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61. *On the Changes in the Heights of Yearly Mean Sea-levels Preceding the Great Earthquakes.**

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Introduction

The data for the mean sea-levels, the barometric height and sea water temperature at the tidal stations, Aburatubo, Hososima, Wazima, Kasiwazaki and Nezugaseki, were kindly placed at my disposal by the Geographical Survey Institute, as well as the data for the mean sea-levels at Hanasaki, Kusiro and Ayukawa, by the Meteorological Agency, to both of which I wish to express my hearty thanks.

The present investigation may be considered to be the supplementary note to my paper[1], already reported, concerning the problem of predicting the occurrence of earthquakes.

The amount of the changes in height of mean sea-level at Hososima immediately before and after the Hiuganada Earthquake was calculated by the similar method as applied in the case of Niigata Earthquake to that at Nezugaseki.[2]

Method of investigation and results

Starting from the monthly mean values of sea-levels, eliminating the general effects of barometric pressure, sea water temperature (or density) and others, by taking the deviations from annual means for each month of many years, and moreover by making the residual corrections due to abnormal barometric pressure and abnormal sea water temperature, we have calculated the values of yearly mean sea-levels, and denoted by $\Delta L''$. In this case, the probable error, $\varepsilon = \pm 5$ mm will be calculated. But for three observed values with no corrections, at Hanazaki, Kusiro and Ayukawa denoted by ΔL, the probable error,

* Communicated by T. MINAKAMI.

1) S. YAMAGUTI, *Bull. Earthq. Res. Inst.*, **38** (1960), 145-175.

2) S. YAMAGUTI, *Bull. Earthq. Res. Inst.*, **43** (1965), 167-172.

$\varepsilon = \pm(10 \sim 15)$ mm must be admitted.

We have taken the thirteen great earthquakes, with magnitude, M, greater than 7.4, epicentral distance, d, less than 400 km, which have occurred in the sea bed or near the coast of Japan, and the investigations on the changes in the height of yearly mean sea levels during the period of several years preceding the earthquakes were made.

In normal cases, the time rate of change in the height of yearly mean sea-level, or that of the ground relative to sea-level, may be observed to be (5–7) mm/year, in the coast of Japan. For reference sake, in the coasts of U.S.A., also, we see the time rate of change about (4–5) mm/year. But, preceding a great earthquake, we often observe greater values, which reach more than three times the normal value, those are (15–22) mm/year, sometimes reaching even 30 mm/year, from the periods over (3–5) years preceding the earthquakes.

In fact, the practical examples are shown in the cases of Kwanto Earthquake, 1923 (Fig. 1), Tango Earthquake, 1927 (Fig. 4), Sanriku Earthquake, 1933 (Fig. 3), Iwaki-oki Earthquake, 1938 (Fig. 3), Tonankai Earthquake, 1944, Nankaido Earthquake, 1946 (Fig. 1 and 2), Tokati-oki Earthquake, 1952 (Fig. 6), Boso-oki Earthquake, 1953 (Fig. 1), Etorohu-oki Earthquake, 1958 (Fig. 7), Niigata Earthquake, 1964 (Fig. 5), Hiuganada Earthquake, 1968 (Fig. 2), and Tokati-oki Earthquake, 1968 (Fig. 6 and 7), related with the corresponding changes in the heights of yearly mean sea-levels at Aburatubo, at Wazima, at Ayukawa, at Ayukawa, at Aburatubo, at Hososima, at Kusiro, at Aburatubo, at Hanasaki, at Nezugaseki and Kasiwazaki, at Hososima, and at Kusiro and Hanasaki,

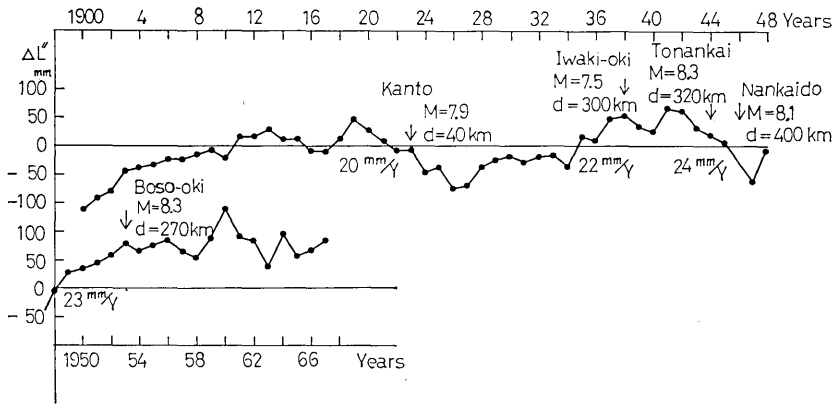

Fig. 1. Yearly mean sea-levels at Aburatubo. 1900~1967.

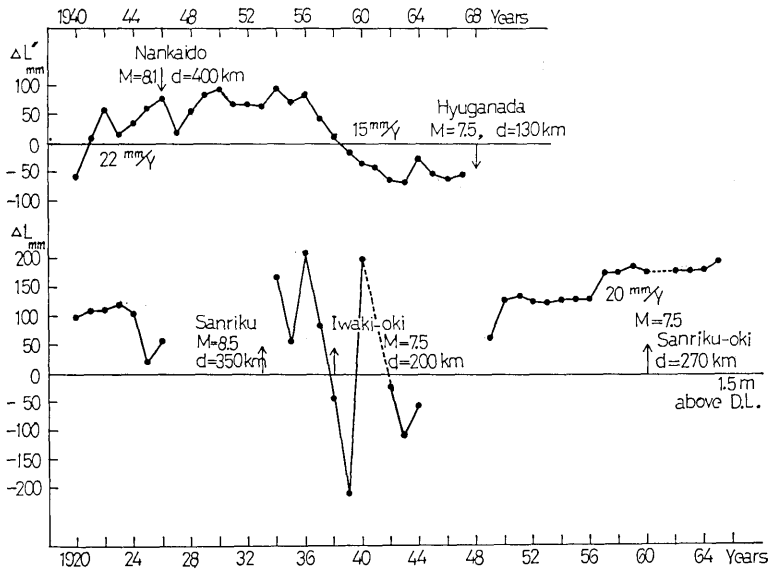

Fig. 2. Yearly mean sea-levels at Hososima (above).
Fig. 3. Yearly mean sea-levels at Ayukawa (below).

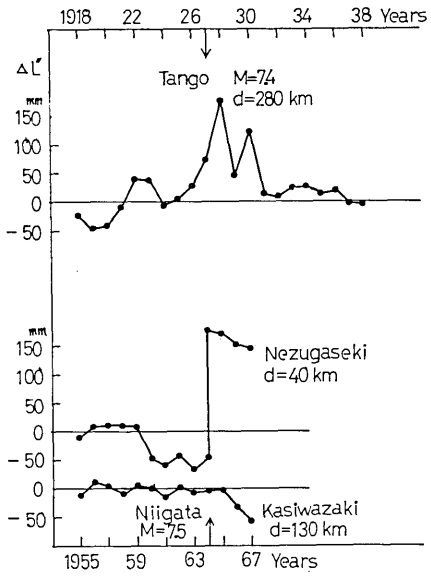

Fig. 4. Yearly mean sea-levels at Wazima (above).
Fig. 5. Yearly mean sea-levels at Nezugaseki and Kasiwazaki (below).

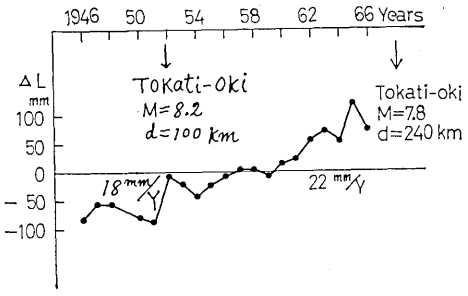

Fig. 6. Yearly mean sea-levels at Kusiro.

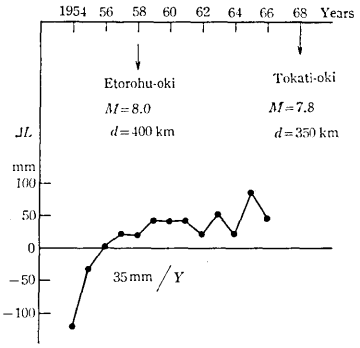

Fig. 7. Yearly mean sea-levels at Hanasaki.

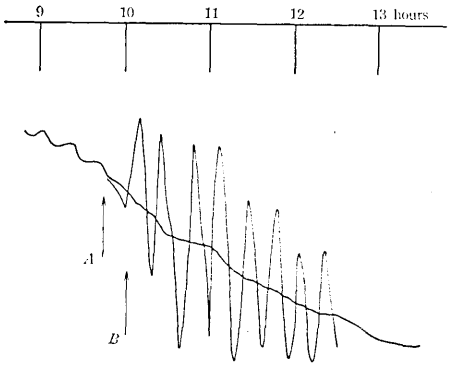

Fig. 8. The trace of "Tunami", April 1968.
A: 9^h42^m Time of occurrence of the Earthquake.
B: 9^h59^m Time of arrival of "Tunami".

respectively.

From Fig. 3, we see, at Ayukawa the large fluctuation of sea-level, probably due to the abnormally great change of the ground following the Great Sanriku Earthquake, March 3, 1933. But we must also take count of the fluctuation of sea-level due to the sea water density variation in very complex distribution by the mixing or the interference of the ocean currents, "Kurosiwo" (warm water), and "Oyasiwo" (cold water), having unfortunately no data of correction for it here.

Finally, we have calculated the hourly mean sea-levels of 48 in number at Hososima before as well as after the Hiuganada Earthquake for each, and obtained the value of the difference, $\Delta L' = -90$ mm. But the values of corrections due to barometric height and sea water temperature were $+63$ mm, and -6 mm respectively, so that the value of the real change in sea-level, $\Delta L'' = -90+63-6 = -33$ mm was obtained. This value of $\Delta L'' = -33$ mm, may be recognized also from the trace, marked on the original tidal curve at Hososima as shown in Fig. 8. The result shows the uprise of the ground relative to the mean sea-level at Hososima, on the occasion of the Earthquake.

The tidal wave or "Tunami" accompanying the Hiuganada Earthquake, arrived at Hososima Bay just 17 minutes after the occurrence of the Earthquake, consequently, some rise of sea-level at Hososima Bay might be supposed. So that the amount of the uprise of the ground, above cited, may exceed the value of 33 mm, considering the effect of "Tunami" upon sea-level.

61. 大地震前の年平均海水面変化について

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海水温度や気圧による年周変化の影響をとり去つた上に，これらの異常変化による残差修正も施した年平均値，$\Delta L''$ についてはその公算誤差は ±5 mm 程度と計算される．それ故に平均海水面に相対的な地面の変化として取り扱うこととする．ただし，生の観測値，ΔL については ±(10～15) mm の誤差を認めなければならない．

1923 年の関東大地震以後 1968 年 5 月までに日本附近の海岸又は海底に起つた，magnitude, $M \geqq 7.4$, 震央距離，$d \leqq 400$ km のもの 13 の地震について調査した．

その結果，時間に対する地面の変化の割合は日本では平常は (5～7)mm/year, (アメリカでも太平洋岸，大西洋岸共に (4～5)mm/year) であるが大地震の (3～4) 年前，場合によつては (5～8) 年も前から連続してその約 3 倍以上の (15～22)mm/year, ときには 30mm/year という大きな割合で変化していることが確められた．その実例は Fig. 1～7 に示されている．こんな場合に傾斜計，伸縮計または地震計等によつて連続観測を行えば或る程度の地震予知が可能であるという考えを強めた．