The Sakura-Jima Eruptions and Earthquakes. I.
[General Account.*]

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With Plates I–VII.

1. *Introduction.* The Sakura-jima (Cherry Island), situated in the Kagoshima Bay, and famous for the eruptions in 1779 and several earlier years, made outbursts in January, 1914, which may be counted, in point of the magnitude of disturbance, as one of the greatest volcanic catastrophes in modern times, and caused at once a multitude of scientific and other men to hasten from different parts of the Empire to the south-western extremity of the old Nippon. There were also a number of foreign visitors, including such high vulcanological authorities as Prof. T. A. Jagger, Jr., and Mr. Frank A. Perrett. The present author, who was despatched as a member of the Imperial Earthquake Investigation Committee, left Tokyo on Jan. 14th, arrived in Kagoshima on the 16th, and remained in the stricken district till the 26th; having paid a second visit to Kagoshima and the Sakura-jima in April last. The following § § give a short preliminary account, from the seismological point of view, of this Sakura-jima eruption, whose occurrence indicated the existence of a clear sequence among the various manifestations of the recent volcanic activity in Japan.

* Translation, with additions, of the present author's article on the Sakura-jima eruptions published in the Toyo Gakugei Zasshi, for March 1914.

2. *Topography.* (See Figs. 1 and 2.) The Sakura-jima is in shape an irregular ellipse, with the longer and shorter diameters of about 9.9 and 8.0 km in the EW and NS directions approximately, the greatest extension being the length of 11.4 km between the ESE coasts and the Hakamagoshi. The latter, a square flat-top piece of ground 0.8 km in length and 72 m in height, is so called from the resemblance of its form to a trapezium, or back head of the Japanese pantaloons when seen from the city of Kagoshima, and is the only portion in the island which is sedimentary in formation, all the rest being covered by volcanic materials. Near the centre of the island there are two high peaks, the Minami-dake (south crater) and the Kita-dake (north crater), respectively 1069.6 and 1133.5 metres in height, which form together with the Futanaka, or slightly depressed intermediate portion, the top ridge, 1.8 km in length running nearly in the S–N direction. Thus, from the E or the W side, the island looks like a truncated triangle and presents a beautiful Fuji type outline with a flat top; while, from the N or the S side, it appears in the form of a pointed cone. On the SE part of the island there is a flat ring-shaped parasitic cone of the Nabe-yama (height=328.4m), opening eastwards and having the maximum base diameter of about 1.5 km. Among the side craters on the west, the most conspicuous is the dome of Hikinohira (height=553 m). Again, the rocky protuberances of the Moe-zaki ("Burning promontary"), the Tatsu-zaki ("Dragon promontary"), and Omoe-zaki ("Great burning promontary"), respectively on the SW, the S, and the NE side of the island were formed by the lava streams attending the eruptions in the historical times. Further, the isle of Moe-jima ("Burning island") and other smaller ones situated off the NE coast of the Sakura-jima are the results of the submarine outbursts,

which followed the great eruption in the 8th year of the Anei period (1779 A. C.), and are collectively known as the "Anei Islands". The small iles of Karasu-jima and Oko-jima, respectively off the W. coast of the Sakura-jima and off the Moe-zaki at its SW corner, are also evidently the results of some of the former eruptions. Finally, as a special geographical feature of the island is to be mentioned the existence of hot springs at Furusato, Yunohama, Arimura, and Krokami, on the SE coast, and of a mineral spring in the shallow sea water close to the beach of Saido at the NW part of the island.

The habitations, distributed among 20 hamlets and situated all along the coast, belonged to the two village districts of Higashi (Eastern) Sakura-jima and Nishi (Western) Sakura-jima, with the head offices respectively at Arimura and Yokoyama, the total population before the present eruption having been 23,738.

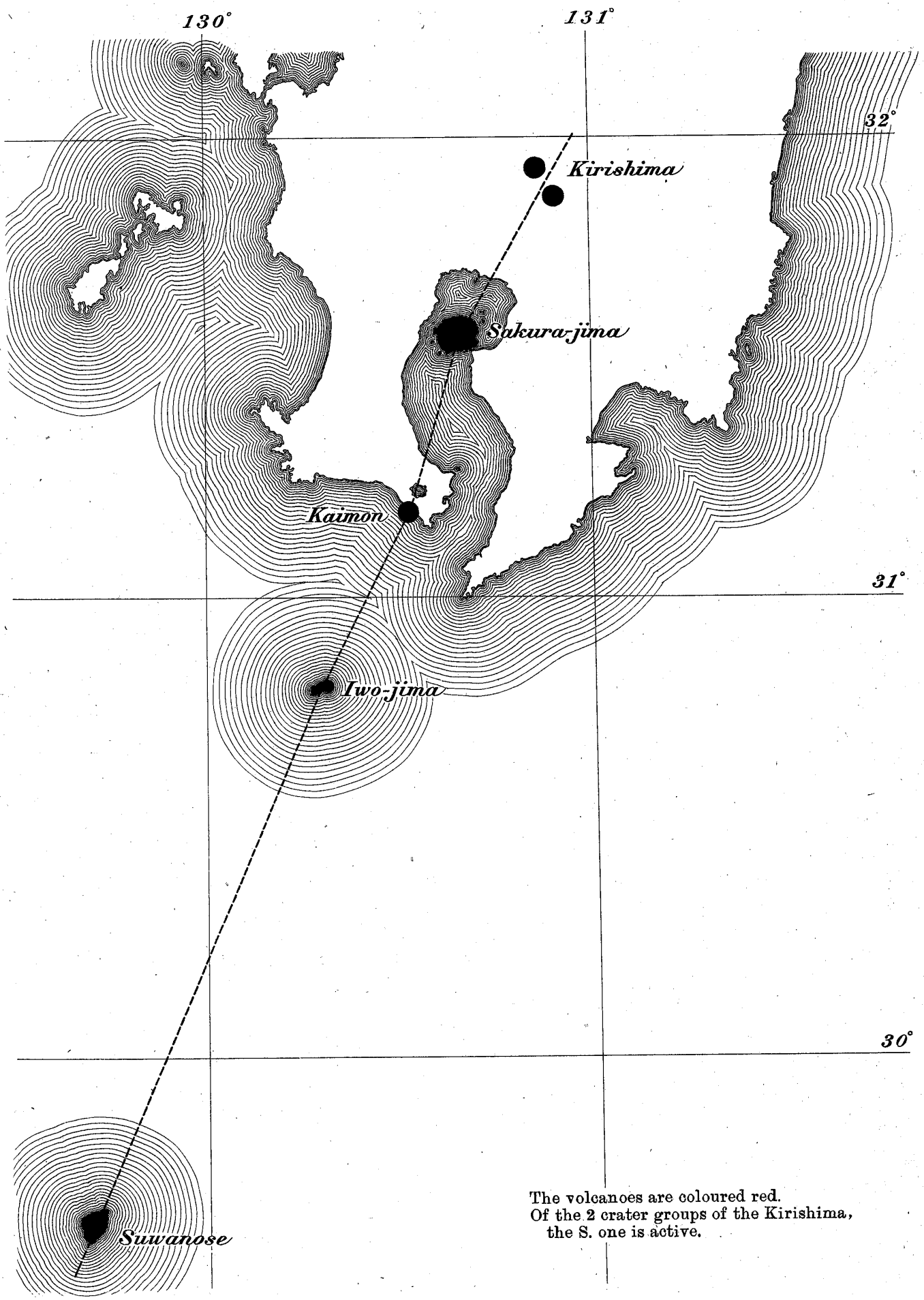
3. *Sea depth and mountain size.* The bay of Kagoshima, about 70 km in length and 20 km in width (Fig. 1), is a depression in the NS direction, doubtless having a connection with the formation of the Kirishima and Sakura-jima volcanic chain and is divided by the Sakura-jima distinctly into the southern and the northern portions. In the southern portion, there exists a sort of terrace with the water depth of up to 50 fathoms for the widths of about 4 and 2 km respectively along the western, or Satsuma, coast and the eastern, or Osumi, coast, while the basin at the middle has a depth of 100 to 122 fathoms. On the other hand, in the northern portion, which is surrounded mostly by steep coast, the depth of water is nearly uniform, ranging from about 70 to 107 fathoms. It is likely that the northern portion is similar in nature to the deep lakes which are found behind the sea-coast volcanoes of the Usu-san and the Tarumai-san, and its

formation must be specially related to the history of the Sakura-jima; it being, in fact, in this nearly closed part of the bay that submarine eruptions produced 3 new islands (Kamizukuri-jima, or "islands formed by the gods") in 764 A.C., and again 8 new islands (the Anei-jima) in 1779–80 A.C. The western water way, or the channel between the Sakura-jima and the coast of the Satsuma peninsula, along which the city of Kagoshima is situated, is 2.3 to 4.1 km in width, with the maximum depth varying from 77 fathoms on the north to 38 fathoms on the south. The eastern water way is, on the other hand, reduced (now *blocked* up) to a narrow strait at Seto, on the SE corner of the island, where for the length of about 1.6 km the width was from 0.7 to 0.4 km, with the maximum depth of 45 fathoms, navigable for large men-of-war.

From the above accounts it will be observed that the Sakura-jima is a small volcano rising out of a shallow sea, the total volume of the island above the water level being 26.5 c. km, which will not be much augmented by adding that of the portion below the sea. In magnitude the Sakura-jima is not much different from the Usu-san,* situated on the Volcano Bay, but equivalent to only one eleventh of the Asama-yama (i. e., of the part above the plateau of Karuizawa on which it stands), and to one-fourtieth of the Fuji-yama, the volumes of these two last mountains being respectively about 290 and 1025 c. km. The smallness of size, coupled with the greatness of activity, probably means the existence of the lava reservoir at an exceedingly near depth of a few kilometres, and the comparative weakness of the mountain frame for resisting the internal explosive condition, as is also the case with the Usu-san; hence the indications of the unmistakable premonitary signs in the form of numerous earthquakes for several hours preceding the

* An account of the Usu-san eruptions is given in the Bulletin, Vol. V, No. 1.

Fig. 1. Map showing the Positions of the Active Volcanoes in and off the S.W. Part of Kyushu.

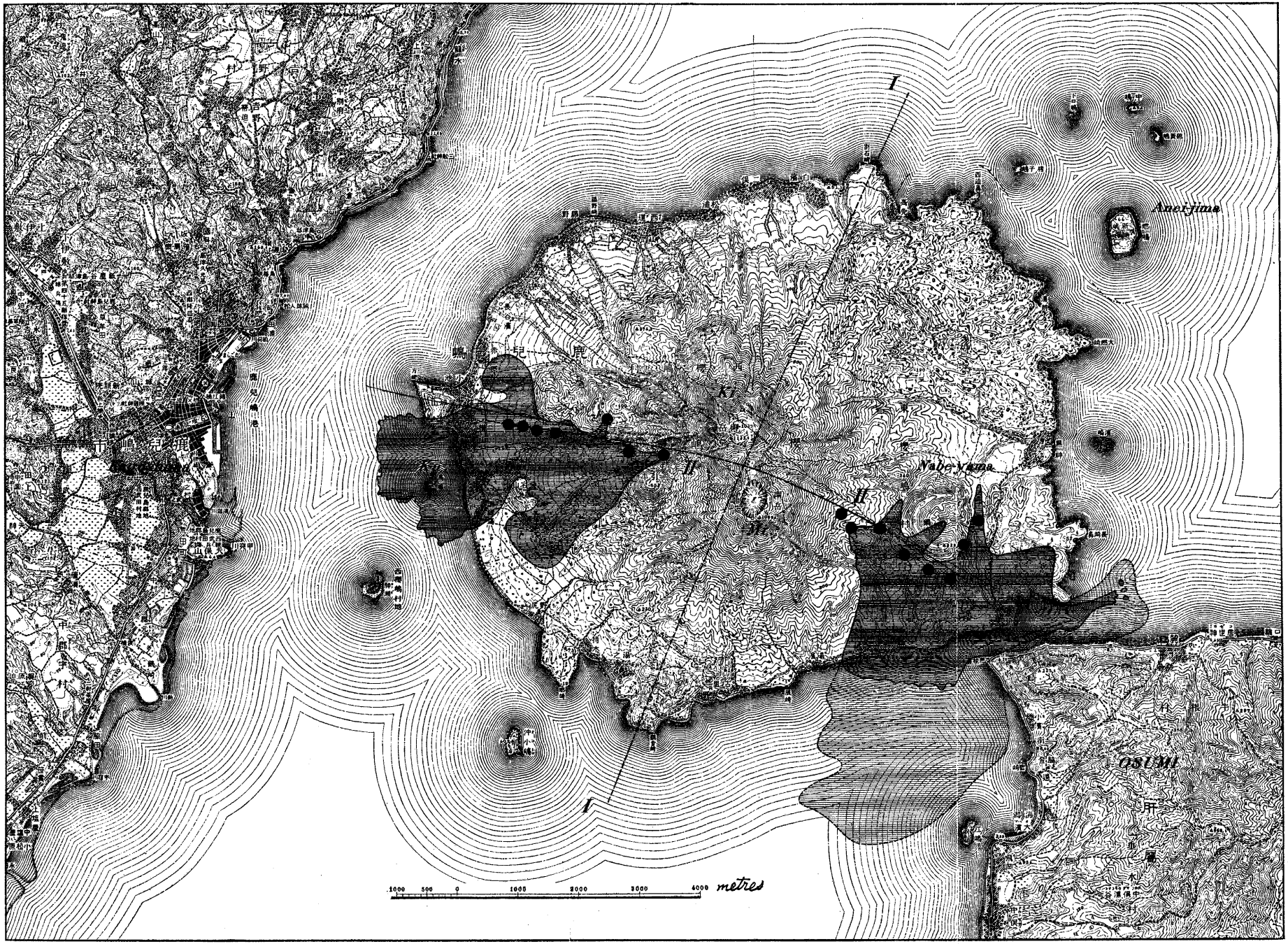


The volcanoes are coloured red.
Of the 2 crater groups of the Kirishima, the S. one is active.

Fig. 2. Map of Sakura-jima, showing the New Areas covered by Lava and the approximate Positions of the Craterlets. (May 1914.)

New Craterlets are indicated by *red dots*.

Mi.....Minami-dake.
Ki.....Kita-dake.
Ka.....Karasu-jima.



eruption in this year as well as that in 1779. Again, the eruptions were very intense and of a lengthy duration, and threw out a considerable quantity of fluid lava, pumice, and ashes, but the individual explosions were not quite so powerful as those of the Asama-yama, which caused not rarely some damage to the buildings 10 to 15 km distant from the crater by the violence of the air concussions.

4. *Simultaneous or successive activity of the different volcanoes.* (***Anei–Temmei–Kansei Epoch.***) The Japanese islands,* which form together a simple arc with steep descent on the convex side into the deep basin of the Pacific, may certainly be regarded as a system of volcanic chain or of earthquake zone, which is still undergoing the stress accumulation. When the latter reaches its limit, telluric disturbances may happen one after the other from various parts of the country in the form of great earthquakes or volcanic outbursts, as the case may be. The epoch of the most violent eruptions in the Japanese history was the interval of $14\frac{1}{2}$ years in the Anei, Temmei, and Kansei periods, namely, between 1777 and 1792. In the first place, the O-shima Volcano began eruptions on Aug. 22nd, 1777 (the 6th year of Anei),** and lasted, with intermissions, till Dec. 18th, 1778, an enormous quantity of lava having been in the meanwhile poured out. Then followed, on Nov. 8th, 1779, (the 8th year of Anei), the great eruption of the Sakura-jima, attended by the remarkable lava outflows and formation of new islands; while the Aoga-shima, one of the Izu islands, commenced powerful outbursts on July 28th, 1780, and continued till April 18th, 1785. Before the activity of

* Limiting, for simplicity's sake, to the Nippon proper, or the 4 large islands of Honshu, Shikoku, Kyushu, and Hokkaido.

** See the Bulletin, Vol. VI, p. 13. The date of the eruption in question there was, by mistake, put on Aug. 21st, 1778.

the latter volcano was brought to end, the Asama-yama broke out in strong eruptions since May 9th, 1783, (the 3rd year of Temmei), culminating in a terrible downrush of the "volcanic avalanches" on Aug. 5th.* Finally, the eruption of the Unsen-dake, in Shimabara (Kyushu), began on Feb. 12th, and terminated with a tremendous catastrophe on May 1st, 1792, (the 4th year of Kansei), when the entire southern slope of the Mae-yama slipped down and was precipitated as an immense avalanch of rocks and earth into the sea of Ariake, producing the great water disturbances, or *tsunami*, which resulted in the devastation along the coasts of the provinces of Hizen and Higo with the loss of nearly 15,000 lives.**

Of the different mountains mentioned above, the Sakura-jima and the Unsen-dake are in Kyushu, while the three others, namely, the O-shima, the Aoga-shima, and the Asama-yama belong to the Fuji volcanic chain, which, rising from the Pacific basin, meets the Japan arc nearly at the middle transversally. Yet, in spite of the wide distance between the two groups, the different volcanoes were thrown into great eruptions one after the other. This characteristic is being repeated at the present epoch.

5. *Recent volcanic activity and Sakura-jima eruption.* An examination of the time distribution of the Asama-yama outbursts indicates the recurrence of the epochs of the greatest eruptive frequency at a mean interval of about $63\frac{1}{2}$ years. Thus the double length of $63\frac{1}{2} \times 2 = 127$, or, say, 130 years, may also be regarded as a possible period in the frequency variation of the eruptions; and it is noteworthy that the Asama-yama, the O-shima, and the Sakura-jima, which made no great outbursts since the Anei-Temmei times, have exhibited, just after the lapse of 130 years, again extraordinary activity within the recent years.

* The Bulletin Vol. VI, p. 106.
** The Bulletin, Vol. I, p. 142.

In Dec. 1907, the Yake-dake, on the boundary of the provinces of Hida and Shinano, commenced explosions, while from 1908 the Asama-yama caused numberless earthquakes and eruptions, many of which latter were of considerable violence. In 1912, the O-shima made magnificent lava outbursts first in March-April and again in September-October. The explosions of the Yake-dake, which reached the climax of intensity in the summer of 1911, thence became gradually weaker, stopping completely since the summer of 1912. The eruption of the O-shima was also brought to an end in the spring of 1913; the Asama-yama, again, evidently approaching the last phase of its present activity from about the latter epoch. The recent eruptive energy of the Fuji volcanic chain manifested by the outbursts of these mountains thus drawing to a close, the Kyushu volcanoes were expected, in obedience to the sequence of events in the Anei-Temmei-Kansei periods, to be now in their turn brought into activity, when, from May 19th, 1913, local small earthquakes began to be frequently felt at the villages of Kakto, Massaki, etc., in the regions at the northern and western bases of the Kirishima-yama, which stands on the boundary of the provinces of Osumi and Hyuga and which had been quiet for the past 10 years. This sudden appearance of seismic disturbances was at once interpreted as foreboding its eruptions and marking the transference of the volcanic activity to Kyushu, and the present author sent, under the date of June 11th, 1913, a semi-official letter to Mr. T. Taniguchi, governor of the Kagoshima-ken, urging the necessity of setting up sensitive seismographs at the Kagoshima meteorological observatory* and carrying on continuous tremor

* The Kagoshima met. observatory is still furnished only with an ordinary Gray-Ewing-Milne seismograph.

observations, as the prefectural districts, with many volcanoes, are often shaken by strong earthquakes, probably also disturbed by volcanic micro-tremors, and especially as the Kirishima-yama was entering upon a period of activity. In the mean while, the seismic disturbances extended to the peninsular part of Satsuma, and at the end of June, a strong earthquake, with numerous after-shocks, took place in the vicinity of the village of Ijuin, some 16 km to the WNW from the city of Kagoshima. The Kirishima-yama broke finally in a strong explosion on Nov. 8th, followed by a second one on Dec. 9th, after which the present author made the intention, at the request of the governor of Kagoshima, of visiting the volcano in question in the course of the following month. On Jan. 8th of this year, the Kirishima-yama made the 3rd strong explosion, and 4 days later on the 12th, at about 10 a.m., there reached to his hand a telegram from the Kagoshima meteorological observatory, mentioning the occurrence of 337 earthquakes in the city between 6 o'clock in the same morning and 3 a.m., on the 11th. Startled by this intelligence which evidently indicated a wonderful increase of the telluric disturbances, the author was on the point of sending to Kagoshima a telegram giving the instruction of carefully watching the condition of the Sakura-jima, which could be the only cause of the unusual seismic phenomena, when came in the newspaper notice announcing the eruption of the same mountain.

6. *Premonitary signs.* Of great importance is the historical knowledge of the eruptions of different mountains, as we may thereby be much aided in considering the premonitary signs and the probable further course or consequence of outbursts from them. Unlike large destructive earthquakes, which originate

along seismic zones, but are not repeated from one and the same centre, the eruptions of a given volcano take place usually from the central crater or from new side vents, being anyhow thus localized to the mountain itself. Hence it may be that the great outbursts from a given volcano at widely different epochs resemble each other more or less, both in the eruptive phenomena and in the precursory events. Thus, for instance, in the eruptions of the Usu-san in 1910, 1822, and 1663, the first smoke explosions took place each time 3 or 4 days after the commencement of the premonitary shakings.* In the case of the great Sakura-jima eruption of 1779, the earthquakes became very frequent from about 11 p. m. on Nov. 7th; on the next day at about 11 a.m., the well waters in the island boiled up, waters were squeezed or shot out from the different sea beaches, and the sea water was turned purple in colour; at 2 p. m. on the same day, a column of gray smokes was thrown up vertically from Futanaka on the top, followed after a short time interval by loud detonations and eruptions almost simultaneously both from the northern and the southern sides of the mountain; the black smokes, which turned the day into a darkest night, being mixed with terrible fires projected high into the heavens and traversed by lightnings in vertical and horizontal directions. This description of the Anei eruption of the Sakura-jima can, almost without alterations, be applied to the recent great disturbance of the island, which I now proceed to sketch briefly.

(I.) *Earthquakes.* In the early morning of Jan. 11th (1914), the people of the city of Kagoshima were generally aroused from sleep by an earthquake at about $3^{h}\ 41^{m}$, which was nothing else than one of the premonitary shakings proceeding from the

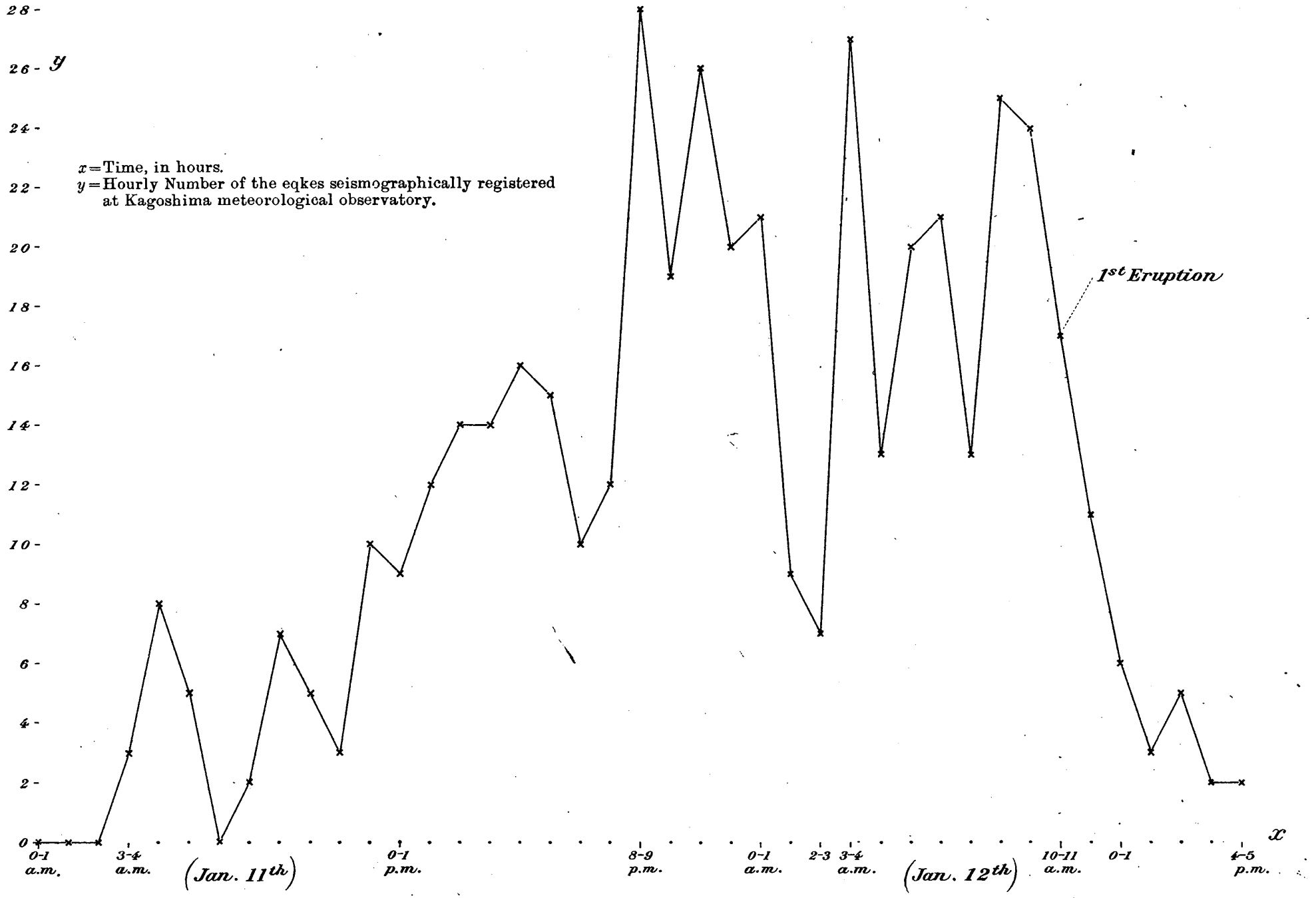
* The Bulletin, Vol. V, No. 1.

TABLE I. HOURLY EARTHQUAKE NUMBER OBSERVED WITH ORDINARY GRAY-MILNE-EWING SEISMOGRAPH AT THE METEOROLOGICAL OBSERVATORY OF KAGOSHIMA, JAN. 11TH—18TH, 1914.

Hour. \ Day.	11	12	13	14	15	16	17	18
0—1 a.m.	—	21	—	1	—	—	—	—
1—2	—	9	—	—	—	—	—	—
2—3	—	7	—	1	—	—	1	—
3—4	3	27	—	—	—	—	—	—
4—5	8	13	—	—	—	1	—	—
5—6	5	20	—	—	—	2	2	1
6—7	0	21	—	—	—	—	—	—
7—8	2	13	—	—	—	1	—	—
8—9	7	25	—	—	—	—	—	—
9—10	5	24	1	—	—	—	—	—
10—11	3	17	—	—	—	1	—	—
11—12	10	14	—	—	—	1	—	1
0—1 p.m.	9	6	—	—	—	2	—	—
1—2	12	3	—	—	1	—	—	1
2—3	14	5	—	—	—	1	—	1
3—4	14	2	—	—	—	—	—	1
4—5	16	2	3	—	—	—	—	—
5—6	15	2	—	—	—	—	—	—
6—7	10	1*	—	—	2	2	—	1
7—8	12	0	—	—	3	—	—	—
8—9	28	1	—	—	—	—	—	—
9—10	19	—	—	—	1	—	—	—
10—11	26	—	—	—	1	—	—	—
11—12	20	—	11	—	1	—	—	—
			5	2	9	11	3	6

* After 6½ p.m. on the 12th, the register is imperfect, as the Gray-Milne-Ewing seismograph was damaged by the strong shock at that time.

Fig. 3. Hourly Frequency Variation of the Earthquakes which preceded the Sakura-jima Eruption of Jan. 12th, 1914.



Sakura-jima, and was followed by numerous others. The annexed table gives the hourly numbers of the earthquakes registered with an ordinary Gray-Milne-Ewing seismograph between the 11th and the 18th, in January, at the Kagoshima meteorological observatory ($\varphi=31°36'N$; $\lambda=130°33'E$), which stands on a colline 120 metres in height outside the city, at a distance of 10.1 km to the N76°W from the centre of the Sakura-jima ($\varphi=31°35'N$; $\lambda=130°39'E$).

According to the above table, the average hourly earthquake frequency was 4.1 between 3 and 11 a.m., on the 11th; was increased to 12.4 during the next 9 hours, namely, between 11 a.m. and 8 p. m.; attained the highest value of 19.5 in the course of the further 14 hours between 8 p. m., on the 11th, and 10 a.m., on the 12th; the greatest hourly number of 28 and 27 having been reached respectively at 8-9 p. m., on the 11th, and 3-4 a. m., on the 12th. The total number of the earthquakes registered at Kagoshima between 3 a. m., on the 11th, and 10 a. m., on the 12th, was 418. In the Sakura-jima, the earthquakes, which were many times more numerous than in Kagoshima, seem to have occurred already from the night of the 10th, becoming stronger from about 3 a. m., on the 11th. At the village of Saido, situated at the NW coast of the island, 66 earthquakes were felt in the course of the single hour from the noon till 1 p. m., on the 11th, against the 9 shocks registered at the meteorological observatory of Kagoshima; the earthquakes, which contained a good proportion of vertical component, were generally announced by a sound like that caused by the fall of a heavy body on the ground, immediately followed by earth tremblings; at 9 a. m., on the 11th, the roads being already slightly damaged at several places. According to the account of the village headman of Higashi Sakura-jima, there was at $5\frac{1}{2}$

a. m., on the 12th, a most strong earthquake, accompanied by sharp vertical jerks.

(II) *Hot Springs, etc.* At the coast of Waki and Arimura, on the southern side of the island, waters began to be issued copiously from several places already in the early morning of the 12th, whose temperature was so high that people had, in time of low water, difficulty to walk across the beaches. At the same time, waters were bubbling up from among the sea, while the hot spring of Arimura was thrown up in jets to a height of 3 feet. It is highly interesting that an analogous phenomenon took place also on the opposite side of the island, namely, at Saido, where the issue of the natural cold spring waters at the beach was considerably augmented, the striking change having been noticed at about $8\frac{1}{2}$ a. m. on the 12th by Mr. Hagiwara, head master of the village school, and many other people. Even on the 22nd of January, when Mr. Hagiwara returned back again to Saido, the waters were still copiously flowing out, such that the point of issue was some 20 metres more inwards than it had used to be. This locality is known as Yuno-saki, literally "hot-water cape," it being likely that formerly there existed some hot springs, whose remnant may be the mineral spring refered to in § 2. One of the wells in the village had its water level, usually at a depth of 8 or 9 feet, raised on the morning of the 12th to within 5 feet from the ground surface.

(III.) *Smokes.* At about 8 a. m., on the 12th, a column of white smokes was suddenly shot up in the form of a pine tree from the top of the Minami-dake, while in the earlier hours of the morning, according to the observations from Kagoshima, several slender filaments of white vapours had been rising from above the layers of mists which shrouded the mountain. Again, according to the observations from the town of Tarumizu, on the

coast of the province of Osumi; white smokes like clouds were floating at about 2 p. m. on the 11th about the SE mid-slope of the Sakura-jima.

The above were the unmistakable premonitary signs of the approaching catastrophe of the volcano, which previously had remained perfectly quiet and, since two decades or so, smokeless, except perhaps a feeble issue of some white vapours once or twice in the year. Taking alarm from the frequent earthquakes, the majority of the inhabitants began to escape from the island already on the 11th, partly westwards to the city of Kagoshima, and partly eastwards to the town of Tarumizu and the neighbouring villages in Osumi. The eruptions finally began on the 12th, at about 10 a. m. But, thanks to the timely warning taken by the people and the prompt and well directed measures of the prefectural authorities in despatching to succour the several steamers, which happened to be in port at the time, the whole inhabitants, over 23,000 in number, were all safely brought out of the danger, with the exception of the two clerks of the village office of Higashi Sakura-jima, who, together with the headman Mr. Kawakami, heroically remained till after the commencement of the eruptions and were drowned in attempting to swim across to the coast of Osumi. In the eruption of 1779, the number of the killed was, under similar circumstances, 144. The comparatively small amount of mortality in the different Sakura-jima eruptions is probably in a part due to the fact that the habitations are situated all along the coasts at some distances from the vents of the outbursts, and also to the fact that the latter do not attain full violence till some time after the commencement.

I can not here pass by without referring to the conduct of the director of the Kagoshima meteorological observatory, Mr. Y.

Katsuno, who rendered an invaluable service in faithfully carrying on the seismographical and meteorological observations throughout the trying hours of general confusion and panic, but who made a curious mistake in insisting till the very last moments on the supposed existence of the origin of the seismic disturbances in the opposite quarters, namely, in the direction of the Ijuin district some 16 km to the NW from the city of Kagoshima. This Sakura-jima eruption was indeed one, which could be predicted by the common sense at least one complete day before. As a successful instance of management with respect to a volcanic catastrophe, I may mention the eruptions in 1910 of the Usu-san, which were attended with no casualty in consequence of the compulsory measures taken by the police inspector, Mr. Iida, who ordered the inhabitants in the vicinity to leave the threatened districts, in strength of my lecture on earthquakes and eruptions, given in 1902, at the Police High School in Tokyo.

According to the graphical representation in Fig. 3, the first eruption took place about 13 hours after the occurrence of the absolute maximum hourly earthquake frequency at 8-9 p.m., on the 11th. It is difficult to explain why a marked frequency minimum did occur at 2-3 a. m. on the 12th. It seems probable, however, that this minimum in the seismic frequency, which must denote a partial decrease in the underground stress, was occasioned by some preliminary smoke emissions from the mountain top and sides, or jetting out of waters from the different places along the coasts.

7. *Eruptions.* The first outburst took place from the west side of the Sakura-jima at about 10 a.m., on the morning of the 12th, from a point above the Yokoyama-mura (height=about 500 m) followed after a short time interval of some 10 minutes

by the outburst from the south shoulder of the Nabe-yama at the east side of the island. The outbursts, which were at the commencement accompanied by no special detonation, rapidly increased in magnitude and intensity.

According to the report of the Kagoshima meteorological observatory, which enjoys the full view of the Sakura-jima, red fires were seen at the base of the smoke column 5 minutes after the commencement of the eruption. The smokes ascended to a height of about 3,000 metres already at 11 a.m., while the lava blocks, several of which had tails of steam and gases, were observed to be thrown out thickly from 11. 30 a.m., when the *shoji* (paper-covered sliding doors) began to be shaken by the air vibrations. At 2. 30 p.m. the whole island was enveloped in white and black smokes, the eruptive noises becoming more and more intense till at 3. 30 p.m. the explosive detonations began to be heard.

The dense black smokes, which were, the weather being quiet, projected finally to a vertical height of over 20,000 feet above sea level, were traversed by electric lightnings in various directions, while the incessant air-quakes, cooperated, so to speak, with the most frequent seismic convulsions of the ground in the development of the awful catastrophe. The panic in Kagoshima was greatly augmented by various ridiculous reports, one of which, relating to the supposed far-reaching fatal consequences of the poisonous volcanic gases, enjoined the people to get beyond the limit of 20 km radial distance. This was most effective in driving the greatest majority of the seventy-thousand inhabitants out of the city, who experienced hardships and privations in the sudden exodus, each endeavouring to get away simply as far as possible, on foot, on vehicle, or by railways. Another supposed danger was in

the possible inrush of enormous *tsunami* (tidal waves), which might sweep away the entire city. When the afternoon of the 12th passed away under such disquieting circumstances, a new and real source of danger appeared in the form of a strong earthquake, which happened at half past six o'clock and knocked down a great many of stone partition and fence walls, which abound in Kagoshima; a number of the dwelling and ware houses, mostly of stone construction, in the lower and soft-soil part of the city and in the new made-ground along the coast, were partially or entirely destroyed. After this earthquake, the volcanic noises and the projection of red hot lava masses became markedly stronger, and the "explosive stage" reached its full intensity between about 11 p.m., on the 12th, and 5 a.m. on the 13th, with the maximum at about 1 a.m. on the latter day. The detonations in Kagoshima during this interval were like those due to the quick firing of artillery pieces and were so loud that the prefectural officers had to stuff their ears with cotton. It was probably at this epoch that local hurricanes were produced by the eruption, which seem to have been specially strong at the west end of the island, in the neighbourhood of the Hakamagoshi, upon which were found transported large uprooted mandarin orange trees, 1 foot or more in stem diameter, and pieces of smashed wooden houses in the village of Yokoyama, situated at the east foot of the above named plateau hill, 72 m. in height. After 10 a.m., on the 13th, the violence of the explosions were greatly reduced, although continuing to happen still almost continuously. On the succeeding evening the volcano presented to the observers in Kagoshima the most magnificent sight, between about $8^h\ 15^m$ and $8^h\ 30^m$, the burning materials being shot high with brilliant display of lightnings, as it were, in a high pillar, and converting the whole mountain slope over Yokohama, from top to

base, into one continuous zone of red hot masses. This was no other than the commencement of the outflowing of the lava streams. On the same occasion the houses in the village of Koike were burnt down. Thereafter the noises were greatly reduced.

Even as late as the 16th (January), when the author arrived in Kagoshima, the sight of the eruptions was very beautiful and grand, the state on the west side being much the same as in Fig. 7, which is a picture taken near the evening of the 15th from the harbour of Kagoshima. The more or less active eruptions on the west side of the island were brought nearly to end on the 25th of January; but those on the east, or the Nabe-yama, side have long kept up their energy, and are making occasional strong outbursts even at the present time (Aug. 1914).

Lava Streams. About 7 and 8 principal craterlets were formed respectively at the west and the east sides of the Sakura-jima, the uppermost one being in the former at an altitude of 500 m, and in the latter at an altitude of 400 m. The lava which flowed out from both of these groups was, like that of the Asama-yama, of very little fluidity, so that it is generally broken up into loose angular blocks. The main branch of the lava stream on the west side seems to have run down before 7 a.m. the next day through a distance of 2,000 m, or in about 12 hours already to within 500 m of the coast, reaching the same on the morning of the 16th. Thus the mean velocity of the descent of the lava stream in question was about 45 m per hour during the 1st $2\frac{1}{2}$ days. The lava stream, which continued its forward progress into the sea, sending up an infinite number of small columns of pure white water vapours, reached at about the noon of the 18th the small Karasu-jima, whose height was 20 metres and was at a distance of about 600 metres from the coast; giving the velocity of the lava motion of about 21

m per hour in the time interval between the 16th and the 18th. When examined on the 20th, this islet had entirely disappeared under the lava in such a way that it was difficult to identify its former position. On Jan. 22nd, the lava stream was moving, at the south base of the Hakamagoshi, with a speed of about 1 foot per hour.

On the other hand, the lava streams from the eastern, or Nabe-yama side, craterlets quickly reached the comparatively deep Seto Strait between the SE end of the Sakura-jima and the Sakkabira promontary of the province of Osumi, and, getting under the sea, was, when seen on the 16th (January), vigorously sending up masses of dense white smokes, the surface water temperature being 49°C (measured on Jan. 23rd). The strait, whose width was narrowed by the lava to about 20 metres on Jan. 24th, was finally blocked up on the 29th of the same month, the Sakura-jima island being thus converted into a peninsula. When viewed at the commencement of April last, the lava mass filling the strait was bulged up into hills 50 m or more in vertical height, still steadily pressing hard upon the former coast of Osumi. (See Fig. 4.)

Areas covered by Lava. Fig. 2 indicates the areas covered at the commencement of May last by the lava which streamed out from the two groups of the craterlets, the forms of the protuberances in the sea, both above and below water, being based on the surveys and soundings undertaken by the Hydrographical Department of the Imperial Navy. On the west side, the lava layers, whose maximum thickness or height was in the earlier days about 60 m, completely buried under them the villages of Yokoyama and Akamizu, reached the extreme extension of 4.8 km in the EW direction, and extended 1,400 m into the Kagoshima Channel. As the depth of the latter, between the city of

Kagoshima and the Hakamagoshi and the former isle of Karasu-jima, is generally less than 24 fathoms, or 44 metres, there was on that side no marked submarine extension of the lava, the top of whose end edge stands high up or is just visible out of the water surface. On the south-east coast of the Sakura-jima the three villages of Seto, Waki, and Arimura were all buried under the lava streams, which flowed, on the north, along the west shoulder and into the crater, of the Nabe-yama. A small hill, 103 m in height, on the SE coast, which had not been covered by the lava at the end of January, was found entirely buried under it at the commencement of April. As the sea off the SE coast of the Sakura-jima was 70 to 90 fathoms (128 to 165 m) in depth, the protuberance of the lava stream into the bay, which remains above the water level, is only about 700 m in maximum width, but the under-water extension is considerable and has the extreme distance of 3.4 km between the SSW end and the above-mentioned former coast hill.

Even at the distances of 2.0 to 2.3 km from the SE coast of the Sakura-jima under consideration, there were marked changes in the water depth revealed by the soundings; thus, for instance, at a point was found a depth of 25 fathoms instead of the former depth of 84 fathoms; at a second point, 26 fathoms instead of 88 fathoms; at a third, 36 fathoms instead of 96 fathoms, etc. These results seem to point to the conclusion that the submerged layer of the lava stream is in its middle and southern parts 50 to 60 fathoms or 90 to 110 metres in thickness. For the west, or Yokoyama side, lava stream, the thikness of the portion projecting into the sea may be taken to be about 30 fathoms or 55 metres. The approximate areas of the lava covered tracts are as follows:—

Area.	Western, or Yokoyama, Side Lava Stream.	Eastern, or Nabe-yama, Side Lava Stream.
Land (i.e. former land) area covered by lava.	5.91 sq. km.	5.25 sq. km.
New lava area above water (or coast increase).	2.42	2.19 Sum, 7.44
Submerged lava field.	—	7.97
Sum.	8.33	15.41

Thus, the total area of the eastern lava field, which is 15.41 sq. km and of which 7.97 sq. km belongs to the submerged portion, is nearly double that of the western, namely, 8.33 sq.km. The sum of the areas of the eastern and the western lava fields is 23.7 sq.km, which is equivalent almost exactly to one-third of the area of the Sakura-jima. Assuming the mean thicknesses of the entire western side lava field and of the land portion of the eastern side lava field to be each 40 m, and that of the rest of the latter to be 100 m, we get the following results:—

(Volume)

Western lava field: .....0.333 c.km.
Eastern lava field: .....1.226 ,,
Sum: .....1.559 ,,

The estimated total volume of the lava, which flowed out from the two sides of the Sakura-jima, is thus about **1.6** c.km, and equivalent to about one-seventeenth of the volume of the mountain, which is =26.5 c.km. The enormity of the Sakura-jima disturbances will be realized from a comparison with the great Temmei (1783) eruption of the Asama-yama; the area and the volume (under the assumption of the mean thickness of 40 m) of the "Oni-oshidashi" or lava stream on that occasion being 6.9 sq.km and 0.27 c.km, which are equal respectively to $\frac{1}{3.4}$ and $\frac{1}{6}$ of the

corresponding quantities of the present Sakura-jima eruption. Moreover, in the Asama-yama catastrophe above refered to, the volume of the lava outflow was only 1/1,000th of that of the mountain.

Precipitation of Lava Fragments and Ashes. The villages of Koike and Akobaru, situated on the west coast to the north of the Hakamagoshi, were, although outside the lava stream areas, completely crushed, burnt, and buried by the showers of more or less pumiceous hot lava fragments projected from the craterlets. The scene in these neighbourhoods was desolate and barren in the extreme; the stones, which also smashed the trees in terrible conditions, having made an innumerable number of the so-called conical holes of various dimensions on the Hakamagoshi and in the tracts adjacent to its N. and E. bases. These facts, in conjunction with the probable gush of hot volcanic gases mentioned in p. 16, seem to indicate that the local explosive effects attending the eruptions were specially strong at the west side craterlets. The precipitation of pumice and ashes was very abundant in the eastern part of the island, being deepest at and about Kurokami, where it amounted to 6 feet or more and buried the houses nearly up to the roof. Fig. 5 illustrates how the gate of the village temple had the two upright stone columns, some 8 or 9 feet in height, buried under the pumice and ashes, only the two horizontal top beams remaining in the air. On account of the prevalence of the westerly winds in the higher atmospheric region all the year round, the ashes of the different volcanic eruptions in Japan are generally carried eastwards, whatever the surface winds may be. Thus, the ashes of the great Sakura-jima eruption of 1779 reached Osaka, Nagoya, and Yedo (Tokyo). On the present occasion, the ash-precipitation reached the Bonin Islands on the SE, and extended to

the NE over Kyushu, Shikoku, and the whole of the Main Island to the west of Mito and Utsunomiya, the extreme eastward radial distance being over 1,200 km. Thus the ash-precipitation was very slight and under 3 mm in Kagoshima situated close enough to the west of the Sakura-jima, while it was very heavy in the northern and central parts of the province of Osumi, the amount ranging from 3 or 5 inches to over 3 feet. The principal axis of the ash-precipitation zone extended from the Sakura-jima in the direction of E. slightly S. to the vicinity of the town of Shibushi on the Ariake Bay. Making the planimeter estimations of the areas enclosed by the different iso-precipitation curves drawn on a map, based on the measurements of the thickness at a number of places in the S. part of Kyushu, the total amount of the pumice and ashes, which fell in the latter only, comes out to be about 0.62 c.km, equivalent to 40% of the total volume of the lava outflow. This is a sufficiently large quantity, which, if distributed over the whole extension of the city of Tokyo, about 80 sq. km in area, would give a mean thickness of about 8 metres.

The total sum of the volumes of the pumice and ashes and of the lava outflow thus amounts to 1.56+0.62=**2.2** c.km, which is equivalent to **1/12**th of the volume of the whole mountain.

The specific gravity of the ashes, which were acidic, determined from the specimens collected in Kagoshima and the Sakura-jima, varied from 0.9 to 1.2, giving the mean value of 1.0. Again, the specific gravity of the lava pieces and bombs found at the west, or Yokoyama, side varied mostly between 1.06 and 1.63, with the mean value of 1.4; while that for the specimens from the eastern, or Nabe-yama, side, was between 1.92 and 2.81, with the high mean of 2.4.

8. *Strong earthquake and small tsunami.* In the strong

Sakura-jima Eruption of 1914.

Fig. 4. Blocking up of Seto Strait, originally 0.7 km in width and 45 fathoms in depth. The right-hand side slope is the former coast of Osumi, while the left-hand side hill, over 50 m in height, is the lava which flowed down from the Sakura-jima.
(April 10th, 1914. F. Omori, phot.)

Sakura-jima Eruption of 1914.

Fig. 5. Scene at the village of Kurokami, on the E. coast of Sakura-jima. The thick precipitation of pumice and ashes buried the two posts of the stone "torii," or temple gate, 8 or 9 ft. in height, leaving only the horizontal top beams in air. Of the houses, only the roofs are left above the ashes. (April 9th, 1914. F. Omori, phot.)

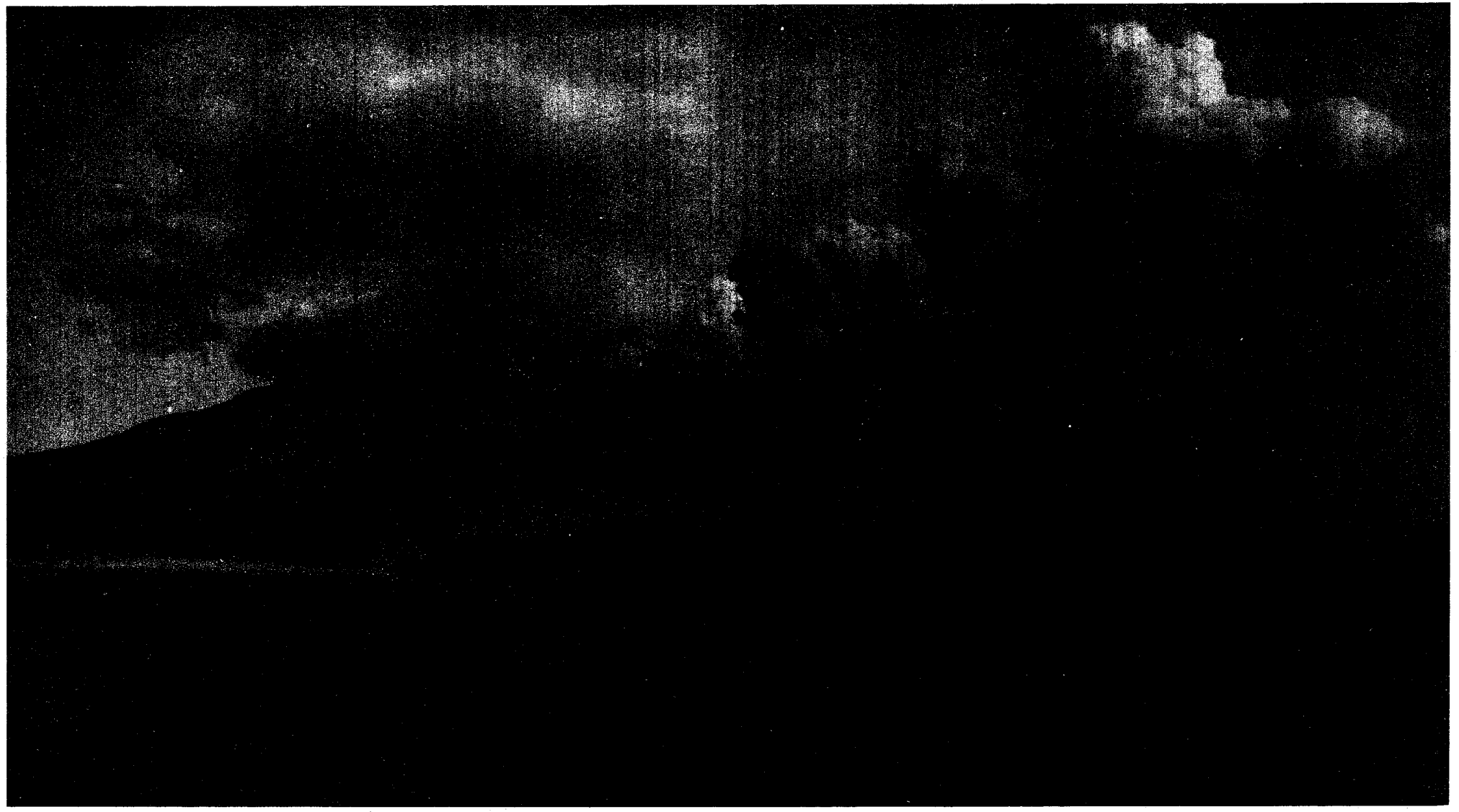


Fig. 6. Eruption of Sakura-jima, seen from the NW, showing the **lava outflow** at the front. The principal explosions are taking place from the back, or Nabeyama, side.
(Jan. 23rd, 1914. F. Omori, phot.)

Fig. 7. Eruption of Sakura-jima. View taken in the evening of Jan. 15th, 1914, from Kagoshima quey, showing the luminous lava projection and electric lightnings. (Yuki, phot.)

earthquake of Jan. 12th, at half past six o'clock in the evening, were killed 7 persons walking in the city streets by the outward overturning of stone fences, and 12 others, on the way of escape to country places, by the crumbling down of high perpendicular road-side cliffs of soft tuff at a place called Tenjinga-seto, outside of Kagoshima. This seismic disturbance, whose preliminary tremor reached Tokyo at $6^h\ 30^m\ 21^s$ p.m., was obviously of the volcanic nature or relation, being, however, unusually large in magnitude. Judging from the tromometer diagrams obtained in Tokyo, it is evident that the Kagoshima (or Sakura-jima, provisionally) earthquake in question must have been several times larger in magnitude than the strong Asama-yama earthquakes of May 26th, 1908,[1] and of July 16th, 1912, or of the strong Usu-san earthquake of July 24th, 1910, at 3. 49 p.m.,[2] which seemed to represent the limiting intensity and size of a volcanic earthquake. A special character of this Kagoshima earthquake is that the intensity of motion was nowhere very severe, the seismic damage in the Sakura-jima itself being, probably on account of the rocky nature of the ground, considerably smaller than in the lower part of the city of Kagoshima. It is thus evident that the earthquake must have been of very deep origin and was probably the result rather of the stress accumulation along the whole volcanic chain in the southern Kyushu, being not at all a simple local shock connected only with the eruptions of the Sakura-jima. This supposition seems probable, as one month later, on Feb. 13th, at 3.37.19 p.m.[3] there took place an earthquake also of no insignificant magnitude during the activity of the Iwo-jima, another of the same volcanic

(1) See the Bulletin, Vol. VI, Figs. 36 and 37.
(2) See the Bulletin, Vol. V, p. 15.
(3) Time of earthquake occurrence indicated by the tromometers in Tokyo.

chain. Strong volcanic earthquakes may possibly be divided into the two categories of (i) local shock, necessarily of shallow focal depth, and (ii) extensive earthquake, of great depth. In both of these cases the surface intensity of the seismic motion would not be so high as in great destructive earthquakes of tectonic origin.

In the city of Kagoshima, which is situated to the west of the Sakura-jima, the earthquake damage done to the various structures indicated very clearly the longitudinal nature of the shock. Thus, the stone fences, which were in the E-W directions, even though of very unstable dimensions, remained standing, while those in the N-S directions were very often *overturned.* On the other hand, in the cases of the wooden houses with plastered or paper-covered walls, the damage was of a different nature: the walls in the E-W directions were much broken by the two systems of *mutually rectangular cracks*, while those in the N-S direction remained mostly intact. According to the ordinary seismograph diagram obtained at the Kagoshima meteorological observatory, the very first earthquake displacement of the strong shock under consideration was directed toward WNW, or radially away from the Sakura-jima.

The 12th of January happened to be the day of full moon and the tide was high in the evening when the strong earthquake took place. Probably 1 or $1\frac{1}{2}$ hours after the occurrence of the earthquake, the waters in the harbour of Kagoshima, whose level was then only about $1\frac{1}{2}$ feet below the top surface of the quey wall, flowed a little over the latter and partially washed the strand streets, a few boats being thereby damaged. This disturbance of the sea waters is to be regarded as a small *tsunami*, whose direct cause was, however, not in the strong earthquake before mentioned, but probably in a small sudden settlement or depression of the bay bottom. (See also § 10.)

TABLE II. DAILY NUMBERS OF THE ERUPTIONS AND EARTHQUAKES OF THE SAKURA-JIMA, INSTRUMENTALLY REGISTERED AT KAGOSHIMA, JAN. 16th TO FEB. 7th, 1914.

Date. (1914.)	Outbursts.		Volcanic Earthquakes not accompanied by Eruptions.		Earthquakes of neighbouring origin.	
	Stronger.	Weaker.	Larger.	Smaller.	Larger.	Smaller.
January, 16*	13	—	1	—	—	—
17	67	1	4	5	2	—
18	53	84	7	9	4	—
19	74	39	1	2	—	—
20	65	78	1	2	2	—
21	37	77	2	4	1	—
22	29	93	3	—	1	—
23	34	82	1	1	—	—
24	40	78	—	1	—	—
25	36	63	3	1	1	—
26	29	101	1	—	—	—
27	35	136	—	4	—	—
28	14	148	2	—	—	—
29	17	147	3	5	—	—
30	1	144	—	3	—	—
31**	5	130	1	2	—	—
February, 1	6	117	2	7	—	—
2	4	108	—	1	—	—
3	2	60	—	2	—	—
4	—	105	1	4	—	—
5	—	82	—	—	—	—
6	2	160	2	2	—	—
7	1	63	1	—	—	—

* Registration commenced from $6^h\ 6^m$ p. m.

** Volcanic tremors were very marked between 9 a.m. and 10 p. m.

9. *Tromometer observations of eruptions.* A 200-times magnification two-component horizontal tremor-recorder, which the author took with him at his first visit to the Sakura-jima in January, was temporarily set up on the solid stone foundation in the instrument room of the Weight and Measure Department, in the Prefectural compound, and the observation was, under the care of my assistant Mr. Kurosaka, started on the 16th of the same month and continued till Feb. 8th, when the seismograph was removed to the village of Furusato in the Sakura-jima. The result of the registration is embodied in Table II, which is the list of the daily numbers during this interval of the larger and smaller volcanic eruptions and of the non-eruptive volcanic earthquakes, and of shocks of the neighbouring origin; the photographically enlarged illustrative diagrams being given in Figs. 8 and 9.

The strong outbursts, or large disturbances, which were at first very numerous, with the daily frequency of 53 to 74 between the 17th and the 20th (January), thereafter markedly decreased, the frequency between the 21st and the 27th being 29 to 40. After Jan. 28th, the decrease was equally remarkable, the mean daily frequency during the next 11 days being only 4.7. On the other hand, the frequency of the weak outbursts, or small disturbances, indicated a tendency of varying in inverse proportion to that of the other disturbances. The daily number of the non-eruptive volcanic earthquakes also shows a tendency of alternating the epochs of maximum frequency with those of the strong eruptions. I must here state that the *large disturbance* means here simply an outburst whose earthquake motion was comparatively large (double amplitude=0.1 mm or so), and the *small disturbance* one whose earthquake motion was small (double amplitude=0.01 mm or so); in either case, no reference being made to the intensity of the sound. A noteworthy fact is that the explosions accompanied

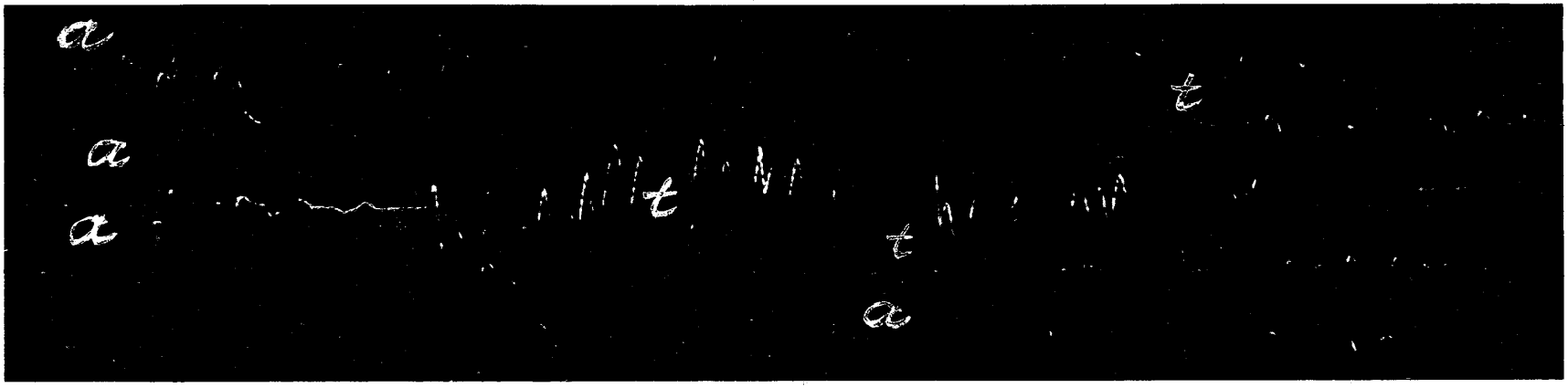


Fig. 8. Tremor recorder observation of Sakura-jima Eruptions at Prefectural Compound, Kagoshima, giving the longitudinal component diagram of **"Small Disturbances"** on Jan. 20th, 1914. Magnification=673. Time scale: 1 Minute=188 mm.

a.....Commencement of an eruption. t.....Minute (time) cutting.

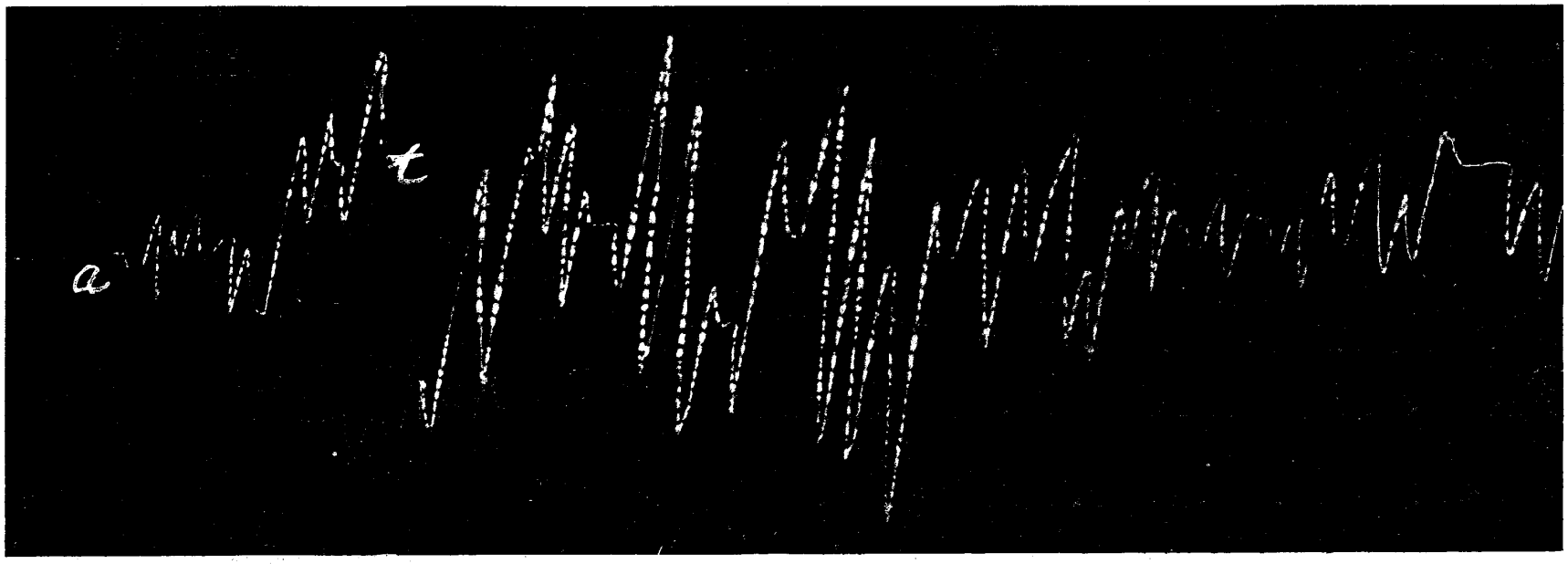


Fig. 9. Tremor-recorder observation of Sakura-jima Eruptions at Prefectural Compound, Kagoshima, giving the longitudinal component diagram of a **"Large Disturbance"** on Jan. 20th, 1914. Magnification=820. Time scale: 1 Minute=225 mm.

by very loud detonations, like, for instance, the outburst from one of the Nabe-yama side craterlets on Feb. 7th, at $11^h\ 25^m$ a.m. which startled the inhabitants of Kagoshima and neighbouring places, caused generally very small amount of the earthquake motion almost undistinguishable from the micro-tremors.* Thus, in the present case there are two kinds of the eruptions, as follows: (i), explosion with a loud detonation, which causes only a very slight amount of seismic effects; and, (ii), non-detonative eruption, which is accompanied by comparatively large earth vibrations. It is likely that the (i) eruptions produce the loud noises by suddenly rupturing or breaking open the partially solidified lava bottoms of the craterlets and are more of the nature of the surface action, while the (ii) eruptions are more important phenomena and consist in powerful projections of ashes and gases along pre-existing channels of deep extension. It thus follows that the mere abundance of the loud detonations, which long continued to disquiet the people of Kagoshima from time to time, is to be represented by the high frequency of the small disturbance, and by no means signified any material augmentation in the activity of the Sakura-jima. If the frequency of the "large disturbances" be assumed to give a measure of the degree or amount of the eruptive activity of the volcano, it will be seen from the above list that the latter is steadily tending back to the equilibrium condition. The decrease rate of the large disturbances was such that at the end of March the frequency was only about $\frac{1}{6,000}$th of that on Jan. 16th-17th, or roughly some $\frac{1}{10,000}$th of what existed at the commencement of the eruptions.

10. *Effect on level of bay water and depression of coast.*

*) Similar peculiarity was observed to a certain extent also in the case of the Asama-yama eruptions. (See the Bulletin, Vol. VII, No. 1.)

According to the tide gauge readings at the Kagoshima harbour in 1903 and 1904, the highest sea level was 12.3 *shaku*[1] which took place on Sept. 11th and Oct. 10th, 1904, the maximum daily range, or the height difference between the low and high waters being about 11.5 *shaku*. After the commencement of the present eruptions of the Sakura-jima, however, there took place abnormal disturbances in the sea level, a height of 12.2 *shaku* having been realized on the occasion of the high tide of March 13 (17th lunar day), inuandating the lower coast parts of the city of Kagoshima and causing some damage to the salt-fields along the beaches of the town of Kajiki and other places. This overflow of the sea waters, quite unusual except in the autumn months, seems to have been the consequence of a general elevation of the mean sea level in the northern part of the bay, the difference between the recent ebb and flow at Kagoshima being 10.4 *shaku*, or 1.1 *shaku* less than the maximum limit before found. Thus, according to the observations started since the 14th of February, 1914, by the Prefectural Engineering Department, the approximate mean height of the sea surface at the same place during the rest of the month was 7.16 *shaku*. It was 0.51 *shaku* lower in March, there being no marked variation between the latter and May, as follows:—

Month.	Mean Monthly Height of Sea Level (Kagoshima Harbour) in	
	1914.	1903 and 1904.
February.	7.16[2] *shaku*	5.95 *shaku*
March.	6.65	5.95
April.	6.54	6.24
May.	6.69	6.23

(1) 1 *shaku*=1 metre /3.3=1 foot very nearly. (2) After the 14th.

From the above table it will be seen that the mean monthly level in February this year was 1.2 *shaku* (=36 cm) higher than in the corresponding month in 1903 and 1904, the difference having been reduced to the mean amount of about 0.5 *shaku* (=15 cm) in March to May. This latter residual amount may denote the amount of the depression of the coast of Kagoshima (see below), while the greater part of the elevation of the mean level during February, and also possibly in January after the eruption, was probably the effect, as Prof. A. Imamura insists, of the temperature increase of the bay waters through the inflow of the lava streams and other circumstances. Anyhow the marked temporary elevation of the sea-level in the bay, also temporarily the case after the eruption of 1779, seems to have already in the greater portion subsided.

Comparing the results of the levelling now being repeated, at the suggestion of the Imperial Earthquake Investigation Committee, by the Military Survey Department with the heights determined in 1892, it follows that there has been a depression, whose amount is about 0.2 m at the coast of Kagoshima and is increased up to 0.67 m at a small promontary about 10 km northwards along the coast.* The greater portion of the depression thus found may possibly be the result or precursor of the great recent convulsions of the Sakura-jima.

11. ***Arrangement of craterlets.*** (Fig. 2.) The different new craterlets on both sides of the Sakura-jima are arranged evidently along a zone (II II), which extends through the centre of the island in an WNW and ESE direction, and to which also belong the extinct parasitic cone of the Nabe-yama on the SE and

*For the communications of these preliminary results I am indebted to the kindness of Mr. M. Sugiyama, of the Military Survey Department.

the dome of the Hikinohira and the (now covered up) Karasu-jima on the W. This zone, whose original formation probably dates back to the epoch of the construction of the mountain itself, is approximately at right angles to the line I I, which connects the Sakura-jima with the active Kirishima-yama on the NNE and the dormant Kaimon-dake, or Satsuma Fuji, on the SSW. It is hereby to be noticed that the line I I represents a part of the extensive South Kyushu volcanic chain and is, in this respect, of primary importance in comparison to the zone II II, which, being none of such a chain, is to be regarded as marking a system of secondary fracture or crack limited to the island itself.

The formation of numerous craterlets on two opposite flanks of the island was also the case with the eruptions of 1779 and 1476; it being obviously easier for the eruptive energy of the Sakura-jima to find vents at or near the base of the mountain than to push up the internal lava to its top.

12. ***Course of eruptive phenomena.*** It is certainly a very difficult problem, involving great amount of responsibility toward the public for several years to follow, to forecast the future condition of a volcano in complex activity with reference to the possibility or non-possibility of the repetition of the strong outbursts and the existence or non-existence of danger to the inhabitants at the mountain base. Yet, as a seismological member of the Imperial Earthquake Investigation Committee, I had to give out in distinct forms my opinions on these questions as soon as possible, in relation to the outbursts of the Sakura-jima, which were obviously to be continued for several months. With respect to the city of Kagoshima the matter was perfectly simple, as explained in the next §. It was, however, after a long consideration that the author decided, on the 20th of January, or one

week after the commencement of the eruption, to allow the fugitives from Nojiri, Furusato, etc., on the SW coast, and those from Take, Fujino, etc., on the NW coast of the Sakura-jima, to return on their own choise to the respective villages, where the ash-precipitation had not been excessive; giving them caution to be careful should frequent or strong earthquake shocks be repeated again in the island. Now, the eruption of Nov. 8th, 1779, (§ 2), was followed, in the course of one complete year beginning with Nov. 21st, or the 14th day from the date of commencement of the disturbance, by the formation of the 8 new islands off the NE side of the Sakura-jima, each time accompanied by sea water disturbances resulting in a small *tsunami*. The possibility of the similar submarine eruptions following the recent catastrophe gave the people of Kagoshima some uneasiness, giving rise at the end of January even to a false report of the appearance of a new island off the SW coast of the Sakura-jima. The reasoning by which I denied the probability of the repetition in the present instance of this particular sort of volcanic phenomena, was as follows:—The craterlets in the eruption of 1779 were formed on the S and NE sides of the island, or roughly parallel to the general direction I I (Fig. 2) of the volcanic chain, along which, and especially, in the northern part of the bay, between the two volcanoes of the Sakura-jima and the Kirishima-yama, submarine eruptions may occur, as in 1779 and 764; while in the present case, the craterlets have been formed along a secondary line of weakness, and not along a volcanic chain, implying the impossiblity of occurrence of new eruptions from points on extention either toward Kagoshima or toward Osumi. As a matter of fact, there has been so far no formation of a new eruption island.

13. ***City of Kagoshima and eruption.*** The city of

Kagoshima, although near enough to the Sakura-jima, is in reality in a position not to be damaged by the eruptions of the latter, and, on receipt of the news of the first eruption on the 12th (Jan.), I sent at once telegrams to the governor of the Kagoshima prefecture and to the editor of the daily paper, the "Kagoshima Asahi," to the effect that in Kagoshima, safe from the visitation of a great destructive earthquake, there was nothing to be feared from the eruption. The following is a note which I have published in Kagoshima on the 16th immediately after my first arrival in the city:—" (i) **Eruption.** The new craterlets are, even the nearest of them, at distances not less than 6 km from Kagoshima. The projection or precipitation of lava pieces, 70 or 80 grams in weight, is limited, even in the strong Asama-yama explosions, to the radial distances of some 4 km. Hence in the Sakura-jima outbursts, in which the individual explosions are not so powerful as those of the Asama-yama, there will be no risk in the city arising from the fall of the lava pieces of non-insignificant dimensions. (ii) **Earthquakes.** The earthquakes, so frequently occurring since the 11th, are of the volcanic nature, and, even when very strong, never attain the intensity of a great destructive earthquake, i.e., will not be able to destroy the ordinary Japanese wooden houses. Brick chimneys, stone fence-walls, etc., of unstable dimensions are, however, easily broken, and care must be paid to make them strong enough. (iii) ***Tsunami*** **(sea waves.)** Should the greater portion of the Sakura-jima be suddenly precipitated into the Bay, then there would be the production of *tsunami*. As, however, there is no prospect of the occurrence of such a convulsion, there is no need of apprehending a great *tsunami*. (iv) **Volcanic gases.** Even if the volcanic gases be strongly thrown toward Kagoshima, there is

no risk of poisoning or suffocation." The people of Kagoshima, which city had been nearly a deserted place since the 12th, began gradually to come back on and after the 16th, while the activity of the Sakura-jima continued to be reduced steadily since the 14th of January.

As shown in § 7, the quantity of the lava outflow from the eastern craterlets group is nearly four times that from the western craterlets group, and taking together the great eruptions of 1476, 1779, and 1914, it is seen that the principal lava outflow took place on the eastern side of the line I I (Fig. 2). This fact may have some connection with the arrangement of the underground lava reservoirs.

14. ***Activity along south Kyushu volcanic chain.*** (Fig. 1.) In the earlier parts of the present year there have been several outbursts in succession from the south Kyushu volcanic chain, which, as Professor Jaggar remarks, proceeded from north to south. Thus, the strong explosion of the Kirishima-yama on Jan. 8th was quickly followed by the great Sakura-jima eruption of Jan. 12th. Then the Iwo-jima (or Kikaiga-shima, well known in Japanese history in connection with Shunkan Sozu, exiled to this island in 1177), situated off the south coast of Satsuma, made eruptions on Feb. 13th, accompanied by several earthquakes, one of which was of a fairly large magnitude (§ 8). Finally, the Suwa-nose-jima, situtated further southwards, made eruptions on March 21st. These four volcanoes, which, together with the Kaimon-dake, form a nearly straight line, are at the successive distances as follows:—

	Apprx. Distance.
Kirishima-yama to Sakura-jima	45 km.
Sakura-jima to Kaimon-dake	46

Kaimon-dake to Iwo-jima 50
Iwo-jima to Suwanose-jima 147

The above mentioned different eruptions have probably brought the volcanic activity in this part of Kyushu to an end for the time, which apparently had the effect of changing the site of volcanic outbursts again to the Fuji volcanic zone, the O-shima having made, after a quiescence of about $1\frac{1}{2}$ years, very powerful lava eruptions for about 7 days between May 15th and 22nd, (1914).

Aug. 1914. Tokyo.