On Experiment of a "Tsunami"

By

Yutaka MIZOGUCHI

(Received March. 31, 1953)

1. Introduction.

Suddenly disturbed motions of fluids are often recognized in natural phenomena. A flood is one case and a "tsunami" is another. In order to obtain the general features about "tsunami", the author proposed to compare the real phenomena with those observed in laboratory. In this paper is reported an experiment with a "tsunami" compared to features of an actual one which occurred at the time of the Tokachioki earthquake. In the deep open sea, a "tsunami" may be considered as a long wave, but in the shallow sea, the motion of fluid can no longer be considered as an ordinary wave. A "tsunami" is rather like the case of a flood.

2. Brief Description of the Tsunami of the Tokachioki earthquake.

A great earthquake was felt in Hokkaido at 10:25 a.m. in the morning of the 4th March 1952. The center of disturbance was at a point 70 Km distant to the east from Cape Erimo (longitude 140 East, latitude 42 North). As to the damage caused by the earthquake, it is reported that many houses, bridges and roads in the districts of Tokachi and Kushiro, Hokkaido, were destroyed.

At the same time, a high tidal wave came to the seashore of the south-east part of Hokkaido and such a wave was observed at many places from Shizunai, Hokkaido, to Ochiishi as shown in Fig. 1. Unfortunately only a few data about "tsunami" were reliable, for the data must depend on the account of the spectators, and at that time they were in such dangerous positions, that their recollection is not to be relied upon fully.

In the case of the tidal wave following the Tokachi quake the first wave came to the shore about 30 minutes after the earthquake, and it became larger and larger. The 4th or 5th waves were the maximum

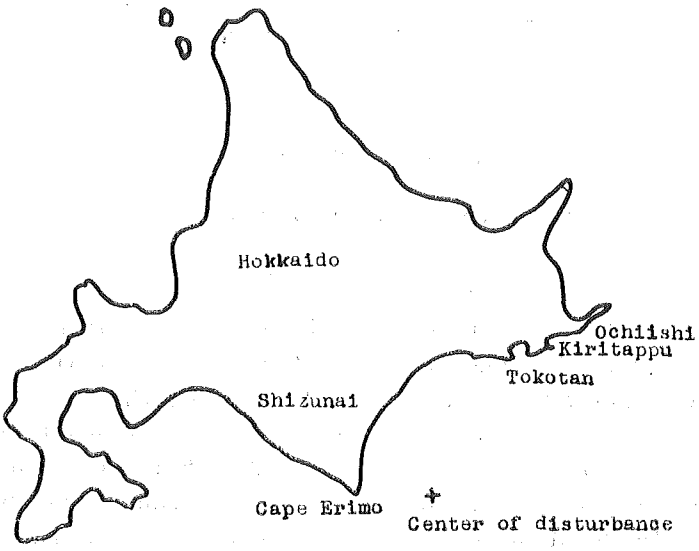

Fig. 1

in height, and from then the waves gradually became weak.

Generally speaking, this "tsunami" was not very violent. The reason may be that the "tsunami" was superposed on the ebb tide. The time of ebb tide on that day was 2 o'clock in the afternoon. As the tidal wave was in some measure canceled by ebb tide, the damage was not very great except in the small town of Kiritappu.

Previously the town of Kiritappu was separated from the main island of Hokkaido by the sea, the width of the channel being 200 m. in 1889. The town was poor in communication facilities, therefore the inhabitants were obliged to reclaim land both sides from the channel and to build a bridge. Further in recent years, the channel has become more shallow and more narrow from drifting sand, and now Kiritappu island is solidly connected with the main land of Hokkaido. Biwase Bay is connected with Hamanaka Bay by a small creek.

The elevation of Kiritappu-town above sea-level is very slight. On the other hand, the variation of the depth of the sea bottom is shown in Fig. 2. From these contour lines we find a submarine valley to exist between Kenbokki island and Kojima.

According to the account of a spectator of Kiritappu, the path of the crest of the "tsunami" is shown as an arrow in Fig. 2. The "tsunami" was recognized at 1 o'clock in the afternoon, with the period

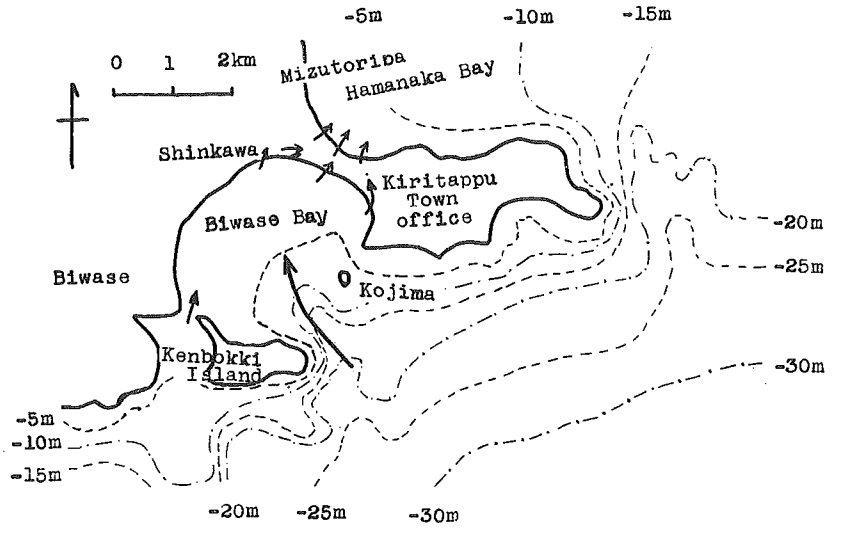

Fig. 2

of 30 minutes and the 4th wave was the maximum. According to the account of a man who was on the roof of a two story house, when the high tide came in, Kenbokki island was hidden from sight by the wave.

The main path of the wave was the channel between the Kenbokki island and Kojima. At fitst the wave struck the land at Shinkawa, and then came to the town office.

The ice-blocks at Shinkawa, were carried to Mizutoriba by the wave of the "tsunami". On the other hand, the houses near the town-office, were carried to Mizutoriba.

3. On the Experiment.

In order to analyse these phenomena, a model of Kiritappu was prepared based on the contour lines of Fig. 2. The ratios were 10000 : 1 in horizontal, and 500 : 1 in vertical.

At first, the model was filled with water as high as the minimum low tide, and then it was arranged to have the level of water rise up suddenly. Fig. 3 is the phenomena photographed by 16 mm cinematographic film.

The topography of the model as it appears in these photographs and

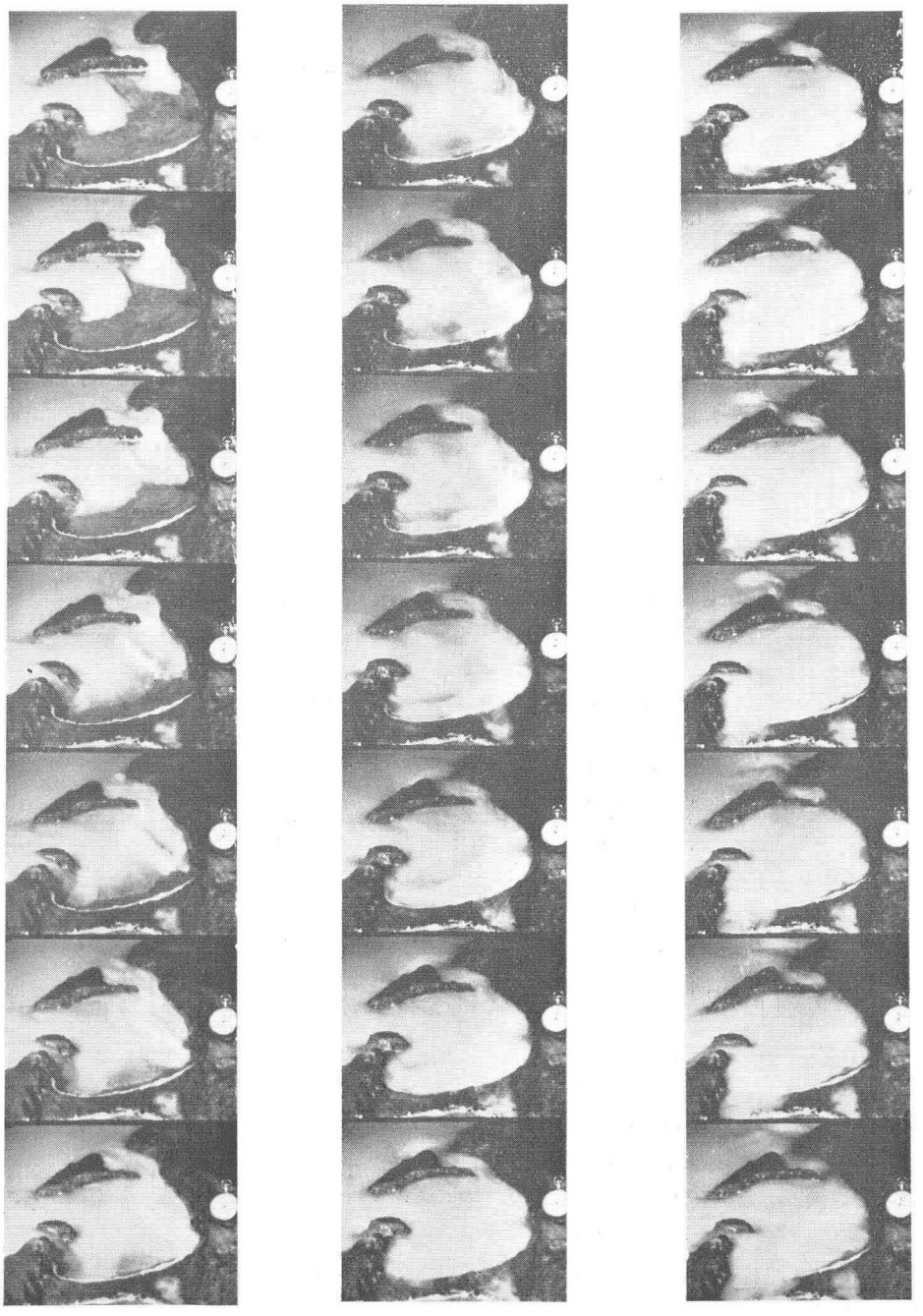

Fig. 3

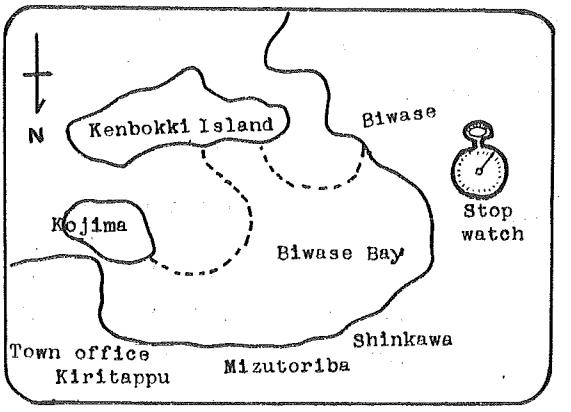

Fig. 4

the corresponding names of places looking offshore are shown in Fig. 4. The white part at the right side in Fig. 3 indicates the stop watch. The hand of that stop watch makes one rotation in 3 sec. As the period of the "tsunami" was 30 min, the time between minimum tide and maximum tide was about 15 min. By the record of the stop watch, the time in experiment is 90/100 sec. $90/100 \text{ sec} \times 1000 = 15$ min.

In Fig. 3 it can be seen that the "tsunami" of the model comes into the bay from the channel between Hokkaido mainisland and Kenbokki island, and between Kojima and Kenbokki island. These two wave fronts came together in Biwase Bay, and went round along the beach of Biwase. At the low place of the land the wave flooded over some part of the town and flowed across into Hamanaka Bay.

The model used in this experiment is on a small scale, but the motion of the waves is very like the real "tsunami".

4. Considerations based on Experimental findings.

As the photographs shown in Fig. 3 were taken from above one side of the model, the reducing ratio is not uniform. After adjusting of the scale of photographs, the velocity of the wave can be measured as in Table 1, between Kenbokki island and Kojima. From the table it can easily be ascertained that the damping coefficient of wave velocity is 1.9.

TABLE 1.

No. of Section	Velocity (m/sec.)
1	4.5
2	3.3
3	2.7
4	1.5

From the model the increasing of water mass at each time interval can be measured. In Table 2 the change of mass, momentum, and kinetic energy are shown.

Table 2.

No. of Section	Mass (kg)	Momentum	Kinetic Energy
1	4.50×10^5	20.25×10^5	91.3×10^5
2	2.70×10^5	8.91×10^5	29.4×10^5
3	1.80×10^5	4.86×10^5	13.1×10^5
4	1.12×10^5	1.68×10^5	2.5×10^5

From these data it can be seen that the wave which came from the deep sea had very large energy. In reality at Kiritappu main wave came through the channel between Kenbokki island and Kojima.

The relation between velocity and depth of sea may be represented by the following formula:

$$u^2 = g\,(h+a)$$

where u is the velocity of wave, g is the accelaration of gravity, h is the depth of the sea and a is the amplitude of the wave. Then the term $(a+h)$ means the distance between the top of the wave and the sea bottom. In this case h is zero, because the "tsunami" come up to a place where there was no water. Put the velocity of wave in Table 1 into the above equation, then the height of the wave is obtained as shown in Table 3.

Table 3.

No. of Section	a (m)
1	2.03
2	1.19
3	0.75
4	0.23

The height of the "tsunami" was, by calculation, about 2m and it receded gradually. This result agrees with the account of the spectators.

5. Conclusion.

Though this experiment was made with a very small model, characteristic features of the experiments resemble very closely those of the real phenomena. The results will give many valuable suggestions to explain the natural phenomena.