33. *Observation of the Deformation of the Earth's Surface in the Vicinity of the Epicentres of the Imaichi Earthquake.*

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1. Introduction.

After the Imaichi Earthquake of Dec. 26, 1949, an observation of the deformation of the ground was carried out with a water-tube tiltmeter and a silica-tube extensometer. The instruments were installed in disused mine at Ochiai Village about several kilometers distant from Imaichi-machi in the S-direction. According to the seismometric observation[1], the epicentres of the main shocks were determined to be 139°39.′9 E, 36°41.′1 N for the first shock and 139°38′.8 E, 36°43′.6 N for the second one, both situated near the observation point. Almost all the aftershocks also occurred in the neighbourhood of the point. Hence, it may be said that the observation was executed at approximately the centre of the seismic activity related to the Imaichi Earthquake. Hitherto we have had some chances for similar observations on occasions of great earthquakes,[2,3] but such observations were seldom carried out at seismic centres as in the present case. Thus it is natural to expect that a comparatively larger deformation would be observed, in case it exists, when compared with the former observations cited above.

2. The circumstances of the observation and the instruments.

The writers set a 24 m water-tube tiltmeter and a 12 m silica-tube extensometer in the so-called Keimei Mine, Ochiai village. Keimei Mine is a molybdenum mine drilled in metamorphosed granite rock at the foot of Mt. Keimei, the ore being out of use these several years. As shown in the map of Fig. 1, the mine is situated at the western part of the Ochiai Village where, as

1) Y. KOSHIKAWA, Read at the July Meeting of the Earthquake Research Institute, 1950.

2) T. HAGIWARA and J. YAMADA, *Special Bull. Earth. Res. Inst.*, No. 5 (1947), 179.

3) *Rep. Spec. Com. Fukui Earthq.* (1950), 124.

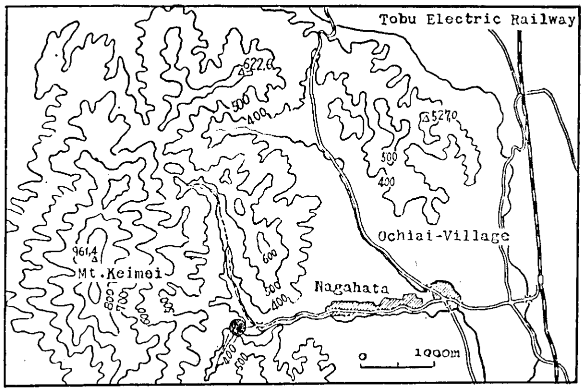

Fig. 1. The map about the observing point, which is indicated with black circle.

already stated in the Introduction, may be regarded as the centres of the aftershocks as well as the main shocks. The main adit of the mine is drilled from the base of a river in the NW-direction about 1 km in length, while many branch adits are bored as shown in Fig. 2. The instruments were installed at a depth of about 50 m from the entrance. Their arrangement is also shown in Fig. 2. Photo. 1 shows the view of the entrance of the adit. The temperature in the mine was always kept at about 13°C within an error of ±0.°5.

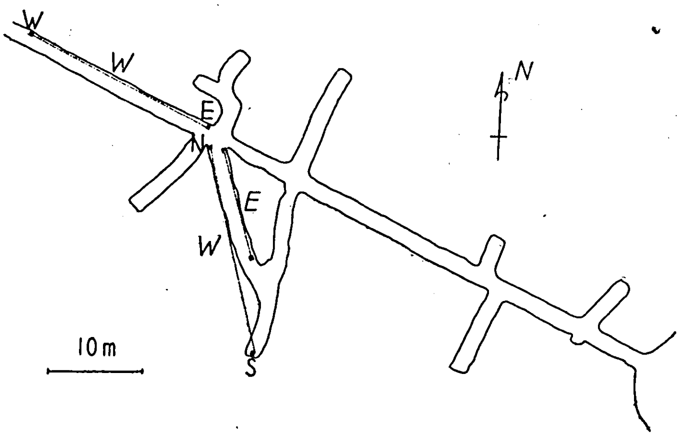

Fig. 2. The plan of the adit.

About 10 days after the occurrence of the main shocks, the concrete blocks for the instruments were constructed. Observation was carried out from Jan.

Photo. 1. The view of the entrance.

15. The instruments used here were almost the same with those used at Aburatsubo,[4] Matsuyama,[5] and Bandojima[3] at the time of Fukui Earthquake. The water-tube tiltmeter, however, was improved so as to measure the absolute difference of the heights of two bench marks which are fixed to the concrete blocks. A water-container is tightly mounted on a gun-metal stand with three legs, one of them made of stainless steel while the other two are gun-metai screws. After setting the stainless one on the bench mark which is also made of stainless steel, the inclination of the stand is adjusted with the screws so as to keep the container's height relatively constant to the bench mark. Two spirit levels attatched to the stand are used for adjustment. Then the water-level in the container is read off with a sharp point of stainless steel, its lower part being a micrometer. When the heights

4) T. HAGIWARA, T. RIKITAKE, K. KASAHARA and J. YAMADA, *Spec. Bull. Earthq. Res. Inst.*, No. 6 (1949). *Bull. Earthq. Res. Inst.*, 27 (1949), 35 and 39. T. HAGIWARA, T. RIKITAKE, and J. YAMADA, *Bull. Earthq. Res. Inst.*, 26 (1948), 24.

5) T. HAGIWARA, T. RIKITAKE and J. YAMADA, Read at the June Meeting of the Earthquake Research Institute, (194?).

of the two bench marks are thus obtained with a pair of the container just mentioned, it is possible to find the difference between the heights of the two bench marks as follows. In the first place, we obtain the two readings h_1 and h_2 respectively for the containers No. 1 and No. 2, which are respectively set on the bench marks A and B. As the zeros of the micrometers are arbitrarily taken, the heights of the water-level above the bench marks A and B become respectively h_1+c_1 and h_2+c_2 where c_1 and c_2 are constants respectively proper to the containers No. 1 and No. 2. Hence the difference between the heights of the two bench marks is obtained as

$$\Delta h=(h_1-h_2)+(c_1-c_2)\,. \quad\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

On exchanging the containers, we have similar readings h_1' and h_2' respectively for No. 1 and No. 2, from which we obtain

$$\Delta h=(h_2'-h_1')-(c_1-c_2)\,. \quad\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Adding (2) to (1), Δh becomes

$$\Delta h=\frac{1}{2}\{(h_1-h_2)-(h_1'-h_2')\}\,,$$

while, subtracting (2) from (1), the instrumental error c_1-c_2, which is peculiar to a combination of two containers, is determined to be

$$c_1-c_2=\frac{1}{2}\{(h_1-h_2)+(h_1'-h_2')\}\,.$$

Thus the change in the difference between the heights of two bench marks can be measured at any time even when we once take off the instrument from bench marks.

The height-differences of the pairs of bench marks (EW) and (NS) were measured at the beginning of the observation. Then the containers were set on N and S, the change being continuously observed. It is difficult, however, to carry out an exact measurement repeatedly, because it is dark in the adit where there is no electric supply and, moreover, the space is very narrow, full of humidity, and there is danger of weathered rocks falling from the ceiling. For these reasons, no measurement has been repeated.

As to the extensometer, since the instrument is just the same with that used at several places cited above, the description of the instrument will be omitted here.

3. The results of the observation.

The water-tube tiltmeter was read twice a day during the period from Jan. 15 to Mar. 22 and once a week after that period. The change in the inclination thus observed is plotted as shown in Fig. 3 together with the result

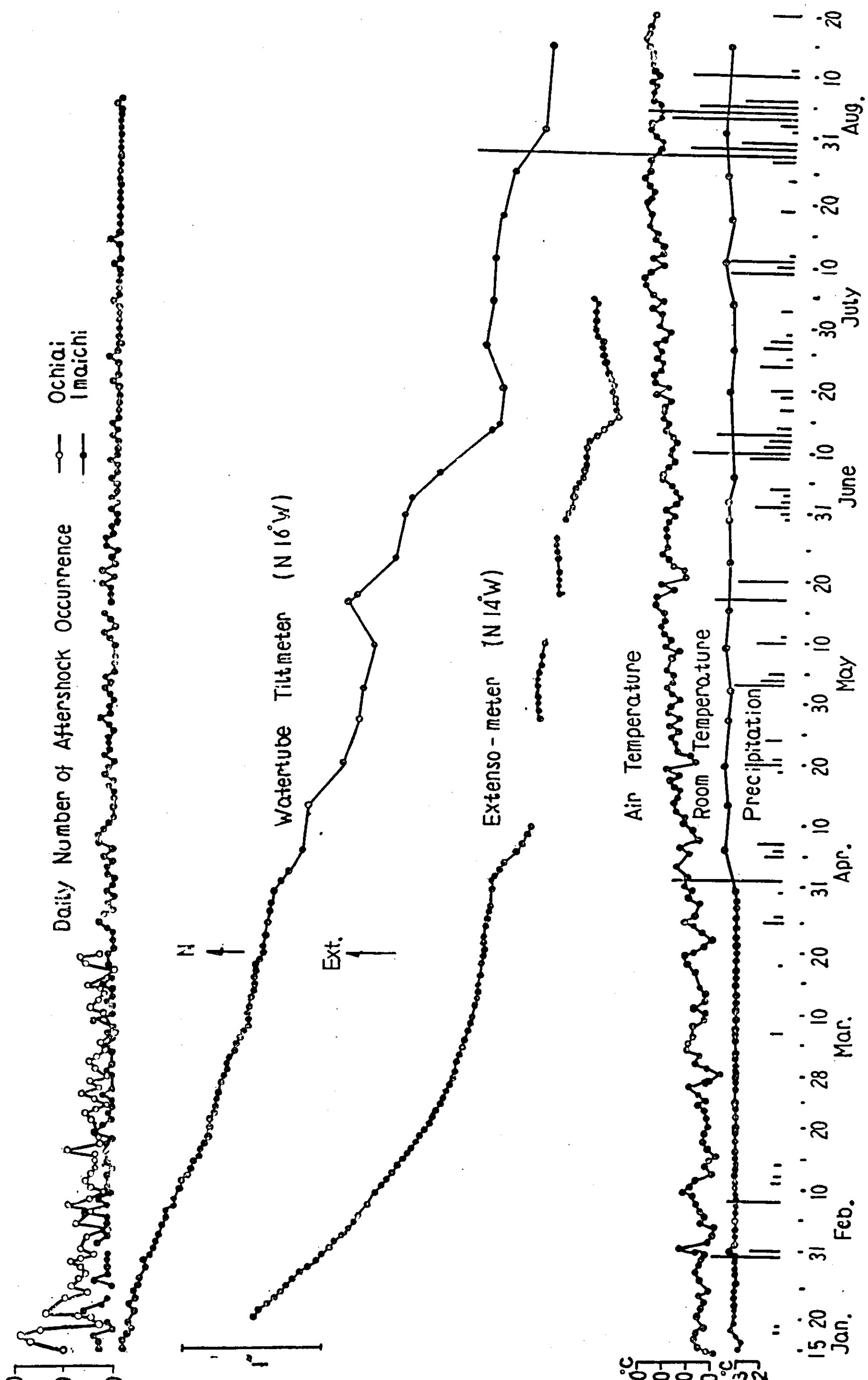

Fig. 3. The results of the observation.

obtained by the extensometer. The daily number of aftershock occurrence observed at Ochiai and Imaichi, air temperature and precipitation at Imaichi are also shown in the figure.

As seen in the figure, the ground tilted to S-direction as much as 3 seconds of arc during the observation period, while it contracted about 10^{-5} in the same direction. The changes observed by the two instruments are fairly parallel with each other. It is also noticeable that the rate of the deformation becomes smaller and smaller with the lapse of time. On the other hand, the daily number of aftershock occurrence also decreases gradually, the behavior of the decrease being fairly the same with that of the deformation during the early period of the observation.

According to the observation hitherto made by the writers at several places, the secular deformation of the earth's surface during the first 30 days scarcely amounted to the order of 10^{-6} as shown in Fig. 4 where the daily

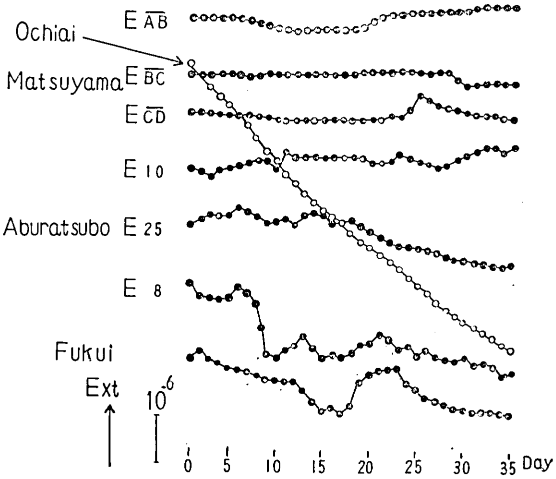

Fig. 4. The change in the extension of the earth's surface during the first 35 days of the observation at Aburatsubo, Matsuyama, Fukui and Ochiai.

means of the deformation recorded by the extensometers at Aburatsubo, Matsuyama, Fukui are illustrated together with that of the present observation. It is remarkable that the ground contracted as much as 5×10^{-6} at Ochiai. As the instruments in these several cases are almost the same, it is of great interest that such large changes were observed only at Ochiai. Taking into consideration the fact that the present observing point is situated at the centre of the seismic area, it might be said that a remarkable change in the strain component of the ground was found at the centre of the seismic activity.

We also observed clearly the earth tide by the extensometer, it amounting to the order of 10^{-8}. However, it is beyond the scope of this paper to study the earth tide in detail.

4. Conclusion.

The writers observed the deformation of the earth's surface in a mine which is situated at the central region of the seismic activity related to the Imaichi Earthquake of Dec. 26, 1949. An abnormally large deformation of the earth's surface of the order of 10^{-5} was observed during 7 months both in inclination and contraction.

The actual observation was made by Messrs. K. Kasahara, J. Yamada, S. Saito and M. Watanabe of the Institute and Mr. T. Honda of the Imaichi Middle School to whom the writers' cordial thanks are due. The writers also express their hearty thanks to Mr. I. Ando of the Keimei Mine through whose courtesies the mine was available for the observation.

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33. 今市地震の震央附近における土地伸縮
および傾斜變化の観測

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1949年12月26日の今市地震後，1950年1月15日より約7ケ月間，その震央附近の鷄鳴鉱山において水晶管土地伸縮計および水管傾斜計による観測を行つた．測定器類は油壷，松山および福井地震の際坂東島において使用されたものとほゞ同一である．従來大地震の際この種の観測をしばしば行つてきたが，今回は本震震源のほとんど直上であり，また余震活動の中心に位置していた．したがつて過去の観測にくらべて，より大きな變動が期待されたのであるが，果して傾斜，伸縮ともに10^{-5}に達する變動を示した．観測はそれぞれ1成分のみであつたので，詳しい議論は出來ないが，このような大きな歪が観測されたことは興味あることゝ思われる．
