2. On the Changes in the Heights of Mean Sea-levels, before and after the Great Earthquakes.

By Seiti YAMAGUTI,

Earthquake Research Institute.

(Read Dec. 22, 1953.—Received Dec. 28, 1954.)

Introduction

Investigations on the changes in the heights of the mean sea-levels have been made, and the results have already been reported in my recent papers[1]. As to the sea-water temperature, which is one of the factors governing the change in the height of mean sea-level, the value at the depth of one meter from the surface was taken, assuming that those at such depths as 100 meters and 200 meters, etc. will show annual changes similar to that near the surface. If a great mass of abnormally cold water will appear in the ocean near the mareographic station, the residual correction due to the sea-water temperature, $\Delta T''$, in the equation, $\Delta L''=\Delta L'-p\Delta b'-q\Delta T'$ will not be sufficient. Thus, in the present study, to eliminate the abnormal effects of ocean currents, the Kurosiwo (Black Current) as well as the Oyasiwo (Kurile Current) upon sea-level, the differentials between the values of mean sea-levels, corrected, $\Delta L''$, at Aburatubo and Hososima, and at Aburatubo and Osyoro were taken, and investigated respectively. The difference of the values of $\Delta L''$, between Aburatubo and Wazima was taken also during the past 10 years. The result was in close parallel to that between Aburatubo and Osyoro, so it was left for further study.

Method of Investigation, and Results

After taking the monthly mean sea-levels, corrected, $\Delta L''$, for Aburatubo, Hososima and Osyoro during the period of about 55 years, namely, from Jan. 1900 to Oct. 1954, the values of differences between Aburatubo and Hososima and between Aburatbo and Osyoro were calculated in order to eliminate the effects, if any, of abnormal ocean

1) S. YAMAGUCHI, *Bull. Earthq. Res. Inst.*, **21** (1943), and *Bull. Geog. Surv. Inst.*, **1** (1948), **2** (1950).

currents, the Kurosiwo and the Oyasiwo and diagrams were plotted with these values of differences and also with that of $\Delta L''$ at Aburatubo, as ordinates against the months taken as abscissa, and three curves were obtained. These two curves for differences are nearly parallel to that of $\Delta L''$ at Aburatubo as shown in Fig. 1, which fact may be considered as showing evidently the vertical movement of the earth's crust relative to the mean sea-level at Aburatubo. The value of difference of $\Delta L''$ between Aburatubo and Wazima during the past 10 years, is also taken and plotted similarly as before. The curve, resembling that of the difference of $\Delta L''$ between Aburatubo and Osyoro, is omitted here.

On the other hand, the mean errors of the mean sea-levels $\Delta L''$ (corrected) as well as ΔL (observed), were calculated as follows:

Successive differences, $\delta\Delta L'' = (\Delta L'')_{n+1} - (\Delta L'')_n$, where n is the number of years or months, for yearly and monthly mean sea-levels (corrected) were taken respectively, and the mean values of $\delta\Delta L''$ were calculated and denoted by m. Next, the absolute values of $|\delta - m|$ were calculated, instead of taking $(\delta - m)^2$, and the mean errors, $\varepsilon = 0.8453 \frac{\Sigma|\delta - m|}{n\sqrt{n}}$, were calculated. For yearly mean sea-levels, the data of the abnormally great changes at Aburatubo, in the years before and after the great Nankaido Earthquake and those at Wazima after the great Tango Earthquake were omitted here. For the values of $\Delta L''$ (corrected) and of ΔL (observed) which are the deviations from the secular mean values for 40 years, the mean errors were calculated similarly as before, $\Delta L''$ and ΔL being considered as errors.

The results are tabulated as shown in Table I.

Table I, a. The mean errors for the values of yearly mean sea-levels, during the period from 1900 to 1950

Stations	Yearly Mean Sea-levels in millimetre				Number of Years, n
	Corrected		Observed		
	$\delta\Delta L''$	$\Delta L''$	$\delta\Delta L$	ΔL	
Aburatubo	16.5±1.3	14.1±0.92	21.6±1.9	38.0±2.3	47
Hososima	23.6±1.8	20.5±1.4	26.6±2.1	27.3±2.5	51
Wazima	19.2±1.4	15.2±1.2	19.6±1.6	23.3±1.6	47
Osyoro	18.1±1.8	18.0±1.2	20.2±1.4	24.3±1.8	45
Mean of above 4 Stations	19.4±1.6	17.0±1.2	22.0±1.8	28.2±2.1	47.5

Table I, b. The mean errors for the values of monthly mean sea-levels, during the period of 10 years (1931～1940)

Stations	Monthly Mean Sea-levels in millimetre				Number of Months
	Corrected		Observed		
	$\delta\Delta L''$	$\Delta L''$	$\delta\Delta L$	ΔL	
Aburatubo	34.5±1.7	28.3±1.5	44.4±2.0	57.3±2.2	120
Hososima	43.8±2.0	31.3±1.6	64.3±2.6	90.0±3.4	120
Wazima	30.9±1.4	26.2±1.2	57.6±2.6	89.0±3.3	120
Osyoro	25.6±1.3	20.6±0.9	49.7±2.1	64.0±2.9	120
Mean of 4 Stations	33.7±1.6	26.6±1.3	54.0±2.3	75.1±3.0	120

From these tables, we may be able to say that, if the changes in the heights of mean sea-levels (corrected) amount to values greater than ±60 mm, which is double the value of the probable error in the case of the monthly mean, and ±36 mm, which is double the value of the probable error in the case of the yearly mean, those values obviously may be considered to show the vertical displacement of the earth's crust relative to the mean sea-level. Comparing these changes of mean sea-levels with the results of observations by tiltometer or of the levelling survey, we find that the former values are always larger than the latter, which fact suggests the subsidence of the earth's crust under the load of sea water at high tide, and consequently, the changes in the heights of mean sea-levels measured from the standard line fixed to the earth's crust, might apparently be exaggerated.

On the curve of the monthly mean sea-levels (corrected) $\Delta L''$ for Aburatubo, we have plotted the months of great earthquakes, which have occured in the same epoch, whose magnitudes, M in Gutenberg's or Pasadena scale, were calculated mostly by Prof. H. Kawasumi, and partly by Prof. Ch. Tsuboi, of the Earthquake Research Institute of Tokyo University, and printed by the Earthquake Section of the Central Meteorological Observatory[2]. The earthquakes with magnitude M, equal to or greater than 7, whose epicentral distance from the mareographic station at Aburatubo, d, being less than 150 kilometers, were taken. Those with magnitude M, greater than 7.3, and epicentral distance, d, greater than 150 kilometers, and less than 500 kilometers were also

2) H. KAWASUMI and C. TSUBOI, *The Magnitude Catalogue of Major Earthquakes which occurred in the Vicinity of Japan* (1885～1950).

taken separately with respect to the regions of Southwestern and Northeastern parts of Japan.

The values of $\Delta L''$ for the months of equal phase measured from the month of earthquake, were averaged for different earthquakes and plotted as ordinate against the months as shown in Fig. 2. a, b, c, d. A rather conspicuous minimum of the curve, i. e. a rather conspicuous upheaval of the earth's crust may be observed in the month immediately preceding an earthquake. In this case, we have taken the means of $\Delta L''$ for each month before and after an earthquake, omitting the months of other earthquakes in count, so that the number of months before and after the earthquakes did not exceed 43, among the total number of 54 months of the earthquakes. The mean errors, ε, of the means of $\Delta L''$, were also calculated and the values ± 4.0 mm$<\varepsilon<\pm 6.0$ mm were obtained. These values of ε are satisfactorily small when compared with the values of $\Delta L''$ in the curve, shown in Fig. 2, as was the case when we picked four stations, Aburatubo, Hososima, Wazima and Osyoro, and such destructive earthquakes, 30 in number, as have occurred in the regions within 250 kilometers from the respective mareographic stations, during the period of about 49 years (1900~1948). As already mentioned in my above cited paper,

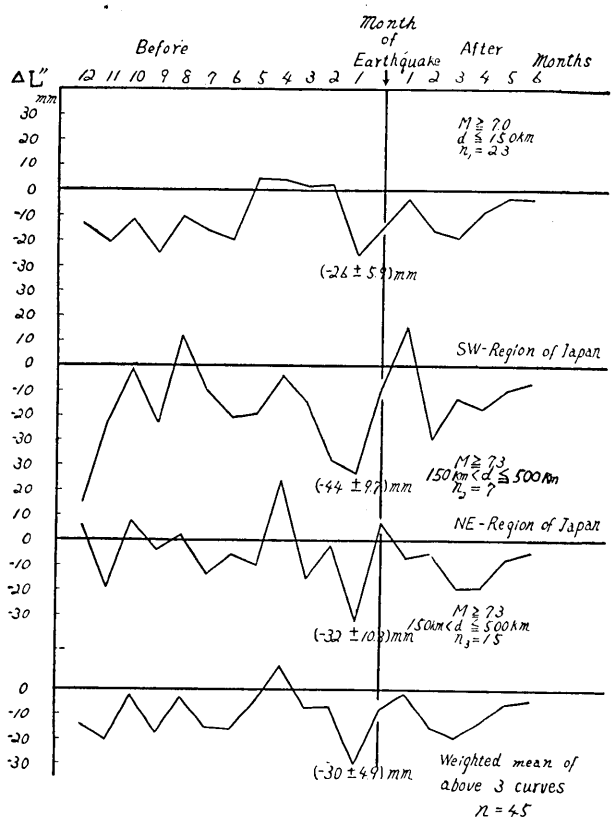

Fig. 2. Monthly mean sea-levels (corrected) $\Delta L''$ at Aburatubo before and after the Great Earthquakent, which accurred in different regions of Japan.

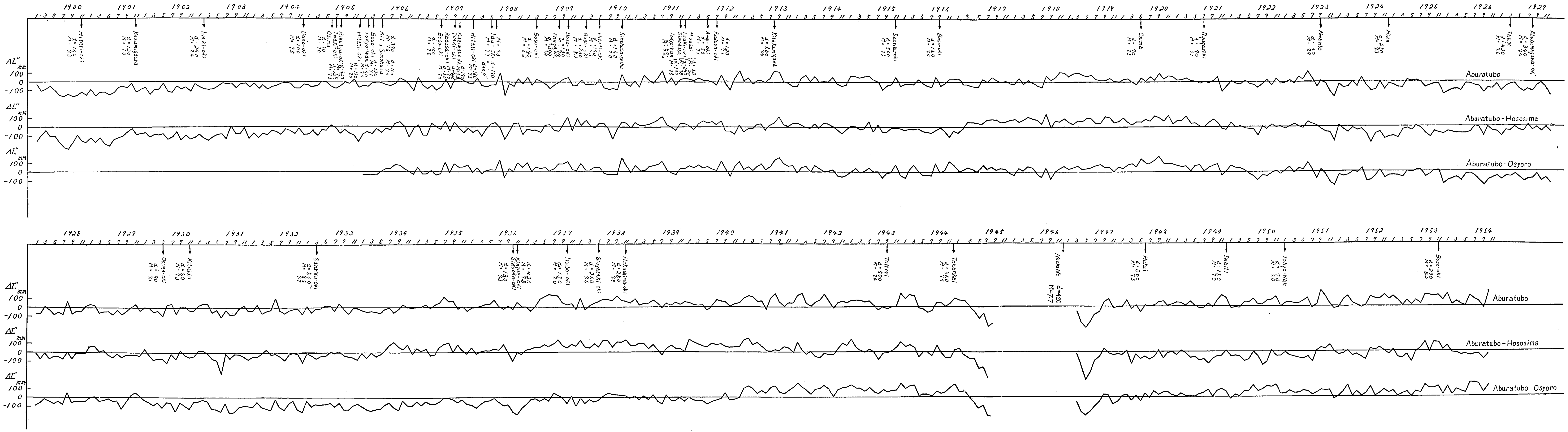

Fig. 1. Monthly mean sea-levels, corrected.

these earthquakes are listed in the Scientific Chronological Table of the Tokyo Astronomical Observatory.

It is interesting to note that both two cases, the present and the preceding investigations, show nearly the same features of curves before and after great earthquakes. In the present case, we have obtained (-30 ± 4.9) mm as the mean value of $\Delta L''$ in the month immediately preceding an earthquake, and in the preceding case, it was (-38 ± 6.5) mm.

From Fig. 1, and 2, we may be able to say as follows:

The changes in the heights of mean sea-level at Aburatubo seem to have more intimate correlations with the occurrences of earthquakes in Southwestern Region than with those in Northeastern Region of Japan. The sea bed of Sagami Bay may be connected more closely with those off Tônankai and Nankai than those off Tôhoku and Sanriku, which suggests that there may exist some fault among the Fuji Volcanic Zone.

In general, the mean sea-levels, corrected, $\Delta L''$ are negative in the nearly months, before and after the great earthquakes. Especially they are greatly negative in the month immediately preceding an earthquake, and they become for one time slightly positive in the months (about four months) before the month of earthquake.

In conclusion, I wish to express my hearty thanks to the Geographical Survey Institute, as well as to the Central Meteorological Observatory of Japan for the many valuable data they put at my disposal throughout my whole investigation.

---

2. 大地震前後に於ける平均海水面の変化について

地震研究所　山　口　生　知

油壺より 150 km 以内の地点に起つた地震と 150 km 以上で 500 km 以内の地点に起つた地震とを別々に考えて，その地震前後に於ける油壺の平均海水面変化の有様を研究した．地震の Magnitude については Pasadena scale で 7 以上のものをとり，又 150 km 以上の所に起つたものについては 7.3 以上のものをとり，而も場所的には西南日本と東北日本とに分類して調べて見た．

平均海水面については天体潮，気象潮，及び海洋潮の修正を施した値を採用したが念のため海洋潮に於て深海に冷水塊でも表はれた場合のことも考慮して油壺と細島の差並びに油壺と忍路との差をも採つて見た．

その結果大地震の 1 ケ月前には確かに平均海水面が著しく下ることが認められた．即ち大地震の 1 ケ月前には相対的に地盤が隆起する可能性が大であることが認められた．
