6. *Observations of the Deformation of the Earth's Surface at Aburatsubo, Miura Peninsula. Part II.*

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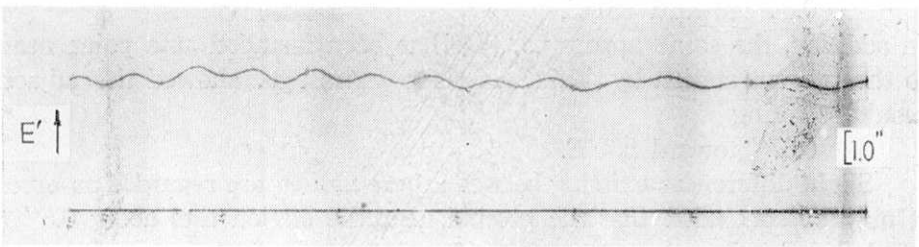
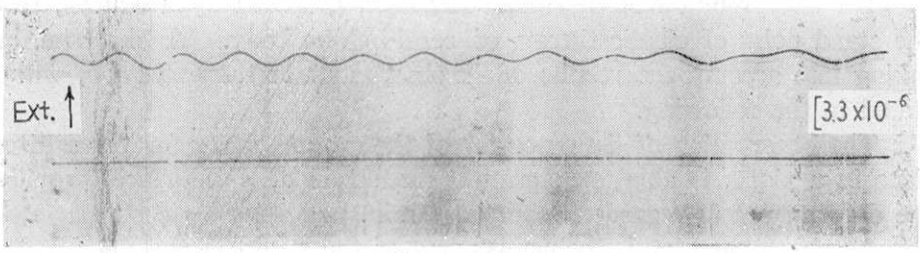
1. In the previous paper[1], the writers reported briefly the outline of the observation at Aburatsubo, which was commenced since the beginning of 1948. Periodic deformation of the earth's surface was remarkably observed there, being as shown, for example, in Photo. 1. The deformation



Tiltmeter.



Extensometer
Photo. 1.

was considered to be due to the variation of the load of sea-water, because the records showed remarkable parallelism between the mode of variation of the ocean tide and extension as well as the tilting of the earth's surface. As already pointed out by R. Takahasi[2], there can be no other causes of such deformation.

1) T. HAGIWARA, T. RIKITAKE and J. YAMADA, *Bull. Earthq. Res. Inst.*, **26** (1948), 23.
2) R. TAKAHASI, *Bull. Earthq. Res. Inst.*, **6** (1929), 86.

2. As already stated, the observation is made for the tilting in two components and for the extension in three directions. It would be sufficient to determine the mode of the deformation in horizontal plane by these observation, if the deformation be regarded as infinitesimal.

As to the tilting, the mode is represented with the direction and the amount of maximum tilting. A pair of water-tube tiltmeters records the tilting amounting to

0.04″ downward to the direction S′ (S22°W)

and

0.51″ downward to the direction E′ (E9°S),

when the sea-surface rises by one metre. Hence the resultant tilting is

0.53″ downward to S64°E,

when the sea-surface rises by one metre. While, the observation with the Ishimoto's all-silica tiltmeters record the resultant tilting

0.54″ toward S51°E.

In addition, the same apparatus, that has been installed at a point nearer to the present station by Takahasi some years ago, showed the adjacent resultant tilting

0.67″ toward S59°E.

Slight differences existing between these values are regarded as errors. It may be concluded that the ground near the station tilts about 0.5″ toward S60°E, when the sea-surface rises by one metre.

An interpretation of the result has been proposed by Takahasi, from the stand point of elastic theory of semi-infinite body. A like trial, but taking into account the results of the observation of the extension, will be stated in the following.

The observation of the extension of the ground, made for three directions in a plane, is able to determine the strain of the surface, provided the deformation is regarded as linear strain.

As shown in Fig. 1, the components of the strain are denoted by e_{xx}, e_{yy}, and e_{xy}. The extension in any direction i will be given, then, by

$$e_i = e_{xx}l^2 + e_{yy}m^2 + e_{xy}lm, \quad \cdots\cdots\cdots(1)$$

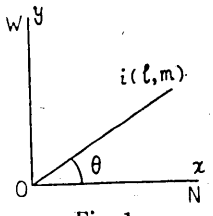


Fig. 1.

where l and m denote the direction cosines of the direction i, taken to the x, y axes. Substituting in l, m the actual values of the direction of N′S′, E′W′, and $8m$ component (which, for the brevity, are named as 1, 2, 3, respectively), we can obtain the components of the strain as the solutions of the next equations,

$$\left.\begin{aligned} e_{xx} &= 0.5858e_1 - 0.1967e_2 + 0.6111e_3, \\ e_{yy} &= 0.1981e_1 + 1.0397e_2 - 0.2399e_3, \\ e_{xy} &= -1.348e_1 - 0.0642e_2 + 1.412e_3. \end{aligned}\right\} \quad \cdots\cdots(2)$$

According to the observation with the extensometers, we get,

$$\left.\begin{aligned} e_1 &= 0.07 \times 10^{-6} \\ e_2 &= 1.44 \times 10^{-6} \\ e_3 &= 0.94 \times 10^{-6} \end{aligned}\right\} \quad \cdots\cdots(3)$$

for the rise of the sea-surface by one metre, which mode can be seen in Fig. 2. Therefore, the components of the strain become

$$\left.\begin{aligned} e_{xx} &= 0.33 \times 10^{-6} \\ e_{yy} &= 1.35 \times 10^{-6} \\ e_{xy} &= 1.09 \times 10^{-6}. \end{aligned}\right\} \quad \cdots\cdots(4)$$

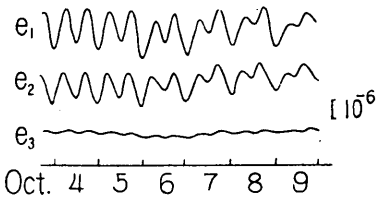


Fig. 2.

The principal axes and the strain diagram are represented with these components. Denoting the principal strain and its direction by e and θ respectively, the following relations are available,

$$\begin{vmatrix} e_{xx} - e & \frac{1}{2}e_{xy} \\ \frac{1}{2}e_{xy} & e_{yy} - e \end{vmatrix} = 0 \quad \cdots\cdots(5)$$

and

$$\tan\theta = -\frac{e_{xx} - e}{\frac{1}{2}e_{xy}}. \quad \cdots\cdots(6)$$

Solving (5), the principal axes are obtained as

$$\left.\begin{aligned} e &= 1.61 \times 10^{-6} \quad \text{(maximum)} \\ &\quad 0.07 \times 10^{-6} \quad \text{(minimum).} \end{aligned}\right\} \quad \cdots(7)$$

The strain ellipse is calculated from (1) as shown in Fig. 3.

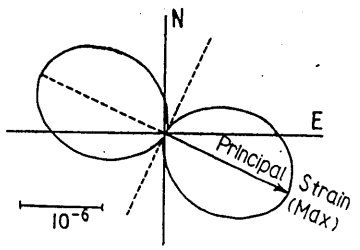


Fig. 3.

It must be noticed that one of the principal axes (maximum) lies in nearly the same direction with that of the maximum tilting, given in the later paragraph. This fact is quite suggestible, though the discussion of its physical meaning will be postponed.

Succeeding to the horizontal extensometers, a vertical one was installed in the same station. The observation with it revealed also an interesting result. It detects the contraction of the ground, when the sea-surface rises, that is,

$$e_{zz} = -\ 1.53 \times 10^{-6} \quad \text{(by one metre rise of sea-surface)} \ldots\ldots\ldots(8)$$

With the aid of (4), the volume dilatation is calculated, amounting to only

$$D = e_{xx} + e_{yy} + e_{zz} = 0.15 \times 10^{-6}, \ldots\ldots\ldots\ldots\ldots\ldots(9)$$

which is regarded as to be zero. This result should be taken into account when we discuss the phenomena theoretically.

3. When we discuss the deformation, the influence of the existence of walls of the gallery on the deformation should be considered. As the apparatus has a long span, which is comparable to the length of the gallery, they can not detect the influence by themselves. For this reason, a short-span extensometer was constructed, and a series of observation were made at several different point in the gallery, in the same direction with one of the long-span apparatus. The observation was made for one or two weeks at each point, and the observed amplitudes was compared with that of the long-span extensometers. Numbers written in Fig. 4 shows the ratio of the both amplitudes, its situation in the figure and the direction of the bar representing the place and the direction where the observation was made. As can be seen in the figure, the irregularity of the amplitudes is not so clear in the gallery, and we may ignore the effect of the cavity due to the gallery, in the present case.

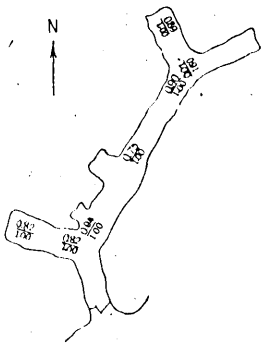


Fig. 4.

4. The mode of periodic deformation of the earth's surface has been studied in this paper. As to the theoretical interpretation of the observed results, some discussion will be made in the following paper.