51. Tunami associated with the Sanriku Earthquake that occurred on November 3, 1936.

By Naomi MIYABE,

Earthquake Research Institute.

(Read Jan. 17, 1937.—Received June 21, 1937.)

1. A severe earthquake occurred on November 3, 1936, the epicenter of which was off Kinkwazan. The shock was felt most severely on the Pacific side of northeastern Japan.

On the Pacific side of the prefectures of Hukusima, Miyagi, and Iwate, it was reported that cracks appeared on the walls of warehouses, window panes shattered, and that banks in several places subsided[1].

It was also noticed by a number of people, as already reported by Takayama[2], that, in Siogama Bay, the sea-level was seen to rise abnormally several tens of minutes after the shock was felt. Elsewhere, as also reported by Takayama, the sea-level rose after the earthquake to such an extent that it almost overflowed the banks. Obviously these reports by laymen are subjected more or less to exaggerations so that they cannot be accepted as being entirely correct. It may however be worth while to ascertain whether or not the tunami really occurred in association with this earthquake.

If the tunami was really associated with this earthquake, it should have been recorded by mareographs at several stations on the Pacific coast. The Mareograms were therefore collected from these stations for the purpose of ascertaining the occurrence or otherwise of the tunami through the courtesy of Mr. H. Matuo, a member of the staff of the Doboku Sikenzyo (Department of Domestic Affairs) to whom our best thanks are due.

Through these mareograms, the occurrence of the tunami associated with the earthquake was verified.

2. The epicenter of this earthquake was determined by the authorities of the Central Meteorological Observatory, to be 38.0 N, 142.0 E. The

1) Kisyô-Yôran. No. 447 (1936), 1166

2) T. TAKAYAMA, *Bull. Earthq. Res. Inst.*, **15** (1937), 179~184

coordinates of the epicenter thus determined may however contain errors of considerable magnitude. These errors may largely be due to the fact that the seismometrical stations are distributed approximately in a line due N–S on the western side of the epicenter, in which case, as just mentioned, it might be difficult to determine the coordinates of the epicenter free of minor errors, as analytically shown in the following:

Let the coordinates of the hypocenter of the earthquake be x_0, y_0, z_0 and the durations of the preliminary tremors at i-th station τ_i. We then have

$$(x_i-x_0)^2+(y_i-y_0)^2+z_0^2=(k\tau_i)^3=D_i^2,$$

and similarly for h-th and k-th stations

$$(x_h-x_0)^2+(y_h-y_0)^2+z_0^2=(k\tau_h)^2=D_h^2$$

$$(x_k-x_0)^2+(y_k-y_0)^2+z_0^2=(k\tau_k)^2=D_k^2,$$

where x_i, y_i, x_h, y_h, x_k, y_k are coordinate of i-th, h-th and k-th stations respectively.

The values of x_0 and y_0 can be determined in terms of x_i, y_i, x_h, y_h, x_k, y_k, and D 's. Taking into account the fact that the values of x are relatively small and that their absolute values are approximately equal, we have, for determinining x_0 and y_0, by solving the foregoing simultaneous equations.,

$$x_0=\frac{1}{2}\frac{\{(D_k^2-D_i^2)-(y_h^2-y_i^2)\}(y_k-y_i)-\{(D_k^2-D_i^2)-(y_k^2-y_i^2)\}(y_h-y_i)}{(x_h-x_i)(y_k-y_i)-(x_k-x_i)(y_h-y_i)}$$

$$y_0=\frac{1}{2}\frac{\{(D_h^2-D_i^2)-(y_h^2-y_i^2)\}(x_k-x_i)-\{(D_k^2-D_i^2)-(y_k^2-y_i^2)\}(x_h-x_i)}{(x_k-x_i)(y_h-y_i)-(x_h-x_i)(y_k-y_i)}$$

The fluctuations in the values of x_0 and y_0 may be mainly due to the errors in τ's or D's in the above expressions. On the other hand, the values of the y's may be taken sufficiently large by proper sellection of the seismometrical stations. while the values of x's are in general small, the values of $(x_{h \text{ or } k}-x_i)$ sometimes becoming zero. Hence, for a rough estimation, the fluctuation in the values of x_0 may be regarded as $\frac{y_k-y_i}{x_k-x_i}$ or $\frac{y_h-y_i}{x_h-x_i}$ times that of y_0, the ratio being very large.

In determining the position of the epicenter of the earthquake from the data given in Kisyô-Yôran, the following method was used. Circles of radii $k(t_i-t_0)$ were drawn with their centers at the respective seismometrical stations, where t_i is the time of commencement of the earthquake shock at the i-th station, and t_0 the time of occurrence of the shock at the hypocenter. An envelope of these circles is then drawn, and the approximate center of the envelope is taken as the epicenter. The constant k is the tangent of the slope of a part of the "Laufzeitkurve", in which the curve is straight.

The coordinates of the epicenter thus determined are

$$\lambda=143.0°\text{E}, \qquad \varphi=38.0°\text{N}.$$

The value of λ is larger than that determined by the Central Meteorological Observatory, the departure amounting to about 100 km, which however is within the range of errors that might have been unavoidable in determining the epicenter in the present case.

3. The mareograms from the various stations along the Sanriku coast are reproduced in Figs. 1~7, and the geographical distribution of the stations is shown in Fig. 8.

From a glance at these figures, we clearly notice the sudden occurrence of an upward movement of the sea-level in the mareograms of Tukihama and Isinomaki and also in the mareograms taken at Onahama and Hatinohe, while, in the mareograms of other stations, trace of a tunami or any movement of the sea-level was not noticed as remarkable. This may be due to the smallness of the amplitude of the tunami, on the one hand, and the local disturbances, such as seiches superposing the curves that show the tides, which cannot easily be separated from the disturbance made by the tunami, on the other.

Since the sudden commencements of the upward or downward movement of the sea-level are clearly noticed in the mareograms of Tukihama and Isinomaki, the time of occurrence of these disturbances at these stations can also be determined with considerable accuracy.

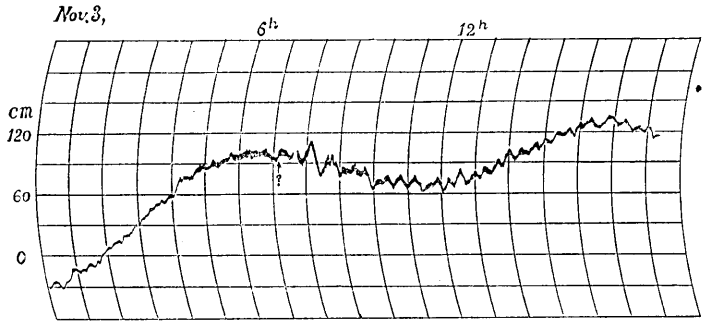

Fig. 1. Mareogram of Hatinohe.

In the mareogram of Onahama, the minor oscillations of the sea-level superpose. The tunami disturbance is however noticeable, its

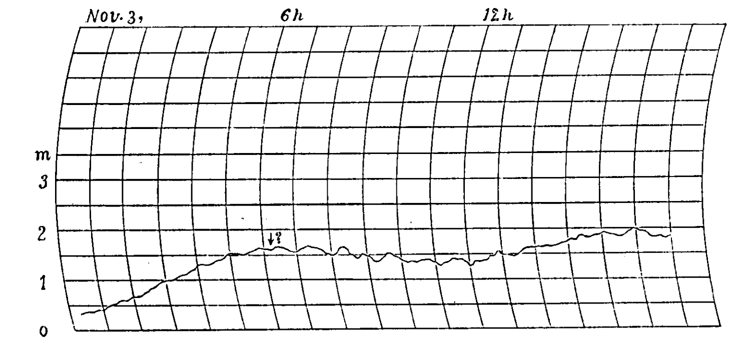

Fig. 2. Mareogram of Kesennuma.

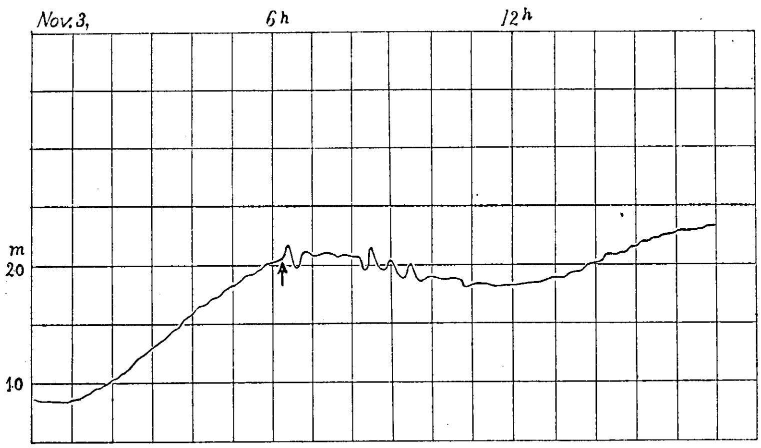

Fig. 3. Mareogram of Tukihama.

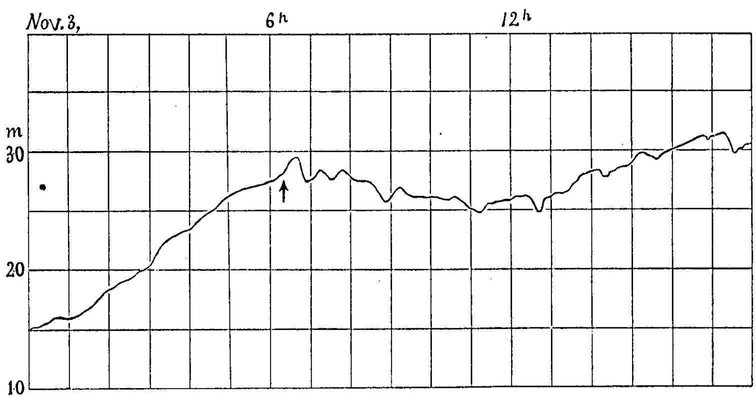

Fig. 4. Mareogram of Isinomaki.

amplitude being slightly larger and the period little longer, though not so markedly as those observed in the mareograms of Tukihama and

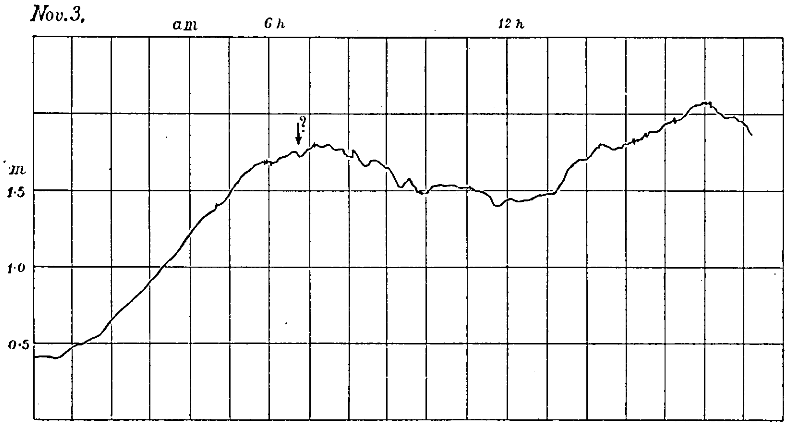

Fig. 5. Mareogram of Siogama.

Isinomaki. In the case of Hatinohe, the determination of the time of commencement of the tunami is more or less difficult. The difficulty lies, on the one hand, in the fact that records of the tide for the interval between 7 h 25 m a.m. and 7 h 40 m a.m. are lacking, on the other hand, to the oscillating motion of the sea-level with periods of about 17~18 minutes and 30 minutes, which seem to be approximately equal to the period of disturbance of the tunami. Oscillation of the sea-level with such a period as just mentioned may be regarded as the proper oscillation of the water of the shelf sea.

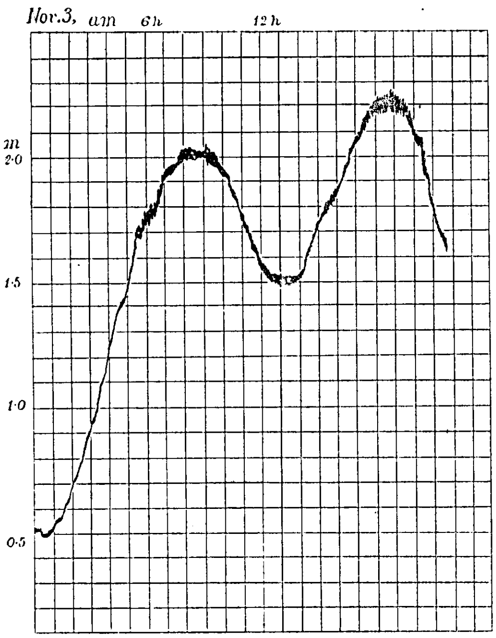

Fig. 6. Mareogram of Hanabutizaki, Siogama.

The disturbances recorded on the mareograms of Hatinohe may therefore be regarded as the oscillation of the water of the shelf sea excited by external disturbances, or tunami. If such is the case, the time of commencement of the tunami should be reduced by several minutes at least, since the amplitude of the oscillation might have increased rather gradually[3].

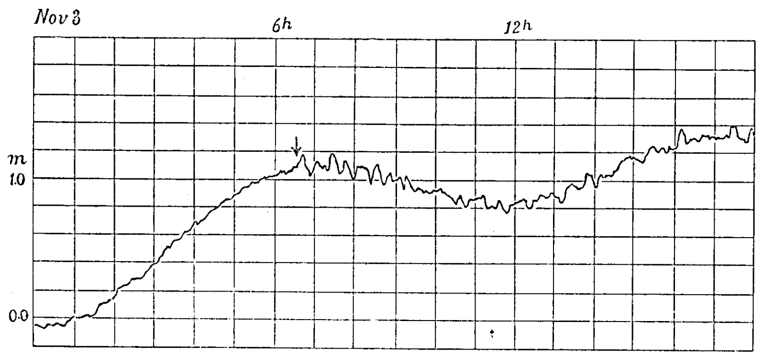

Fig. 7. Mareogram of Onahama.

Table I. Time of commencement of the tunami.

Name of st.	Time of commen't.	Approx. period	Travel time
Hatinohe	7 h 05(25) m	32 m	69(89) m
Kesennuma	6 h 20 m?		34 m
Tukihama	6 h 14 m	20 m	28 m
Isinomaki	6 h 20 m	40 m	34 m
Siogama	6 h 45 m		59 m
Siogama (Hanabuti-hama)	?		
Onahama	6 h 39 m		53 m

Under these circumstances, the time of commencement of the tunami for each station was determined as shown in Table I.

4. By assuming the velocity of propagation for the tunami $\sqrt{gh}$ as done in the previous study[4], the position of the center of the tunami was determined, based on the data given in Table I.

For use in computing the velocity of propagation of the tunami, the distribution of depths of ocean bed in the region under consideration was reproduced from hydrographic charts issued by the Hydrographic Department of the Imperial Navy, as shown in Fig. 8.

Fig. 8. Mareograph stations and center of the tunami.

3) M. NAKANO, *Proc. Phys. Matsh. Soc., Japan*, **14** (1932), 44~56.
4) N. MIYABE, *Bull. Earthq. Res. Inst.*, Suppl. Vol. 1 (1934), 112~126.

To determine the center of the tunami, we first tried to take the mareograph stations as temporary centers of the tunami and construct the wave fronts as referred to their respective stations at the time of occurrence of the earthquake. These wave fronts are shown in Fig. 8 by heavy dotted lines. The area within the envelope of these wave fronts may then be regarded as the center or the central region of the tunami.

The epicenter of the earthquake determined in the preceding paragraph and that determined by the Central Meteorological Observatory both lie in the area thus obtained, marked by ❂ and ⊙ respectively, as shown in Fig. 8.

5. Concluding remarks. In discussing the relation between the crustal deformation and the mechanism of earthquake occurrence, Ishimoto[5] took the earthquake in question as an example of an earthquake that was not accompanied by after shocks, and consequently was not accompanied by either tunami or crustal deformation. According to the writer's opinion, however, it may not be appropriate to take the earthquake referred to even if Ishimoto's hypothesis is probable. The fact that the after-shocks of this earthquake were not felt even by instruments may be due to the great distance of the epicentre and the smallness of the amplitudes of oscillations caused by the after-shocks.

---

5) M. ISHIMOTO, Disin, **9** (1937), 108~117. (in Japanese)

51. 昭和11年11月3日の三陸地方の地震に伴つた津浪

地震研究所 宮部直巳

昭和11年11月3日三陸附近に强震があつて輕微ながら，福島，宮城，岩手各縣の太平洋岸には被害があつた．

この地震に伴つて津浪らしいものが觀察された報告があつたので，太平洋岸各地の驗潮記錄を蒐めた．それ等の記錄は第1乃至7圖に示してある．津浪といつても，その津浪による被害は勿論なく，又，深く陸上に浸入したといふやうなこともなかつたのであるけれども，驗潮記錄にも見える樣に，津浪らしいものゝあつた事は否定出來ないものゝやうである．併し，若したしかに津浪があつたとしても，その振動の振幅は比較的小さいもののやうに思はれるから，潟の靜振等の重つてゐる2～3の例では，津浪の始まりが明瞭を缺いてゐる場合がある．それで，驗潮記錄の上で，津浪の到達時刻を充分精密に讀みとることは困難であるが，數分の誤差を許容するとして，各驗潮儀所在地における津浪到達時刻は本文第一表の樣になる．そこで津浪の傳播速度を$\sqrt{gh}$（hは海水の深さ）として，津浪の中心の位置を求めてみると，大體に於いて，震央と思はれる場所に一致する．

是等の事實から考へて，この地震に伴つて津浪があつたとしてもよいやうに思はれる．

最近 石本博士は，餘震に關して興味ある考を述べて居られる．その中に，餘震を伴はない地震は地殼變形，從つて．その地震が海底に起つた場合には津浪を伴はないといふことを述べられた．併し，その1例として，卽ち，餘震を伴はず從つて津浪を伴はなかつた地震の1例として，この昭和11年11月3日の三陸の地震を擧げて居られることについては，筆者は贊意を表し難いのである．石本博士の考察は妥當であつても，少くとも上述の事實を肯定する以上，この地震に津浪が伴はなかつたとすることには同意出來ない．餘震を感じなかつたといふ事實が若しあるとするならば，それは，震央距離が陸地から少くとも200 kmは離れて居ることを想起しつゝ，餘震の震度が充分大でなかつたことを併せて考慮することによつても說明されるであらう．