55. *A Study on the Propagation of Microseismic Waves. Part V.*

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Introduction.

In 1929, L. Don Leet[1] proposed a method of determining the direction of approach of microseisms at a station equipped with three-component seismometer assuming microseisms as Rayleigh waves.

In 1935, A. W. Lee[2] proposed a statistical method to determine the direction of approach of microseisms by examining the most probable phase differences between the horizontal- and the vertical-components on assumption that microseisms are Rayleigh waves. He applied this method to the records of microseisms observed at Kew-Observatory to determine the direction of approach of microseisms, and emphasized that Love-waves were not to be found in microseismic waves.

We[3] also applied his method to the records of microseisms observed at Tokyò University, but we could not get such clear results as those obtained by Lee.

In 1938, J. B. Ramirez[4] described the orbits of an earth particle in accordance with the records of microseisms observed with the three components of Galitzin-Wilip seismographs at Florissant station, and he concluded that microseismic waves were of the Rayleigh-wave type. On the other hand he observed microseisms by means of the tripartite method at St. Louis and determined the mean directions of approach of microseisms, and he emphasized that all the determined directions of incoming microseisms at St. Louis point to a deep barometric low over the ocean.

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1) L. DON LEET, *Publ. Dominion Obs., Ottawa*, **7** (1931).
2) A. W. LEE, *Proc. Roy. Soc., London*, **149** (1935), 183–199.
3) F. KISHINOUYE and R. IKEGAMI, *Bull. Earthq. Res. Inst.*, **25** (1947), 43–48.
4) J. E. RAMIREZ, *Bull. Seism. Soc. Amr.*, **30** (1940), 28–35, 128–139.

L. Don Leet[5] applied further his above-mentioned method to the study of a microseismic storm in New England, and he obtained the results that microseisms do not radiate exclusively from the center of a well-developed low-pressure storm area, and that their directions of approach are correlated with the position of a cold front associated with the generation of the storm when passing over the ocean. In 1948, he[6] asserted again his results. Thereafter he[7] argued with S. Katz[8] about this hard problem.

As stated above, many studies concerning the type of microseismic wave-motion have been published, but we think that these studies have some weak points, respectively. Namely, Lee's method is unfit for studying the directions of approach of individual microseismic waves, because his is a statistical method. Ramirez obtained his results by simply contrasting the mean directions of approach of microseismic waves at St. Louis with the paths of an earth particle at Florissant about 21.8 km. apart from St. Louis. It seems to be improper to treat the results observed at two points standing apart from each other with equal weight, in studying microseismic waves.

Leet's method has also some weak points because he made use of only the three-component records observed at one station, Harvard, and did not obtain the direction of approach of microseismic waves which ought to have been compared with the orbits.

Thereby in addition to the tripartite observations, we intended to get the records of three-component tromometer at one of tripartite stations so as to clarify the relation between the orbits of an earth particle and the determined direction of approach of these waves.

We were able to set up our three-component tromometer at the end of February, 1951, but could record microseisms for only one day i. e. March 8, 1951, when the amplitudes of microseismic waves were fairly large and regular. In this paper we will report the results obtained by the records.

Microseisms of March 8, 1951.

We used in this research four horizontal tromometers[9] which

5) L. DON LEET, *Geophysics*, **12** (1947), 639–650.
6) L. DON LEET, *Bull. Seism. Soc. Amr.*, **38** (1948), 173–178.
7) L. DON LEET, *ditto*, **39** (1949), 249–255, **40** (1950), 229–304.
8) S. KATZ, *ditto*, **39** (1949), 181–186.
9) F. KISHINOUYE, *Bull. Earthq. Res. Inst.*, **20** (1942), 215–219.

were adjusted to $T_n=10$ sec., $v=\infty$, $V=2000$, and one vertical tromometer[10] which was adjusted to $T_n=6.5$ sec., $v=6.33$, and $V=840$ as shown in Table I. One horizontal tromometer was set up in NS-component at the two stations, C and E of Fig. 1 of our last paper, Part III[11], respectively, and two horizontal- and one vertical-tromometers were set up in NS-, EW- and UD-components at F-station.

We could obtain simultaneously the orbits of an earth particle at F-station and the directions of approach of microseismic waves at the tripartite stations, C, E and F.

There is a certain amount of difference between the constants of horizontal component and those of vertical component mentioned above, but the difference in the phase lag caused by the differences of constants of tromometer is only 1°24′ to the forced vibration of 4 sec. period as shown in Table I. This difference is only about 0.016 sec., converted into time, and it may have scarcely no effect upon the orbits of an earth particle.

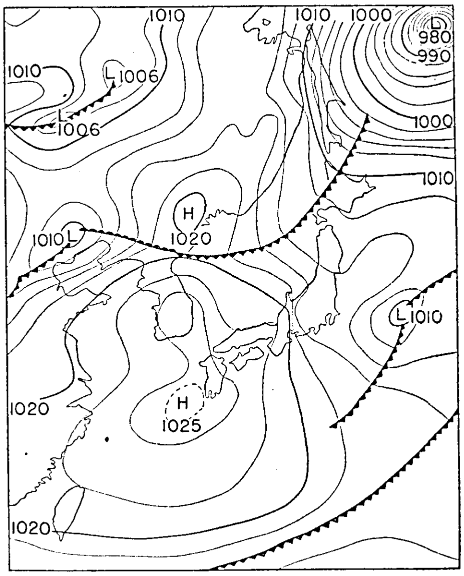

Fig. 1. Weather map for 9^h00^m a. m., March 8, 1951.

Table I. Constants of the tromometers.

	Period of free vibration	Damping ratio	Geometrical magnification	Period of forced vibration=4sec.	
				Phase lag	Magnification coeff.
NS- and EW-components	sec. 10	∞	2000	136°24′	0.86
UD-component	6.5	6.33	840	135°	1.14

On March 8, 1951, there were two barometric lows over the

10) This vertical tromometer was also designed by F. KISHINOUYE, and the paper about this was read at the monthly meeting of the Institute on July 6, 1943.

11) R. IKEGAMI and F. KISHINOUYE, *Bull. Earthq. Res. Inst.*, **29** (1951), 305–312.

Pacific Ocean on the east of Kwantô-District and Kamchatka Peninsula, respectively, and the cold fronts stretched southeastwards from the respective lows as shown in Fig. 1. It was blowing 20~25 m./sec. from the previous day and the Pacific Ocean near Kwantô-District was very rough.

Fig. 2 shows a part of the records of microseisms obtained under the weather condition mentioned above.

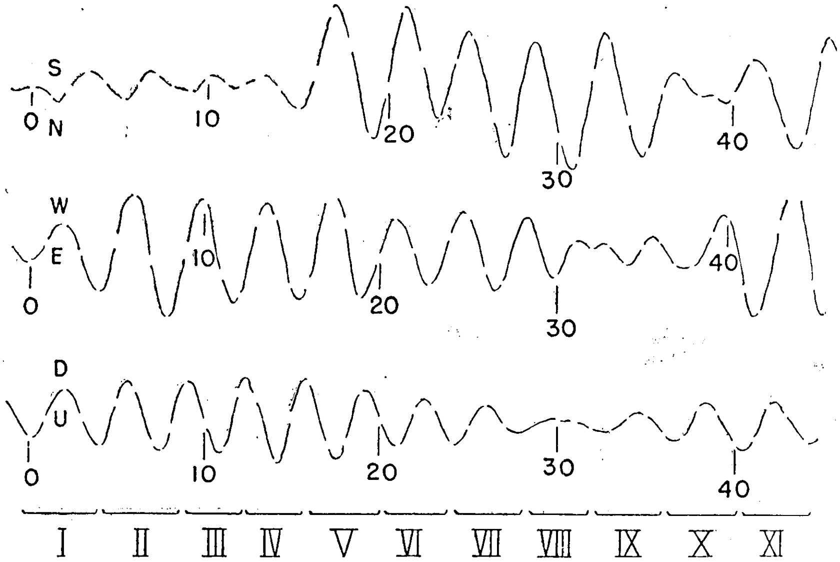

Fig. 2. A part of the three-component seismogram at F-station. (This figure is one half of the actual size.)

The projections of the path of an earth particle on horizontal, meridional and prime vertical planes, which were illustrated in accordance with the three-component records observed at F-station, are shown in Fig. 3. We have given the orbits of five wave-portions, V, VI, VII, VIII and IX, illustrated in Fig. 2, because the orbits of the other wave-portions show also, on the whole, the same tendency. In Fig. 3, the direction of approach of a microseismic wave judged from the orbit is shown by an arrow, and the direction determined by tripartite method on the same wave is shown by a dotted arrow. The tendencies will be made clear by a glance at these figures. Namely, the waves, V, VI and VII express the well-developed forms in three components, and an earth particle is revolved on the vertical plane nearly elliptically. The directions of approach judged from the

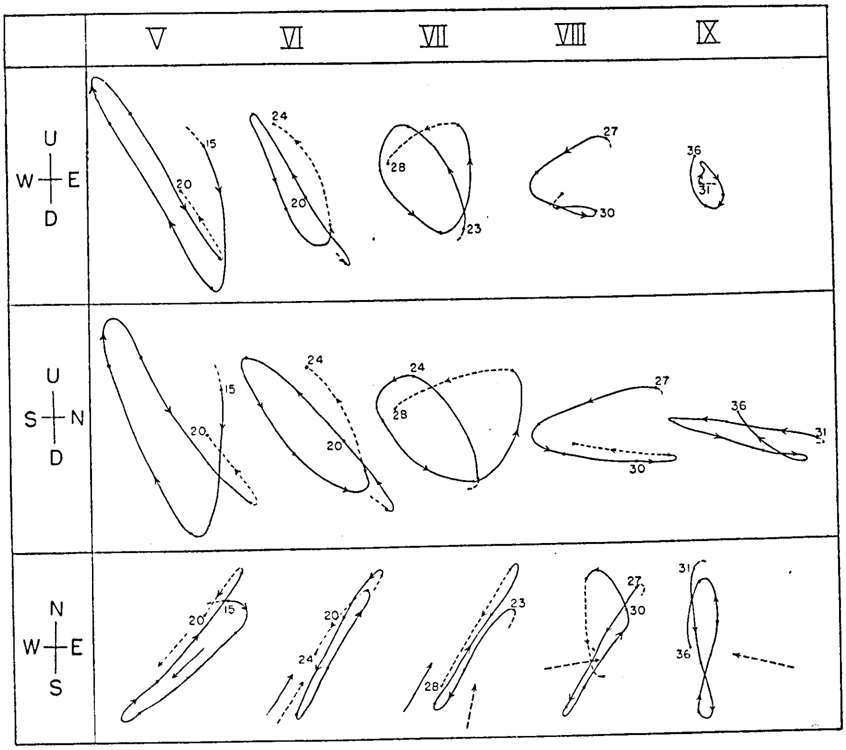

Fig. 3. Projection of the path of an earth particle. Orbits, V, VI, VII, VIII and IX, correspond to the wave-portions, V to IX, of Fig. 2, respectively. The arrow shows the direction of approach of a microseismic wave judged from the direction of rotation of orbit, and the dotted arrow shows the direction of the same wave determined by the tripartite method.

orbits are quite in agreement with the directions determined by tripartite method. But it is very suggestive that the direction of the wave-portion V is quite opposite to the direction of the wave-portion VI though no irregularity is to be seen on the records of these waves, and in all probability this fact seems to afford a key for the solution of the nature of microseismic waves.

We found also that the directions of approach of the individual microseismic waves are fairly scattered about, and that they are radiated from a fairly wide area rather than from a restricted source.

In the wave-portions VIII and IX the amplitudes of vertical motion become remarkably small, and only the motions of horizontal component are developed. We could not decide the direction of approach of these waves by the orbits, but judging from the directions determined by tripartite method, we found that these waves were of the Love-wave type, and that the direction of the wave-portion VIII was nearly opposite to that of the wave-portion IX.

In 1947 Leet[12] pointed out that there seems to be no doubt about the existence of also a horizontal motion with no vertical component. In our previous paper we[13] again pointed out the same fact, which can now made clearer by adding the records of vertical component.

The results mentioned above are those obtained at a single day, i. e., March 8, 1951, but we think the results suggest that the origin of microseisms is exceedingly complex.

In conclusion, we wish to express thanks to the staffs of the Tokyo Astronomical Observatory for setting our instruments, and to Mr. J. Moroga, Mr. H. Yoshioka and Miss M. Kotaka for the aids they offered in the observations.

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55. 土地の脈動の傳播性の研究 (第5報)

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3 點觀測法によつて脈動波の到來方向を調べると同時に，3 觀測點の內少くとも 1 點に 3 成分の地震計を据えて到來方向の判つたその同じ脈動波が如何なる型の表面波であるかを調べた。即ち 3 觀測點 C, E, F の內 F 觀測點に上下成分を加へた 3 成分を設置して目的を達する事が出來た。

今回報告するものは 1951 年 3 月 8 日の唯 1 日の記錄に基くものであるが，それでも可成り興味ある結果が得られた。

i) 連續した脈動波について地面の動き方から判斷して，レーリー型と思はれるものとラブ型と思はれるものとの兩型の脈動波が見られた。

ii) レーリー型の部分については，上下成分と水平成分を組合せた地動の向きから判斷した脈動波の到來方向と，その同じ脈動波について 3 點觀測法によつて決定した到來方向とは殆ど一致してゐた。

iii) 上下成分の振幅が極端に少さくなつた部分では，レーリー型に於けるように地動の向きからは到來方向を決める事は出來ないが，3 點觀測法から決めた到來方向から考へて，この部分は明らかにラブ型の表面波の性質を示してゐた。

iv) 兩型の脈動波共一見連續してゐる如く見える相隣つた波に於ても，その到來方向が全く逆向きになる場合がある。

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12) L. Don Leet, *Geophysics*, **12** (1947), 639-650.

13) R. Ikegami and F. Kishinouye, *Bull. Earthq. Res. Inst.*, **29** (1951), 305-312.