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On the Shimabara Earthquake of Dec. 8, 1922.*

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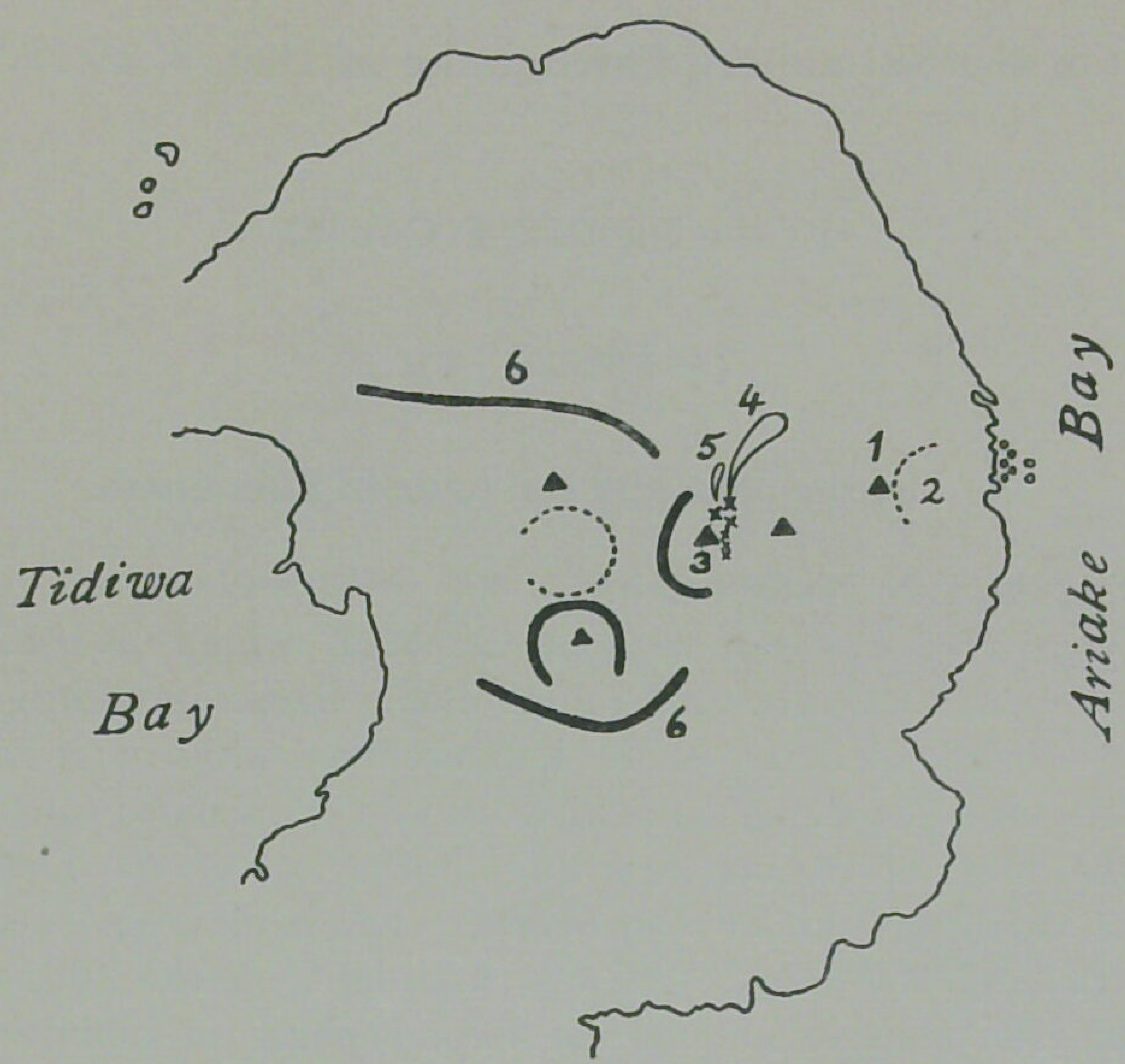
(*With Plates* I—VII.)

A. Unzen-dake and the town of Shimabara.

Going back to historical times, the great outburst of Unzen-dake in the year 1792 was part of a phenomenon which had been going on for over four months. As premonitory shocks preceding the first period of volcanic activity, there had occurred already in the winter of 1791 several earthquakes which caused landslides on the hills around the town of Obama, resulting in the loss of two lives through burial of dwellings under the debris. Landslides also occurred at Shimabara and Mae-yama. At past midnight on the 10th of February, 1792, the volcano entered its second phase of activity with an explosive outburst. Detonations could be heard coming from Fugen-yama, one of its loftiest peaks, when at the same time a vent was formed near the shrine of Fugen, from whence were projected steam, earth, stones and immense quantities of mud. After this the volcano entered its third phase of activity with outpourings of molten lava. On the 25th of February disturbances started from a ravine called Anasako and lava began to flow out from the 30th. From April 21st the earthquakes gradually increased in intensity, and with every shock loosened quantities of rocks and sand which poured down from the mountain slopes. From midnight of that day until the dawn of the following, the earthquakes were particularly violent, causing damage to the castle of Shimabara with some casualties. On the 29th at the village of Nakakoba, situated on the southern flank of the mountain, a grove of camphor trees measuring 120 meters by some 50 to 60 meters was suddenly dislodged and hurled into the ravine below, practically filling up the hollow. Two very severe shocks occurred on May 21st. The whole southern flank of Mae-yama, from summit to base, broke away and considerably altered the shape of the mountain.

* Articles contributed by Dr. Omori to the "Gakugei" Magazine.

Fig. 1. Unzen Volcano. (1/300,000)



1. Maeyama. 2. Scars. 3. Fugen-dake.
4. Lava-flow of 1792. 5. Lava-flow of 1657. 6. Somma.

(After Imamura.)

Unlike the main peaks of Unzen-dake, Mae-yama is an isolated mountain quite distinct from the former and is composed of old and friable volcanic rock. Prior to the final outburst of May 21st there were several landslides on this old mountain. Even at the present day the scars on the sides of Mae-yama are plainly visible as reminders of the numerous landslides including the large one of May 21st, the whole forming a horse-shoe shape. The great disturbance of May 21st may be regarded as immense landslides induced by earthquakes.

There is, nevertheless, an idea prevalent that the great landslides of Mae-yama was due to an explosive outburst, pointing out as proof the

Shimabara is the name of a coast-town on the island of Kiushiu, the southernmost of the four large islands constituting Japan proper. The town lies on a small peninsula on the western side of Ariake Bay, and situated about 68 km. due east of the well-known city of Nagasaki.

Yama, san, zan all mean mountain.

Take and *dake* also mean mountain, but more often a peak.

horse shoe shaped scar aforementioned, but facts to support such a view are entirely wanting. That the scars should take the form indicated is not at all uncommon in the circumstances. Against the prevailing view, moreover, there are the following serious objections :—

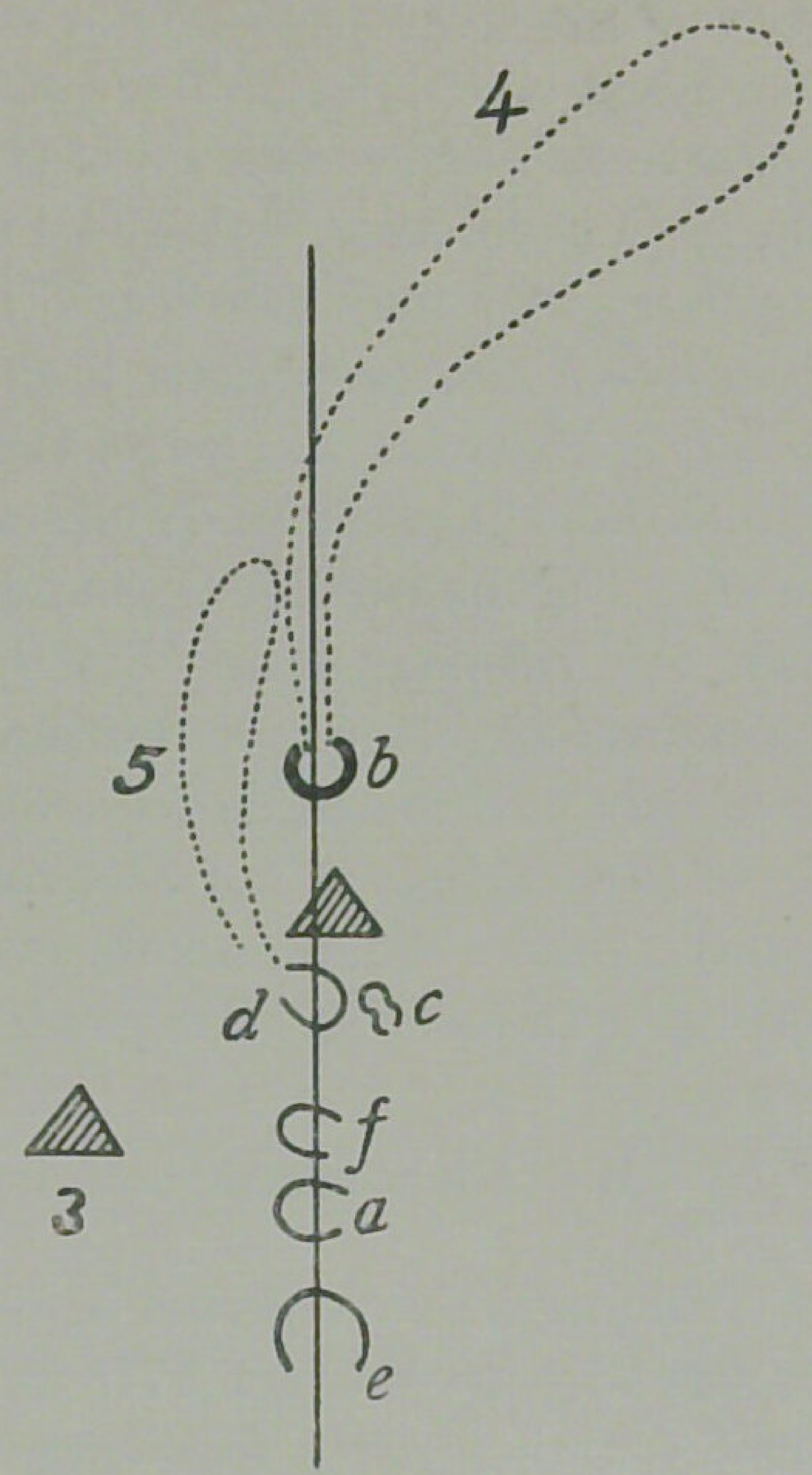
(a) Granted that there was an explosive outburst sufficiently violent to have caused the landslides, we should then in that case expect the projection of ashes to prodigious heights, which, upon being wafted eastwards by the upper air currents, would cross Kiushiu and eventually fall in Shikoku as well as on parts of the main island of Japan, but nothing of the kind has happened.

(b) Again, on the preceding assumption, the sound of the explosions ought to have been audible for a radius of between something like 5 to 25 kilometers distant, but no such sounds were heard.

(c) As usual sequence of events in a volcanic eruption, we generally have as the first phase of the activity, premonitory earthquakes with some emission of smoke, the latter taking on an explosive character upon reaching the second phase, whilst outpourings of lava characterise the third period of activity. The great outbursts of Unzen-dake which took place between the latter part of 1791 and March 1792 passed through all these three phases in due order. If, however, for the sake of argument, we admit that in the final month of May, 1792, Maeyama did break out in eruption, then it must have done so without passing through any of the usual periodical phases of activity.

(d) There is no mention whatsoever in the annals of the time about the landslides having occurred as a result of an eruption.

Fig. 2. New craterlets of Unzen Volcano.



a–c. Craterlets of 1792.
d. Craterlet of 1657 and 1792.
e, f. Old craterlets.
3. Fugendake.
4. Lava-flow of 1792.
5. Lava-flow of 1657.

(After Imamura.)

The volcanic idea of the Mae-yama landslides might be dismissed as nothing more than mere speculation were it not for the fact that the future safety of Shimabara hinges on the verity or otherwise of this theory, and if the great landslides of Mae-yama in 1792 were really the results of an explosive outburst of this mountain, then we cannot escape the conclusion that in this old volcano there lie dormant dire potentialities for a powerful eruption which may be released in all its fury at any future moment, in which event the precarious position of Shimabara town and vicinity is obvious. However, in view of the four objections above given, I make bold to state that the great landslides were due, both directly and indirectly, to the effects of the earthquakes and not to any eruptive forces. Mae-yama is an old, extinct volcano and being composed of old and friable rock, landslides took place as a result of the strong earthquakes, but now that the loosely held materials have dropped off the mountain slopes, a repetition of these things is not be expected even should earthquakes visit the locality again. Furthermore, even should Unzen-dake erupt again with copious outflows of lava, no particular danger need be apprehended.

B. The volcanic activity of Unzen-dake in Shimabara.

The most active period in the history of Japanese volcanic eruptions was the 13 years between 1778 and 1792, during which interval there occurred eruptions of the following volcanoes :—the great outburst of Oshima (Idzu province) and that of Sakurajima between 1778 and 1782, the fearful eruption of Asama-yama in 1783, the detonations of the extinct volcano Hakone-yama, and finally the great eruption of Unzen-dake which continued for four months between the winter of 1791 and the spring of 1792. This eruption started from Fugenyama, one of the loftiest peaks in the central part of the Unzen-dake range, with outpourings of lava which flowed down the valley channels for a distance of more than four kilometers with, however, no casualties. Finally on the 21st of May, 1792, there was a deafening detonation, followed by a great landslide from the slope of Mae-yama, mentioned in the preceding paragraphs, and distant about four kilometers from Fugen peak, resulting in the descent of a terrible mudstream into the Ariake sea, causing thereby a large tidal wave. Mae-yama, however, being an old extinct volcano was destitute of volcanic energy, and while the earthquakes from Unzen-dake were not particularly severe, the worst ones were wont to cause earth-cracks from 5 to 10 cm.

wide, besides causing the cantings of dwelling houses and overturning of warehouses and the great landslide of Mae-yama.

Fully 120 years had elapsed since the turbulent years of 1778–1792, when with the year of 1909 was ushered in a new period of pronounced volcanic activity which lasted until 1915. This interval witnessed violent outbursts of the three very similar volcanoes of Oshima, Asama and Sakurajima, so that the disturbances of 1778–1792 were repeated in the same order even to the detonations of Hakone-yama, together with the disturbance of Unzen-dake, which latter, had been anticipated as the culmination of these activities. In these circumstances the numerous earthquakes which visited Nagasaki and vicinity at the time were nothing more than local shocks of volcanic origin.

According to the tromometer of the Seismological Institute (Tokio), the earthquake which was felt at 1 h 52 m 30 s on the 8th (Dec. 1922) was quite strong, the maximum having reached 2.8 mm. so that it was equal in severity to the strong shock that was felt at 6.30 in the evening of January 12th, 1914, which latter took place about ten hours after Sakurajima had began its eruption. At 7 h 23 m 58 s there was a small shock followed by one at 11 h 04 m 07 s, which could rank next in severity to the first one, and with a maximum movement of 1.7 mm., while another small shock was felt at 2 h 19 m 31 s in the afternoon. All these were comparatively strong shocks, and Shimabara and vicinity soon became the seat of frequent earthquakes of varying intensities.

Judging from the behaviour of Unzen-dake in the past, it is quite possible that earthquakes such as have recently happened may repeat themselves during the course of the next few weeks, but nothing of a destructive nature need be expected. We are now witnessing the usual characteristics of volcanic earthquakes, just as what happened during the eruption of this same volcano in 1792, and even should an eruption now take place there is no cause for uneasiness. That Unzen-dake will immediately begin an eruption is difficult to believe, and even were it to commence and keep up for some months, so long as the outbursts do not assume an explosive character, nothing serious is likely, still less a repetition of the disaster of 1792. Even should there be lava flows, they will go down the valleys and quiet down after travelling a few kilometers without endangering life or property. As to the earthquakes, while they may not be strong enough to overturn the Japanese style wooden houses, buildings and warehouses of bricks or stone may be overturned, but what needs to be particularly emphasised is the danger of falling rocks and debris from the hillsides. (Penned on the spot by the author on December 8th, 1922.)

C. The Earthquake of Shimabara Peninsula.

INTRODUCTION. The islands of Hokkaido, Honshiu, Shikoku and Kiushiu, together comprising the Japanese island chain, form a conspicuous arc with marked dissimilar features for the inner, or concave, side as contrasted with the outer, or convex, side of the arc. Judging by the systematic way in which the volcanoes and seismic centres are distributed, the Japanese island arc may, in a broad sense, be regarded as one great volcanic or seismic zone. Consequently, whenever the crustal stress accumulates the whole island arc is affected, and great eruptions and forcible earthquakes occur simultaneously in various parts of the country. In view of the intimate connection between volcanoes and earthquakes, it follows that whether they originate at widely separated localities, or whether they have occurred in the past or quite recently, or whether they may occur in the future, they all are more or less inter-related, so that careful observations of the distribution of these phenomena with respect to periodicity as well as to locality, ought to yield data justifying reasonable anticipations regarding the usual trend of these activities. Or we might say that every volcano has its particular characteristics, or *habits* so to speak, and in a way, the earthquake zones have also their respective habits, such as whether they are generally weak or strong, or whether their activities are generally preceded by feeble foreshocks or otherwise. It is the careful observations of these habits that is extremely desirable. Now, not only the Japanese island arc, but the entire Pacific margin may be regarded as one great seismic zone. It is noteworthy that in Japan and the Aleutian group, and in the clearly established island arcs of Java and Sumatra, the inner, or concave, side is generally the volcanic zone, whereas the outer, or convex, side is the seismic zone.

VOLCANIC EARTHQUAKES. Of types of these there are several and examples of some of them follow.

(a) Firstly, we have those which take place some hours, or even some days, before the actual eruption. Notable examples are furnished by the succession of shocks which heralded the Usu-san eruption of 1910, in Hokkaido, and the violent eruption of Sakurajima in 1914. In both cases the fore-shocks, gradually increasing in strength, kept on for from two to as much as four days after which the volcanoes burst out with all their fury, but the earthquakes, after having reached their maximum intensity, gradually quieted down. In the case of the eruption of Yake-dake, situated on the boundary of the provinces of Hida and Shinano, and which started at 7.35 on the morning of June 6th, 1915, a succession of shocks kept up with hardly an intermission for almost 35 minutes before the eruption broke out.

(b) Secondly, we have those premonitory shocks, which, instead of gradually increasing in intensity, start off with several sudden strong shakings followed by a number of after-shocks, which, gradually diminishing in intensity, quiet down altogether when after a few quiet days the volcano begins its work. The examples fitfully illustrating this type are the two severe Asama shocks of May 26th, 1908 at 9.15 a.m. and of July 16th, 1912 at 7.46 a.m. These were followed by several hundred after-shocks that lasted for several days, but in both of these cases the eruptions of Asama-yama took place almost a year later. An historical example is that of the earthquakes which started to violently shake the environs of the town of Obama, in the Shimabara peninsula, on Dec. 10, 1791, which were followed in February of the succeeding year by an eruption of Fugen-dake.

(c) At certain periods volcanoes quite extinct like Hakone-yama become the seat of earthshaking detonations which are volcanic earthquakes.

(d) When explosions or eruptions originate in volcanoes the ground tremors that occur are volcanic earthquakes, although they are extremely feeble. This was experienced during the recent activities of Asama-yama when we were descending the mountain and were at a distance of about 4 km. from the summit. Tremors took place nearly 10 seconds before we heard the thunderous report of the explosions, but the tremors were not felt by our unaided senses.

We may say then that earthquakes felt at the base, or in the vicinity of it, are volcanic earthquakes, be the latter active, dormant or extinct, and whether an earthquake is volcanic or otherwise, there is no fundamental difference in their respective natures, the difference being simply confined to geographical characteristics. However, volcanic earthquakes do not go beyond a certain stage of intensity, being mainly local shocks of limited severity.

D. The Violent Shimabara Earthquake of 1922.

(An outline sketch.)

From about 4.15 p.m. of December 7th, 1922, there were felt several earthquakes, and while they were all fore-shocks, at about 1.50 a.m. of the following day there came the first severe shock. Another big one came at about 11.03 a.m. of the same day, although, by the tromometer at the Seismological Institute, Tokio, the maximum movement of the second severe shock was only slightly more than half that of the first big shock, that is to say, the first one was the most energetic of all the shocks that came, besides causing the most damage. Moreover, while the first strong shock overthrew houses, caused casualties and did other damages in the four villages of South Arima, North Arima, West Arie and East Arie, all lying in the southern part of the Shimabara peninsula, the second strong shock threw down houses, caused many casualties and did considerable havoc throughout the district lying between Obama hot-springs in the western, up to Kitamura in the northern, part of the peninsula. This difference in the affected areas was due to migrations of the seismic center, and, as will be shown hereinafter, the origin of the first strong shock was underneath the base of Fugen-dake, whereas that of the second strong shock was at a point underneath the southwestern base of the mountain, hence close to Obama. Again, according to the tromometer records of the Seismological Institute, Tokio, there were two fairly strong shocks at about 7.22 a.m. and at 2.17 p.m., respectively, on the 8th, which, when compared with the first and second severe shocks were quite feeble, but were felt rather strongly at places near the origin. The shaking which took place at 2.17 p.m. had as its epicentre a place very close to the city of Nagasaki, which had already suffered more or less from the effects of the first severe shock so that this city suffered again, although to a lesser extent with only such damages as cracks in walls and overthrown brick walls, etc. The number of after-shocks was, however, enormous, and, according to the tromometer records of the Nagasaki Meteorological Observatory, the number registered up to 5 p.m. of the 8th had reached already 600, including the fore-shocks which occurred about 4 p.m. of the 7th. After this the shocks began to diminish in frequency, but from the commencement up to noon of the 11th, the number of shocks registered reached the enormous total of 1417, although the majority of them were sensible only to instrumental records.

The casualties were as per Table I, namely, 27 killed and 35 wounded; 131 dwellings and 295 warehouses and outhouses destroyed.

Table I.

Village	Killed	Wounded	Collapsed houses	
			Dwelling	Non-dwelling
Kita-arima	13	16	46	142
Minami-arima	2	2	8	3
Higasi-arie	4	6	18	59
Nisi-arie	2	1	9	4
Katusa	2	2	7	17
Kutinotu	1	4	3	1
Obama	3	4	20	46
Kita-kusiyama	0	0	5	9
Minami-kusiyama	0	0	8	4
Dôsaki	0	0	1	3
Hutu	0	0	1	0
Hukae	0	0	1	1
Yamada	0	0	2	5
Hukabori	0	0	1	1
City of Nagasaki	0	0	1	0
Total	27	35	131	295

In the above table the casualties at Obama were mainly the result of the second strong shock which came at 11 a.m. on the 8th, while those of the rest were due to the first strong shock which came at 1.50 a.m. There was no damage to speak of at the Obama hotspring resorts. In the outskirts of the Unzen Kôen (Hot Springs Gardens) the second shock was felt more strongly than the first one, and while there were cracking of walls, overturning of stone fencings and such minor damages, the buildings did not suffer. At the Unzen Shrine a portion of the stone fencing was thrown down, but none of the stone lanterns were overturned, while at the Unzen Kôen neither the solfataras nor the fumaroles showed any signs of change.

The hamlet of Hashiguchi in North Arima was a heavy sufferer with destruction of 13 dwellings out of a total of 22 and 11 persons killed, while at the hamlet of Nakasugawa in North Arima four people were killed.

Table II. Casualties in the village of Kita-Arima.

Hamlet	No. of houses	Collapsed houses		Killed	Wounded
		Dwelling	Non-dwelling		
Hasiguti	22	13	9	11	11
Haiki	20	4	5	1	1
Oriki	48	1	10	1	1
(Other)	983	28	18	0	3
Total	1073	46	42	13	16

Table III. Casualties in the village of Higasi-arie.

Hamlet	No. of houses	Collapsed houses		Killed	Wounded
		Dwelling	Non-dwelling		
Kubo	—	1	2	0	2
Nakasugawa	—	4	4	4	2
Ogawa	—	7	15	0	1
Yamakawa	—	4	18	0	1
Onoue	—	0	2	0	0
Kabakawa	—	3	17	0	0
Total	—	19	58	4	6

In Kita-Takaku County, no dwelling collapsed, but some warehouses and outhouses collapsed as follows :

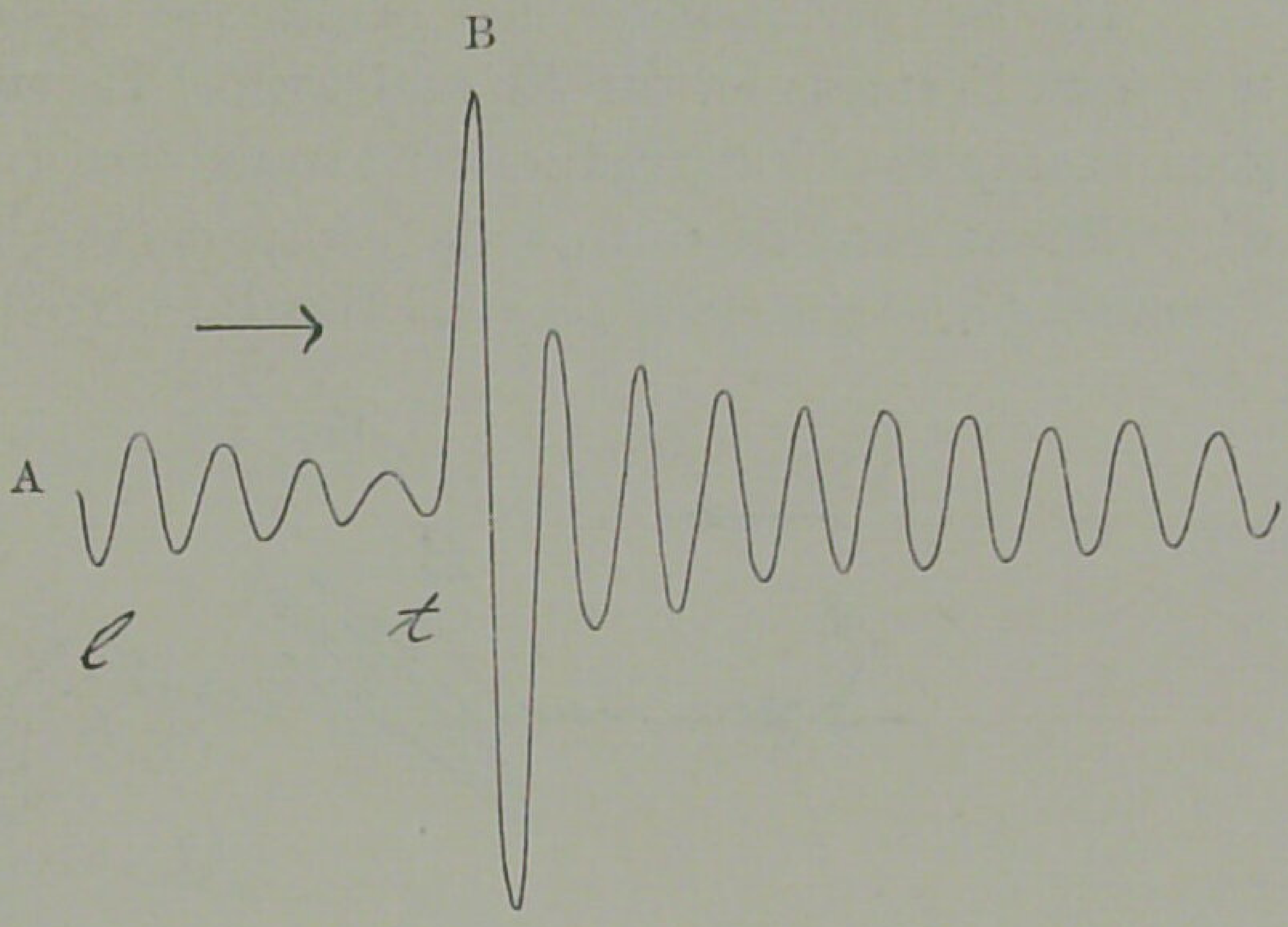
Ono Village 15, Tayui Village 4, Moriyama Village 3,
Enoura Village 4, Toisi Village 1.

A SHORT ANALYSIS OF EARTHQUAKE MOTION. As illustrated in Fig. 3 the earthquake motion begins with slight tremors A and after a little interval reaches the main phase B, after which it gradually diminishes in intensity. The preliminary tremor is therefore AB, and whether it be a sensible vibration or a microtremor, so long as it has originated at a near distance its duration is generally a few seconds or some tens of seconds, so that the distance of the seismic origin can be determined by an observer from the following formula

$$x \text{ km} = 7.42\, y \text{ seconds}$$

where x=distance from the observer to the origin and y=observed duration of the preliminary tremor. The explanation of the preliminary tremor is that from the source of the vibrations are propagated outwards, and simultaneously, two different waves, one longitudinal (A, Fig. 3) and the other transverse (B), but since the longitudinal waves have a higher velocity of propagation than the transverse waves, the former outraces the latter so that as the distance from the origin increases, the time difference in the arrival of the two waves also increases, or, in other words, the duration of the preliminary tremor is increased.

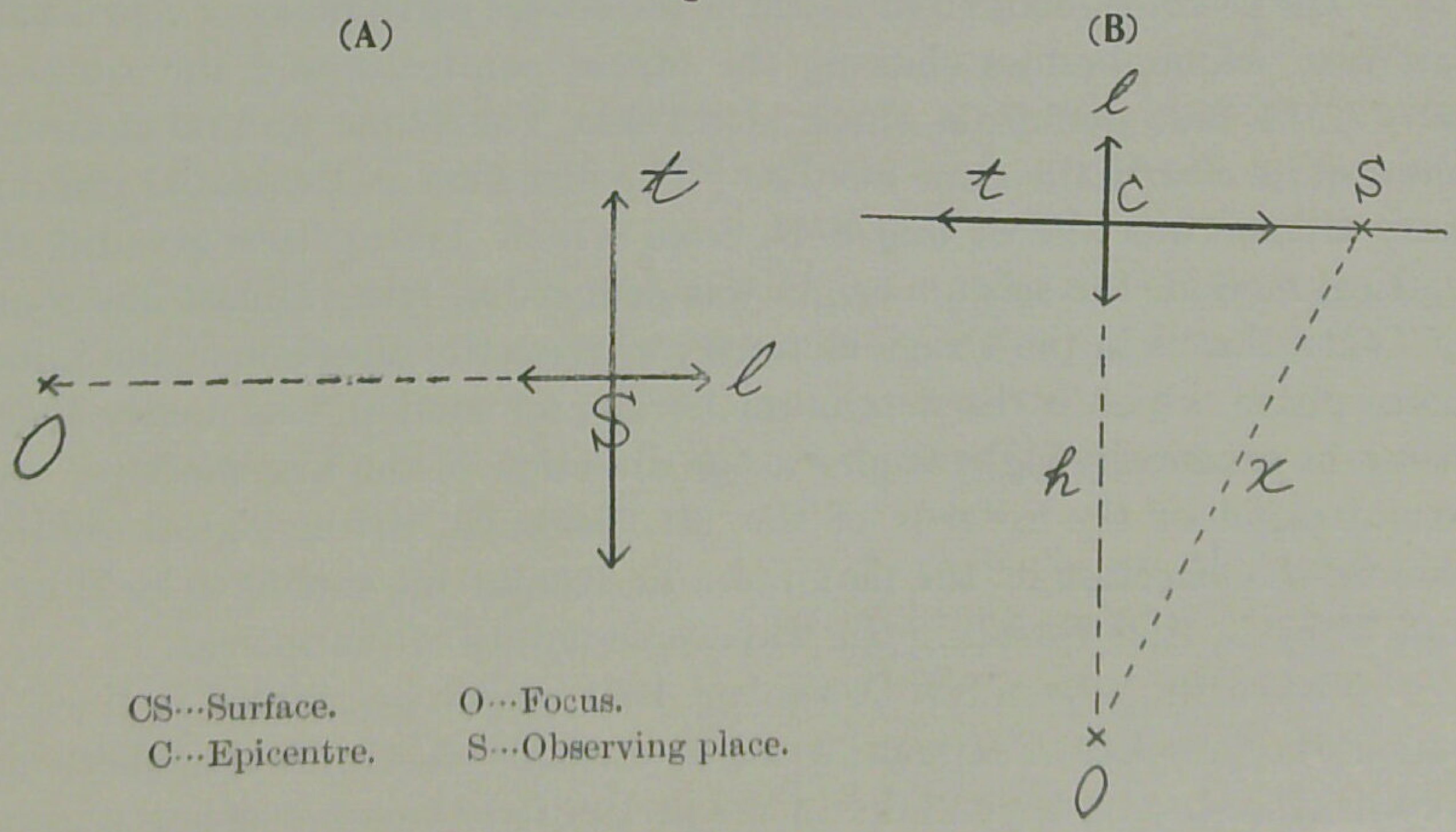
Fig. 3.



Ordinary earthquake motion.
A···Preliminary tremor. B···Principal portion.

In Fig. 4 the straght line OS represents the distance between the seismic origin O and the observing station S. The longitudinal waves

Fig. 4.

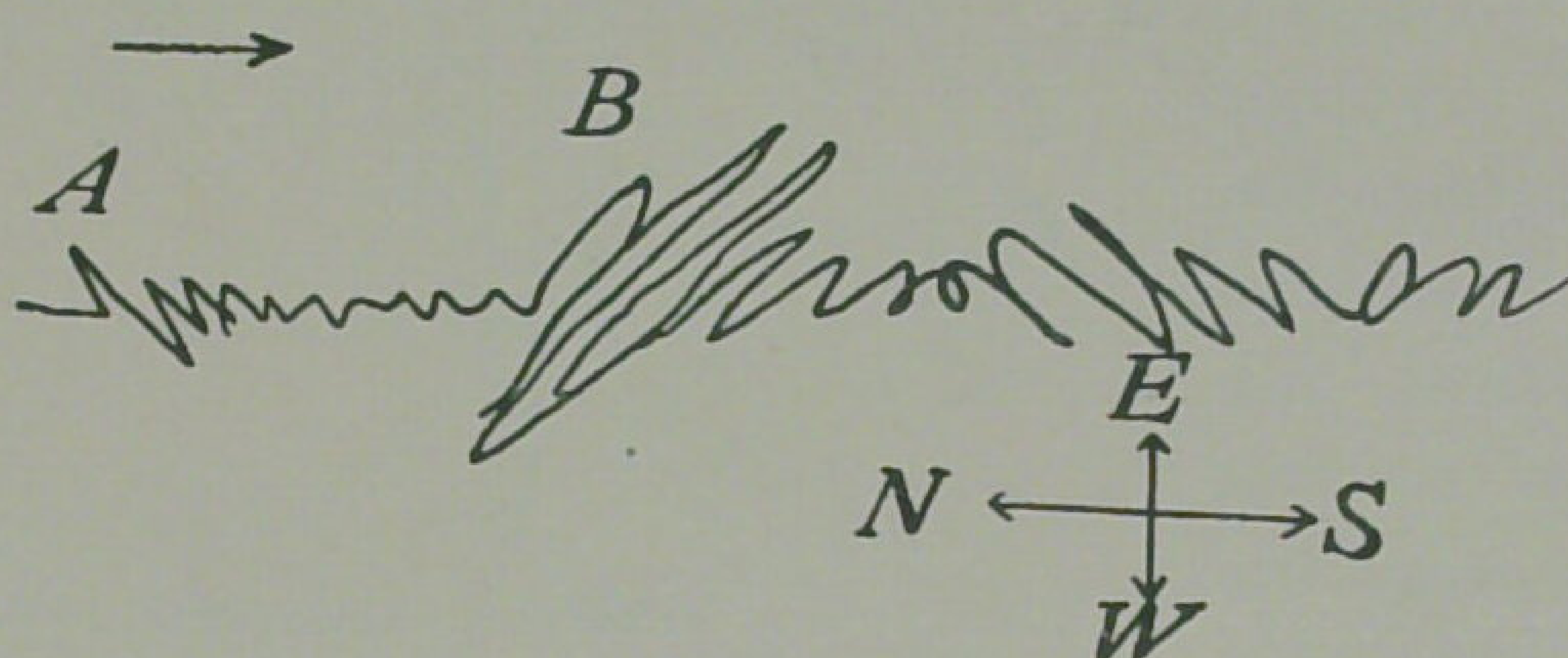


CS···Surface. O···Focus.
C···Epicentre. S···Observing place.

travel parallel with this line, thus indicating the direction of the origin, while the transverse waves being propagated in a direction at right angles to this line OS, do not indicate in a direct manner the direction of the origin.

The two earthquakes that originated at sea in a northeasterly direction from Formosa on the 7th and 15th of December of last year, furnished good examples of longitudinal and transverse waves. As actually registered (without resolution into its components) by the Duplex Pendulum Tromometer of the Seismological Institute, Tokio, Fig. 5, the initial tremor

Fig. 5.



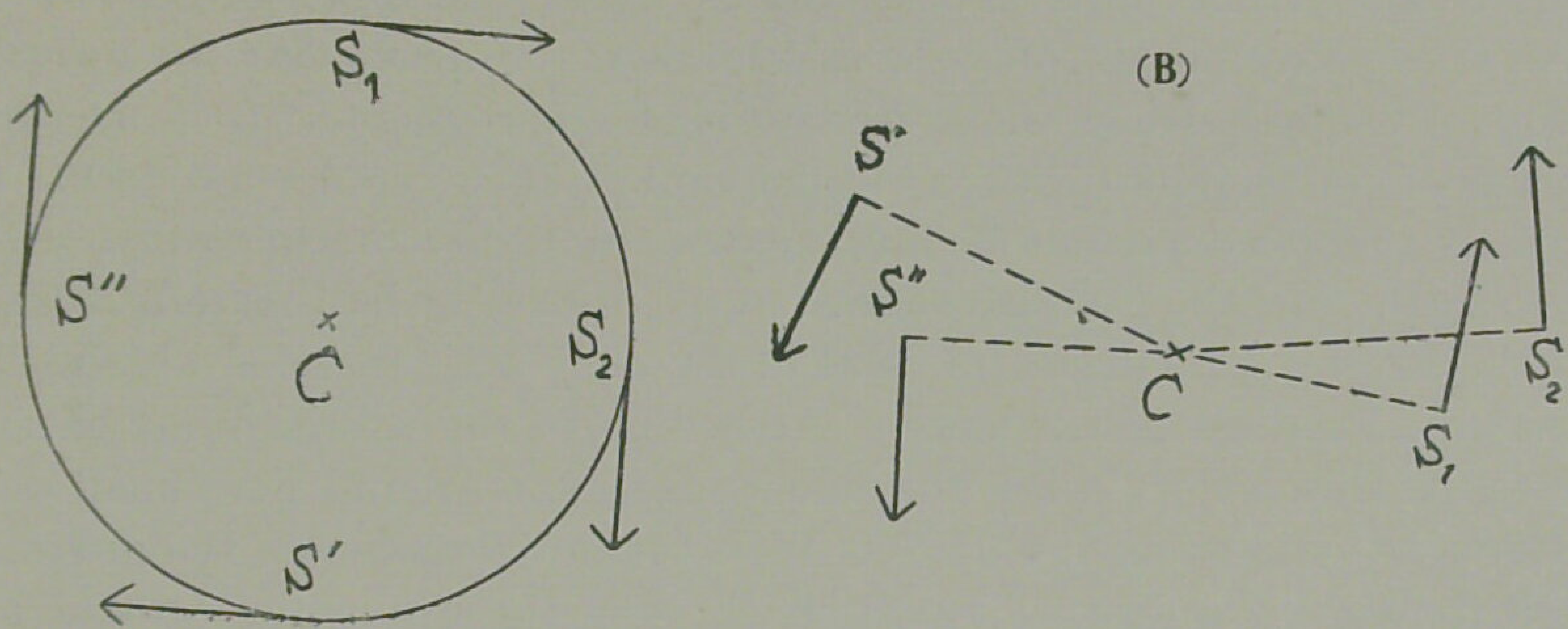
Horizontal earthquake motion.
A···Longitudinal waves or preliminary tremors. B···Transverse waves or principal portion.

had a NE–SW direction thus indicating the direction of the epicentre, while the maximum horizontal motion shown at the commencement of the phase vibrated in a NW–SE direction, hence perpendicular to the first named motion.

The records obtained at Tokio of the severe earthquake of April 26th last year, which, besides shaking the Miura peninsula and the southern part of the Boso peninsula, shook also Tokio, Yokohama and its environs, show quite clearly the same results. The direction of the initial preliminary tremor was almost due S–N, from which, taking into account the vertical motion, the seismic origin was deduced as lying almost due south of Tokio, that is in the Uraga channel; whereas the direction of the initial main phase, which is the maximum horizontal motion, was nearly E–W, hence at practically right angles to the direction of the first motion. An examination of the records of the Mt. Tsukuba Seismological Station showed the direction of the maximum horizontal movement to be E by S and W by N, thus revealing the transverse nature of the waves.

The earthquake of 8th December, 1921, which originated in the S.E. part of the province of Hitachi was also strongly felt in Tokio, where the records also showed beyond doubt the preliminary tremors as longitudinal waves and the main motion as transverse waves. Again, in the case of the three severe earthquakes of June 20th, 1894, of December 8th, 1921, and of April 26th, 1922, seeing that, as compared with the maximum horizontal movement, the maximum vertical motion was very small, not more than about one-tenth of the former, it follows that the transverse waves which constitute the maximum motion are, in the main, horizontal vibrations moving normally to the vertical plane joining the origin, the

(A) Fig. 6.



Diagrams illustrating the direction of the destructive earthquake motion in the neighborhood of the epicentre C.

s_1, s_2, s', s''···Different observing places in the epicentral area.

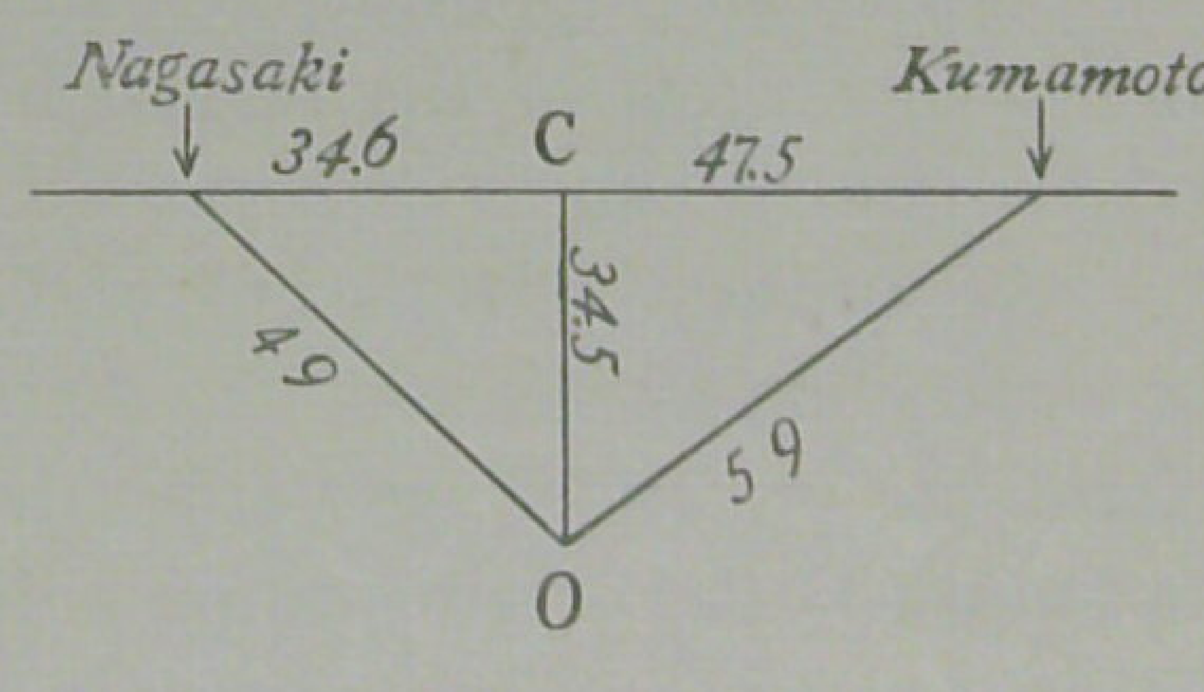
epicentre and the observer's station. At all events, since at the epicentre, longitudinal waves become vertical movements while the transverse waves become horizontal movements, the vertical motions are comparatively weak, so that the strong motions are mostly horizontal. The fact that massive temple gates and the pedestal plates of stone lanterns and other objects in the Mino-Owari earthquake of 1891, and in the Shonai earthquake of 1894, moved laterally from one foot to as much as three feet, cannot but suggest very strong lateral movement, so that in the matter of earthquake proof construction the consideration of the horizontal motions is of paramount importance, far more so than the vertical motion, and so long as the effects of the former have been allowed for the effects of the vertical motion can be disregarded.

Assuming the transverse waves to constitute the principal motion of the earthquake movement, the actual displacement and the maximum acceleration, or, in other words, the destructive energy would be at its maximum at the origin, diminishing in intensity as it recedes from it, that is varies in inverse ratio to its distance from the seismic focus. If we take D for the focal depth and r for the distance from the observer's station to the epicentre, then both the amplitudes of vibration and the maximum acceleration vary inversely as $\sqrt{D^2+r^2}$, which fact would seem to disprove the idea that the seismic damage will be heaviest in the region where $r=D$, that is in the region whose epicentral distance equals the focal depth, rather than in the epicentral area.

OBSERVATIONS AT THE NAGASAKI METEOROLOGICAL OBSERVATORY. In connection with the recent earthquakes, the credit for the very complete tromometrical observations that were obtained at this station goes to the director, Mr. Mayeda, and his staff. In particular, the records taken of the first strong shock (see abridged reproduction in Pl. II.) by means of the Imamura pattern Seismograph in their regular use, form extremely valuable materials for investigation and study, inasmuch as, with the exception of the records obtained at the Seismological Institute, Tokio, of the severe earthquakes of 1894, 1921 and 1922, there is absolutely nothing like them in existence. According to the seismograms of the Nagasaki Observatory, while the actual maximum ground movement was 41 mm. in a direction N. 6° E–S. 6° W, if the initial motion of the preliminary tremor A was directed almost E–W, then the two motions would be perpendicular to each other. Since the origin lay to the east of Nagasaki, the preliminary tremor started with longitudinal waves, changing to transverse waves upon reaching the maximum phase, just as in the various examples cited. Now as AB is the preliminary tremor and B is clearly the beginning of the main vibration, the duration of the preliminary tremor is undoubtedly 6.6 sec. and calculating by means of the equation already given, the distance from Nagasaki to the origin works out to 49 km.

THE ORIGIN OF THE FIRST SEVERE EARTHQUAKE. As the seismograms and the tromometer records of the three observatories of Nagasaki, Kumamoto and Kagoshima clearly showed the duration of the preliminary tremors as well as the directions of the initial motions, the position of the epicentre, together with the focal depth, were readily determined, as in Table IV.

Fig. 7.



The durations of the preliminary tremors as registered by the observatories of Nagasaki, Kagoshima and Kumamoto being respectively 6.6, 8 and 18 secs., by describing on a map three circles with each

Table IV. Results of observation of the first severe shock.

Station	Duration prel. tr.	Focal distance	Epicentral distance	Direction of initial phase	Focal depth
Nagasa k	6.6 s.	49 km.	34.6 km.	S 84° E	
Kumamoto	8.0	59	47.5	S 70° W	34.5 km.
Kagosima	18.0	133	128.5	S 10°.6 E	

one of the three stations as centres and with corresponding focal distances derived from the above data as radii, we get a spherical triangle at the intersections of these circles, in which we must find the epicentre. (Pl. III.) Now the initial preliminary tremor indicated by the tromometer at the Kumamoto Observatory was extremely large, namely, 1 mm. and clearly indicated a S 70° W direction, and that of Kagoshima Observatory was 0.46 mm. with a S 10°.6 E direction, whilst that of the Nagasaki Observatory gave a direction of nearly S 84° E, so that the point of intersection of the directions of the longitudinal vibrational waves as registered at these three stations must also be the epicentre. The epicentral position as deduced by the preceding two methods lies near the point indicated by a cross on map, Pl. III. An essential condition for the determination of the epicentre is that all the observing stations when computing the focal distance should get identical results for the focal depth. As shown in Fig 7, the focal depth of the first severe shock was about 34 km. The epicentre marked by a cross in Pl. III lies in the southern part of the Shimabara peninsula and to the west of East Arie village ; and also to the N.E. of the hamlet of Hashiguchi, North Arima, and a little to the north of the seashore of North Arie, while its distance from the Nagasaki Observatory is E by S., and approximately 34 km.

E. The Earthquake of the Shimabara Peninsula.

OBSERVATIONS AT KAGOSHIMA. The tromometer records of the recent earthquakes obtained by this observatory were very satisfactory, and much credit is due to its director, Mr. Maruoka. The magnitudes of the preliminary tremors and the directions of the shocks felt during the 8th of December are as follows :—

Table V. Results of seismic observation at Kagoshima Meteorological Observatory.

No.	Time of commencement	Initial phase	
		Magnitude	Direction
1	1h 52 m.	0.46 mm.	S 10°.6 E
2	11 04	0.38	S 12° E
3	14 17	0.12	S 19° E
4	2 10	0.068	S 19°.7 E
5	7 22	0.096	S 11°.6 E
6	22 33	0.046	S 21° E

By producing the lines representing these tremors in opposite directions they would point to the seismic origin, although the directions will not all be the same. For example, the origin of no. 2 points somewhat more to the west than that of no. 1 while the direction of no. 3 inclines still further to the west; and although shock no. 3 was not particularly energetic as felt at this station, the proximity of its origin to Nagasaki accounts for the very severe shaking felt at the latter city, and the more or less damage suffered there.

DIRECTION OF THE MAXIMUM HORIZONTAL MOVEMENT. As stated in a previous paragraph, destructive shocks felt at a station are mainly horizontal movements of transverse waves, and as its direction is normal to the vertical plane including the origin, the epicentre and the observing station, the direction of the maximum movement of two points lying, one on either side of the epicentre, are at right angles to each other, as shown in Fig. 6. In these circumstances the direction of fall of brick chimneys, stone lanterns, gravestones, and other such columns, invariably coincide with the direction of the maximum horizontal motion.

DIRECTION OF EARTHQUAKE MOTION WITHIN THE SEVERELY SHAKEN AREA. Within the severely shaken area, particularly in the villages of East Arie and North Arima (including the hamlets of Hashiguchi and Tanigawa), the overturned objects display a remarkable uniformity in direction as will be seen from the annexed tables :—

Table VI. Direction of overturning of stone-lanterns, grave-stones, &c.

Higasi-Arie	N, N, N, N, N, N10°E, N10°E, N10°E, N10°E, N15°E, N25°E, N25°E, N25°E, N25°E, N30°E, N30°E, N30°E, N35°E, N40°E, N40°E, N40°E, N40°E, N45°E, N75°E, N50°E, N60°E, N5°W, N5°W, N5°W, N5°W, N10°W, N10°W, N15°W, N25°W, N35°W, N50°W, N70°W, N80°W, N85°W, W, S, S, S, S, S, S20°E, S20°E, S65°E, S10°W, S20°W, S25°W, S30°W, S55°W, S65°W, S70°W, S85°W
Kita-Arima	S, S, S, S5°W, S5°W, S15°W, S10°W, S10°W, S10°W, S10°W, S15°W, S15°W, S15°W, S20°W, S20°W, S20°W, S20°W, S20°W, S20°W, S25°W, S25°W, S25°W, S25°W, S25°W, S30°W, S30°W, S35°W, S35°W, S35°W, S40°W, S10°E, S25°E, S25°E, S25°E, S30°E, S60°E, E, N15°W, N25°W, N, N5°E, N5°E, N30°E, N50°E, N60°E, N60°E, N80°E

In the meizoseismic area, the direction of overturning, which indicates those of maximum seismic motion at each locality due to the first severe shock, come out on the average as follows :—

Table VII.

A				B	
Kita-Arima	Urata & its vicinity	Kutinotu	Nakatuka	Higasi-Arie	Dôsaki
S 8° W	S 8° W	S 16° E	S 13° E	N 3° E	N 48° E

In A the direction was practically south, and in B northwards, as shown in map, Pl. I ; the locality marked with a cross being the epicentre so that the directions are in practical agreement with the diagram, Fig. 6, B. The direction of the maximum movement at Nagasaki was initially N 60° E, but as its opposite direction becomes S 60° W, it would come under A.

EXAMPLES OF SIMULTANEOUS OCCURRENCES OF EARTHQUAKES AND VOLCANIC ERUPTIONS BUT AT WIDELY SEPARATED LOCALITIES. The case of the recent first severe Shimabara earthquake and the eruption of Oshima in the Idzu island group, which took place almost simultaneously, is listed below with other similar occurrences.

(1) On the 8th of December, 1921, at 9.31 p.m., a severe earthquake shook the Kwanto regions, while during the period from about December

8th to the 10th, there was an eruption on the island of Suwanose lying to the south of the province of Satsuma, in Kiushiu, actively projecting smoke and flame.

(2) At 10.11 a.m. of April 26th, 1921, there was a severe earthquake in the Kwanto regions (Uraga Channel), whereas at 5 p.m. on the 25th there were eruptions of Asama-yama.

(3) On December 8th, 1922, at 1.52 a.m. and at 11.04 a.m., Shimabara peninsula and environs were violently shaken, whereas from about the same day the volcano of Mihara in the Idzu island group started into eruption with issue of lava, and did not become quiescent until January of the following year.

NAGASAKI EARTHQUAKES—PAST AND FUTURE. In the recent earthquake, within the reclaimed ground section of the city, there were some damages such as those to brick factory chimnies and dislodging of plaster walls and ceilings. The maximum horizontal movement as registered at the local observatory was 41 mm., but the movement at places on soft ground would have been quite double of this. However, when compared with the movement at Tokio on the occasion of the severe earthquake that originated in the Uraga Channel on the 26th of April, last year, it is not quite 32% of the Tokio movement. The earthquakes which shook Nagasaki during the years 1791–1792 at the time of the activities of Unzen-dake, were of the same order of magnitude. At any rate, the northern part of Kiushiu is one of the zones of low seismicity in this country, hence the district is regarded as immune from very destructive shocks. This is bourne out by the fact that the historical record of earthquakes for Nagasaki is quite a small one, as will be seen from the following lists.

(1) The 14th of October, 1691, was a Saturday, when at dawn the inhabitants were aroused by two violent shocks, and although they were both short ones, lasting not more than 30 seconds, they were very severe, so much so that the pilot of a Dutch vessel anchored in the bay was thrown out of his bunk, while on shore dogs and poultry set up quite a commotion. (I am much indebted to Mr. D. Arai of Nagasaki who kindly allowed me to extract the foregoing from his copy of Kaempfers "Japan.")

(2) From about 1 on the morning of the 31st of October, 1725, severe earthquakes began to rock the city, and continued for three days when over 80 shocks were counted.

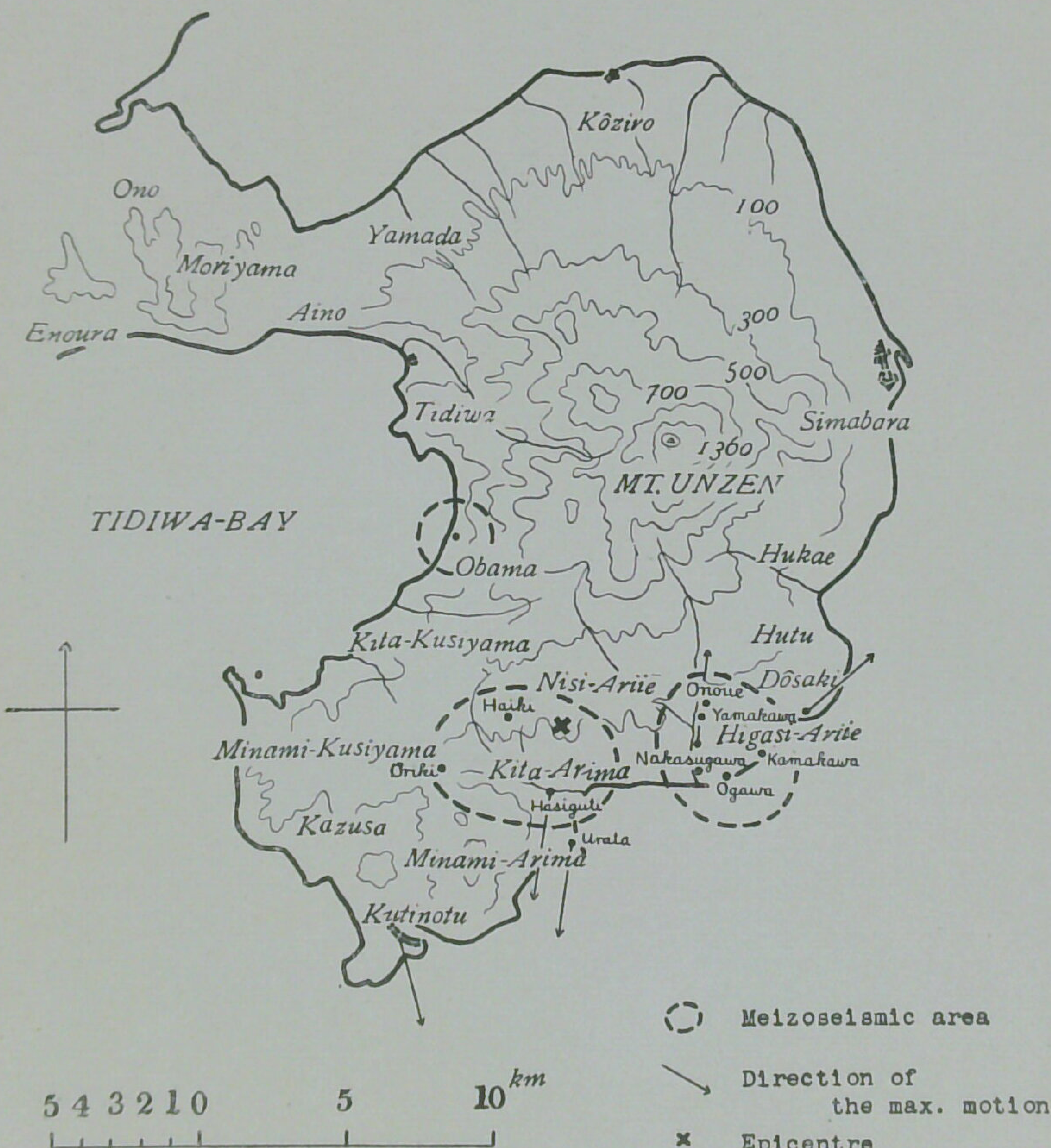
The earthquakes of 1691 having occurred more than 30 years after the eruptions of Unzen-dake of 1657 and 1663, it is not possible to conceive of any connection existing between the two phenomena, although, if some such a conception is permissible, the claim for it should belong to the eruption of Aso volcano which broke out in 1691, the very same year.

The earthquakes of 1725 did not follow close on the heels of the activities of the Kiushiu volcanoes, which were the violent outbursts of Kirishima in 1716 and 1717. Between the years 1717 and 1733 Asama had erupted several times, while the Iwate volcano erupted in 1719, but during all this interval, Unzen-dake, situated so close to Nagasaki, failed to evince the slightest sign of activity. This would support the conclusion that the Nagasaki earthquakes were of a purely local character, and while the shocks were somewhat strongly felt, the damage wrought was slight, hence far from being destructive. In these circumstances our belief is that, although strong earthquakes may visit Nagasaki in future, it is not likely that they will be worse than example no. 2 above, nor much stronger than those just recently experienced, therefore, with reasonable care and attention bestowed on the construction of houses, and also in civil works as well, towards making them as near earthquake-proof as possible, immunity from future earthquake disasters ought not to be unattainable.

CONCLUDING REMARKS. While such disasterous earthquakes as the Tokaido earthquake of Dec. 23, 1854, and the Nankaido earthquake of the day following, both of which originated in the sea-bottom of the Pacific facing the outer side of the Japanese island arc, and having no connection whatsoever with any volcanic system, may be extremely destructive, there is, however, a limit to the destructivity of volcanic earthquakes. The recent earthquakes which originated in the Shimabara peninsula may well be regarded as volcanic in nature, and the first severe shock that emanated from the southern base of Unzen-dake at 1.52 a.m. of December 8th was almost of the same order of magnitude as the strongest one of the many shocks that originated with the eruption of Sakurajima in 1914, although it was a little stronger than the shocks that accompanied the recent eruptions of Asamayama and Usu-dake (Hokkaido). At all events, it would seem to typify the strongest shock that is ever likely to shake the Shimabara peninsula and environs, and even were more or less heavy shocks to occur in this region in the future, they are not likely to be disasterous ones, nor is it likely that they would repeat themselves in the same locality. Again, although as a result of the severe earthquake of the 21st of May, 1792, an enormous landslip took place from the slope of Mayeyama, precipitating into the Sea of Ariake such an avalanche of soil and debris that a big tidal wave resulted, the forces that induced this landslide having done its work and gone, there are at present no potential causes remaining that are at all likely to bring about the repetition of such a gigantic land-slide. Moreover, as a result of the great changes of 1792, the base of the mountain is now at such a distance from the sea that the tidal-wave hazard is also non-existent.

Neither is there any cause for anxiety over the habits of Unzen-dake in the future. While the destructive energy of volcanoes in blasting away parts of its sides, in short, its explosive outbursts, are terrible to contemplate, the eruptions of Unzen-dake will be confined to gentle or moderate actions without at all reaching the explosive stage. In both the eruptions of 1657 and 1792, lava flowed out from a spot a little below the northeastern part of the summit of Fugendake, but there were no showers of sand or ashes, and the whole action was so quiet and orderly that people visited the scene of action with impunity. There are good reasons for assigning Unzen-dake's present centre of volcanic activity to a place near the summit of Fugen-dake (peak). On the other hand, the chances of a new eruption breaking out from such a seat of ancient activity as Unzen-Kôen are scarcely worth considering, and furthermore, even should Fugen-dake itself break out again in the future, the most it is likely to do is to repeat such action as has been described in this paragraph, so there need be no misgivings in connection with the future behaviour of this volcano. (A descriptive outline of the eruption of Unzen-dake of 1792 was contributed by the author to the Feb. number of the " Gakugei Zasshi.")

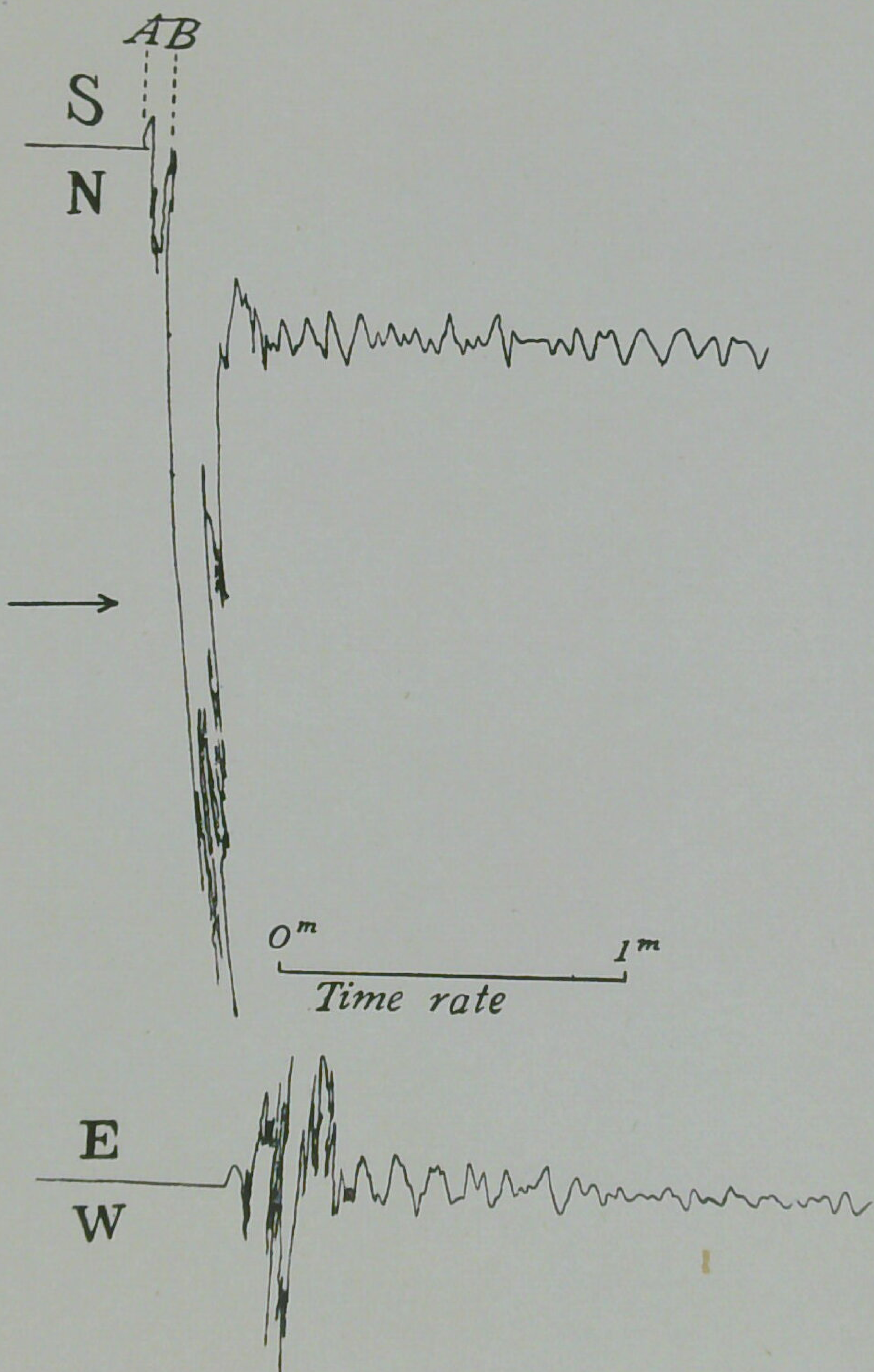
Seismic area of the Shimabara earthquake.



(After Imamura and Kodaira.)

Nagasaki observation of the earthquake of Dec. 8, 1922, at 1 h 50 m.

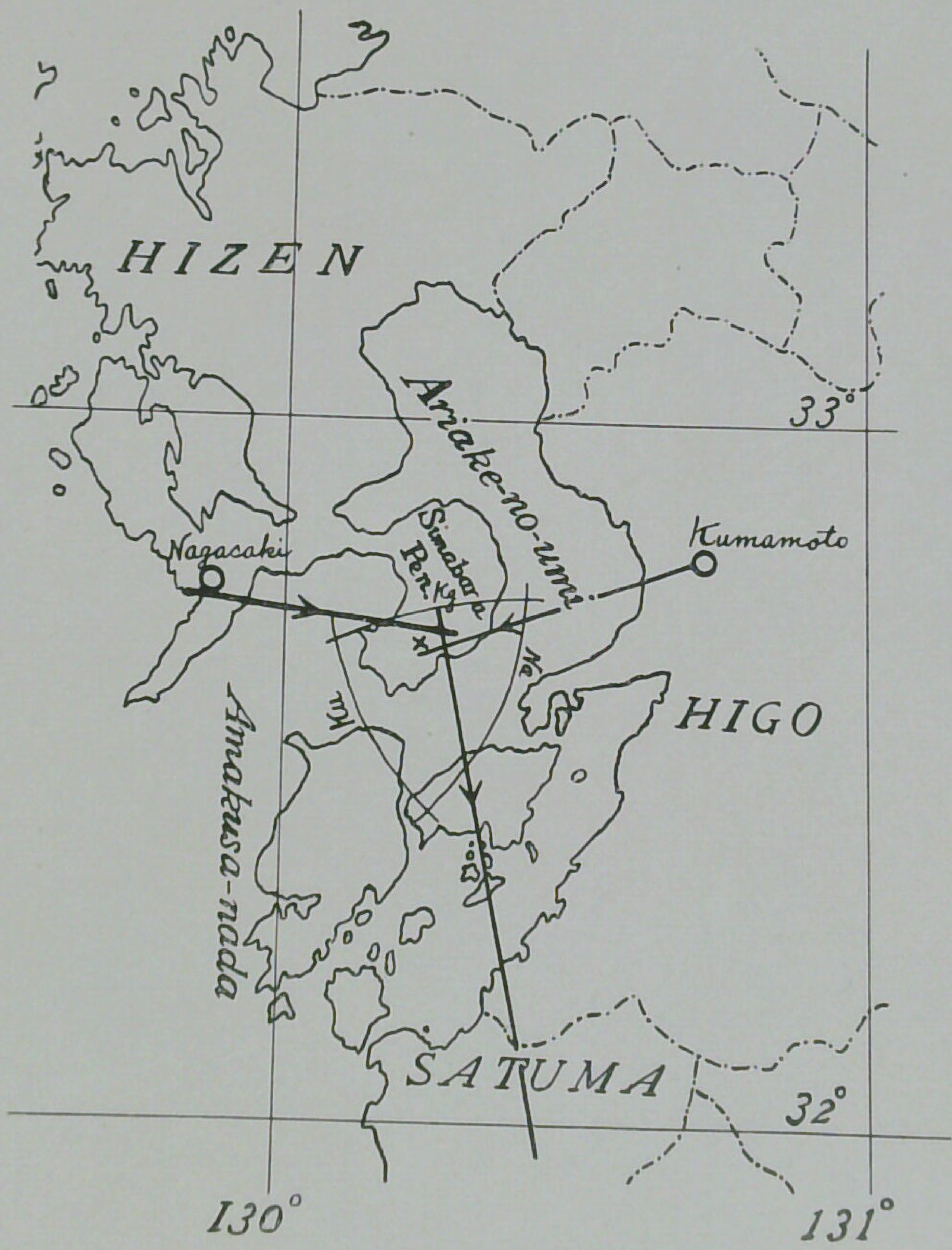
(Statical magnification = 2.)



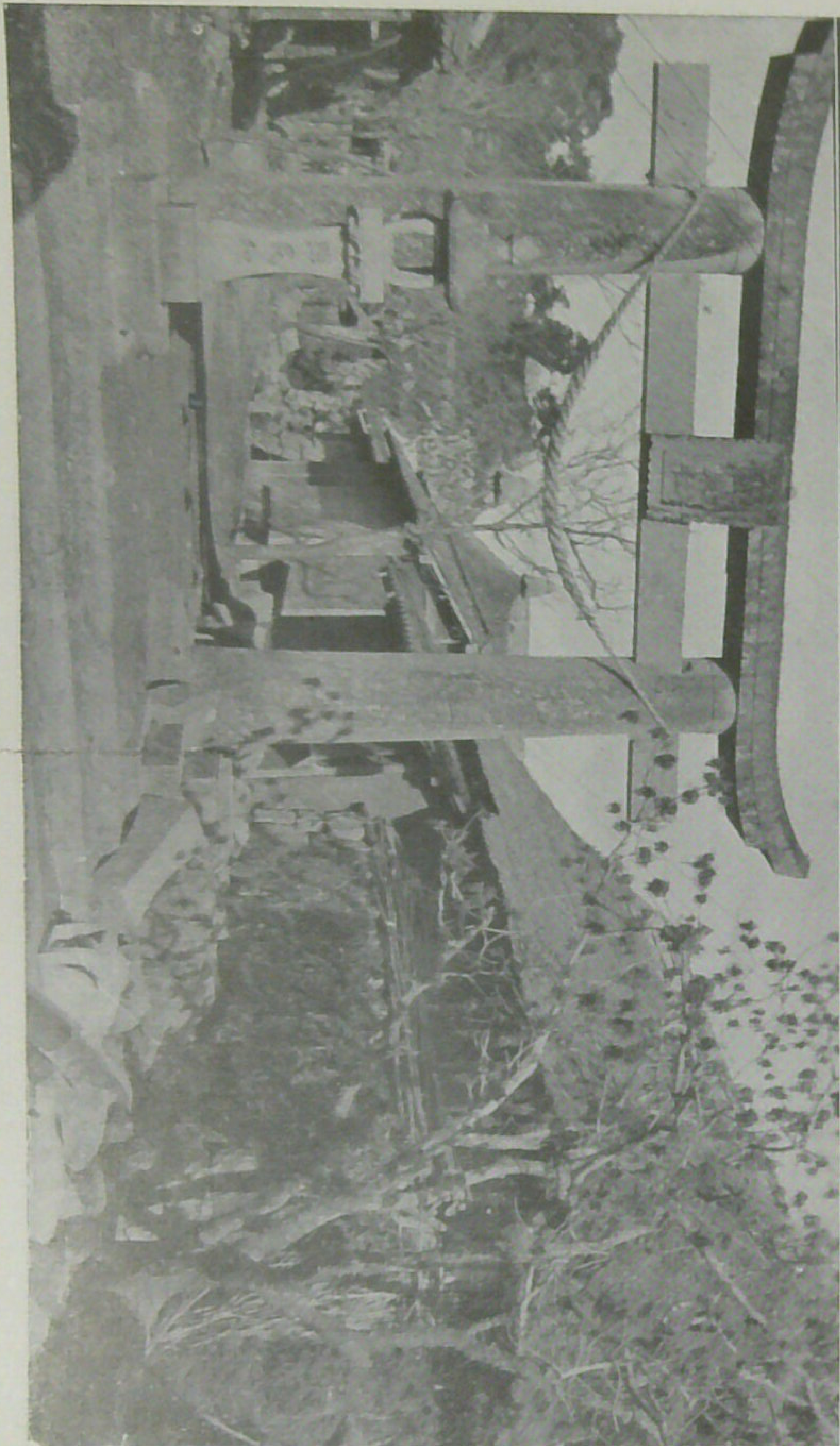
Pl. III.

Map showing the position of epicentre of the first shock as revealed by the observations at the different stations.

arrow............direction of initial phase,
arc ....focal distance (calc.),
cross ....epicentre.

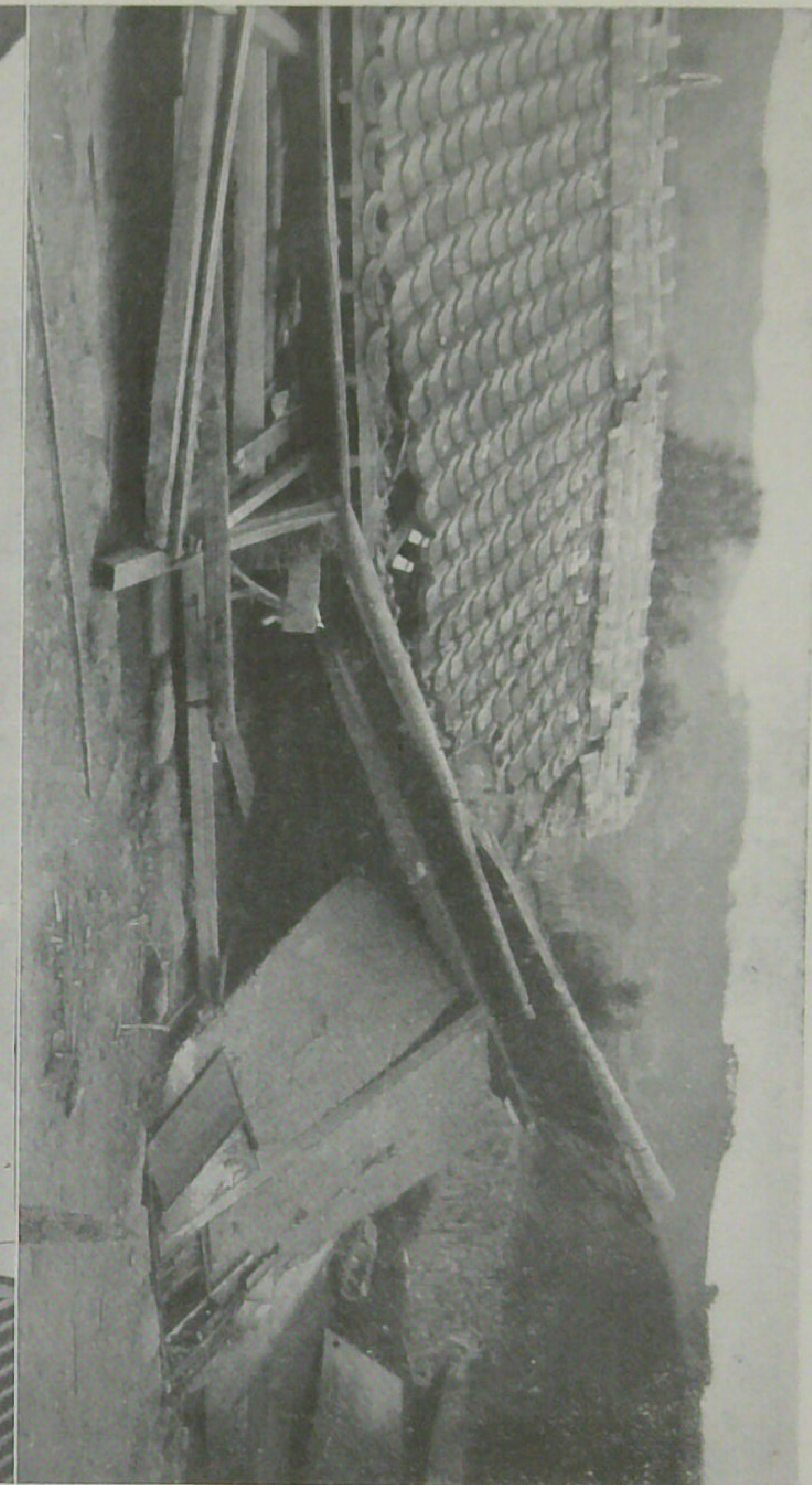


Pl. IV.



A *Torii* at Higashi-Arie displaced as much as 5 cm. One of a pair of stone lanterns in front overturned and the other remained intact.

A *Torii* (shrine-gate) overturned at Sukawa, Nishi-Arie.



A collapsed house at Tsukanoyama, Minami-Kushiyama.

A five-storied stone monument at Higashi-Arie overturned, the two upper stories eastwards and the three lower ones westwards.

A warehouse at Hashiguchi, Kita-Arima. Its longer side was parallel to NNE.

A warehouse at Kitano, Obama, with its longer side parallel to E-W. It was built upon a loosely constructed stone-foundation.

A warehouse at Kitano, Obama, with its longer side parallel to S-N. Badly damaged.

A dwelling at Kitano, Obama, with its longer side parallel to E–W. 8 pillars broken.

A warehouse at Kitano, Obama. Badly damaged.

Report on the Changes in the Land-Level in Connection with the Simabara Earthquake of 1922.

By A. IMAMURA.

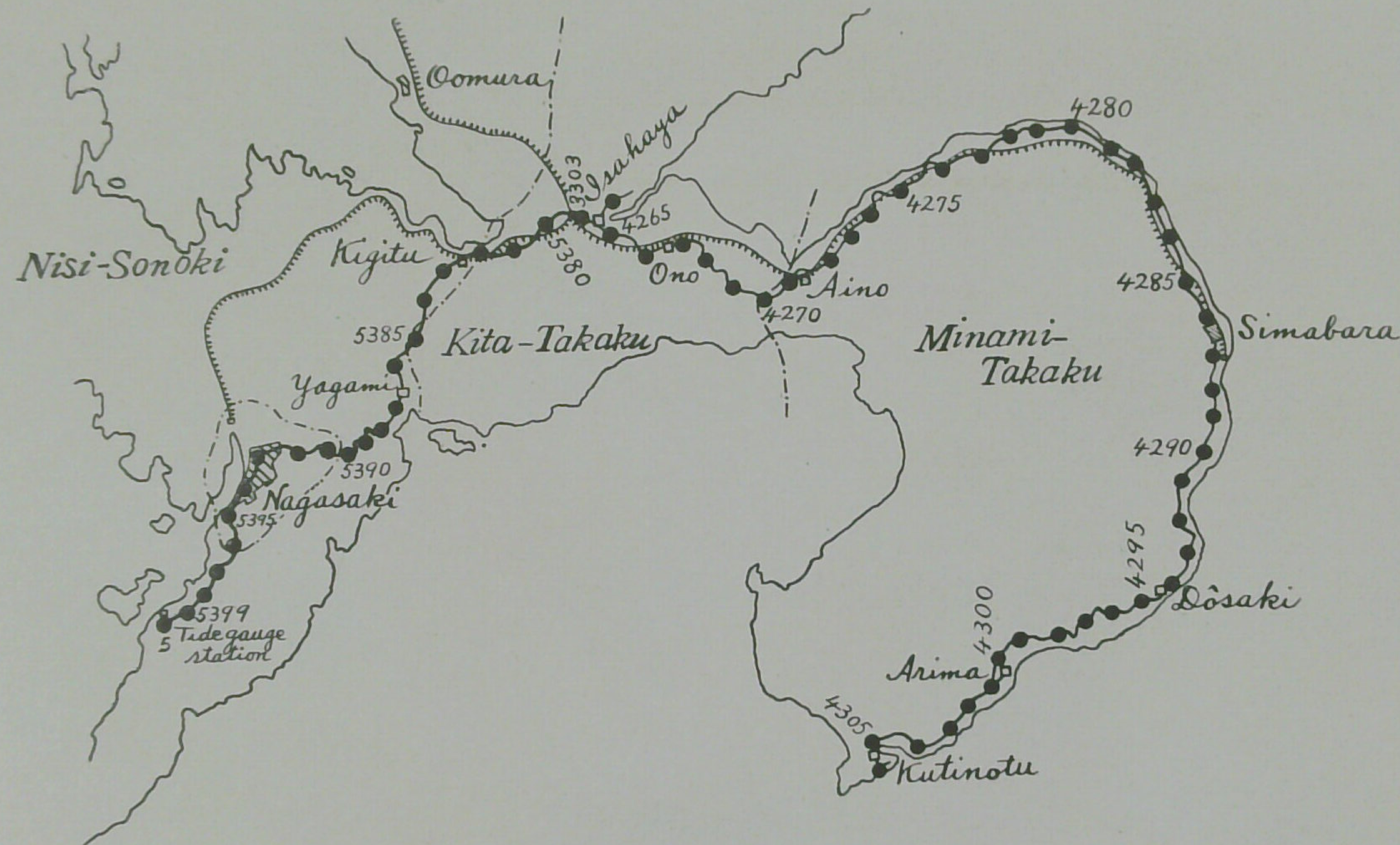
(*With Plates* I and II.)

Realizing that, in connection with the earthquake that shook Simabara and environs on the 8th of December, 1922, some displacement more or less in the land-level would be inevitable, the late Dr. Omori, with the assistance of the Imperial Academy, succeeded in arranging for a survey of the affected area at the hands of the Land Survey Department. This body promptly organized a suitable surveying party and commenced work in June, 1922, but Dr. Omori, unfortunately, did not live to see the completion of the work. The survey was, however, pushed forward, and with the aid of funds augmented by our Committee in October of the same year, the work was in due course brought to a conclusion when reports on the result of the survey were presented by the two members of the Survey, Messrs. Y. Ogata and J. Onohara. It is with much pleasure that I take this opportunity to offer our thanks to the Imperial Academy who sponsored the undertaking, and to the governing council of the Land Survey Department as well as to the two gentlemen above mentioned.

A perusal of the reports makes it clear that changes in the land-level did take place, thus vindicating our anticipations. It must be noted, however, that the last surveys were made as far back as 30 years ago; the section between Isahaya and Kutinotu in July–September, 1894, and that between Isahaya and Hukabori during October–December, 1897. While in the circumstances, some changes more or less during the interval must be expected, the mean tide-level at the Hukabori Tide-gauge station showed a rise of only 2 or 3 cm., which difference, when compared with the results of the surveys for sea-level made before and after the interval in question, is altogether negligible in the first approximation. The outstanding changes observed in the land-level will now be given.

(1) Between benchmarks No. 5381 and 5394, that is between Kigitu and Nagasaki, the maximum uplift reached 64.5 cm. It is likely that these marks were once removed without any notice being given to the military authorities.

Map showing B.M. line from Hukabori to Kutinotu.



Pl. I.

Precise Levelling between Hukabori and Kutinotu: Comparison of the Heights before and after the Simabara Earthquake of Dec. 8, 1922. (Continued.)

Bench mark	Height in 1925 α	Height in 1894–1897 β	Height difference $\alpha-\beta$	Bench mark	Height in 1925 α	Height in 1894–1897 β	Height difference $\alpha-\beta$
	m	m	cm.		m	m	cm.
5395	13.3503	13.3273	+ 2.30	4278	4.0062	3.9559	+ 5.03
5394	2.7586	2.7440	+ 1.46	4279	4.1786	4.1228	+ 5.58
*5393	15.0352	14.6728	+ 36.24	4280	3.8360	3.7760	+ 6.00
*3592	46.6466	46.0018	+ 64.48	4281	4.1764	4.1203	+ 5.61
5391	143.6248	143.5976	+ 2.72	4282	4.2254	4.1714	+ 5.40
5390	210.3740	210.3479	+ 2.62	4283	4.4294	4.3734	+ 5.60
5389	106.8628	106.8287	+ 3.41	4284	4.4759	4.4165	+ 5.94
5388	16.3916	16.3663	+ 2.53	4285	8.5423	8.4903	+ 5.20
5387	3.1283	3.1083	+ 2.00	4286	7.5696	7.5229	+ 4.67
5386	16.1633	16.1456	+ 1.77	4287	3.3882	3.3734	+ 1.48
5385	26.6275	26.6074	+ 2.01	4288	3.1712	3.1837	− 1.25
5384	29.9065	29.8798	+ 2.67	*4289	17.4938	17.1513	+ 34.25
5383	4.0029	3.9798	+ 2.31	4290	28.3879	28.3869	+ 0.10
5382	8.4753	8.4480	+ 2.73	4291	15.1645	15.1518	+ 1.27
5381	10.2860	10.2599	+ 2.61	4292	3.4829	3.4961	− 1.32
5380	18.7110	18.6801	+ 3.09	4293	3.7311	3.6887	+ 4.24
3303	8.8817	8.8427	+ 3.90	4294	6.6462	6.6034	+ 4.28
3303	8.8817	8.8427	+ 3.90	4295	4.5750	4.5363	+ 3.87
4265	4.8434	4.7966	+ 4.68	4296	21.7369	21.6918	+ 4.51
4266	3.0276	3.0988	− 7.12	4297	12.0113	11.9734	+ 3.79
4267	2.8812	2.8706	+ 1.06	4298	3.6481	3.6158	+ 3.23
4268	3.8414	3.7948	+ 4.66	4299	3.3483	3.3114	+ 3.69
4269	61.8540	61.7711	+ 8.29	4300	3.9871	3.9548	+ 3.23
4270	4.2160	4.1460	+ 7.00	4301	3.4725	3.4439	+ 2.86
4271	4.0771	3.9987	+ 7.84	4302	4.0689	4.0320	+ 3.69
4272	4.9610	4.8926	+ 6.84	4303	4.3557	4.3232	+ 3.25
4273	5.1619	5.0967	+ 6.52	4304	6.3451	6.3153	+ 2.98
4274	6.4285	6.3650	+ 6.35	4305	2.7348	2.7328	+ 0.20
4275	4.4967	4.4383	+ 5.84	4306	15.1522	15.1422	+ 1.00
4276	5.7650	5.7079	+ 5.71	(7)	61.3313	61.2914	+ 3.99
4277	4.7964	4.7448	+ 5.16				

* B. M. No. 5393, 5392 and 4289 had been removed from their original positions before the second survey was carried out.

Seismographic Study of the Simabara Earthquake.

By A. IMAMURA.

(*With Plates* I and II.)

With reference to the severe earthquake which visited Simabara peninsula on the 8th of December, 1922, several reports and addresses were made at the committee meetings by members at the time, but, unfortunately no summarised report has yet been presented. It was consequently arranged that, as the late Dr. Omori's contribution, a generalised report be compiled by using as material the articles which were contributed by the deceased to the " Gakugei " magazine, together, amongst other matters, with the results of the surveys made of changes in the seal-level in the affected districts. While engaged in this work, however, as a result of my own independent investigations of the seismograms and reports of the earthquake in question, I arrived at certain conclusions which are diametrically opposed to those reached by our late esteemed colleague. These were duly laid before the members at one of our meetings for their discussion, but I do not deem it inappropriate to set down here again the points over which we are in disagreement, and which are as follows :—

According to Dr. Omori

(a) " The maximum phases, which are mainly transverse waves, " become horizontal vibrations with a direction at right angles to the " vertical plane including the origin, the epicentre and the observer's " station.

(b) " Since at the epicentre, longitudinal waves become wholly " vertical vibrations while the transverse waves become wholly hori- " zontal vibrations, even at the epicentre the vertical motions are " comparatively small so that the energetic motions are mostly the " horizontal ones. At the epicentral regions in the Mino-Owari and " Sakata earthquakes, massive temple gates and pedestals of stone " lanterns moved as much as 1 foot to 3 feet, indicating strong hori- " zontal movements so that in the matter of earthquke-proof construc- " tion it would seem that the horizontal motions are far more to be " dreaded than the vertical ones, so that as long as the structures are "built to withstand the former no attention need be paid to the "latter.

(c) "According to the seismograms obtained at Nagasaki the "maximum actual ground movement was 41 mm. with direction "N 6° E and S 6° W so that if the commencement of the preliminary "tremor were nearly E–W, the direction of the two motions would be "perpendicular to each other.

(d) "The duration of the preliminary tremor works out to 6.6 "sec., the correctness of which is beyond doubt."

Now, as stated by Dr. Omori, the direction of maximum motion as registered by the Nagasaki seismograph was N 6° E and S 6° W, but it would seem that an error was inadvertently committed in placing the direction of the initial preliminary tremor as E–W. As the preliminary tremor was 3.3 mm. S and 1.9 mm. E this makes an angle of 36° with the direction of the maximum phase above mentioned, hence, if anything, it is nearer to a parallel direction than one at right angles. In all probability it arose through Dr. Omori having accepted as axiomatic his generalization as quoted in (a) above. It is of course true that in the case of distant earthquakes, in seismograms of horizontal motion, the preliminary vibrations (longitudinal waves) and the maximum vibrations (transverse waves) are generally normal to each other, but for near earthquakes this does not always follow; at times they coincide and at others they may be oblique to, or at right angles, to each other. Actual instances of this have been multiplied several times since the last great earthquake. In horizontal motion seismograms the reason for the transverse waves making various angles with the longitudinal waves seems to lie in the simple fact that the former waves in their propagational path from the origin to the observing station, vibrate in a line perpendicular to the direction of the wave transmission, and in their passage the vibrations may travel, not necessarily in a horizontal direction, but in all directions about a point, according as they are influenced by the nature of the original impulse which set them in motion or by boundary conditions existing in the media through which they travel. Misinterpretations, such as have been pointed out, do not seem to be confined to any one observer, for, in connection with the great Kwanto earthquake of 1923, Dr. Jaggar, basing his observations on my data for Hongo, Tokio, of N 38° W and S 38° E as the direction of the main phase, took a straight line perpendicular to this in determining the direction of the seismic origin. (Bulletin of the Seismological Society of America, vol. 13, no. 1.) Taking the direction of Nagasaki's preliminary tremor as S 30° E, Kumamoto's as S 70° W and Kagoshima's as S 11° E, and combining the three we get the origin as being situated in the neighbourhood of A in the annexed map, Pl. I.

There is next the disagreement with respect to the period of 6.6 sec. as the duration of the preliminary tremor. Our lamented colleague was quite positive as to the correctness of this result, but Mr. S. Maeda, director of the Nagasaki Observatory, doubted it. One of his contentions was that, inasmuch as the durations of the preliminary tremors of the aftershocks ranged from 2 to 3 sec., the duration of 6.6 sec. given for the preliminary tremor of the main earthquake itself was exceedingly doubtful, and that, rather the point where the vibration became somewhat larger ought to have been taken as the boundary line of the two motions, which would then give a result of 3.3 sec. While I am in sympathy with this argument, taking into consideration the preliminary tremor and the direction of the initial phase, I prefer to regard them as belonging directly to the earthquake which took place at 1 h 49 m 57 s in the morning, and as the foreshock of the earthquake which caused the greatest damage to the Simabara peninsula. In other words, I should like to regard these disputed shocks as Twin Earthquakes.

This, in fact, is the conclusion I came to after close examination at Nagasaki of the seismograms covering several days following the severe earthquake. It was found that seismograms of after-shocks, particularly those coming immediately after a big shock, resembled each other fairly closely, whereas in seismograms of the big shocks themselves, the forms of the vibrations preceding the maximum phase showed no similarities, but did so in the succeeding vibrations. This was specially noticeable in the Kagosima seismogram (see Pl. II) in that, with the exception of the biggest shock, the various directions, particularly those running E–W, and the vertical motions showed pronounced similarities in their seismograms. In the case of the vertical motions, they began with large vibrations mostly of about the magnitude of wave no. 19 (see Pl. II), after which it assumed the maximum phase. Compared with these, the seismograms of the biggest shock showed quite different characteristics, consisting of small vibrations at the commencement but gradually increasing in size. What claims our special attention at this stage is the close resemblance between the form of the vibrations immediately following the maximum phase of the biggest earthquake and the form of the maximum phase itself of the second severe earthquake of 11 a.m. The ordinary seismograph at Hukuoka also showed these peculiarities, which for lack of a better name I shall call "two step" motions, meaning that, whereas in the usual order of things a preliminary tremor is followed simply by the principal phase, in this case the order is repeated, that is a preliminary tremor (p in the plate, A) smaller than the same phase of the second severe shock (P in the plate, B) is immcdtately followed by another set of preliminary tremor (P in the plate, A) after which come again the two-stepped principal phases (s and S in the vertical seismogram). Further, in the Hukuoka seismogram just mentioned, particularly in the vertical motion, a fairly large vibration follows one second after the initial tremor implying a distinct and separate earthquake.

Now, as just mentioned, if we regard the first big shock as a twin earthquake, then, on the principle that seismic motions due to earthquakes originating from a common source are similar, seismograms taken simultaneously of earthquakes originating from near localities should resemble each other, since, if otherwise, it would be contrary to the principle involved.

Twin earthquakes are not so rare as might be supposed ; we have had experiences of them in the earthquakes that originated at sea off Kasima on the 31st of May, this year ; also in the northwestern part of Kasumigaura and the northern part of Tokyo Bay on the 30th of October last. On the assumption that the severe earthquake as mentioned in the previous paragraphs was a twin earthquake, I have analysed them as follows :—

Station	Difference of time arrivals of P.	Dur. prel. tr. of the biggest shock.	Focal distance.
	sec.	sec.	km.
Nagasaki	3.3	3.6	27
Kagosima	3.3	18.8	140
Hukuoka	1.2	12.7	95

By combining the above results the origin of the severest shock is at a point B, lying to the west of Simabara peninsula in Tidiwa Bay.

Lastly, there is the disagreement in regard to the relative strengths of the longitudinal waves forming the vertical motion and the transverse motion waves forming the horizontal motion. Our late colleague, accustomed to seismograms of earthquakes with epicentre at some distances away, erred in assuming that the preliminary vibrations of earthquakes, whether originating comparatively near or distant, always consisted of minute vibrations, or "tremors," as the name implies, thus inadvertently introducing errors into his observational results for stations situated in the epifocal area. It is only quite recently that we have had opportunities of studying earthquakes of which Tokyo was the epicentre ; several having occurred this year. In this class of earthquakes it was found that the preliminary vibrations, instead of being a tremor, exhibited the largest vibrations of the entire motion, so that the transverse waves were weaker, or, at the most, equal to it in strength, which simply means that the vertical motions were of a higher order of energy than the horizontal ones.

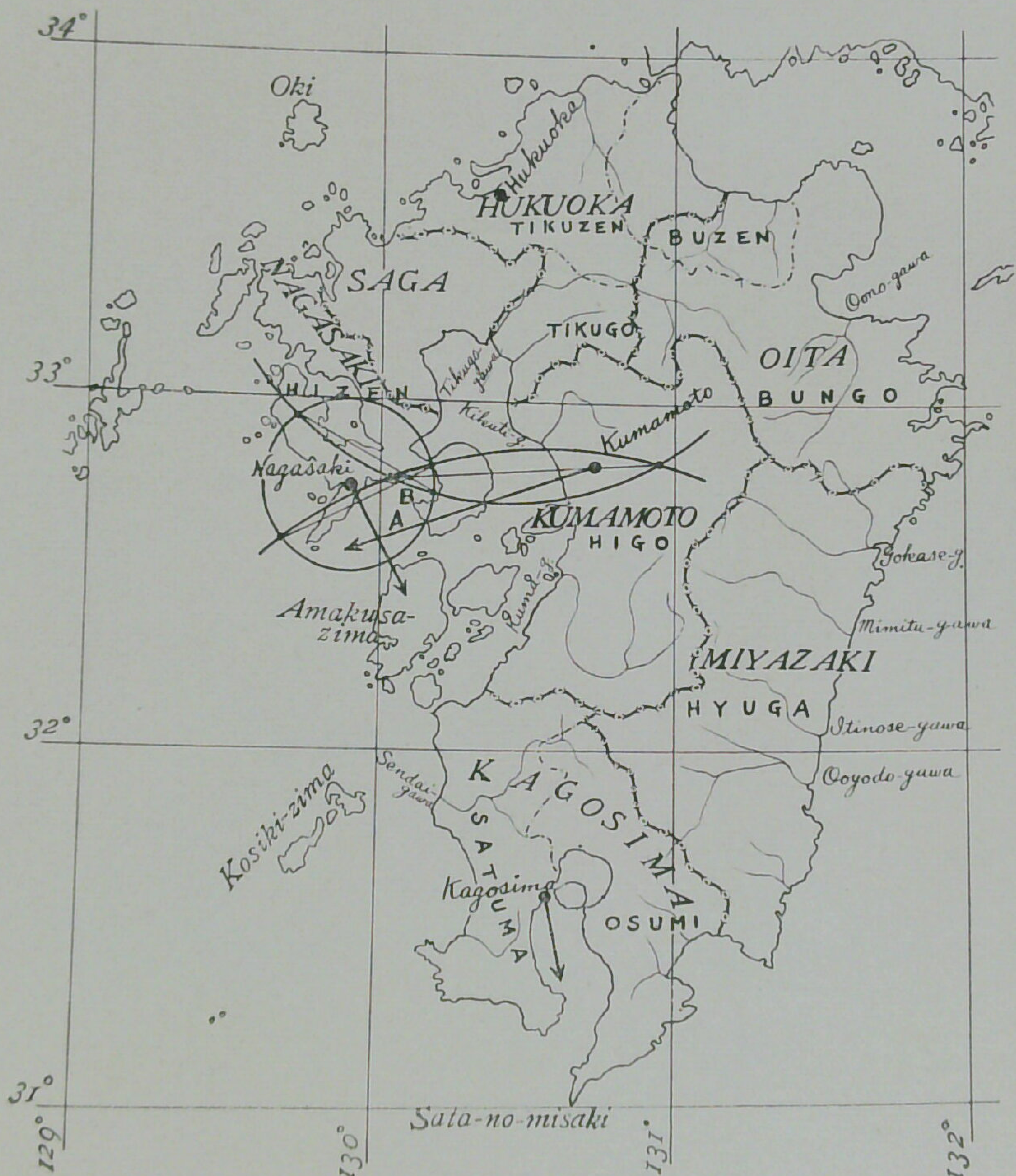
It seems, furthermore, that inasmuch as the periods of vibration of the longitudinal waves are comparatively small, the energy of the waves during its propagation is rapidly absorbed by the surrounding media, with the result that at a distance away from the origin it is reduced to a mere tremor.

The late Dr. Omori attributed the large displacements by overthrow of simple objects in the meizoseismal area, solely to horizontal motion, but the fact that these large displacements occurring within a limited area all take place in a parallel direction and towards the same direction and never opposite to each other, and also together with the fact that these displacements occur in the same manner at repeated occasions, cannot be explained except as the results of strong vertical motions as well as horizontal. At all events, while the destructive energy of earthquakes at regions situated at distances somewhat remote from the origin may be traced to horizontal motions, for the case of the epicentral regions and vicinity, there are reasons which do not permit us to disregard the effects of the vertical motions as also being a contributing factor.

November 16th, 1924.

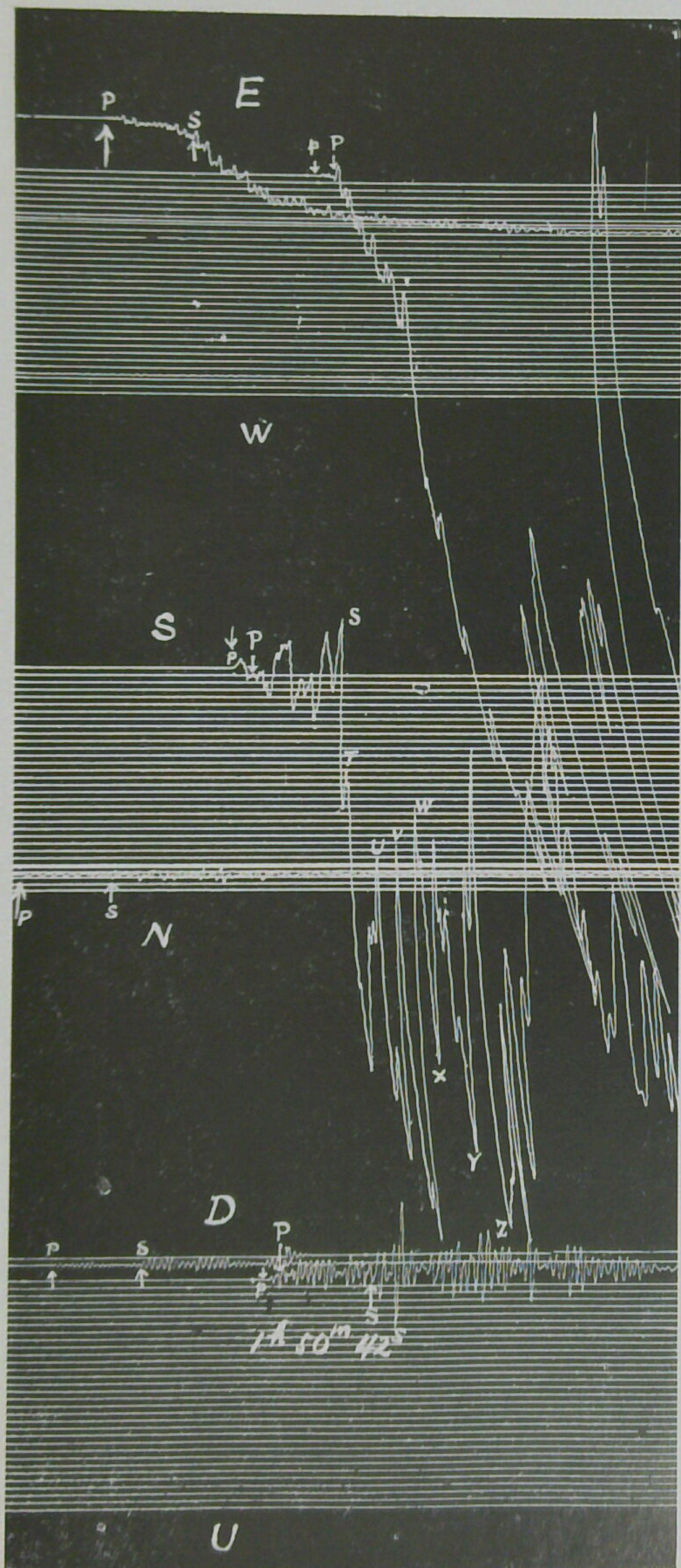
Pl. I.

Map showing the position of epicentre.

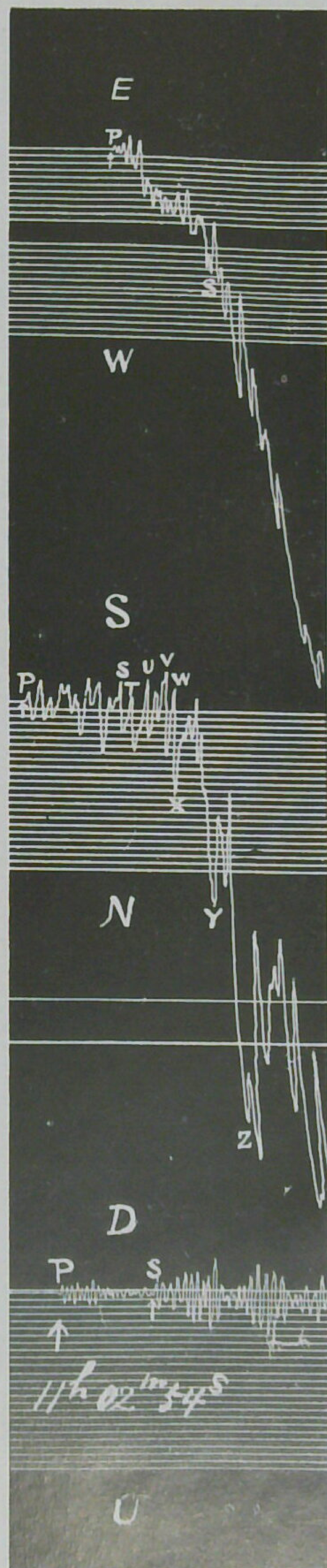


Kagosima observation of the Simabara earthquakes of Dec. 8, 1922, (A) at 1 h 50 m, and (B) at 11 h 2 m.

A



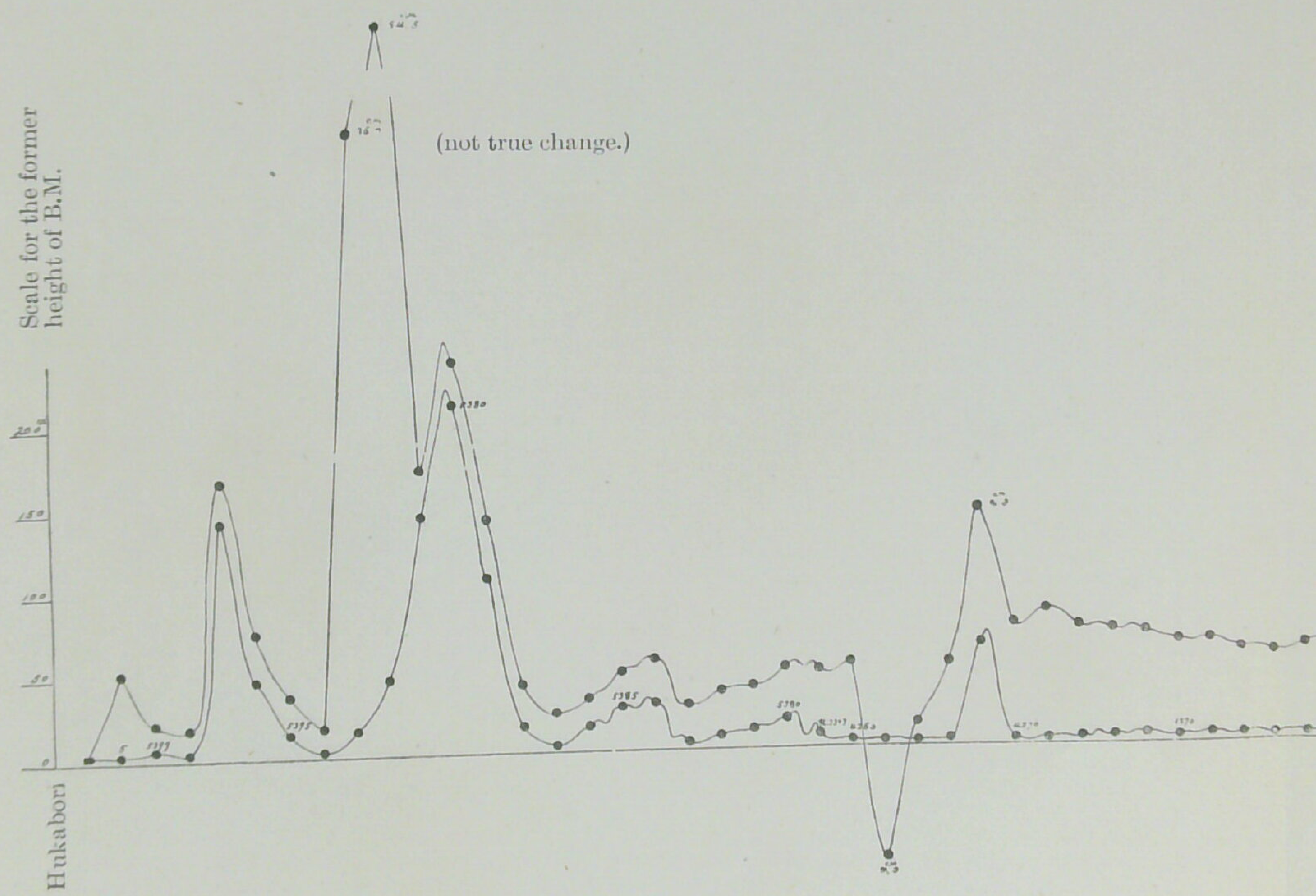
B



Statical magnification = 2, time rate = 4 cm. per min.

Diagramatic view of the former heights and the changes

The heights of B.M. in 1894–1897 are indicated by the lower curve with the scal
The changes of heights of B.M. relative to the above-mentioned curve are indica
Each dot indicates the position of B.M.



ghts and the changes of heights of B.M.

r curve with the scale on the left hand side.

oned curve are indicated by the upper curve with the scale on the right hand side.