*31. On Micro-earthquakes Observed After the Imaichi Earthquake, Dec. 26, 1949.**

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1. C. F. Richter and J. M. Nordquist[1] observed small aftershocks, the principal shock of which occurred near Riverside, California, on Feb. 18, 1948. The Benioff seismometer at Riverside recorded 98 aftershocks during Feb. 18 and 19. The magnitude of the smallest aftershock was determined to be 0.4 in Richter's scale, and the energy released in the shock was 10^{12} ergs in the order of magnitude.

The present authors made the observation of very small aftershocks of the Fukui Earthquake[2] during the period from July 14 to Aug. 8, 1948 by means of the electromagnetic seismometers, of which the magnification was about 40,000 for the vibration of 20 c/s, and found that the micro-earthquakes, having the amplitudes of about a few hundredths of a micron, were occurring every three or four minutes on the average.

They also carried out the observation of micro-earthquakes in June, 1949, at Washishiki, Tokushima Pref., and at Kagami, Kochi Pref., in Shikoku District.[3] At Washishiki 16 micro-earthquakes were recorded during 16.6 hours, and at Kagami 9 were recorded during 43.2 hours. It is remarkable that many micro-earthquakes were registered at Washishiki and Kagami, although 30 months had elapsed after the Nankai Earthquake, Dec. 21, 1946.

The results of the observations above mentioned show that many micro-earthquakes can be registered if the sensitivity of seismometers is sufficiently high, especially in the area where aftershocks of an earthquake occur frequently, and moreover, Ishimoto-Iida's formula holds good between their frequency of occurrence and their amplitudes.

The present authors made the observation of micro-earthquakes after the Imaichi Earthquake, Dec. 26, 1949, for a further research on micro-earthquakes.

2. The seismometers used were of horizontal component type having the

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* Communicated by T. MATUZAWA.

1) C. F. RICHTER & J. M. NORDQUIST, *Bull. Seism. Soc Amer.*, 32 (1948) No. 4.

2) T. ASADA & Z. SUZUKI, *Geophy. Notes*, 2 (1949) No. 16.

3) Z. SUZUKI & T. ASADA, *Geophy. Notes*, 2 (1949) No. 17.

natural period of 1.2 seconds. Their transducers were of moving coil type. The type-D vibrators for YEW oscillograph were connected. The shunt resistances of 20 ohms were used and the seismometer-pendulums were over-damped. The frequency response curve of this seismometer is seen in Fig. 1. These seismometers are more sensitive than those used in the case of Fukui Earthquake. The frequency response curve of a Benioff vertical seismometer with a micro-moll-galvanometer is also given in Fig. 1 for reference' sake. The difference between the two curves is essential for obtaining legible records of such micro-earthquakes.

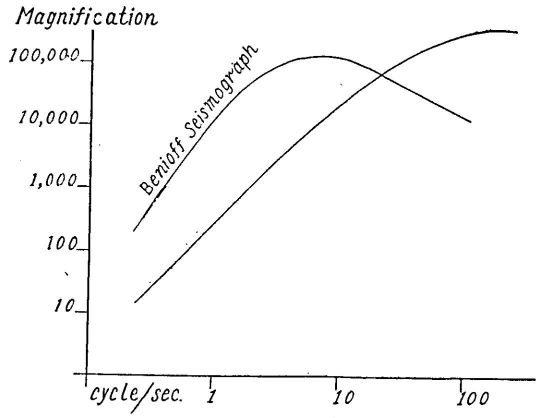

Fig. 1.

Three seismograms were recorded side by side on a photographic paper which was carried by a tape-recorder at the approximate speed of 9 cm/min or 30 cm/min. The temporary tripartite station was set at Tamozawa, Nikko, Tochigi Pref., the one side of the triangle being 150 meters long. The observation was made during the period from Dec. 29, 1949 to Jan. 10, 1950, and seismometers were operated exclusively at night, when the ground was not much disturbed by artificial noises. The total duration of the observation was 17.7 hours and 623 micro-earthquakes were registered, that is, they occurred every 1.7 minutes on the average.

3. The secular change in the frequency of occurrence of micro-earthquakes is given in Fig. 2. Those of the earthquakes registered by Ishimoto-accelerometers at Nikko and Imaichi are also seen in Fig. 3, A and B respectively. The tendency of the secular decrease in number of earthquakes recorded in a day is seen in all cases. The frequency distribution of $P—S$

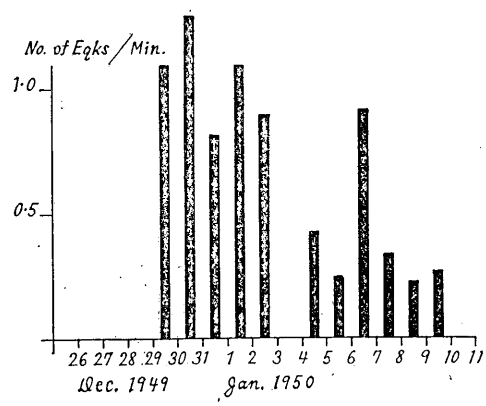

Fig. 2.

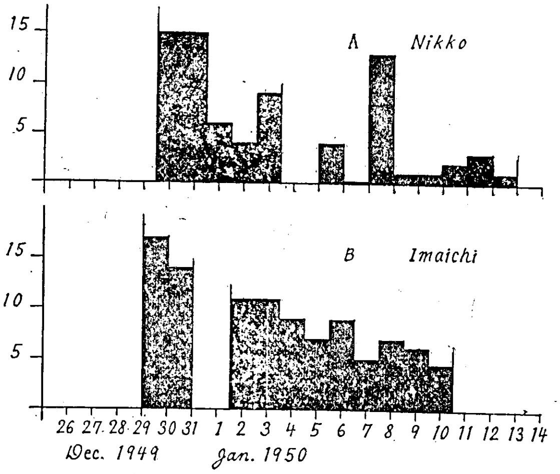

Fig. 3.

duration times of micro-earthquakes and of shocks recorded by the Ishimoto-accelerometer are shown in Fig. 4. The distributions in both cases are considerably different from each other. But it is premature to conclude from this fact that the geographical distribution of the foci of micro-earthquakes and those of comparatively large shocks are different. If the predominant periods of earthquake-motions are dependent on their epicentral distances, the earthquakes having larger epicentral distances might be missed more frequently in the observation by the electromagnetic seismometers than in the case by the Ishimoto-accelerometer, because the sensitivity of the electromagnetic seismograph becomes lower as the period becomes longer, then it is possible that the frequency distributions of $P-S$ intervals of earthquakes recorded by the electromagnetic seismometers and those of shocks recorded by the Ishimoto-accelerometer are apparently different.

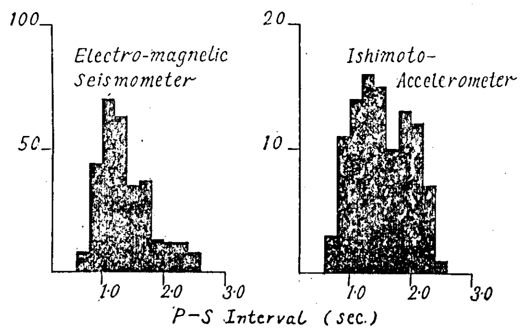

Fig. 4.

The frequency distribution curves of trace-amplitudes of micro-earthquakes and shocks registered by Ishimoto-accelerometer are given in Fig. 5. Both curves coincide well with Ishimoto-Iida's formula. (Earthquakes which belong

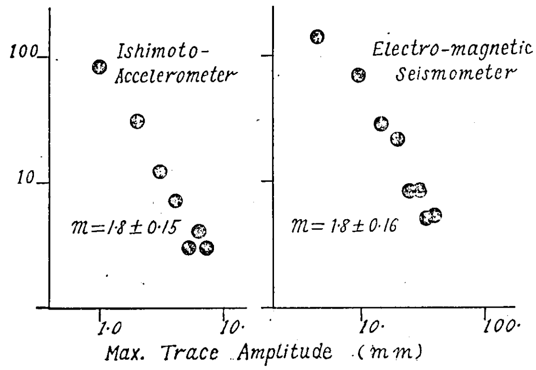

Fig. 5.

to the group of the smallest trace-amplitude are excluded in Fig. 5 in both cases.) The magnification of the seismometer used in the present case was too small to detect the "minimal earthquake", of which the amplitude is so small that Ishimoto-Iida's formula does not hold. More sensitive seismometers equipped with filters to suppress the background noises will be necessary for the study of the "minimal earthquake".

The values of "m" in Ishimoto-Iida's formula,

$$n(a)\,da = ka^{-m}da$$

obtained from the data in Fig. 5 by the least square method are 1.8 in both cases. This coincidence of the values of "m" was the case in the study of aftershocks of the Fukui Earthquake.

4. As the seismometers used were of horizontal component type, we can compare the magnitudes of the observed micro-earthquakes with that of the "minimal recorded earthquake" observed by Richter and Nordquist. The smallest micro-earthquake registered at Nikko has a trace-amplitude of about 1 mm, and its $P-S$ intervals is about 0.8 sec. The magnification of the seismometer was 6×10^4 for the vibration of 20 c/s, which was predominant in the earthquake-motions at Nikko as seen in Fig. 10. As Omori's constant connecting the $P-S$ interval and the hypocentral distance was determined to be 7 in the vicinity of Nikko by the members of the Earthquake Research Institute, Tokyo University, the hypocentral distance of the smallest micro-earthquake was about 6 km. Now it may be assumed that the amplitude decays in proportion to the square of the hypocentral distance. Then the amplitude of the smallest micro-earthquake would be 0.17μ, if it were recorded by the Wood-Anderson seismometer (magnification: 2800) at a station of which the hypocentral distance is 100 km, this value corresponding to magnitude -0.77

in Richter's scale. By the relation between energy and magnitude,[4]

$$\log E = 12 + 1.8\,M,$$

the energy released in the smallest micro-earthquake is estimated at 4×10^{10} ergs.

The energy can be estimated by another method. Assuming that the energy is emitted uniformly in all directions from the focus, the energy flux $\overline{F}$ which passes through a certain spherical surface around the hypocenter is expressed as

$$\overline{F} = \frac{1}{2} \cdot 4 \cdot \pi \cdot \rho\, p^2\, r^2\, A_r\, V_s$$

where ρ is the density; $p = 2\pi/T$; A_r is the amplitude on a spherical surface whose radius is r; V_s is the velocity of the waves. Adopting $\rho = 2.7$, and $V_s = 3.0$ km/sec., we obtain $\overline{F} = 8.1 \times 10^{10}$ ergs/sec. If the duration of vibration at the focus is assumed to be 1 sec, the total energy released in the smallest micro-earthquake is 8.1×10^{10} ergs.

In both cases stated above the energy released in the smallest micro-earthquake is 10^{10} ergs in the order of magnitude, the value being one hundredth of the energy of the "minimal recorded earthquake".

5. The direction of the approach of initial waves and their apparent velocity could be calculated, as the tripartite station method was made use of. The frequency diagram of the directions is shown in Fig. 6. The distribution of the approach of wave fronts has a maximum of frequency between S 60° E and N 30° E. On the other hand, most of the foci of comparatively large aftershocks determined by the net of temporary seismological stations were located in the direction between S 30° E and S 60° E from Nikko. This result leads to three inferences: the first is that the geographical distributions of foci are actually

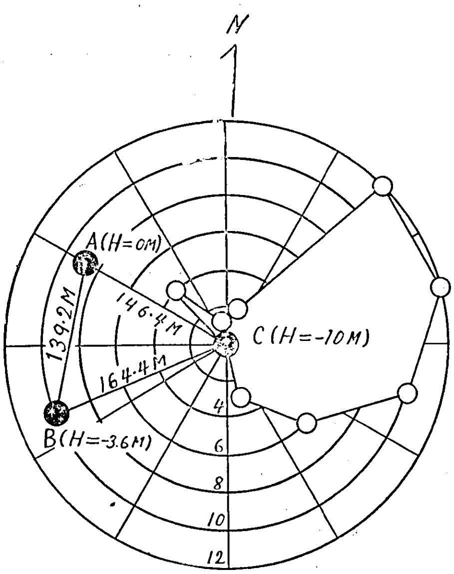

Fig. 6. H: relative heights of the stations.

4) B. GUTENBERG & C. F. RICHTER, "*Seismicity of the Earth*" (1949).

different in both cases; the second is that the difference is an apparent one mainly caused by the difference in the ground structure near each station of the tripartite net; and the third is that the above result is caused partly by the first reason and partly by the second one. It will be necessary for the study of this problem to know the underground structure near the stations by seismic prospecting or other methods.

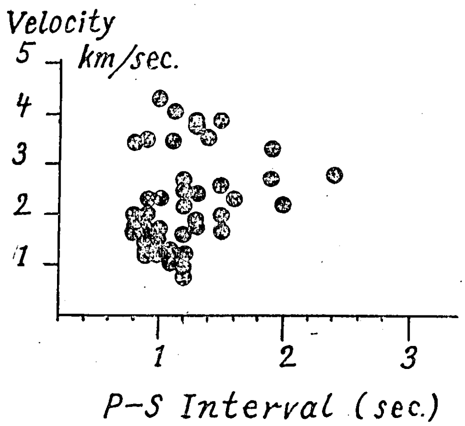

Fig. 7.

The relation between the *P—S* interval and the apparent velocity obtained by the tripartite station mothod is given in Fig. 7. The velocity of the *P*-wave in the upper layer is estimated at 1 or 2 km/sec.

In conclusion the writers wish to express their thanks to Prof. T. Matuzawa and Prof. H. Kawasumi for their kind advices, to Prof. C. Tsuboi for his kind encouragements, and Mr. Y. Tomoda for his helpful assistance during the period of the observation.

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31. 今市地震の際の微少地震に就て

地球物理學教室 {淺田敏 / 鈴木次郎}

1949年12月26日に發生した今市地震後に著者等は日光町田母澤に於て微少地震の觀測を行つた. 用いた器械は電磁式水平動地震計で20サイクルの振動に對して約60,000倍の倍率を持つて居る. これは福井地震の際に用いたものより高感度である.

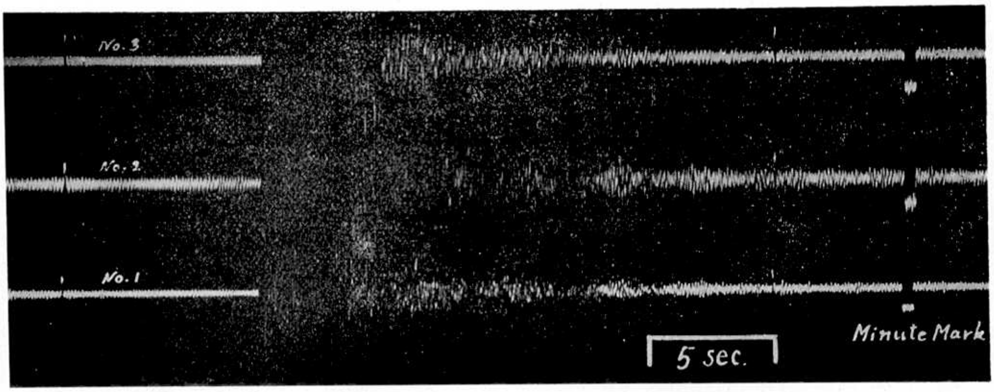
觀測は12月29日より1950年1月10日まで, 夜間のみ行われ, その結果は次の如くである.

1) 微少地震は平均して1.7分に1回の割合で記録された.

2) 最も小さい地震のエネルギーは10^{10}エルグのオーダで Richter 等によつて報告された最も小さい地震の1/100の大きさである.

3) 石本飯田の式はやはり, 此等の微少地震にもあてはまつて居る.

4) 地震波の初動の波面の進行方向は, 三點觀測法によれば E 及 NE が多い.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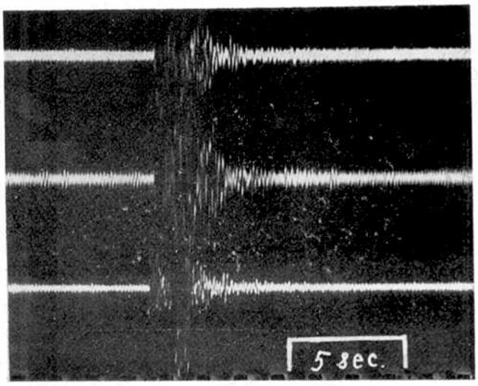
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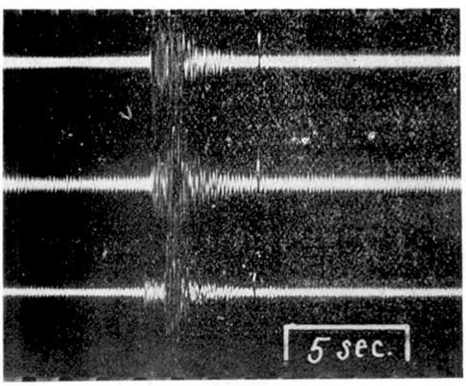
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