9 a.m. and  $0\frac{1}{2}$  p.m., 16th. It may be noted that the trace of the severe earthquake at  $6\frac{1}{2}$  p.m. on the 12th, was followed for about an hour by increased barometric vibrations, so that it is likely that the seismic shock caused, or was followed by, a temporary increase in the explosive activity.

The account of Kagoshima meteorological observatory on the course of the eruption (§ 23) is on the whole in accord with the

Fig. 24. Barogram obtained at the Kagoshima Meteorological Observatory, Jan. 11th-16th, 1914.



indications of the barogram, which gives a faithful record of the progress of the explosive activity both of the detonative and non-detonative character.\* From what has been said in § 23, I believe the highly explosive stage of the eruption to have ended at about 6 a.m. on the 13th, and been succeeded for about  $4\frac{1}{2}$  hours, till  $10\frac{1}{2}$  a.m. on the same morning, by non-detonative explosions, namely, those which threw out a great quantity of smoke and ash, without being accompanied by very loud sounds.

The maximum amount (double amplitude) of the barometric disturbance at Kagoshima was about  $2\frac{1}{2}$  mm, the distance of the place of observation from the principal origin of explosion, supposed to be one situated near Hikinohira on the W., or Yokoyama, side of Sakura-jima, being about 8.6 km.

**25. Sound area.** In fig. 25 are indicated the places affected by the sound waves due to the outbursts of Sakura-jima on Jan. 12th and 13th, 1914. The area, in which the air commotions had no audible effects, but were strong enough to shake houses or doors and shojis, extended N.E.wards to the provinces of Bizen, Mimasaka, and Bitchu, in the vicinity of the city of Okayama, and also to the Kii peninsula and the S. part of Yamato, the greatest radial extension being about 585 km. The detonative sound was heard in Kyushu (except some of its W. portions), at the S.W. end of Honshu, the W. part of Shikoku, and in a small area extending over the Kii channel; the extreme radial distance being about 500 km. The sound area was of course included in the air-shakings area, their boundaries on the W., N.W., and S.W. sides being close to each other.

A note-worthy fact is that the sound was not heard within a small E.-W. area in central Kyushu, which stretches from the

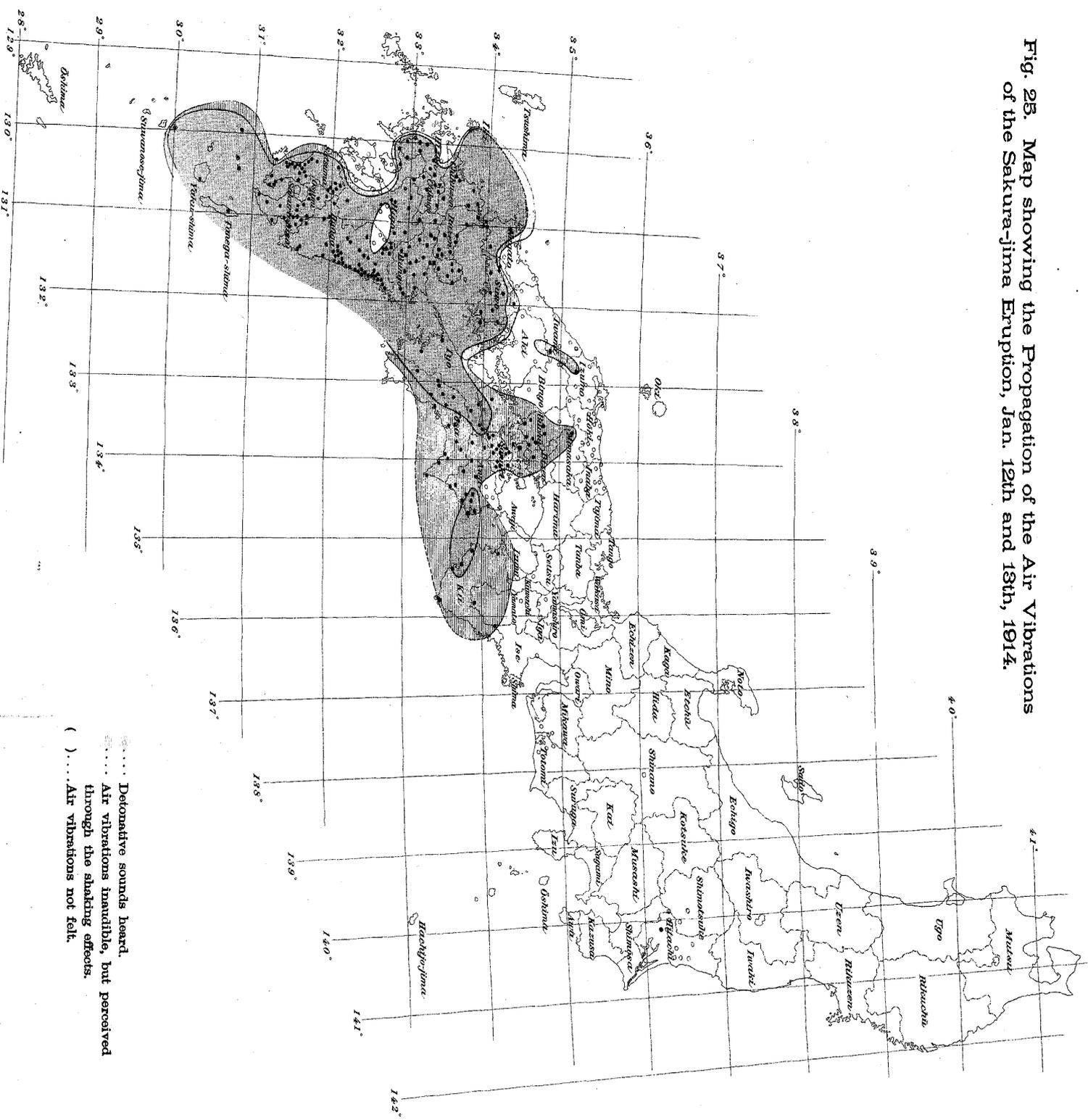
\* See the Bulletin, Vol. VII, p. 191.

central part of the province of Higo to the N.W. part of Hyuga, forming the "silence zone." (See also § 26.)

**26. Area in which volcanic sounds were heard earliest.** In fig. 28 are indicated the places where the detonative sounds of the Sakura-jima eruption were heard between a little past 10 and 11 in the morning, or in the afternoon hours, of the 12th (Jan., 1914). It will be observed that the sounds were heard earliest in the S.E. portion of Kyushu, comprising the E. half of Satsuma, the entire province of Ōsumi, and the S. half of Hyuga, and in a zone which stretches from the head of Ariake Sea in Kyushu to the S.W. part of Shikoku, comprising the N.E. portion of Hizen, the two entire provinces of Chikugo and Bungo, the E. half of Buzen, the N. part of Higo, and a portion of Iyo. It is quite remarkable that at many places in the N. half of Hyuga, the sounds were not heard at all, while in the central and S. portion of Higo the sounds were heard only at late hours at a few places; these regions forming the "silence zone" lying between the two above-mentioned districts where the sounds were perceived earliest and loudest.

**27. Relation between times of arrival of sound and of commencement of ash-precipitation.** In § 24, I expressed the view that the most active stage of the detonative explosions ended at 6 a.m. on the 13th (Jan. 1914), followed for about  $4\frac{1}{2}$  hours by the stage of powerful non-detonative explosions, when great amount of ash must have been freely emitted from the volcano. This supposition fits well with the course of the ash-precipitation, which became thicker about 11 hours after the commencement. As assumed in § 32, the ashes first precipitated at the different distant places seem to have been thrown out from Sakura-jima at about 6 p.m. on the 12th, when the powerful detonative explosions began. We may

Fig. 25. Map showing the Propagation of the Air Vibrations of the Sakura-jima Eruption, Jan. 12th and 13th, 1914.



..... Detonative sounds heard.  
 ..... Air vibrations audible, but perceived through the shaking effects.  
 ( ) ..... Air vibrations not felt.

now further assume that the ashes more copiously precipitated later on to be those due to the non-detonative stage of the eruption, whose commencement was at about  $11\frac{1}{2}$  or 12 hours after that of the violently detonative stage. (See fig. 23.)

**28. Relation between sound and ash-precipitation areas.** The ash-precipitation area and the *direct propagation branch* of the sound area of a *strong* volcanic outburst tend to extend in a similar easterly direction, on account of the prevalence of westerly winds in the higher atmospheric region. In the numerous recent explosions of Asama, the ash-precipitation area was always a narrow zone, which formed in larger eruptions approximately the middle axis of the sound area. Such was also the case with the tremendous outburst of Bandai-san in 1888, and seems to be the necessary consequence of a mere powerful explosion, shattering a portion of a mountain or bursting the hardened surface of lava mass at the bottom of a crater, accompanied by the production of a comparatively small amount of volcanic dust. On the other hand, the several eruptions of Asama, which were non-detonative, often caused a notable precipitation of ash.\*

In the Sakura-jima eruption of 1914, the individual explosions were not so violent as the stronger among the recent Asama-yama outbursts, while an enormous quantity of smokes and pumiceous matters were ejected simultaneously from at least half a dozen craterlets 100 to 150 m in diameter. Hence, as can easily be imagined the ash-precipitation area was much more extensive than the sound area; the greatest radius of the latter being 585 km, and that of the former not less than 1290 km.

**29. Duration of volcanic sounds and air shakings at distant places, on Jan. 12th and 13th, 1914.** In Table XVII is summarized the reports of dif-

\* See the *Bulletin*, Vol. VI, Part 1, and Vol. VII, Part 1.

ferent meteorological stations and other observing places at distances from Sakura-jima relating to the time of commencement and the duration of the sound and shaking effects. As will be seen from the graphical illustrations in fig. 30, the sounds became inaudible or were much weakened at the majority of places at 6 a.m. or thereabout, on the 13th (Jan.), this being the time when the loud detonations ceased to be heard in Kagoshima. With regards to the time of commencement of the sounds, there is also some correspondence among the different localities. Thus, in the distant provinces of Kii, Iyo, Tosa, and Sanuki, in Shikoku, and in the neighbourhood of Shimonoseki Strait (province of Suwo and part of Chikzen), the sounds, which were not strong, began to be heard first at about 6 p.m. on the 12th; this being the time when the detonations became louder in Kagoshima, and also at different places in the southern part of the province of Hyuga, lying at no great distance from Sakura-jima, and in the eastern part of Hizen. Again, at some places in the distant provinces of Suwo, Iyo, and Kōchi, the sounds were feeble and began at 2 to 4 p.m. (12th); this corresponding roughly to the time (about 2 p.m.) when the sounds became louder in Kagoshima, at the N.E. base of Mount Kirishima, and in the province of Bungo.

On the whole the sounds increased in intensity at about 2 p.m. in the eastern part of the strong-sound zone lying immediately to the N. of the silence zone (fig. 26), and then at about 6 p.m. in the S. part of Hyuga and at the W. part of the first named zone; these have corresponding phases in the Kagoshima barograph observation and mark the times when the explosive intensity of Sakura-jima was increased. The highly explosive stage of the eruption lasted for about 16 hours between 2 p.m., on the 12th, and 6 a.m., on the 13th.

**30. Sounds of after-explosions.** The following list gives a short account of the observation at different places of the sounds of the *after-explosions*, or small outbursts which occurred during several days following the great explosive stage of Sakura-jima eruption on the 12th and early morning of the 13th, Jan., 1914.

SOUNDS OF THE AFTER-EXPLOSIONS: TIME OF OCCURRENCE  
AT DIFFERENT PLACES.

MIYAZAKI PREFECTURE (Province of Hyuga):

*Miyazaki meteorological observatory.* 13th: 1.35-1.50 a.m.; 3.40-4.41 a.m.; 7.40-7.50 a.m.; 8.50 p.m., 3 times; 11.35 p.m. 14th: 6-7 a.m. 15th: 8.50-9.05 a.m.; 3.10 p.m.; 9.05 p.m., once; 9.40-11.30 p.m. 16th: 2.40 a.m., once, thence continued till 10.20 a.m.; 4 p.m.; 8.45 p.m., strong, once. 17th: 0.10 p.m. More or less till 20th. 21st: 8.18 a.m.; 2.30-6.00 p.m.

小林 *Kobayashi* (Nishi-Morokata County). 13th: throughout the day. 14th: throughout the day, there being a very loud detonation at 10.07 p.m. Occasional strong or feeble sounds till April.

加久藤 *Kakto*. 13th: 1.32-3.16 p.m., very loud; 5.02 p.m. 14th: 4.55 p.m. 16th till 17th, occasionally.

KAGOSHIMA PREFECTURE:

口之島 *Kuchino-shima*. Till the 19th, several times daily.

FUKUOKA PREFECTURE (Provinces of Chikzen and Chikugo):

*Fukuoka met. observatory.* 14th: 9.50.33 p.m., twice. 16th: 9.41.10 p.m., twice; 9.43.55 p.m., twice. 20th: 6.47.30 a.m., twice, with 2 sec. time interval.

柳川 *Yanagawa*. 11.47 a.m., 12th, till 4 a.m., 13th. 15th: 11 a.m.; 2.10 p.m.; 4.15 p.m.; 6.10 p.m.; 8.30 p.m. 19th: 1.53 p.m.; 11.50 p.m. 20th: 4.10 p.m.; 6.10 p.m.; 6.35 p.m.; 7.10 p.m.; 7.15 p.m. 24th: 3.35 p.m. 29th: 5.30 p.m.; 7.10 p.m.

福島 *Fukushima*. 14th: 10 p.m., twice.

久留米 *Kurume*. 16th: several times.

甘木 *Amaki*. 13th, 14th, 15th: several times each day. 29th: 5.40 p.m., twice.

## ŌITA PREFECTURE (Province of Bungo):

*Ōita met. observatory.* Till the 18th, occasionally.

日田 Hida. Till the 15th, occasionally.

## SAGA PREFECTURE (Province of Hizen):

*Saga met. observatory.* Till the 21st, 2 or 3 times daily.

伊萬里 *Imari.* 20th: 5.30 p.m., twice.

三養基 *Miyaki.* 14th: 0.30–1.00 p.m. 20th: 8.30 p.m.

神崎 *Kanzaki.* 13th: throughout the day. 14th: 10 p.m., loud detonation. 15th: 10 a.m., loud sounds, continuing till afternoon. 16th: 2 a.m. 20th: 1 a.m., twice.

武雄 *Takeo.* 14th: afternoon.

According to the above list, the eruptive sounds were heard mostly for about 10 days or much more at the following places:— (A), Kobayashi, Kakto, Kuchino-shima, and Miyazaki; and (B), Yanagawa, Fukuoka, Kurume, Amaki, Saga, Kanzaki, Miyaki, Ōita, and Hida. The (A) group places, belonging to the Kagoshima and Miyazaki prefectures, are at radial distances not exceeding 83 km; while the (B) group places, belonging to the Saga, Fukuoka, and Ōita prefectures are at radial distances varying from 177 to 223 km and are arranged along a zone parallel E.–W. nearly and across the northern part of Kyushu. The space between these groups of places, where volcanic sounds were not heard (at least, not reported) after the 12th and 13th (Jan. 1914), forms the usual *silence zone*. (See fig. 27.) It will be seen that the map is very similar to that (fig. 26) showing the distribution of the places where the detonation was heard very loudly on Jan. 12th, 1914.

Some of the sounds due to the explosions between the 13th and 16th, Jan. 1914, were very loud at Kanzaki (Hizen), and at Miyazaki, Kakto, and Kobayashi (Hyuga). Amongst the others, the detonation at about 10 p.m., on the 14th, was heard at Fukuoka, Fukushima, Kanzaki, and Kobayashi.

At Fukuoka and Amaki in Chikzen, and Imari and Kanzaki in Hizen, the volcanic detonation was generally composed of two sounds with a time interval probably of some 2 sec. This seems to be a phenomenon similar to what took place in the propagation of strong sound waves from the crater of Asama-yama.\*

**31. Propagation of strong detonative sounds.** The air disturbances caused by the outbursts of Sakura-jima were perceived as loud sounds in the E. portion of Satsuma, nearly the whole of Ōsumi, the S. half and the N.E. corner of Hyuga, the whole of Chikugo, nearly the whole of Bungo, the N. portion of Higo, the E. portion of Buzen, and the N.E. portion of Hizen, and at a number of places in the three Shikoku provinces of Tosa, Awa, and Iyo. As will be seen from Table XVII, the sounds were there in great many cases like gun boomings or thunder peals, accompanied by strong shakings of houses, doors, and shojis. With the exception of the Shikoku provinces, the first arrival of the perceptible air vibrations in these districts was generally in the fore-noon of the 12th (Jan. 1914).

As will be seen from the map (fig. 26), the sound waves of the eruption was perceived with great intensity in the following two districts:—(A), a semi-circular area occupying the S.E. portion of Kyushu, namely, the eastern portion of Satsuma, the whole of Ōsumi except its southern end, and the S. half of Hyuga; (B), an irregular arc or zone across the N. portion of Kyushu in an E.W. direction, namely, the whole of Bungo and Chikugo, the N.E. corner of Hyuga, the S.E. portion of Buzen, the N. portion of Higo, and the E. portion of Hizen. The formation of the (A) area is due to the direct eastward sound propagation from Sakura-jima, while the (B) area is separated from the other by the silence

\* See the Bulletin, Vol. VI, p. 75.

zone, including the S. portion of Hizen, the central and S. portions of Higo, and the N. portion of Hyuga. At several places in the (B) area, the detonations were extremely loud.

**32. Arrival of volcanic sound waves at different places.** Table XIX gives, with respect to the Sakura-jima outbursts on Jan. 12th and 13th, a comparison of the times of the first arrival at different places of the air concussions or vibrations, namely, of either the detonative sounds or the inaudible aerial waves causing shaking effects.

The comparison of the distribution of the time of the sound arrival in Kagoshima prefecture (provinces of Satsuma and Ōsumi) with those in all the other prefectures noted in Table XIX is as follows :—

**TABLE XV. TIME OF FIRST SOUND ARRIVAL AT DIFFERENT PLACES IN KAGOSHIMA PREFECTURE COMPARED WITH THOSE FOR OTHER PREFECTURES.**

Kagoshima Prefecture.		Other Prefectures.	
Time of Commencement.	Number of Places.	Time of Commencement.	Number of Places.
10-10 $\frac{2}{3}$ a.m. ....	52	10-10 $\frac{1}{2}$ a.m. ....	20
11-11 $\frac{1}{2}$ a.m. ....	3	11-12 a.m. ....	16
		1 p.m. ....	6
2 p.m. ....	3	2 p.m. ....	3
3 p.m. ....	1	3 p.m. ....	3
		4-4 $\frac{1}{2}$ p.m. ....	11
		5-5 $\frac{1}{3}$ p.m. ....	8
6-6 $\frac{1}{2}$ p.m. ....	8	6-6 $\frac{5}{8}$ p.m. ....	17
		7-7 $\frac{1}{2}$ p.m. ....	5
		8 p.m. ....	1
		9 p.m. ....	2
		10 p.m. ....	1
		12 p.m. ....	1

From Tables XVIII and XIX, it will be seen that the air vibrations began to arrive, (i), for a great majority of places at 10 to 10½ a.m., and in the next instance, (ii), at about 6 p.m., on the 12th. The first of these two epochs corresponds of course to the commencement or earlier part of the eruption, while the second probably marks the time when the latter entered on the more explosive stage. Naturally the sounds were heard at the earlier epoch (i) at several places in the Kagoshima and Miyazaki prefectures near the volcano. This was, however, also the case to a notable extent in the Ōita, Fukuoka, Kumamoto, and Saga prefectures (provinces of Bungo, Buzen, Chikzen, Chikugo, and Hizen, and the N. part of Higo), which is separated by the *silence zone* from the neighbourhood of Sakura-jima. (See §§ 30 and 31.) The sound waves arrived at the later epoch (ii) at places further distant from the volcano, in the prefectures of Kōchi (Tosa), Yamaguchi (Suwo and Nagato), Okayama (Bizen, Bitchu, Bingo, and Mimasaka), etc. In the Nagasaki prefecture (Hizen), which is situated to the N.W. from Sakura-jima, the air waves were perceived also at the (ii) epoch.

**33. Remarks on sound areas.** What has been stated in §§ 25, 26, 30, and 31, with regards to the propagation of the eruptive sounds in their different aspects, is summarized in the following table, in which (A) is the area of direct sound propagation, or that including the volcano itself, and (B) the detached sound area situated to the north of the silence zone and extending nearly in an E.W. direction.

TABLE XVI. SOUND-AREAS AND SILENCE ZONE OF THE  
SAKURA-JIMA ERUPTION, 1914.

Sound Area. (R=Radial Distance)	Strong sound. (Fig. 26.)	Sounds of after- eruptions. (Fig. 27.)	Earlier sound propagation. (Fig. 28.)	Mean.	General sound pro- pagation. (Fig. 25.)
<b>A Area.</b>					
R, max. (N.E.)	114 km	102 km	111 km	110 km	— km
<b>B Area.</b>					
Inner boundary: R, max.	153	186	158	166	—
„ R, min.	139	158	140	146	114
„ R, mean.	152	173	144	156	—
Outer boundary: R, max.	247	230	{ 248 (N.); 373 (N.E.)	—	140
„ R, min.	195	210	200	202	—
„ R, mean.	215	225	—	220	—
Central line: R, mean.	177	196	195	<b>190</b>	—
Width, max.	107	—	112	110	—
„ mean.	68	64	93	75	—
<b>Silence Zone.</b>					
Central line: R, (N.E.).	135	116	135	129	—
„ R, (N.).	104	—	105	105	—
„ R, (N.N.W.).	—	128	—	—	—
„ R, mean.	.....	.....	.....	.....	<b>127</b>
Width: E. part.	51	108	44	—	—
„ Central part.	—	108	—	—	26

From the above table we see that the extensions and distances of the propagation areas remained nearly alike in the three cases of the strong detonation, and of the sounds of the after-explosions and of the earlier portion of the main eruption (figs. 26, 27, and 28). Thus, the maximum radius of the (A) area, in the N.E. direction, had the mean length of 110 km, while the mean radii of the inner and outer boundaries of the more or less arcual (B) area were respectively about 156 and 220 km, with the mean width, or N.S. dimension, of about 75 km. It is interesting that

Fig. 26. Map of Kyushu, indicating the Propagation of the Strong Detonative Sounds.

(●).....Loud sounds heard.

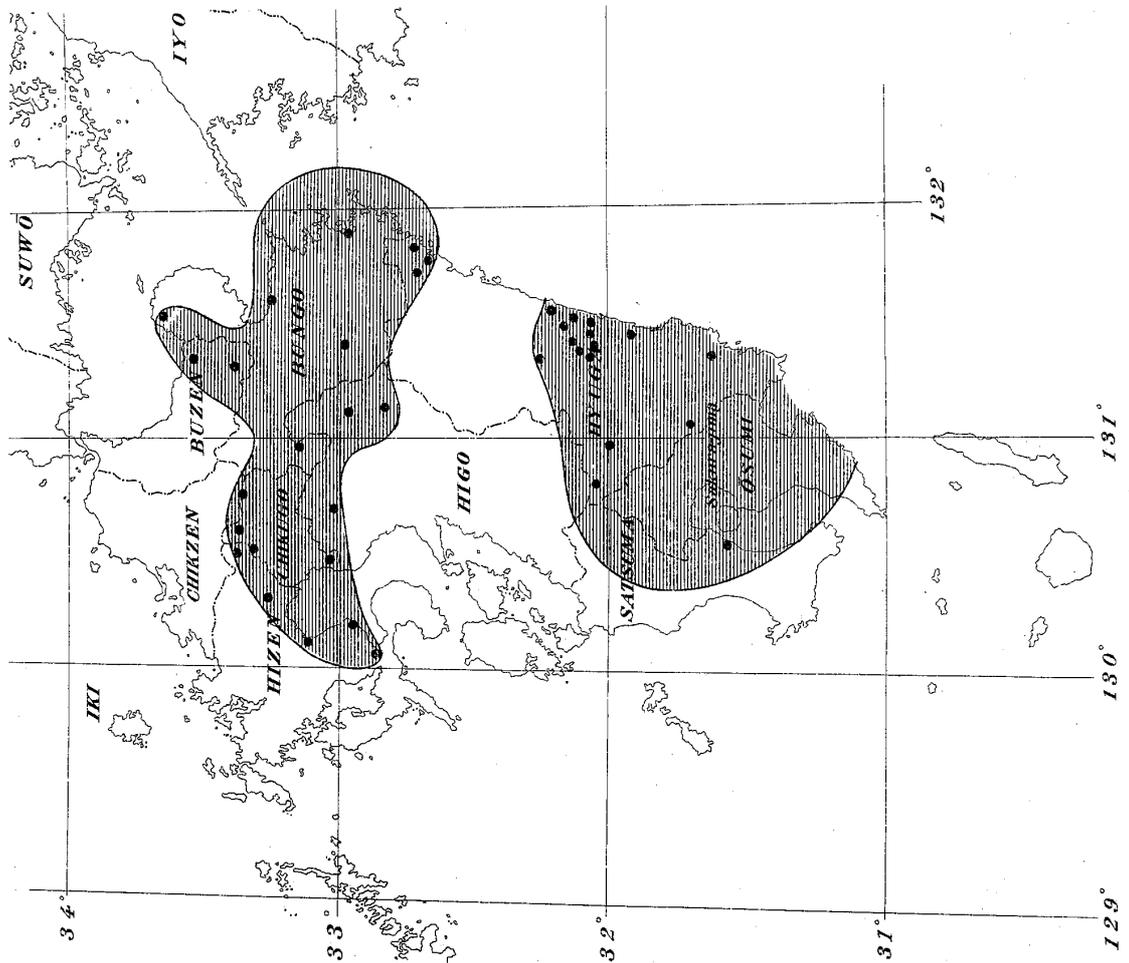
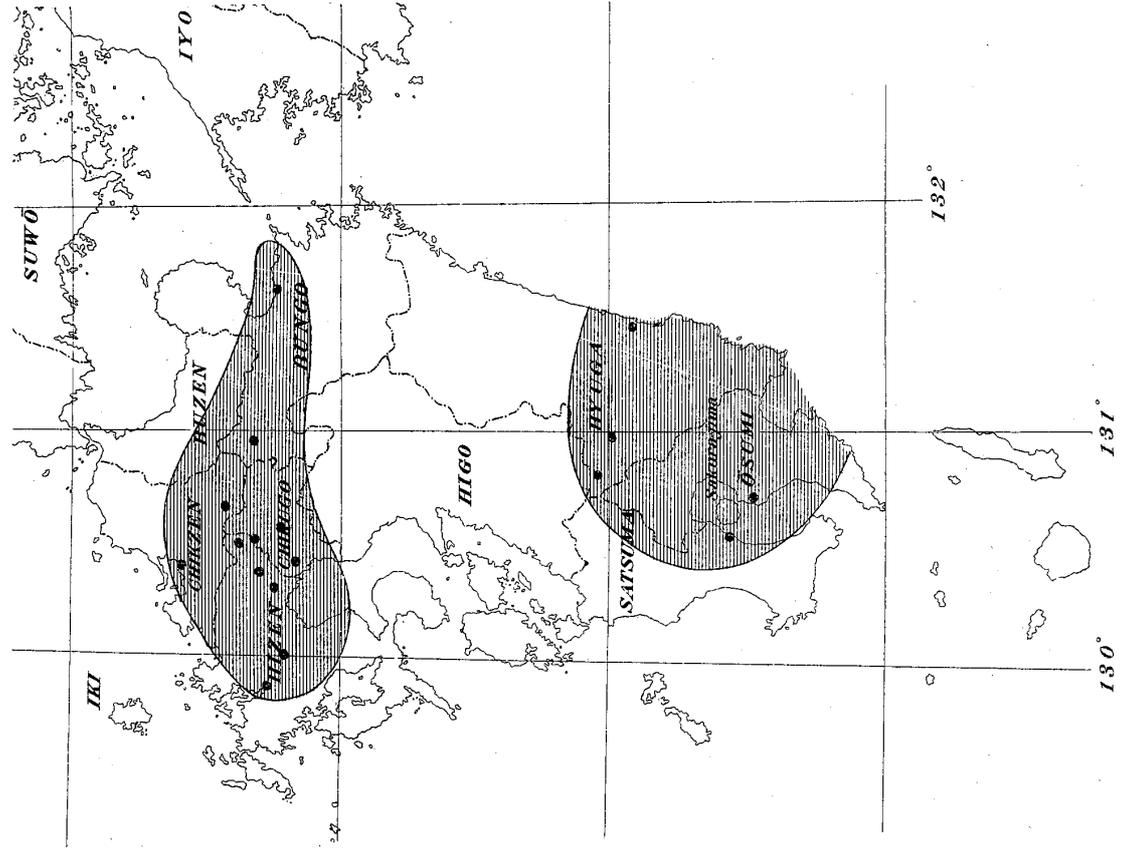


Fig. 27. Map of Kyushu, indicating the Propagation of the Sounds of the After-eruptions.

(●).....Sounds heard on or after Jan. 14, 1914.



Sakura-jima Eruption of Jan. 1914.

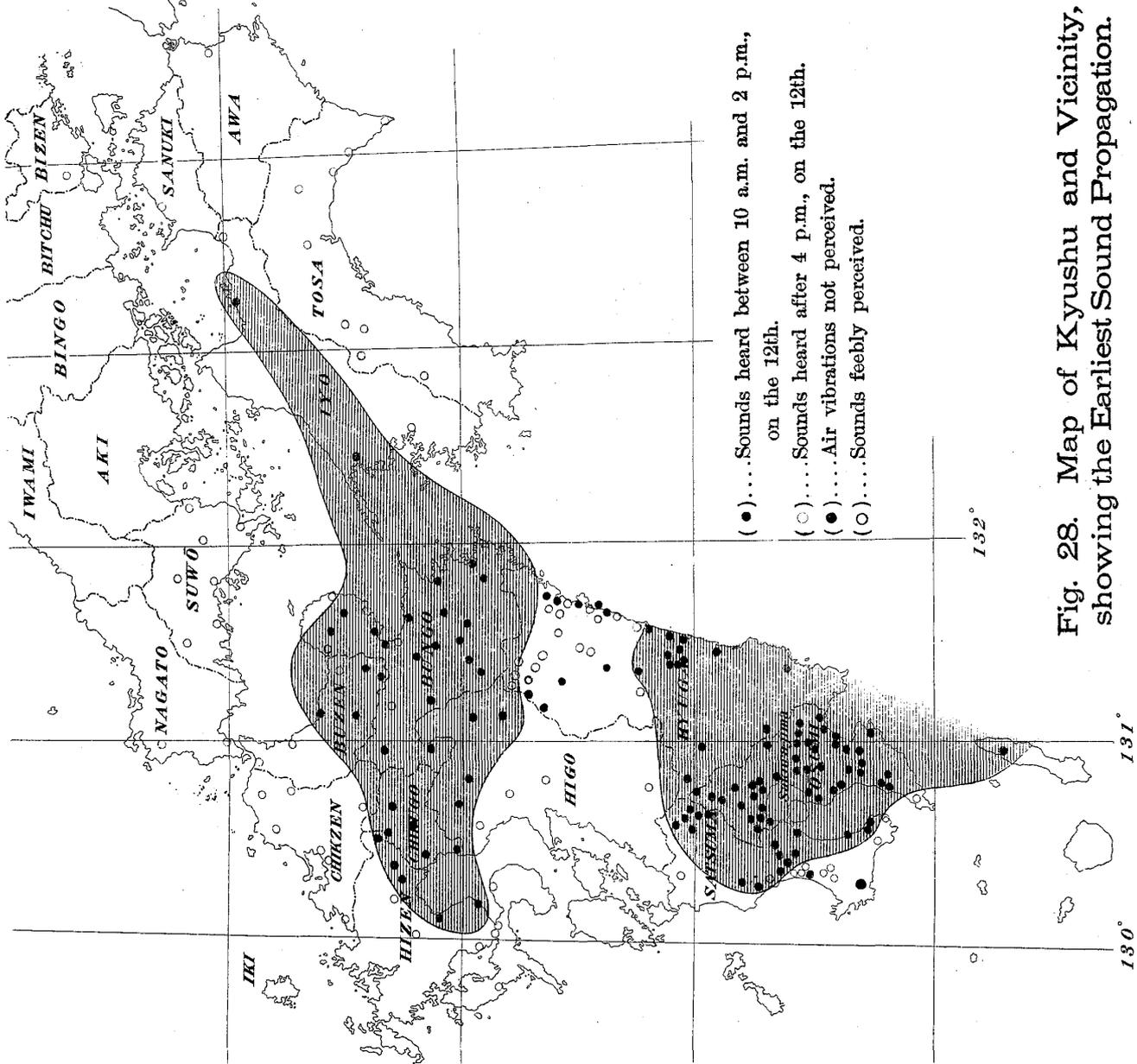


Fig. 28. Map of Kyushu and Vicinity, showing the Earliest Sound Propagation.

Fig. 29. Map of Kyushu, indicating the Area of Ash-Precipitation on Jan. 17th, 1914.

(●).....Place where the ash-precipitation took place.

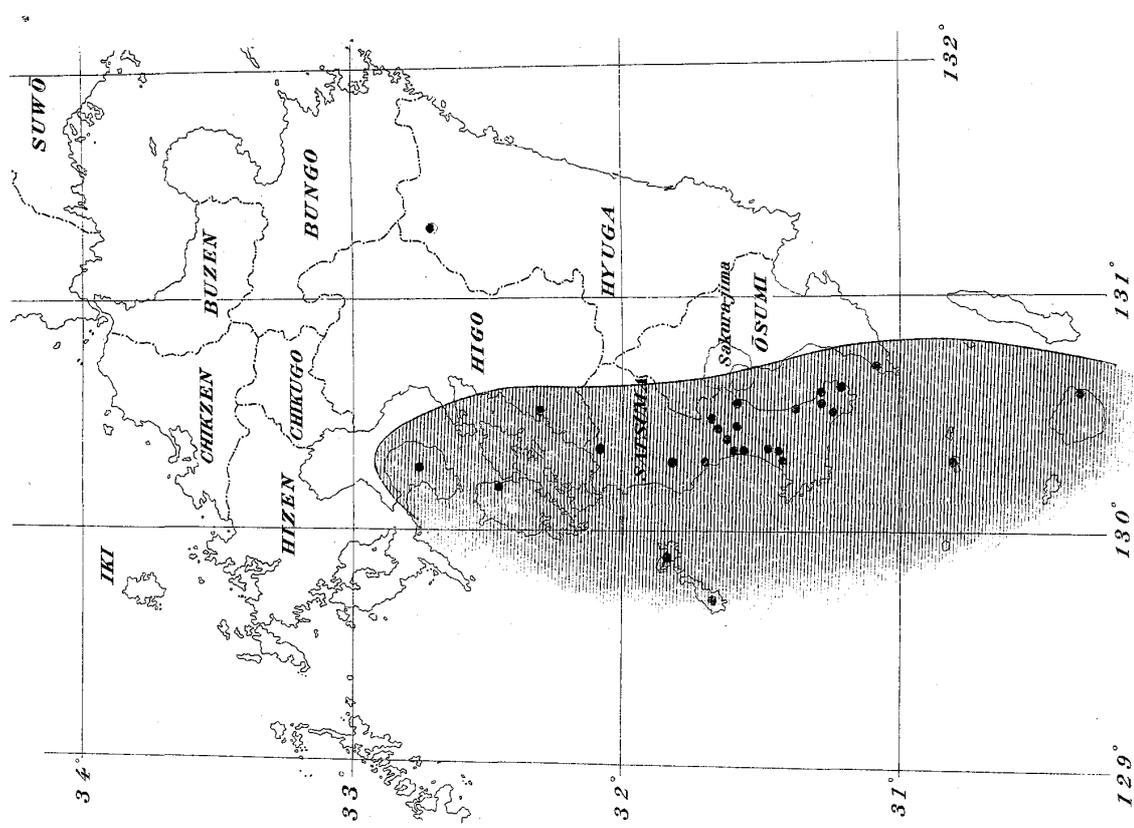
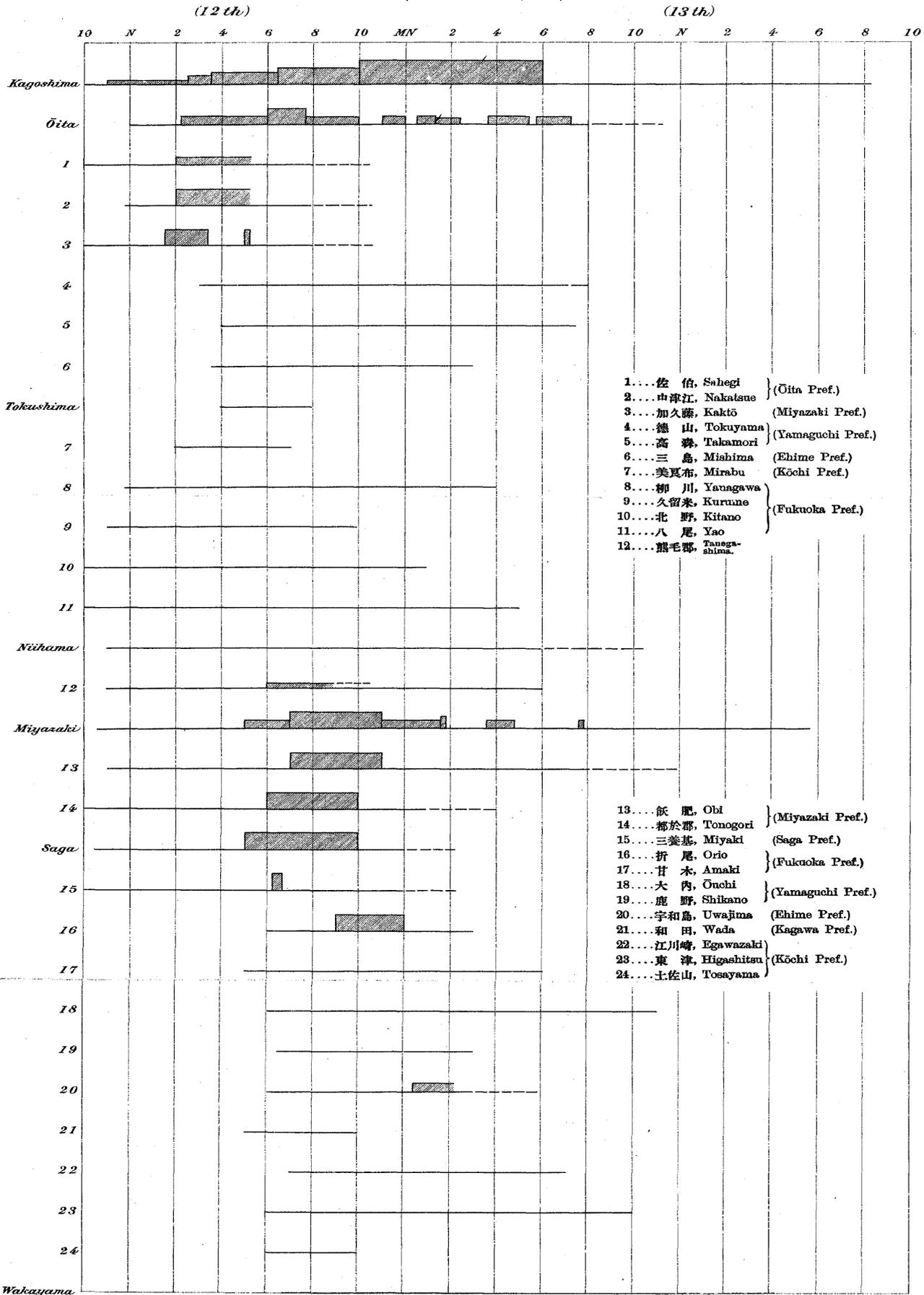


Fig. 30. Diagrammatic Representation of the Times of Arrival of the Successive Sound Phases at different places.

(Jan. 12th and 13th, 1914.)



(In each diagram, the greater height or thickness is intended to indicate an increased sound intensity.)

the average value of the radius of the middle point in the (B) zonal area is 190 km and practically identical with the result obtained for the case of the Asama-yama explosions, in which the centre of the detached sound area was westwards at a distance of 186 km from the volcano. (See the Bulletin, Vol. VII, fig. 43.)

The width of the silence zone was, as may be expected, great and equal to about 108 km in the case of the comparatively feeble sounds of the after-explosions; being much smaller, and about 40 to 50 km, in the case of the stronger sounds. Yet the middle axis of the silence zone was at a nearly constant radial distance of about 120 km; this being again approximately equal to the mean distance for the case of the general sound propagation during the first two days of the eruption, (fig. 25), in which the silence zone was reduced to a very small space, of inner and outer radii respectively of 114 and 140 km, (with the width of only 26 km, and the length of 65 km), the centre being at a distance of 127 km from Sakura-jima.

TABLE XVII. DURATION OF VOLCANIC DETONATIONS AT DIFFERENT PLACES.

(The time relates, if not otherwise mentioned, to the 12th of Jan., 1914.)

Prefecture. (Province).	Place.	Occurrence of Sounds and Air Shakings.
Miyazaki. (Hyuga.)	Miyazaki Met. Observatory.	Sounds like distant thunders, (with very slight shaking effects), from 10.30 a.m., thence gradually increasing. Air shakings stronger since 5 p.m., 12th, maximum in force at 10.20-11.05 p.m., thence slightly decreasing. (The sounds remained in the mean-while nearly constant in intensity.) Stronger again at 1.35-1.50; 3.40-4.51; 7.40-7.50 a.m., 13th; thereafter feebler.
	Miyazaki county office.	(Sounds, from 10.40 a.m., strongest at 7-10 p.m., 12th; declining from 6 p.m., 13th.
	飫肥 Obi.	Sounds, from 11 a.m., strongest at 7-11 p.m.

TABLE XVII. (Cont.)

Prefecture. (Province.)	Place.	Occurrence of Sounds and Air Shakings.
Miyazaki. (Hyuga.)	加久藤 Kakto.	{ Sounds, from 10.03 a.m.; strong and like boomings of guns in battle, with air shakings, from 1.32 to 3.16 p.m., also at 5.02 p.m.
	都於郡 Tonogori.	{ Sounds, from 10 a.m., stronger after 6 p.m. Air shakings, from 1 p.m.; very strong from 6 p.m.
Ōita. (Bungo.)	Ōita Met. Observatory.	{ Sounds: from noon, like distant thunders; from 2.10 p.m., like boomings of guns (with strong shakings); strongest at 6-7½ p.m., thence lessening in intensity. Between 11 and 12 p.m., 5 or 6 detonations. 0.30-1.10 a.m. (13th), quiet; 1.10-2.20 a.m., some weaker sounds; 3.40-5.20 a.m., stronger again; 5.45-7.10 a.m., very strong, thereafter weakening.
	佐伯 Sahegi.	{ 10 a.m., strong shakings; 2 p.m., sounds like boomings of guns.
	中津江 Nakatsuye.	{ 11.50 a.m., sounds like boomings of guns; 2 p.m., very strong.
Kumamoto. (Higo.)	Kumamoto Met. Observatory.	{ 4.25-30 p.m., faint sounds like distant thunders.
Saga. (Hizen.)	Saga Met. Observatory.	{ From morning, sounds like gun boomings; 5-10 p.m., stronger.
	三養基 Miyaki.	{ Sounds, from 10 a.m., strongest at 6.10-6.30 p.m.
Kagoshima. (Satsuma.)	Tanega-shima.	{ Sounds like gun boomings, accompanied by shakings, began at 11 a.m. and increased in force toward the evening, continuing till 6 a.m., 13th.
Fukuoka. (Chikzen, Chikugo, Buzen.)	柳川 Yanagawa.	{ Sounds, from 11.47 a.m. to 7 p.m.; more or less till 4 a.m., 13th.
	大牟田 Omuta.	{ Sounds at 11 a.m.; stronger from 4 p.m., with shakings.
	久留米 Kurume.	Sounds, from 11 a.m. to 10 p.m.
	北野 Kitano.	Sounds, from 10 a.m. to 1 a.m., 13th.
	甘木 Amaki.	Sounds, from 5 p.m. (12th) to 6 a.m., 13th.
	東郷 Togo.	Sounds, from 9 p.m. (12th) to 1 a.m., 13th.
	折尾 Orio.	{ Sounds from 6 p.m.; strongest from 9 to 12 p.m.; continued till 3 a.m., 13th.
八屋 Hachiya.	{ Sounds, from 10 a.m. to 4 p.m.; also from 5 p.m. (12th) to 5 a.m., 13th.	

TABLE XVII. (Cont.)

Prefecture. (Province.)	Place.	Occurrence of Sounds and Air Shakings.
Kōchi. (Tosa.)	江川崎村字下山 Shimoyama.	Sounds, from 7 p.m. (12th) to 7 a.m., 13th.
	東津野村芳生野 Yoshibuno.	Sounds, from 6 p.m. (12th) to 10 a.m., 13th.
	土佐山村桑尾 Kuwao.	Sounds, 6-10 p.m.
	美良布村上野尻 Kaminojiri.	Sounds, 2-7 p.m.
Ehime. (Iyo.)	Niihama Met. Observatory.	{ Sounds like gun boomings, from a little before noon till evening. Shojis shaken till morning, 13th.
	宇摩郡三島 Mishima.	{ Slight shakings, from 3.40 p.m. till 3 a.m., 13th.
	八幡濱 Yawatahama.	{ Sounds, from 6 p.m., strongest at 0.20 a.m., 13th.
Kagawa. (Sanuki.)	和田 Wada.	Shakings, from 5 to 10 p.m.
Yamaguchi. (Nagato, Suwo.)	大内村 Ōuchi.	Sounds, from 6 p.m. (12th) to 11 a.m., 13th.
	徳山 Tokuyama.	„ „ 3 p.m. (12th) to 8 a.m., 13th.
	高森 Takamori.	„ „ 4 p.m. (12th) to 7½ a.m., 13th.
	鹿野 Shikano.	„ „ 6½ p.m. (12th) to 3 a.m., 13th.
Tokushima. (Awa.)	Tokushima Met. Observatory.	Sounds, with shakings, 4-8 p.m.
Wakayama. (Kii.)	Wakayama Met. Observatory.	Sounds, from 6½ p.m. to 13th, afternoon.

TABLE XVIII. LIST OF PLACES WHERE ON JAN. 12TH, 1914, STRONG VOLCANIC DETONATIONS WERE OBSERVED.\*

(The time relates, if not otherwise mentioned, to the 12th of Jan., 1914.)

Place.	Time of Commence- ment of Detonations.	Intensity of Detonations.
Miyazaki Prefecture. (Province of Hyuga.)		
都之城 Miyakonojō.	10 a.m.	Loud, shaking doors and shojis very much.
小林 Kobayashi.	10 a.m.	Very strong.
高鍋 Takanabe.	Noon.	{ Like boomings of guns, shaking doors and shojis.

\* In the Kagoshima prefecture, the sounds were loud in the E. portion of Satsuma and in nearly the whole of Ōsumi.

TABLE XVIII. (Cont.)

Place.	Time of Commencement of Detonations.	Intensity of Detonations.
Miyazaki Prefecture. (Province of Hyuga.)		
富田村 Tonda.	—	Strong, with much shakings.
新田村 Niuda.	—	<i>Do.</i>
都於郡村 Tonogōri.	10 a.m.	{ Stronger after 6 p.m., and accompanied by air shakings after 1 p.m.
三財村 Sanzai.	—	{ Very violent and like thunders; shakings also very strong.
三納村 Minō.	—	{ Violent, air shakings also being excessive as to render habitation in houses with glass windows dangerous.
川南村 Kawanami.	—	Strong, like distant thunders.
東米良村 Higashi-mera.	—	<i>Do.</i>
木城村 Kijō.	—	Strong, with shakings.
上穂北村 Kami-Hokita.	—	<i>Do.</i>
北川村 Kitagawa.	—	Strong, with much shakings.
南浦村 Minami-Ura.	2 p.m.	Violent.
北浦村 Kita-Ura.	—	Strong.
宮崎町 Miyazaki.	—	<i>Do.</i>
飫肥町 Obi.	11 a.m.	Violent.
加久藤 Kakto.	—	Very strong and like gun boomings in battle.
Ōita Prefecture. (Province of Bungo.)		
大分町 Ōita.	Noon.	{ Strong, like boomings of guns, with excessive shakings.
佐伯町 Sahegi.	10 a.m.	{ Began with strong shakings; sounds like boomings of guns, from 2 p.m.
三重村 Miye.	10 a.m.	{ Like boomings of guns, with very strong shakings.
竹田村 Takeda.	10 a.m.	<i>Do.</i>
中津江村 Nakatsuye.	11.50 a.m.	Like boomings of guns, with violent shakings.
津房村 Tsubusa.	—	Very strong in the afternoon.
四日市村 Yokkaichi.	—	Strong from 1 p.m.
東都甲村 Higashi-Togo.	Forenoon.	Excessively strong in the night.

TABLE XVIII. (Cont.)

Place.		Time of Commencement of Detonations.	Intensity of Detonations.
Kumamoto Prefecture. (Province of Higo.)			
高森	Takamori.	Noon.	{ Like boomings of distant guns. Some doors and shojis were overthrown.
宮地	Miyazi.	—	Detonations were excessive.
山鹿	Yamaga.	10 a.m.	Like boomings of guns.
Saga Prefecture. (Province of Hizen.)			
三養基	Miyaki.	10 a.m.	{ Violent, like boomings of guns or distant thunders.
藤津	Fujizu.	8 a.m.	{ From 6-7 p.m. the sounds became louder, and like the reports of guns fired at some distance. Heard toward S.E.
佐賀	Saga.	Morning.	{ Like boomings of guns, accompanied by shakings; strongest at 5 p.m. Heard toward S.E.
Nagasaki Prefecture. (Province of Hizen.)			
小長井	Konagai.	10 a.m.	{ Excessively strong, and like boomings of guns; accompanied by shakings. Heard toward S.
諫早	Isahaya.	—	Strong, like distant thunders. Heard toward S.
Fukuoka Prefecture. (Province of Chikzen, Chikugo, Buzen.)			
大牟田	Ōmuta.	11 a.m.	{ Like distant thunders, with shakings; strong from 4 p.m.
久留米	Kurume.	11 a.m.	Very loud in the afternoon.
北野	Kitano.	10 a.m.	{ Like boomings of guns; shakings became violent from 5-6 p.m., 13th.
吉井	Yoshii.	5 p.m.	Very strong after 3 p.m., 13th.
折尾	Orio.	6 p.m.	{ Like boomings of guns; very strong from 9 to 12 p.m.
八屋	Hachiya.	10 a.m.	Strong, with slight shakings.
Kōchi Prefecture. (Province of Tosa.)			
江川崎村字下山	Shimoyama.	7 p.m.	Rolling sounds continued throughout the night.
大野見村字吉野	Yoshino.	3 p.m.	Shakings strongest at 5 a.m., 13th.
地藏寺	Zizoji.	—	Shakings strong at 6 p.m., 13th.
Tokushima Prefecture. (Province of Awa.)			
日野谷	Hinoya.	Afternoon.	Shook as in a strong earthquake.

TABLE XVIII. (Cont.)

Place.	Time of Commencement of Detonations.	Intensity of Detonations.
Yehime Prefecture. (Province of Iyo.)		
宇和島 Uwajima.	6 p.m.	{ Like boomings of guns, shaking shojis slightly. Very strong after midnight.
八幡濱 Yawatahama.	6 p.m.	{ Loud detonations, causing slight shakings; heard toward S.W.

TABLE XIX. SOUNDS OF SAKURA-JIMA ERUPTIONS OBSERVED AT DIFFERENT PLACES.

(The time relates, unless otherwise mentioned, to the 12th of Jan., 1914.)

Prefecture. (Province.)	Time of Comm't	No. of Places.	Time of Comm't	No. of Places.	Time of Comm't	No. of Places.
Kagoshima. (Satsuma, Ōsumi.)	{ 10-10 $\frac{3}{4}$ a.m. .. 52 11-11 $\frac{1}{2}$ a.m. .. 3		{ 2 p.m..... 3 3 p.m..... 1		6-6 $\frac{1}{2}$ p.m. .... 8	
Miyazaki. (Hyuga.)	10 $\frac{1}{2}$ -11 a.m. .. 5		—		—	
Ōita. (Bungo.)	10-12 a.m. .... 21		{ 1-2 p.m..... 2 3 p.m..... 2		4 p.m..... 2	
Kumamoto. (Higo.)	10-12 a.m. .... 4		—		4 $\frac{1}{2}$ -7 p.m. .... 5	
Saga. (Hizen.)	8-10 a.m. .... 2		2 p.m..... 1		5-6 p.m..... 2	
Nagasaki. (Hizen.)	10 a.m. .... 1		—		4-6 p.m..... 4	
Fukuoka. (Chikzen, Chikugo, Buzen.)	11 a.m. .... 6		1-2 p.m..... 2		{ 5-7 p.m. .... 5 9-11 p.m. .... 3	
Yehime. (Iyo.)	11 $\frac{1}{2}$ a.m..... 1		3 p.m..... 1		6 p.m..... 1	
Kōchi. (Tosa.)	—		2 p.m..... 1		{ 4-5 p.m..... 2 6 p.m..... 3 7-9 p.m..... 3	
Kagawa. (Sanuki.)	—		1 p.m..... 2		5 p.m..... 1	
Yamaguchi. (Suwo, Nagato.)	—		1-3 p.m..... 2		{ 4 $\frac{1}{2}$ -7 p.m. .... 5 0-3 a.m. (13th).. 3	
Nara. (Yamato.)	—		0 $\frac{3}{4}$ p.m. .... 1		6 $\frac{3}{4}$ p.m. .... 1	
Okayama. { Bizen, Bitchu, and Mimasaka.	—		—		{ 4-6 p.m..... 5 10 p.m. .... 1	
Shimane. (Iwami, Izumo, Oki.)	—		—		6 p.m..... 1	
Tokushima. (Awa.)	—		—		4 p.m..... 1	
Wakayama. (Kii.)	—		—		6 $\frac{1}{2}$ p.m. .... 1	