4. *On the Central Area of Seismic Sea Waves.*

By Syun'itiro OMOTE,

Earthquake Research Institute.

(Read Mar. 15, 1948.—Received June 20, 1948.)

To determine the central area of tsunami, or earthquake sea waves, on the basis of the data obtained from mareographic records, was the object of Dr. Miyabe's[1] interesting study, the first of its kind ever to be made, at the time of the Sanriku Earthquake of Mar. 3, 1933.

The great earthquake that took place on December 21, 1946, was also accompanied by violent tsunami waves, and the disturbance of the sea-water left good records at various mareograph stations in Japan. These records have been collected by the present writer and reproduced here in Fig. 1. From these records it was easy to find out the lengths of time that had elapsed between the commencement of the earthquake motions and the arrival of the tsunami waves at the respective stations. The lengths of time needed by tsunami waves to reach the stations are shown in Table 1. The average errors that might be involved in them will be about ± 5 minutes at the maximum. Five of these mareograms may be understood to contain also the records of the disturbance of sea-waters due to the earthquake motions. The probable errors of travel times measured at these stations do not exceed ± 2 minutes.

Table I.

	Station	I wave h m	II wave h m	II–I m		Station	I wave h m	II wave h m	II–I m
A	Hosozima	4 56	5 20	24	F	Matsusaka	5 30	5 56	26
B	Uwazima	5 02	5 31	29	G	Uchiura	5 00	5 20	20
C	Osaka	6 20	6 45	25	H	Ito	5 05	5 28	23
D	Sakai	5 53	6 15	22	I	Tokyo	6 20	—	—
E	Shimozu	4 50	5 15	21	J	Choshi	6 05	6 20	15

Now, taking each station as an imaginary wave source, and assuming that the tsunami waves started from this point into the offing with the propagation velocity of a long wave; we can draw the curve of the imaginary wave front after the lapse of time that is equal to the observed travel time needed by the actual waves to reach each station. The curves drawn in this way, pertaining to the various stations, are shown with short lines in Fig. 2. The area bounded by them may be taken as the origin, or the central area, of the tsunami waves. The boundary curve of this area is referred to as C—I. The linear dimension of C—I is about 300 km.

Now, if we concentrate our attention to the initial part of the tsunami records, we notice that the tsunami begins with rather small up and down motions, which soon after are followed by large waves with a long period. We will call this latter wave the Second Wave (Wave II for short) and distinguish it from the wave that arrives at the station earliest, which will be called the First Wave (Wave I).

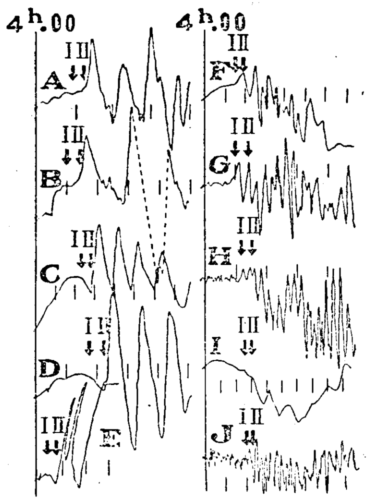

Fig. 1. Mareograms of the Nankai Earthquake of 1946.

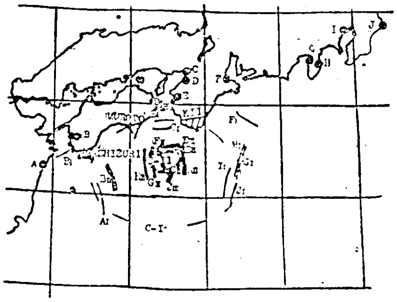

Fig. 2. Central area of the Nankai Tsunami. Letters attached to each curves are correspond to the respective station from which they were imagined to have started. Saffixes I and II represent respectively the I and II waves.

Glancing at Fig. 1, we notice that the two types of waves, I and II, are distinctly observed in most of the records. When, however, the commencement of Wave II was not clear, the following methods were taken. We first read out from the records the oscillation period of the large Second Waves and determined the time of the first maximum. Then we took a point at half the length of the period of Wave II backward from this first maximum, and decided this to be the time of the commencement of Wave II. The commencement of wave II in each record is shown in Fig. 1, and its travel times tabulated in Table I. The imaginary fronts of Wave II pertaining to the respective stations are shown with heavy curves in Fig. 2. Though these wave fronts intersect each other, it is possible to think of the area that is enclosed by them. The outermost margins of this area are bounded by a heavy dotted line marked C—II.

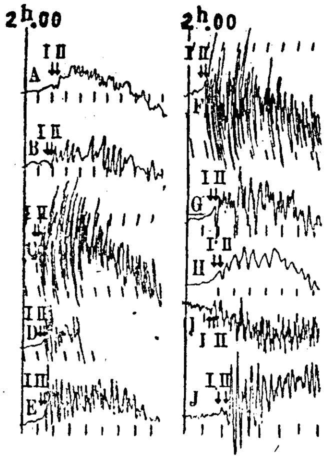

Fig. 3. The mareograms of the Sanriku Tsunami of 1933.

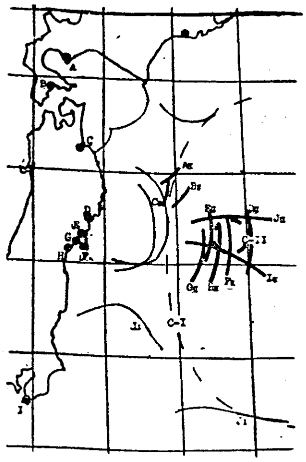

Fig. 4. The central area of the Sanriku Tsunami.

As the second example we will take up the Sanriku Tsunami[2] of 1933. The central area of this Tsunami with respect to Wave I was thoroughly studied by Dr. Miyabe, the result of which study is reproduced

Table II.

	Station	I wave h m	II wave h m	II-I m		Station	I wave h m	II wave h m	II-I m
A	Muroran	3 55	4 11	21	F	Ayukawa	3 05	3 15	10
B	Hakodate	3 48	4 04	16	G	Ishinomaki	3 40	3 45	5
C	Hachinohe	3 08	3 31	23	H	Shiogama	3 38	3 45	7
D	Kesenuma	3 39	3 50	11	I	Mera	3 21	3 34	13
D	Tsukihama	3 24	3 30	6	J	Chichizima	3 54	4 15	21

here in Figs. 3 and 4. In the mareographic records in Fig. 3, we were able to distinguish the two types of waves, I and II, in the same manner as we did in the case of the Nankai Earthquake.

On the other hand, as Dr. Miyabe had already pointed out in his paper, in some mareographic records one could observe a smaller movement of the sea water lasting for some time before the conspicuous rise or fall of the water began. Our Wave I seems to agree with Dr. Miyabe's smaller movement occurring first, and Wave II with the conspicuous rise or fall that follows. The travel times of these waves are shown in Table 2.

The heavy curves in Fig. 4 represent the wave fronts with respect to Wave II, worked out from the wave fronts of Wave I that had been given by Miyabe. The area enclosed by the heavy curves of Wave II fronts is very small compared with the central area of Wave I.

Up to the present time, the central areas of Wave I of five earthquakes[3] have been calculated. The five earthquakes are listed in Table III, together with the linear dimensions of the central areas of Wave I.

Table III.

No	Date	Epicentral region	R: Radius of felt area	Linear dimension of central area.
1	III, 3, 1933	Sanriku	920	600
2	XI, 3, 1936	Kinkazan	440	90
3	V, 1, 1939	Oga	410	50
4	VIII, 2, 1941	Kamuizaki	495	210
5	XII, 7, 1944	Tōnankai	570	130
6	XII, 21, 1946	Nankai	760	350

The relation between the linear dimensions of the central areas of tsunami waves and the radii of the felt areas of the respective earthquakes is given in Fig. 5. The magnitude of an earthquake will be represented by the linear function of the radius of its felt area, and so it may also be safely concluded that the greater the earthquake is, the greater is central area of tsunami waves too.

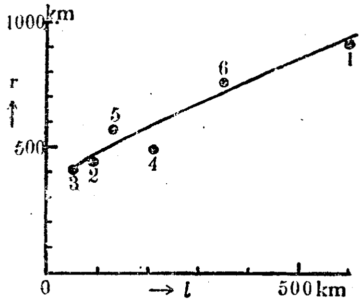

Fig. 5. l; length of the central area. r; radius of felt area,

The Nankai Earthquake was accompanied by a marked upheaval of land[4] at the southern parts of Muroto, Ashizuri and Kii Peninsulas shown as hatched areas in Fig. 1. We at once notice that the marginal lines of this upheaved areas are located so near the C—I curve marking the boundary of the central areas of tsunami. In the case of the Tonanki earthquake of 1946, the crustal deformations were not so conspicuous, but still some evidence of such deformation was clearly discernible[5], and again the C—I curve was so near the shore lines. This seems to indicate that the central area determined from Wave I represents the area within which the crustal deformations have taken place.

Secondly, let us examine the area encircled by the curve C—II, which is the original area of Wave II. The data here collected are not numerous enough to enable one to draw any definite conclusion, but it can be surmised that this area represents the place where the discontinuities of the earth's surface happened at the ocean bed.

Conclusion.

In this paper we distinguished two types of waves, I and II, in the initial part of mareographic records, and concluded that they came from different origins. The central area responsible for Wave I has a linear dimension of several hundred kilometers, and is supposed to be the region within which the crustal deformations have taken place. Wave I of the tsunami records is supposed to have emanated from the marginal zones of the deformed area. On the other hand, the central area responsible for Wave II has a linear-dimension of only 10 km or so, and it may be concluded that some actual discontinuity, such as a fault, which has taken place on the crustal surface of the sea-bottom, has sent out waves of large enery, which then are recognized as Wave II in mareographic records.

---

1) N. MIYABE, *Bull. Earthq. Res. Inst. Suppl.* Vol. I (1934), 112.
2) *Bull. Earthq. Res. Inst. Supple.* Vol. I, Part 2, 7.
3) N. MIYABE, *loc. cit.*, 1), 114.
N. MIYABE, *Bull. Earthq. Res. Inst.*, **15** (1930), 837.
F. KISHINOUYE and IIDA; *Bull. Earthq. Res. Inst.*, **17** (1939), 733.
N. MIYABE, *Bull. Earthq. Res. Inst.*, **19** (1941), 104.
S. OMOTE, *Bull. Earthq. Res. Inst.*, **24** (1946), 31.
4) T. NAGATA, *Bull. Earthq Res. Inst.*, **25** (1947).
5) OMOTE, *loc. cit.*, 3), 47.