130. *Analytic Investigation of the Great Kwantô Earthquake.*

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The origin of the destructive earthquake which visited S. E. Japan on Sept. 1, 1923, viewed in a broader way, should cover the land and seabasin which have thereby undergone those conspicuous topographical changes. Nevertheless, it is to be admitted that the seismic commotion which caused the gigantic destruction primarily started from the seismic focal zone crossing the heart of the Sagami Bay in the direction NW-SE. The present note is to show that that tremendous earthquake consisted of a group of the earthquakes which originated at different points in the zone and took place one after another within an interval of 10 seconds or more, each shock being distinguishable from its forerunners, where they exist, by its predominant beginning. This is revealed by a comparative study of the seismograms which are due to that destructive earthquake and its aftershocks and were recorded by instruments available at Tokyo and a few other stations.

Fig. 1-3 represent the main shock in its actual register and analytic review. Fig. 1 is a reproduction of the register obtained by the two-time seismograph¹⁾ and reduced into a half, thus indicating the earth's movements in actual magnitude. Fig. 2 is one given by the natural size seismograph.²⁾ A glance shows that both indicate quite inconsistent characters, but in eliminating the slow vibration, which occupies the whole course of the preliminary tremors and was caused possibly by the earth's tilting,³⁾ they give a practically identical diagram as roughly illustrated in Fig. 3. Then follows another difficulty, for the diagram thus deduced is by no means similar to that due to any of the aftershocks, particularly of those which originated at the same zone, as, for example, that on July 12, 1924 (Fig. 6.). This difficulty, however, can be eliminated if my assumption of the multiple origins be granted.

1) As regards its instrumental constants refer to the Proceedings, II, 3, p. 131.

2) Ditto.

3) The Proceeding, II, 3, pp. 129-132.

Before going on further, let us see how a simple shock originating in the same seismic zone of the Sagami Bay comes out in the register at Tokyo. As an example we may take the earthquake just cited. It had its epicentre at 8 km. WSW of Kamakura and was registered by the new portable tromometers ($V=50$, $T=8$ sec., $\nu=1.6:1$)¹⁾ at Kamakura and Tokyo as shown in Fig. 4 and 6. The Kamakura register reveals that the motion consisted essentially of a single vibration indicated by a predominant wave $\bar{S}$ ($T=0.55$ sec., $2a=1.6$ mm.) at the beginning of the principal portion, other minor vibrations ($T=0.4$ sec. in average) being the earth's movement special to that locality (Fig. 4 and 5). The Tokyo observation, however, exhibits a quite different feature (Fig. 6). Not only it indicates an isolated wave $\bar{S}$ (the movements being much smaller during the subsequent 5 sec.) at the head of the principal portion, but also a series of equally, or more, conspicuous waves as shown in the following table.

Phase	$\bar{S}$	a	b	c	d	e	f
Time of arrival (in sec.)	0	5.0	12.3	23.6	33.5	45.5	70.0
Vibration period (in sec.)	0.55	0.67	1.20	1.62	1.20	1.66	2.77
Double amplitude(in mm.)	0.07	0.04	0.14	0.13	0.12	0.15	0.11

The distinction of these different phases would be an interesting problem in itself; the wave a may possibly correspond to $\bar{S}r$, i. e., the phase $\bar{S}$ once reflected at the surface of the lower layer of discontinuity, while b - f , or at least some of them, may correspond to the same phase refracted to the upper layers of the sedimentary formation. But my present object of enumerating them is just to show the complexity and endurance of the earth's movements in Tokyo, however simple the original shock at the Sagami Bay may have been.

Naturally the great earthquake of 1923 might not have been of such a simple origin, for its preliminary tremors and especially the initial part or, speaking more strictly, the first 10 sec. of its principal portion in the Tokyo register consist of successively augmenting vibrations instead of mere solitary waves. On this ground and in consideration of the similarity of seismograms which usually exist between the shocks of the same or near origins, the main shock may be analysed as follows. (See Fig. 3.)

I. $\bar{P}$ - A and $\bar{S}$ - a correspond to the beginnings of the $\bar{P}$ and $\bar{S}$ phases of

1) Bull. of the Earthquake Research Institute, no. 1, pp. 8-21.

the first earthquake. It was not so big a shock; the curve is similar or rather almost identical to that of the aftershock on Sept. 1, 1923, at 12 h 40 m.¹⁾

II. A-B and α -c correspond to the $\bar{P}$ and $\bar{S}$ phases of a very large earthquake which took place 3 sec. later than the first. The seismogram is similar to that due to the aftershock which originated near Odawara on Sept. 1, 1923, at 14 h 22 m.²⁾

III. $\bar{B}$ - $\bar{S}$ and f - g correspond to the $\bar{P}$ and $\bar{S}$ phases of a very sharp earthquake which took place 7.5 sec. later than the first.

Other details of these earthquakes are to be seen from the following table.

No	$\bar{P}$		Duration prel. tr.	Epicentre	
	2a	Direction*		λ	ϕ
I	1.1 mm.	N35°E upward	9.8 sec.	139° 25'	35° 7'
II	5.6	S60°W downward	9.4	139 9	35 31
III	9.1	NE upward	8.4	139 25	35 17

* Correction due to the orientation of the instrument is taken into account.

Possibly there occurred more earthquakes, especially in the southeastern part of the seismic focal zone, but so far I have been unable to analyse.

The latter two of the three earthquakes just alluded to might otherwise have been merely different phases of the continuous action of one earthquake and of its propagation manifesting multifarious effects at different moments and places as indicated above. However it may be, it would at least be admitted that the earth's movements in Tokyo on this occasion were far more complex than usual though it is pretty much so even in the ordinary case. The principal portion of earthquake motions which caused injuries to structure is known to be a simple vibration with straight path as in the case of the Uraga Channel earthquake of April 26, 1922,³⁾ or with parabolic path as in the case of the Ryûgasaki earthquake of Dec. 8, 1921.⁴⁾ But the destructive Kwantô earthquake of 1923 shows a new feature in the very complicated kind of motions which may be called an aggregation and repetition of the two categories described above. This adds a new problem on the construction of earthquake-proof house, to which I wish to call attention of investigators.

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- 1) Reports of the Imp. Earthq. Inv. Comm., no. 100 A, p. 59 and fig. 58.
 - 2) Ditto, p. 59 and fig. 61.
 - 3) Seismological Notes of the Imp. Earthq. Inv. Comm., no. 3.
 - 4) Ditto, no. 2, fig. 4.

Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

Fig. 5.

Fig. 6.