

shells must be in the main the result of the precipitation of pumice during the previous eruptions of Sakura-jima, probably in 1468 to 1476. At the s. end of the islet the shell-bearing layer lies directly on the well developed strata of clay.

Throughout the islet here and there are found large blocks of loose and well burnt lava placed on the pumiceous surface layer. These were probably projected in 1779 from some of the neighbouring eruptive vents prior to the elevation.

## CHAPTER V. ON SUCCESSIVE OCCURRENCES OF EARTH- QUAKES AND VOLCANIC ERUPTIONS.

**27. Successive Occurrences of Earthquakes.** The severe Kagoshima earthquake of Jan. 12th, at 6. 28 P. M., was preceded by a shock in the central part of the Inland Sea, which took place on the same day at 6. 12 P. M. (See Table XI.) These two earthquakes, whose time interval was only 16 minutes, may be regarded as being co-relative. The direct distance between the centres of the two earthquakes was 375 km. The Inland Sea earthquake, whose origin was situated near the Myojin islet (明神嶋), at  $\varphi=34^{\circ} 8' N.$ ,  $\lambda=133^{\circ} 13' E.$  was not destructive and had a small area of sensible motion, the maximum radius being 145 km. The major and minor diameters of the strong intensity area were about 56 and 37 km. respectively.

The following are examples of successive occurrences of destructive earthquakes from the Inland Sea and from some other part of Japan.

(i). The earthquake on June 2nd, 1905, at 2. 39 P.M. caused some damage both on the Sanyo-do and the Shikoku coasts, namely, at Kure, Edajima, and Hiroshima, as well as at Mitsugahama, Gunchu and Matsuyama, resulting in the casualty of 188 persons and the total destruction of 64 houses. Simultaneously with this disturbance in the western part of the Inland Sea there took place numerous shocks at the island of O-shima (Izu) and the vicinity, which began on May 28th. Among these there were two strong earthquakes which occurred respectively on the 5th, at 1.45 A.M. and on the 7th, at 2.39 P.M. The second shock was semi-destructive and produced in the island of O-shima a partial collapse of three houses, and cracks and falling down of roads and stone fence walls at 674 places. The after-shocks continued till the 15th of the same month. (ii). Three among the group of the destructive

Anei Islets Group.

(F. Omori, phot.)



Fig. 66. Moe-jima seen from the East.

(Oct. 1916.)



Fig. 67. Nakano-shima (Pumice Islet) seen from the Moe-jima.

(Oct. 1916.)



Fig. 68. Iwo-jima, showing the arc form.

(Oct. 1916.)

Moe-jima and Shell Layer.

(F. Omori, phot.)



Fig. 69,a. View of the S. E. Cliff of the Islet, containing Shells in the Surface Layer (××).

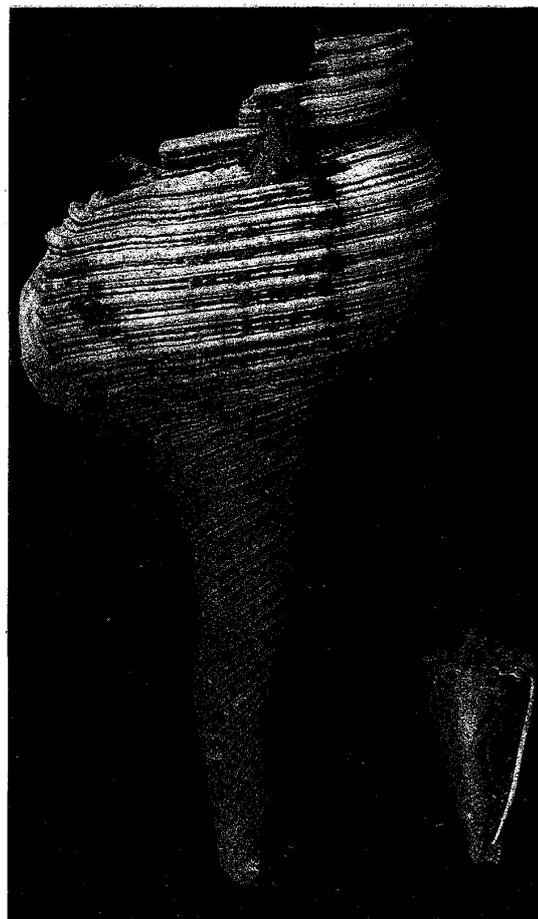


Fig. 69,c.

Fig. 69,b.

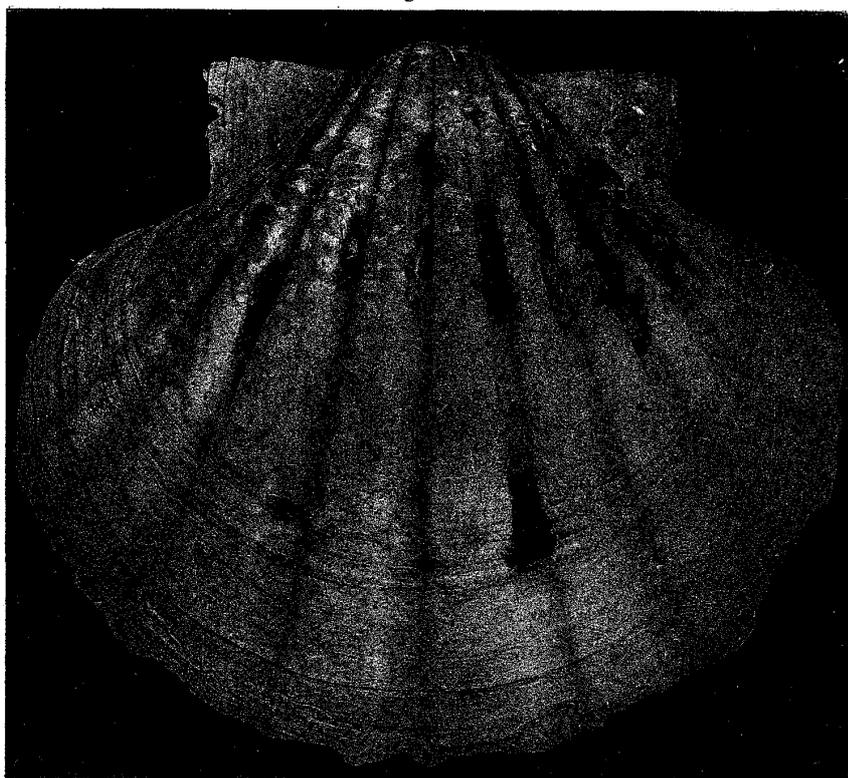


Fig. 69,d.



(b), (c), (d). Some of the Shells, in natural size.

Sakura-jima.

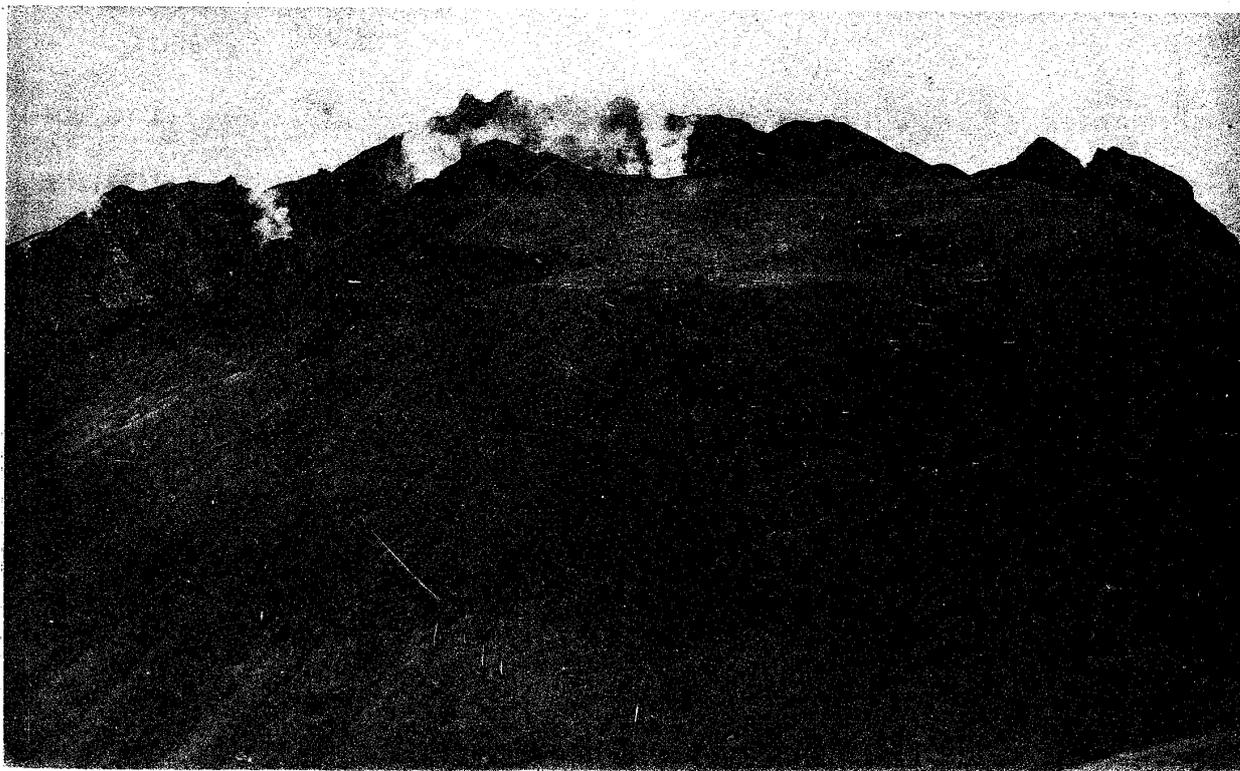


Fig. 70. Naka-dake Crater, seen from the Kita-dake; with the S. Cliff Wall of the Minami-dake shown on the back-ground. (Jan. 1915. M. Ueda, phot.)

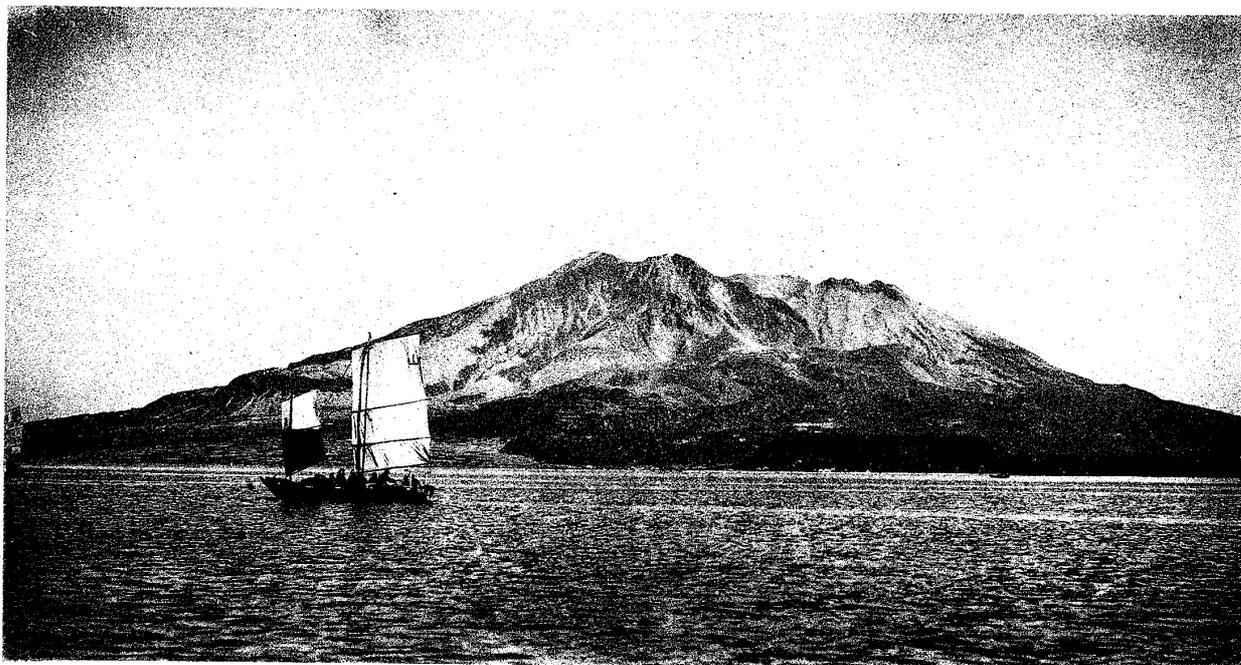


Fig. 71. Sakura-jima seen from the Kagoshima Channel, Oct. 1916. (F. Omori, phot.)

Table XI Observation of the two Strong Earthquakes on Jan. 12, 1914.

Meteorological Observatory.	Time of Occurrence.	Intensity.	Remarks.
<b>Inland Sea Earthquake.</b>			
Shisaka-jima.	6 11 29 P.M.	Moderate.	{ Quick in nature, accompanied by sound.
Niihama.	6 11 58	"	{ Quick in nature, accompanied by sound. Houses shaken.
Tadotsu.	6 12 09	"	{ Quick in nature, with vert. motion.
Kure.	6 12 28	"	" " " "
Hiroshima.	6 12 25	"	" " " "
Kochi.	6 12 03	"	Doors shaken.
Besshi.	6 11 40	Slight.	{ Slow in nature, accompanied by sound. Doors shaken.
Matsuyama.	6 11 59	"	Quick in nature.
Okayama.	6 12 18	"	" " " "
<b>Sakura-jima Earthquake.</b>			
Kagoshima.	6 30 00 P.M.	Destructive.	Accompanied by sound.
Kmamoto.	6 28 55	Moderate.	Duration long.
Miyasaki.	6 29 20	"	Houses shaken.
Saga.	6 29 30	Strong.	Quick in nature.
Nagasaki.	6 29 27	Moderate.	Slow in nature.
Sasebo.	6 28 45	Slight.	" " " "
Fkuoka.	6 28 50	Unfelt.	" " " "
Nase (Oshima).	6 28 53	"	" " " "
Hiroshima.	6 30 05	"	Slow in nature.
Hamamatsu.	6 28 45	"	Quick in nature.
Osaka.	6 29 28	"	" " " "
Tokyo.	6 30 21	"	" " " "

earthquakes in the Ansei period furnish an interesting case of the successive westward transference of seismic activity. The great earthquake of Dec. 23, 1854, at 9 A.M., originated off the coast of Tokai-do. The next day, the 24th, at 5 P.M., there took place the equally great Nankai-do earthquake, the two seismic centres being separated by a mutual distance of 320 km. These sub-oceanic shocks were followed on the 26th, at 10 A.M., by a seismic disturbance at the western part of the Inland Sea, which caused damage at Osu and Yoshida, in Iyo, and at Oita and Kokra at the N. E. part of Kyushu. (iii). The famous violent earthquake on Sept. 4th, 1596, the first year of Keicho, which destroyed the magnificent castle buildings of Toyotomi Hideyoshi at Fushimi, near Kyoto, did not happen alone, but was preceded by the destructive shock of Oita and Beppu on the 1st of the same month, which originated in the bay of Beppu, at the extreme west of the Inland Sea. This latter earthquake, accompanied by *tsunami* (tidal waves), is well known on account of the submergence of the Uryu-jima, which had been a populous islet near the coast of Oita. (iv). The two severe earthquakes on Jan. 17 and April 30, 1897, which caused some damage about the town of Suzaka in the vicinity of the Asama-yama volcano, were each time preceded by a strong shock in the western portion of the Inland Sea, and followed by another off the southern Pacific coast of the Main Island, as shown next:

Date and Time of Occurrence.	Position of Eqke. Origin.	Major and Minor Diameters of the Area of Sensible Motion.
Jan. 17, 1897; 0.49 A.M.	Inland Sea (off the coast of Aki).	250 × 140 <i>ri</i> .*
„ „ „ 5.36 A.M.	Suzaka (Shinano.)	130 × 110 „
„ 18, „ 9.27 P.M.	Pacific Ocean (near Izu.)	120 × 90 „
April 19, 1897; 9.30 A.M.	Inland Sea (off the coast of Aki).	170 × 120 „
„ 30, „ 4.02 P.M.	Suzaka (Shinano.)	130 × 90 „
„ 16, „ 0.14 A.M.	Pacific Ocean (off the coast of Totomi).	90 × 80 „

Examples like these seem to indicate the existence of the mutual connection between the seismic disturbances of the Inland Sea and those of other parts of Japan, volcanic or otherwise. (v). As a further example, may be mentioned the Inland Sea earthquake on March 17, 1649, which was

\* 1 *ri* = 3.927 km.

felt strongly in Iyo and Aki, and damaged the *ishigaki* (stone retaining walls) of the three castles of Uwajima, Matsuyama, and Hiroshima. This was preceded and followed by destructive shocks of local nature in the Kwanto provinces of Musashi, Sagami, and Shimotsuke, as follows: (1). June 16, 1647. The two provinces of Musashi and Sagami were strongly shaken. Damage was done to the *ishigaki* of the Yedo castle and the mansions of the daimyos. The head of the bronze Daibutsu (huge image of Buddha) at Ueno was thrown down. The ferry landing of the Banyu-gawa was also damaged. (2) June 12, 1648. A strong shock took place in the vicinity of Hakone-yama, causing damage to the mountain paths. (3). July 29, 1649. The earthquake was strongly felt in Musashi and neighbouring provinces, damaging the *ishigaki* of the Yedo castle, and overthrowing the residences of several daimyos. The head of the Daibutsu at Ueno was again thrown down. At Nikko, the stone fence of the Toshogu shrine was thrown down at several places. (4). Sept. 1, 1649. The shock was felt strongly in Musashi, causing some damage to the Hirakawa gate of the castle of Yedo. At Kawasaki 100 dwelling houses were destroyed. In the year 1649 the Shirane-san (Nikko), the Asama-yama, and the Aso-san were in eruption. Among these four Kwanto earthquakes, (2) and (3) seem to have been of volcanic origin. So was also the case with the Kagoshima earthquake of Jan. 12, 1914, and the Oshima earthquake of (i), and the two Suzuka earthquakes of (iv), and possibly also the Beppu earthquake of (iii).

**28. Volcanic Eruption and great Tectonic Earthquake.** In connection with the destructive Sakura-jima earthquake at 6. 28 P. M., on Jan. 12, 1914, I may mention the great Kisagata earthquake on July 10, 1804, (文化元年六月四日象潟大地震), when the ground was elevated some 3 metres for the length of over 10 miles along the coast of the Japan Sea, at the foot of the Chokai volcano. It was on this occasion that the lake of Kisagata, formerly famous for its beautiful scenery and known as the Matsushima of Dewa (Provinces of Uzen and Ugo), was uplifted and dried, so that its numerous islets crowned with pine trees are at the present day left amid the converted cultivated fields. It is scarcely to be doubted that the Kisagata earthquake was connected with the great eruption in 1801 of the Chokai-san which resulted in the formation of the new lava dome called the Kyowa-dake (享和岳), the present central and highest peak of the volcano. The last great explosive eruption of Mount Fuji on Dec. 16, 1707, (寶永四年十一月廿三日), which resulted in the formation of a

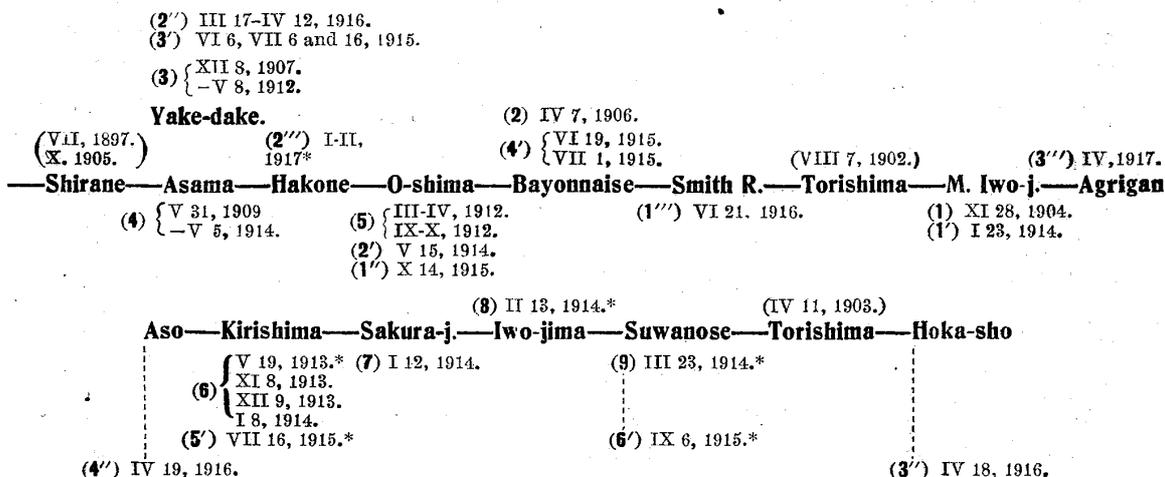
new large cinder mound "Hoei-san," may also be supposed to have been connected with the earthquake on Oct. 28, of the same year, (寶永四年十月四日), which is regarded to be the greatest among the earthquakes experienced in Japan since the earliest historical times, and whose destructive motion area stretched from the northern part of Kyushu to the central part of Suruga in Tokaido. Again, the earthquake on Aug. 23, 1856, (安政三年七月廿三日), which was felt strongly along the s. e. coast of Hokkaido and produced tidal waves (*tsunami*) at Hakodate and along the coast of Yufuts (Tomakomai), was followed 28 days later, on Sept. 20 of the same year, by a great eruption of the Komaga-take volcano, situated on the southern border of the Volcano Bay. It is to be noted that the eruptions of Chokai-san, Komaga-take, and Fuji-san here mentioned were all markedly strong disturbances which continued for several days or several weeks. The destructive earthquakes which followed or preceded these volcanic outbursts may be regarded, together with the Sakura-jima earthquake on Jan. 12, 1914, as furnishing examples of non-local tectonic seismic disturbances connected with great volcanic manifestations. That such should be the case is easy to understand, as some of the volcanoes at considerable mutual distances, notably the Sakura-jima, the O-shima (Izu) and the Asama in 1777-1783 and again in 1909-1914, made eruptions successively in the course of a short time interval; it being thus evident that the volcanic stress is wide-reaching and affects simultaneously the whole island arc of Japan. This condition may of course lead, or may be precursory, to the occurrences of earthquakes of large extension. On the other hand, it is quite conceivable that the volcanic eruptions tend to relieve the stress accumulation within the earth's crust in the neighbouring area, thereby preventing the occurrence, or reducing the frequency, of seismic disturbances. Thus, the relation of volcanic and seismic phenomena may be summarized, as follows: Volcanic earthquakes, or those having origin under or near an active, dormant, or dead volcano, are usually limited in area and of no great intensity, belonging to the category of what may be termed a small local destructive shock;\* in some rare cases, however, the eruptions are connected with large tectonic earthquakes.

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\* An earthquake whose intensity is not enough to destroy ordinary wooden Japanese houses.

29. **Successive Occurrences of Volcanic Eruptions.** The occurrence in the recent years of the eruptions from the different mountains unmistakably indicates the existence of a close relation between the Fuji and Kyushu volcanic chains, as is illustrated below.

**SCHEMATIC ILLUSTRATION OF THE SUCCESSIVE OCCURRENCES OF THE ERUPTIONS.**



The series of the eruptions were repeated in four periods, or cycles, of successively decreasing intensity, as follows:—

- (i) 1904 to 1914: M. Iwo-jima (South Sulphur Island); Bayonnaise Rocks; Yake-dake; Asama; O-shima; Kirishima; Sakura-jima; Iwo-jima; and Suwanose-jima.
- (ii) 1914 to 1915: M. Iwo-jima; O-shima; Yake-dake; Bayonnaise Rocks; Kirishima (eqkes. only); Suwanose-jima (eqke. only).
- (iii) 1915 to 1916:—O-shima; Yake-dake; Hoka-sho (near Formosa).
- (iv) 1916-1917:—Smith Rocks; Hakone (eqkes. only).

1st Period. (1), the disturbance began near the south extremity of the Fuji volcanic chain, on Nov. 28, 1904, with the submarine eruption off the N. E. coast of Minami Iwo-jima of the Volcano Islands group, resulting in the production of an ephemeral islet. (2), On April 7, 1906, there followed a submarine eruption near the Bayonnaise Rocks situated 110 km. to the south of the Hachijo-jima. (3), then took place on and after Dec. 8, 1907, outbursts from the Yake-dake volcano in the Japan Alps, near the northern extremity of the Fuji chain. (4), there soon followed the activity of the Asama whose

\* Earthquakes only.

premonitory sign occurred in the form of a violent local earthquake on May 26, 1908, resulting in the strong explosions first on May 31 and Dec. 7 of 1909. The explosive violence of the Asama was greatest during 1912 and in the summer of 1913. (5), in the mean while, the O-shima was also thrown into an unusual activity and made splendid firework-like outbursts of lava in March-April and in Sept.-October, 1912. Toward the end of 1913, the three great volcanoes of the Fuji chain, namely, Asama, Yake-dake, and O-shima, passed the climax of their activity and were all brought to a state of rest. This meant the removal of the seat of volcanic activity to Kyushu. (6), initiated by the occurrence since May 19, 1913, of a group of local earthquakes in the neighbourhood of the Kirishima volcano, which had been dormant for the 10 years since 1904. The disturbance in the stress equilibrium of the earth's crust soon spread to the peninsula of Satsuma, and the town of Ijuin and the vicinity were shaken at the end of June of the same year by a severe earthquake and numerous secondary shocks. On Nov. 8 and Dec. 9 the Kirishima finally broke out into strong explosions. Thence the seismic and volcanic activity in the southern part of Kyushu underwent a rapid development, and the 3rd explosion of the Kirishima on Jan. 8, 1914, was followed, (7), 2 days later by the occurrence since the night of the 10th of the local earthquakes at Sakura-jima whose frequency rapidly increased; no less than 337 shocks having been registered even in the city of Kagoshima by means of an ordinary seismograph at the meteorological observatory during the 27 hours between the 11th, 3 A.M. and the 12th, 6 A.M. The great eruption of Sakura-jima finally began on the same morning at 10 o'clock. (8), after the Sakura-jima outburst, the telluric disturbance spread further southwards, resulting in the strong earthquake on Feb. 13 at Iwo-jima, one of the Satsuma islands group. (9), there was also a strong earthquake on March 23 at the Suwanose-jima situated further south.

*2nd Period.* After the Sakura-jima eruption of Jan. 12, 1914, the volcanic activity reverted at once to the Fuji chain and, (1'), it was only one week later that the Minami Iwo-jima became again the scene of disturbance; a submarine eruption occurring at the same spot as in 1894 and resulting likewise in the formation of an ephemeral island. (2'), the O-shima made a third marked lava eruption on May 15. (3'), the Yake-dake quickly followed in the series and made an explosion on June 6, 1915. (4'), On June 19 and July 1 of the same year submarine eruptions took place from the vicinity of the Bayonnaise Rocks. Thereupon the volcanic activity was again transferred to Kyushu, and there followed, (5'), a strong earthquake on July 16 in the vicinity of Kirishima, and, (6'), another on Sept. 6 at the Swanose-jima.

*3rd Period.* The telluric disturbance went back to the Fuji volcanic chain for the 3rd time, and resulted, (1''), in the small outburst (smoke emission) of O-shima on Oct. 10-31, 1915. (2''), the Yake-dake made small explosions on March 17 and April 12, 1916. Then there followed slight disturbances in Kyushu: (3''), the submarine eruption on April 18, 1916, near the islet of Hoka-sho (vicinity of Formosa), and, (4''), a small eruption of the Aso-san on the next day, the 19th.

*4th Period.* The 4th stage of activity along the Fuji volcanic chain consisted of, (1'''), the submarine smoke emission in the vicinity of the Smith Rocks on June 21, 1916; (2'''), the local earth-sounds (*jinari*) and earthquakes of the Hakone in Jan. and Feb. 1917; and, (3'''), an eruption in April 1917 of the Agrigan island in the Marianas.

Of the four cycles of the volcanic activity above described, the 1st was the most powerful. The 2nd cycle was much weaker, while the 3rd and the 4th were very feeble.

**30. Concluding Remarks.** Through the liberality of the Imperial Earthquake Investigation Committee the present author was enabled to visit Sakura-jima several times during the course of, and after, the recent eruption, carrying on, amongst the others, tromometer observations of the after-eruptions and volcanic earthquakes. The eruption in question was, as far as the amount of lava outflow and ash precipitation is concerned, the greatest which happened in Japan during her historical times. This circumstance, coupled with the small size of the island volcano, caused a marked subsidence of the adjacent ground, especially of the bottom of the sea lying behind it, or to its north. Thanks to the kindness of the authorities of the Military Survey and the Hydrographic Office, laborious series of the precise leveling and soundings were carried on in the areas concerned, determining exactly the amounts of the displacements of the ground due to the great eruption and of the subsequent recovery.

The Sakura-jima outburst in conjunction with the Usu-san eruption of 1910 gives much light on the process of formation of *volcanic lake*, situated behind a volcano, and also the building up of the volcanic chains actually going on at present. The foregoing pages constitute a modest geometrical and seismological reports on the great Sakura-jima eruption of 1914, and the course of the after-events followed for the next 8 years.\*

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\* For an excellent petrological and geological study of the eruption the reader is referred to Professor B. Koto's paper, "the Great Eruption of Sakura-jima in 1914," published in Jour. Coll. Sc., Tokyo Imp. University, 38, Art. 3, (1916).