Abnormal Variations of Earth–Currents Accompanied with the 'Boso–Oki Earthquake', Nov. 25, 1953

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§ 1. Introduction

A great earthquake occurred at 17 h 49 m (G. M. T.), Nov. 25, 1953, the epicenter of which is located at 34.°1 N, 141.°9 E (Fig. 1). It is called the "Boso-Oki Earthquake". Its magnitude is 8 which is nearly equal to that of the great Kwanto Earthquake (1923). Fortunately, the "Boso-Oki Earthquake" was not so disastrous on land, for the epicenter was situated far off the coast of the Boso Peninsula. But the magnitude is so great that we can have a good test case available to study whether or not any variations of earth-currents do occur before and after an earthquake occurrence.

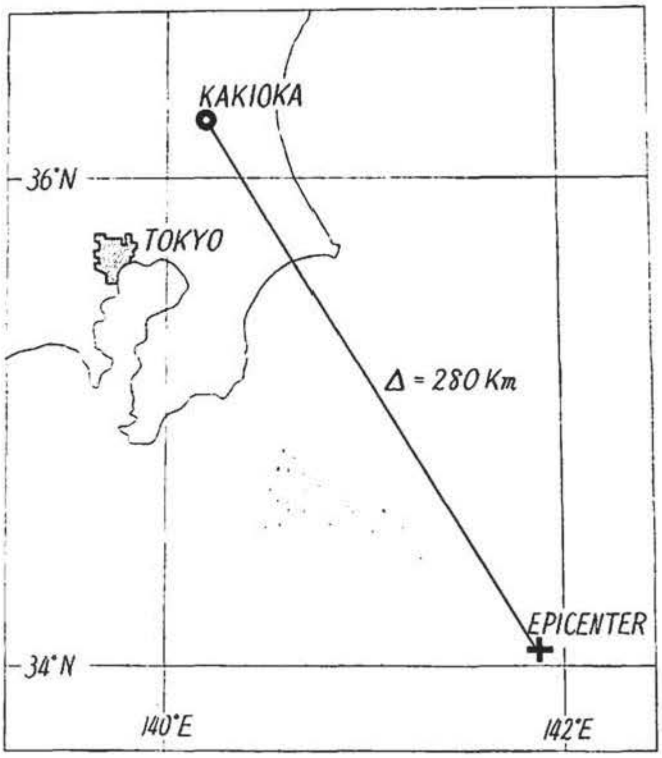

Fig. 1.

It has been said by many investigators that some abnormal variations of the earth-currents were observed before and after the occurrence of some large earthquakes. Firstly, T. Yoshimatsu[1] has studied rather systematically the relationship between the earth-currents cotinuously observed at Kakioka and earthquakes by means of his so-called "difference curve" method.

Concerning the present earthquake, the author firstly has applied his method for the earth-currents observed at Kakioka, and secondly has made a study of the variations of the amplitude ratio of the so-called universal earth-currents and observed earth-resistivities.

§ 2. Difference of the earth-current potentials

If V_a and V_b are the earth-current potentials simultaneously observed by the equidirectional base lines A and B, in a limited region respectively, the value, $D=V_a-kV_b$, is considered generally to be a constant for time, provided that a constant k is suitably chosen. D obtained thus is a potential from which the so-called universal earth-cnrrents are removed. So far as an electrically uniform structure of subterranean masses is concerned, the constant k is equal to the ratio l_a/l_b, where l_a and l_b are the base lengths of A and B, respectively. But in actual case, the subterranean electrical structure is too complex to use l_a/l_b in the place of the constant k. Now the latter value is given by the next formula,

$$k=\frac{1}{N}\sum_{n=1}^{N}(\Delta V_{an}/\Delta V_{bn}), \quad\cdots\cdots\cdots\cdots\cdots\cdots\cdots (1)$$

where ΔV_{an} and ΔV_{bn} are the amplitudes of the n-th variation of the universal earth-current potentials simultaneously observed by the base lines A and B, respectively.

In the eastward component of the earth-currents at Kakioka, the ratio of the universal earth-current potential gradients, $k.\ l_b/l_a=(\Delta V_a/l_a)/(\Delta V_b/l_b)$, has been determined for many base lines. In the present paper, for B the eastward base line, which is 1.5 km long, is used, and for A the equidirectional one of 0.1km in length, set up near the west electrode of B, is used. (Fig. 2)

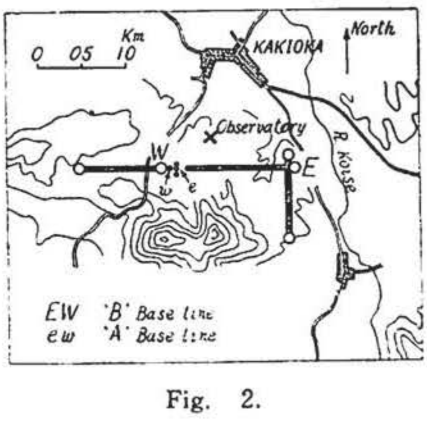

Fig. 2.

The constant k is determined by (1) for about fifty short period variations of the universal earth-currents which occurred in several days including the day of the earthquake occurrence. The hourly values of D are shown with the smoothed curve in Fig. 3 from Nov. 21 to Nov. 30, 1953. That is the same curve as is called the "Difference curve" by Yoshimatsu.

As it is seen in the figure, the value D is nearly constant, but it increases before the Boso-Oki Earthquake occurrence. It cannot be determined whether the opening of the variation of D is the small oscillation on Nov. 23 or the rather abrupt increase at 12h (G. M. T.) on Nov. 25. The former oscillation may be related to the small earthquake which occurred at 04 h (G. M. T.) Nov. 24, 1953, with the epicenter near that of the Boso-Oki Earthquake.

During the period in which D-curve was evaluated, the rainfall was very small; that was only 1.7 mm in amount, and it rained in 7 h-16h (G. M, T.), Nov. 26. As the rainfall began after the opening of the clear increase of D, it cannot be considered that there is any relation between the former and the latter.

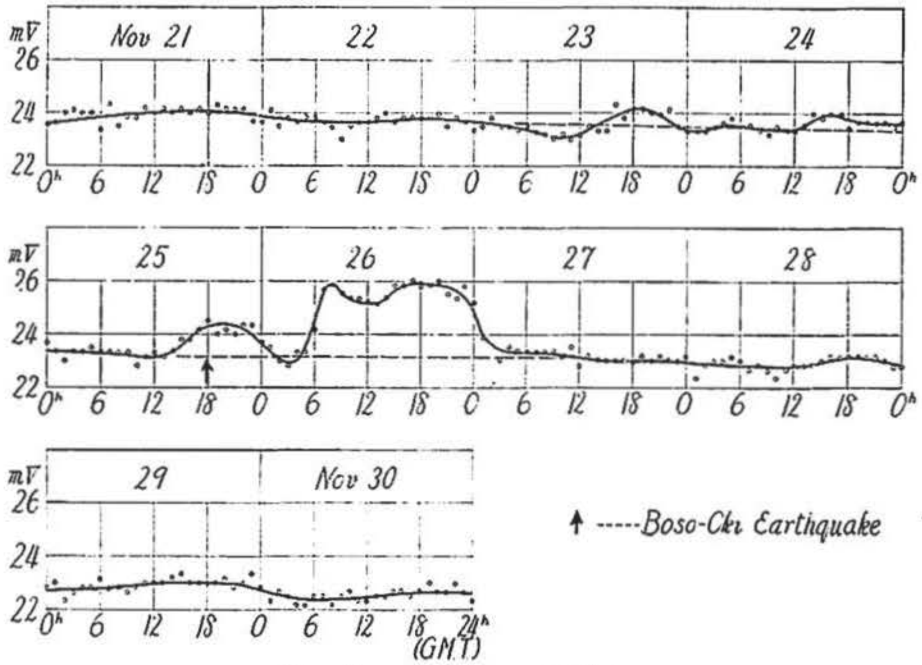

Fig. 3. D-curve at Kakioka

The variation of the value D at the present earthquake, Δ D, is positive, provided that the potentials V_a and V_b are taken to be positive when the west electrodes are at high potential. That is the same type as is called the "I-type" by Yoshimatsu. The D-curve of the "I-type" is in accord with his results obtained on the earthquakes which occurred southerly off the Kanto District.

The maximum value of ΔD, $(\Delta D)_{max}$, calculated by Yoshimatsu's empirical formula,

$$(\Delta D)_{max} = a \frac{\Delta + \varepsilon}{(\Delta^2 + b^2)^m}, \quad \cdots\cdots\cdots\cdots (2)$$

Δ: the distance between the epicenter and the earth-currents lines in 100 km unit,

a, b, ε and m are certain constants, is 0.9 mV in amount, which is smaller than the observed value, $(\Delta D)_{max}=1.1$ mV for the former half——from 12 h Nov. 25 to 3 h Nov. 26——or $(\Delta D)_{max}=3.1$ mV for the latter half——from 3 h Nov. 26 to 3 h Nov. 27. The fact is considered to depend on the greatness of the magnitude of the earthquake concerned.

The magnitude of Boso-Oki Earthquake is 8. On the other hand, mean magnitude of the earthquakes used by Yoshimatsu for obtaining the formula (2) is 6.3. It is also reported by him for Tonankai Earthquake, of which magnitude is 7.4, that the observed $(\Delta D)_{max}$, 1.1 mV, is greater than the value calculated by the formula (2), 0.8 mV.

§ 3. The amplitude ratio of the universal earth-current potentials and the earth-resistivities.

In § 2 k is taken to be the mean of the amplitude ratios of the universal earth-current potentials for several days including the day of the earthquake occurrence.

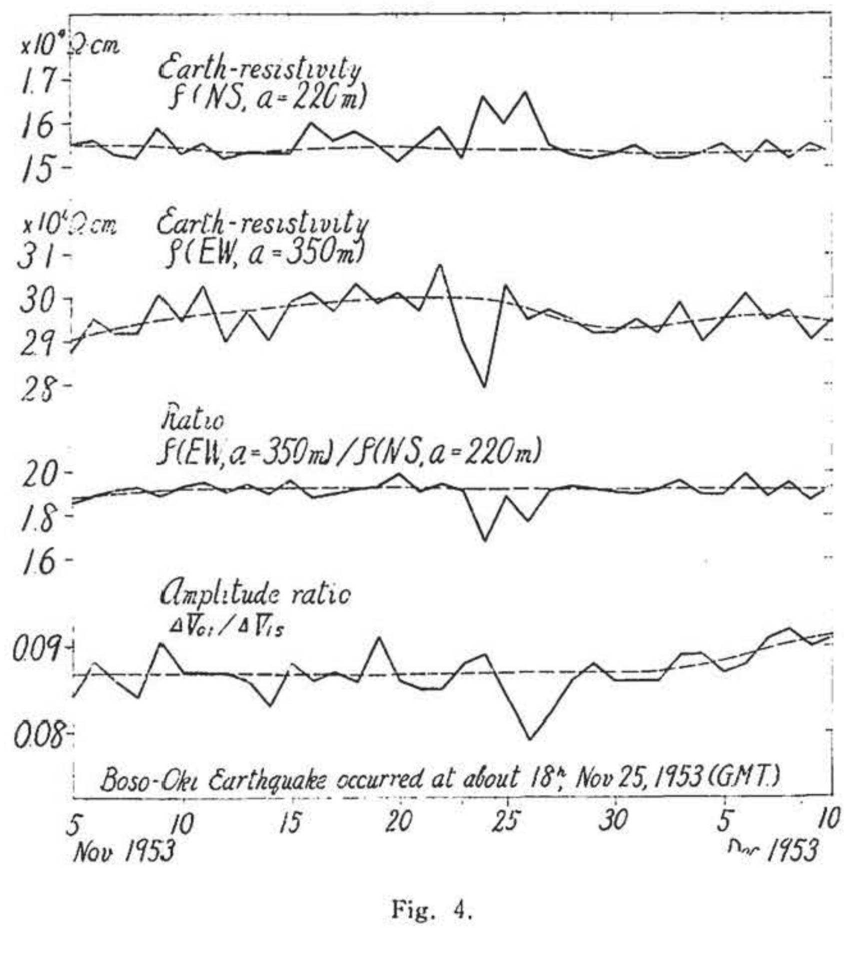

Fig. 4.

Here, we should consider the time variation of k or the amplitude ratio. Generally speaking, the amplitude ratios are different for the different kinds of variation. It is affected by many factors which are of the period and the spatial distribution of the equivalent overhead currents of the variation concerned and the electrical structure of the subterranean masses. But, in the present paper, we are concerned with the mean of the amplitude ratios for many kinds and large number of vaiations. Again, to avoid ambiguity, we will take into consideration only such a variation as is induced by the equivalent overhead current system, which is parallel to the circle of the latitude, for example, s. s. c., s. i. and the peak variation[2].

Thus the obtained daily means of the amplitude ratio, k, are shown in Fig. 4 from Nov. 5 to Dec. 10, 1953.

The daily mean of k is considered to change its level around the day of the earthquake occurrene. The general tendency of the curve given by the means for several hours is the same as the above.

Next, the observed earth-resistivities are shown for the same period in Fig. 4. ρ (NS, a=220 m) and ρ (EW, a=350 m) are the earth-resistvities observed along northward and eastward lines, respectively, where a is the distance between two adjacent electrodes in the Wenner's 4-electrodes method. At Kakioka, the earth-resistivities are being observed once a day by manual operation for three components. One of them, ρ (EW, a=700 m), is excluded from the present study, because of the difficulty of knowing the day-to-day change eliminating the error of the measurement.

Some deviation from the general tendency of the time variation of the earth-resistivities are also found for some days around the earthquake occurrence.

§ 4. Discussions of the observed change in the "D-curve", the amplitude ratio and the earth-resistivities.

Firstly, it is doubtful that the variation of D is a result of the variation of the amplitude ratio, k, and has no physical meaning. By the correction of the D-curve due to the variation of k itself, no alteration of the D-curve is brought in.

The writer already reported[3] that concerning the effective earth-resistivities it seems likely that a border exists dividing the region, in which the earth-currents lines were set up, in two portions with different resistivities. We call here the one side of the border "A-region", and the other "B-region". If we consider that in A-region ρ (EW, $a=350$ m) and ΔV_a represent the earth-resistivity and the amplitude of the universal earth-current potentials, respectively, and in B-region ρ (NS, $a=220$ m) and ΔV_b represent the same. The decrease of $\Delta V_a/\Delta V_b$ for some days around the earthquake occurrence is in accord with the decrease of ρ (EW, $a=350$m)/ρ (NS, a=220m) qualitatively.

The electrodes arrangement for the measurement of the earth-resistivities are shown in Fig. 5, together with the regions A and B and the base lines A and B.

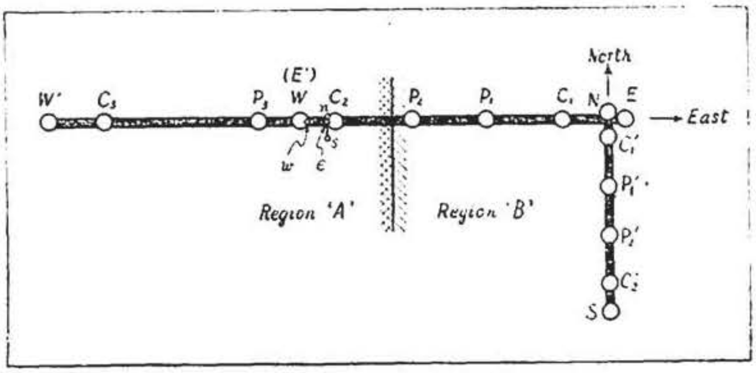

Fig. 5. The electrodes arrangements for the regular observations of the earth-current potentials and earth-resistivities at Kakioka.
E, W, e and w are the same electrodes as is shown in Fig. 2.
C_1, P_1, P_2 and C_2 and C'_1, P'_1, P'_2 and C'_2 are the electrodes used for the measurements of ρ (EW, a= 350 m) and ρ (NS, a=220 m) respectively, and C_1, P_2, P_3 and C_3 are the electrodes for ρ (EW, a=700 m).

But the north- and southward distributions of the masses of the different effective resistivities have been scarcely known, and furthermore it is not considered that there is a clear border line which divides the region in A and B. The above representations of the earth-resistivities and the earth-current potentials are those conveniently chosen. Then the observed decreases of the two ratios may only mean the simultaneous decreases of the earth-resistivity and the amplitude of the universal earth-current potentials in the westward region (or increase in the eastward region).

The opening of the decrease or increase of the earth-resistivities and the amplitude ratio may be an interesting matter, but detailed discussion cannot be done because the earth-resistivities were observed only once a day.

The variation of D is not considered to be an apparent one deduced from the variation of the earth-resistivities, as described in the former part of this section. But it may be caused by an origin in the earth crust itself——(including the contact potentials of the electrodes).

It was also reported by some writers[4] that the some variations of the earth-potentials explained by the streaming potentials were observed when a heavy load or a low atmospheric pressure approached to the station. These streaming potentials may be the one cause of the present variation of the earth-potentials. But, the writer is more interested in some other actions——including the polarization at the border which divides the region concerned into the two regions A and B.

It is worthwhile to show the D-curve observed at Haranomachi, in which no distinct variation is seen (Fig. 6). In this observation of D-curve, the eastward line of 1.3 km in length is taken as B, and that of 0.3 km as A.

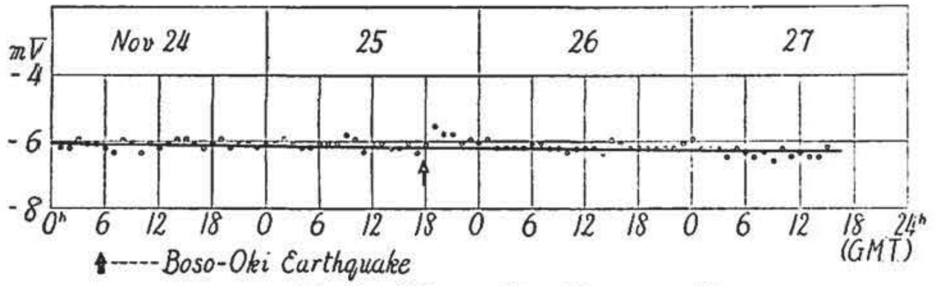

Fig. 6. "D-curve" at Haranomachi.

§ 5. Conclusion

After the researches of the earth-currents at Kakioka at the time of the occurrence of the Boso-Oki Earthquake, it was found that some abnormal variations in the earth-potentials, the amplitude ratio of the universal earth-current potentials and the earth-resistivities commenced several hours or even days before the earthquake occurrence.

The variation of the amplitude ratio is explained by that of the earth-resistivities, but the variation of the earth-potentials cannot be considered as the apparent variation deduced from the former two variations.

The physical mechanism, by which the observed abnormal variations are brought about, is still unknown. However, in the region of a complicated electrical structure, it may be considered that some electrical variations observable in earth-currents are found around the time of an earthquake occurrence, provided that there is an adequate energy in quality and amount. It is desired in future to study more deeply and quantitatively about this point together with the skilful and rather large scale laboratory experiments.

Acknowledgement——The auther wishes to express his cordial thanks to Dr. T. Yoshimatsu, who is now the Director of the Kakioka Magnetic Observatory, for his constant guidance in this field of study. Many thanks are also extended to Mr. Oshima, Director of the Haranomachi Branch of the Kakioka Magnetic Observatory, who calculated the D-curve at Haranomachi.

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