Seismographic Study of the Simabara Earthquake.

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(*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 sea-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 Naga-

saki'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 1h 49m 57s 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 peculiari-

ties, 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 immedtately 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

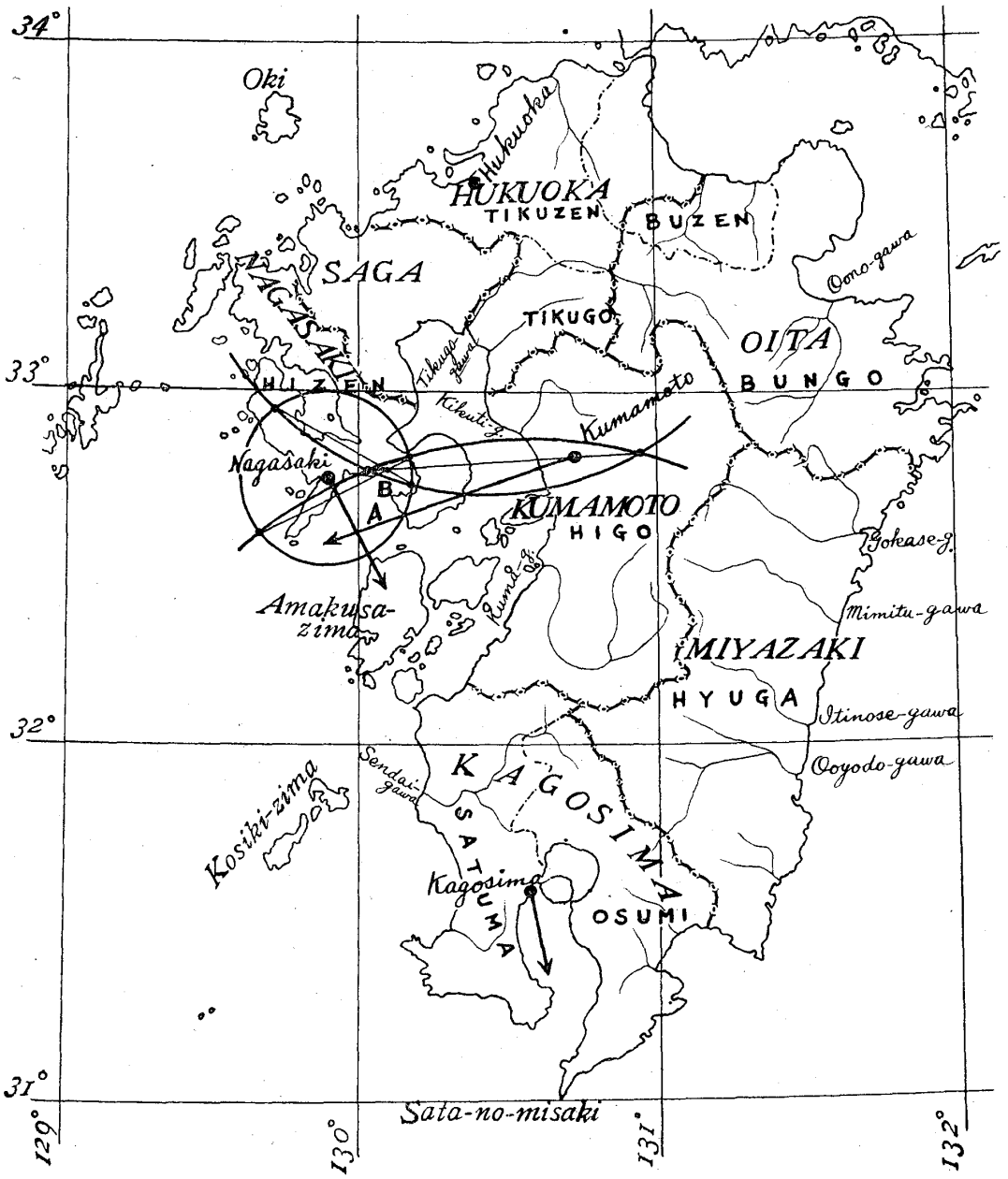
introducing errors into his observational results for stations situated in the epifocal area. It is only quite recently that we have had opportunities of studying earthquakes of which Tokyo was the epicentre; several having occurred this year. In this class of earthquakes it was found that the preliminary 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.

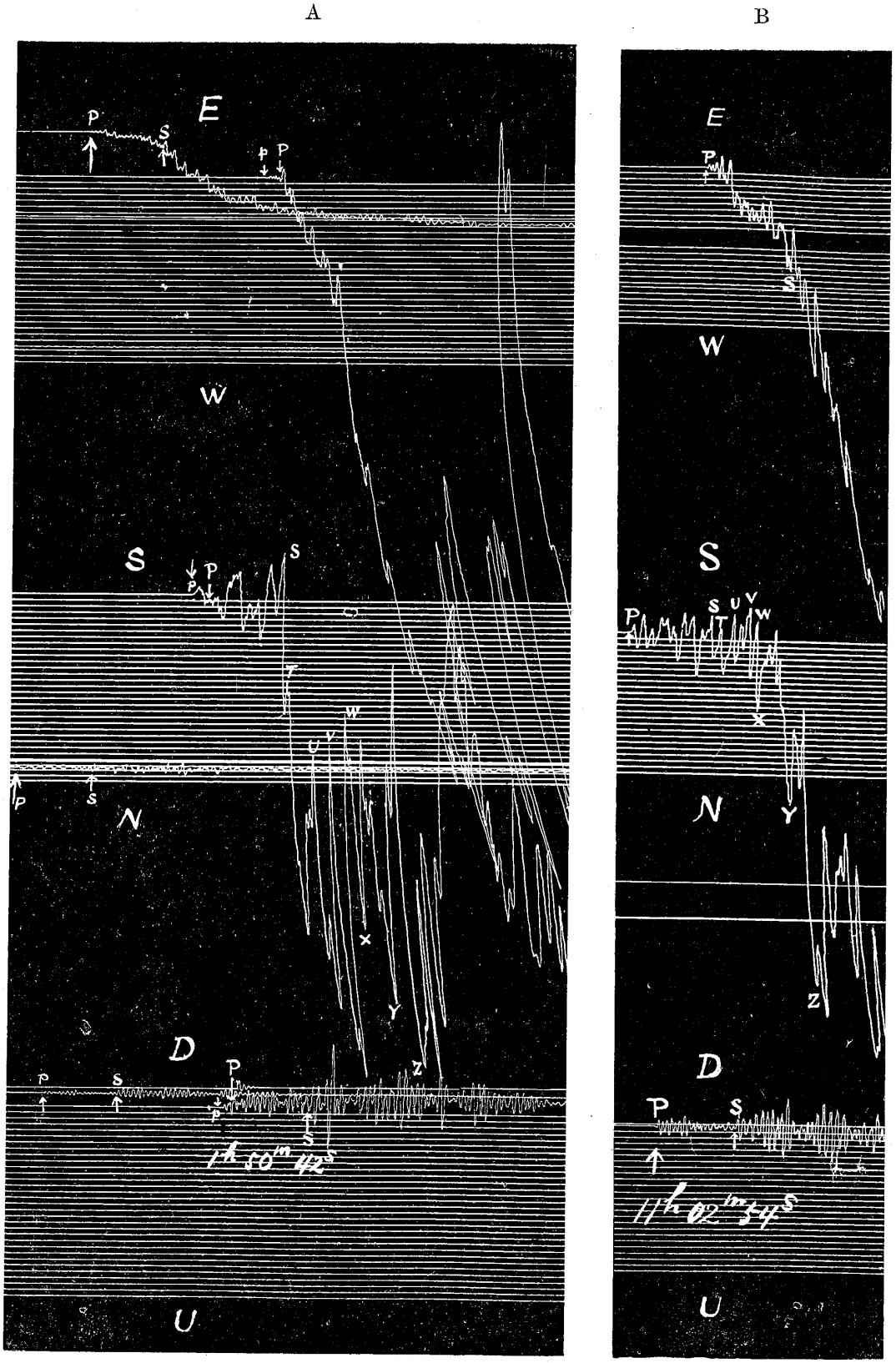
The late Dr. Omori attributed the large displacements by overthrow of simple objects in the meizoseismal area, solely to horizontal motion, but the fact that these large displacements occurring within a limited area all take place in a parallel direction and towards the same direction and never opposite 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.

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.



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