9. *A Study of Microseisms after A. W. Lee's Method.*

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INTRODUCTION.

The direction of the propagation of microseisms have been brought to focus of discussions. In countries except Japan there are many researches concerning the travelling directions of microseisms[1]. The conclusions were that the microseisms are propagated in the earth's crust from origin, which is caused by a storm depression, to the observatories. In those studies, microseisms were assumed that they are Rayleigh waves, and under this assumption their travelling directions had been discussed.

Turning to the studies of microseisms in Japan, these are also many researches concerning the characters of the microseisms[2]. The results of the studies in Tokyo do not always agree with those obtained in the other countries. Although there is nearly no objection to the point that the microseisms are caused by a storm depression, we could not obtain the clear results that the direction to their origin, or to the centre of the storm.

As a conclusion to this question, one of the writers mentioned that "microseisms are combinations of two stationary waves excited by oceanic waves in some manner yet unknown[3]".

In this paper, we again deal with the direction of microseismic motion and inspect the microseisms obserbed at Hongo. In Tokyo, by the same method as that of A. W. Lee[4] who discussed the microseisms observed at the Kew Observatory.

1) S. K. Banerji: *Phils. Trans. Roy. Soc. London*, **229** (1930), 287-328. A. W. Lee: *Proc. Roy. Soc, London*, **149** (1935), 183-199. J. E. Ramirez: *Bull. Seism. Soc. America*, **30** (1940), 35-84, 139-178. M. H. Gilmore: ditto, **36** (1946), 89-120. ect.

2) F. Omori: *Bull. Imp. Earthq. Investig. Comm.* **3** (1909), 1-35; 4 (1913), 109-147. n. Matuzawa: *Journ. Fac. Sci. Imp. Univ. Tokyo* **2** (1926-1930). 205-263. F. Kishi-Touye: *Bull. Earthq. Res. Inst.* **13** (1935). **18** (1940), ect.

3) F. Kishinouye: Ditto, **18** (1940), 402-418.

4) A. W. Lee: loc. cit.

If the periods or the phases of every component are remarkably different each other in Tokyo, it will be absurd to attempt the present investigation. But we applied the method, because the periods and phases, in comparison with Lee's records, are in good agreements.

AN OUTLINE OF LEE'S METHOD.

For the convenience of describing our results, we mention the outline of Lee's method.

First, for the purpose of this investigation the phases at the beginning of the minute marks, on the seismogram are allotted numbers according to a scale, Fig. 1. from 0 to 15. The entries 0 and 8 indicate that the beginning of the break coincides with the crest and trough respectively.

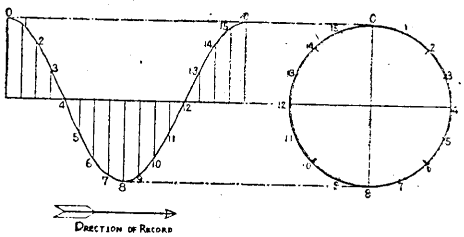

Fig. 1. Scale of tabulation for phase angles.

Next, on the tabulation of the phases of the microseisms, we see each phase difference between the different components, and tabulate the number of occurrences of these specified phase differences. By these results we examine statistically the most probable phase differences. On the basis of these results and the asumption that microseisms are Rayleigh waves, we can deduce the arrival direction of this microseiems.

APPLICATION OF THE METHOD TO THE MICROSEISMS AT TOKYO, AND COMPARISON BETWEEN LEE'S RESULTS AND OURS.

(1) Lee's Method.

We again used the data which one of the writers previously used. Those data had been obtained from the records of the large microseisms on Oct. 21, 1938 and Aug. 31, 1938 observed at the Tokyo University. Those seismograms were recorded by Omori's seismographs which have two horizontal and one vertical components. The constants of these seismographs were shown in Table I of the previous paper[5].

On the record on Oct. 21, we picked up the data in every 50 minutes at about 11h, 16 h, and 20h on that day to examine how the arrival direction of the oscillations changed according to transfer of the centre of

5) F. Kishinouye: loc. cit., p. 403.

depression, if the microseisms were propagated truely from its origin.

In every one of these four occasions, the measurements of the phases are made at every minute marks in fifty minutes on the basis of the scale, Fig. 1. Next, the phase differences between the components are calculated. On that occasion, it is not necessary to consider the phase lag between the components, because the phase lag of these seismographs between the components were nearly equal to each other. Finally, the numbers of occurences of specified phase differences are counted. The distributions of the number of these differences are shown in Table 1.

Table I.

(a)	0	1	2	4	3	5	6	7	8	9	10	11	12	13	14	15	—	1—7	9—15
NS —UD	4	3	2	2	4	3	2	2	5	4	1	3	6	3	2	2	3	18	21
EW—UD	2	2	1	4	4	1	3	6	2	5	6	4	1	1	3	3	3	21	23
EW—NS	3	9	4	1	3	2	2	4	4	1	3	4	2	4	1	4	0	25	19
(b)																			
NS —UD	3	1	2	3	2	3	3	3	2	4	5	3	2	1	4	6	4	17	25
EW—UD	0	0	2	3	3	4	2	6	6	1	5	3	3	4	2	4	3	20	22
EW—NS	5	4	2	1	5	5	0	3	2	4	3	1	3	3	4	3	3	20	21
(c)																			
NS —UD	4	3	2	3	2	2	2	4	3	3	0	2	3	4	1	4	9	18	17
EW—UD	3	1	0	2	3	1	2	6	3	2	5	2	2	4	1	3	11	15	19
EW—NS	3	3	2	0	4	4	3	4	1	5	4	3	5	2	4	2	2	20	25
(d)																			
NS —UD	4	4	5	1	3	4	6	4	1	5	2	3	2	3	4	0	0	27	19
EW—UD	3	3	2	0	2	5	5	6	3	2	2	4	1	2	5	5	1	23	21
EW—NS	4	4	4	2	1	2	5	2	3	3	2	3	4	2	4	5	1	20	23

The values of these distributions are smoothed by overlapping groups of five values, giving double weight to the second and fourth, and treble weight to the third; thus, if F_n denotes the number of observation of any phase differece (n), the smoothed frequency expressed as the percentage of the total number of values is

$$F'_n = \frac{F_{n-2}+2F_{n-1}+3F_n+2F_{n+1}+F_{n+2}}{9} \times \frac{100}{50}.$$

These smoothed frequencies for the four above mentioned cases and one of Lee's cases are shown in Fig 2. In Fig. 2(e), which is Lee's results, there are clear maximum values at 270° and 90°, on NS-UD and EW-UD components respectively. This fact will be a strong evidence to deduce that the waves arrived from north-west, if the microseismic oscillations may be considered as Rayleigh waves.

On the other hand, in Fig. 2 (a), (b), (c) and (d), or in the results at Tokyo, the phase difference curves are smooth in comparison with (e)-curve, and maximum value are not clear, therefore we could not deduce the arrival directions from these results.

Incidentally, the situations and tracks of the depressions (typhoon) at these cases were shown in the previous report.

(2) Comparison of microseisms at two places according to their orbits.

Assuming that the microseismic oscillations are a kind of Rayleigh waves, the arrival direction of the waves may be deduced on the basis of the rotating direction of the orbits of an earth particle.

The portions of the records, obtained at Kew on Jan. 11, 1930, are conveniently shown in the Lee's paper. We took a copy and enlarged that record, and described the orbits of microseisms in the prime vertical plane and the meridional one, pairing the UD-component with NS- and EW-component respectively. These orbits are shown in Fig. 3(a).

Judging from those orbits,

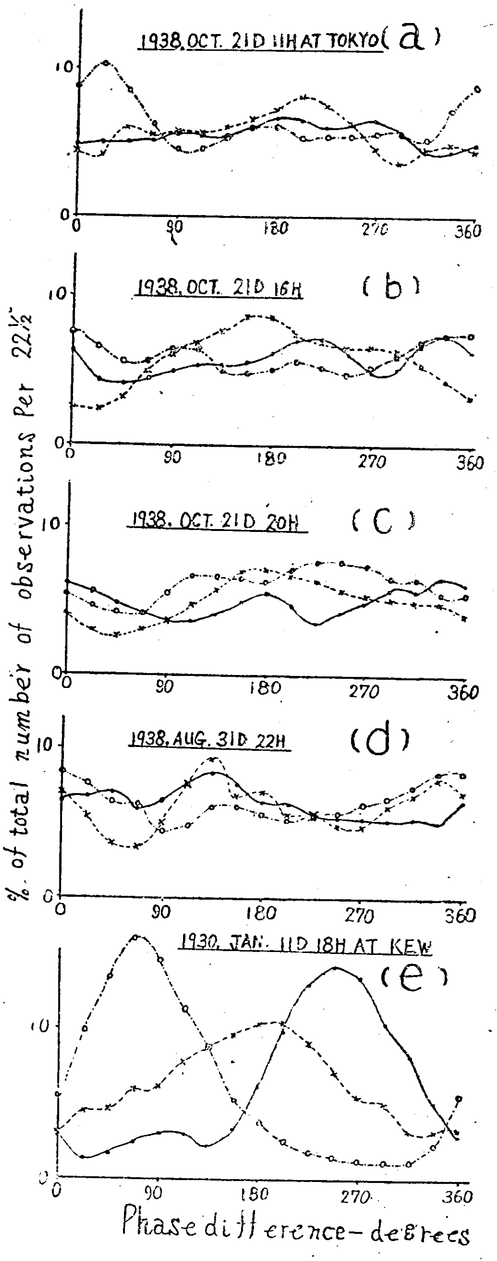

Fig. 2. Smoothed frequencies of specified phase differences between the components of the microseisms.

—●—●— NS~UD
---○---○--- EW~UD
---×---×--- EW~NS

a regular rotation of the constant direction of an earth particle will be distinctly seen. It suggests Rayleigh waves came from north-west or south-east.

On the other hand, describing the orbits on the basis of the records at Tokyo, these orbits were formed as shown in Fig. 3(b). The latter does not show the arrival direction so clearly as the former.

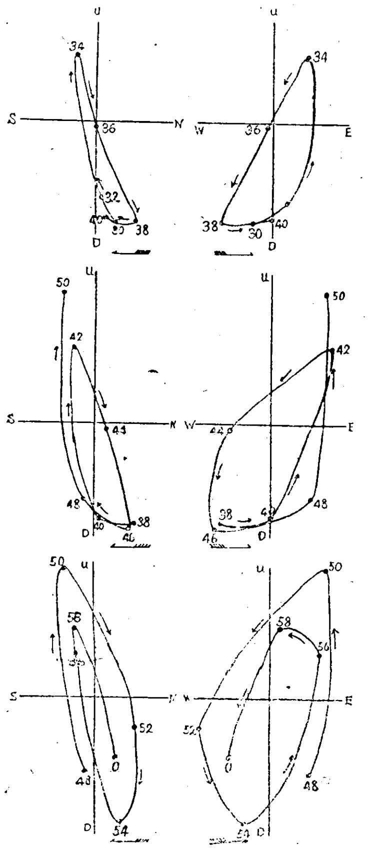

Fig. 3 (a) The orbits of an earth particle at Kew Observatory.

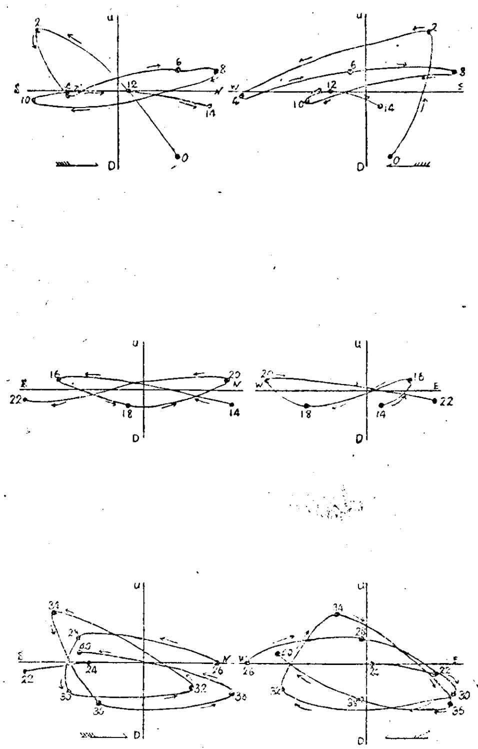

Fig. 3 (b). The orbits of an earth particle at Tokyo Observatory.

Additional remark: J. E. Ramirez[6] also determined the arrival direction of the microseismic waves by the same method in his paper. In the diagrams of the orbits, the constant rotations of particle were clearly shown.

6) J. E. Ramirez: loc. cit., p. 145.

CONCLUSION.

From the above mentioned results, it may be considered that the microseisms are Rayleigh waves which travel from an origin to a station on the earth's surface, in England or America, but in Tokyo, the microseisms do not clearly show their arrival direction. The cause of this results be considered in many ways, and now we do not discuss about this problem, because this queation contains still many unknown problems.