13. *A Study on the Propagation of Microseismic Waves.*

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1. Recently in America and some other countries, the microseisms are regarded as progressive waves caused by ocean storm, and the detect of it by the observations of microseisms is put to practical use to some extent[1]. In Japan many studies on microseisms were made, but the propagation of them have not been ascertained yet.

For the purpose of studying the propagation of them, we tried observations from Nov., 1948 to Feb., 1949 at the Koishikawa Botanical Garden in Tokyo, where no disturbances were caused by traffics during the winter.

The apparatuses used were the portable tromometers which were designed by one of us[2], and we adjusted their period of free vibrations to 10 sec., their magnification to 1920, and the damping to critical. The speed of recording bromide-paper was 4.5 mm/sec.

2. In order to study the phase differences of the waves, when the intervals between the two tromometers are apart far at a distance, we set up one of them at a fixed position and the other at the distance of 1.48, 10 and 50 meters in sequence, and observed the microseisms simultaneously. In the case of 1.48 and 10 m, the records of both tromometers showed the same phases, and we could not distinguish a time lag of the phases of both positions as shown in Fig. 1.

At the distance of 50 m, the arrival times of both phases were slightly different, but those time differences were too short to measure.

From the observations mentioned above, we see that there is difference in the arrival times between two positions as distance increases.

Thereupon, we tried to observe it at the distances of 164 and 266 m again. We could read a difference of the arrival times at both positions on these records. From these records, we obtained about 3.4 km/sec as

1) J. E. RAMIREZ, *Bull. Seism. Soc. Amr.*, **30** (1940), 35—84, 139—178.
M. H. GILMORE, *ditto*, 36 (1946), 89—120.
M. H. GILMORE and W. E. HUBERT, *ditto*, 38 (1948), etc.

2) F. KISHINOUYE, *Bull. Earthq. Res. Ins.*, **20** (1942), 215—219.

average velocity of propagation of the microseisms. This value might be near the maximum value of the true velocity, or the true velocity of microseisms might be less than this value.

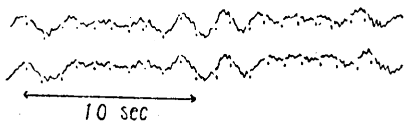

Fig. 1. The records of two tromometers, 148 cm apart.

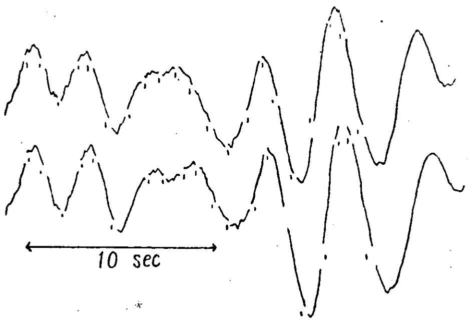

Fig. 2. The upper record shows microseisms at the bottom of the pit. (The depth was 130 cm.)
The lower, at the surface of ground. (The interval was 7 m.)

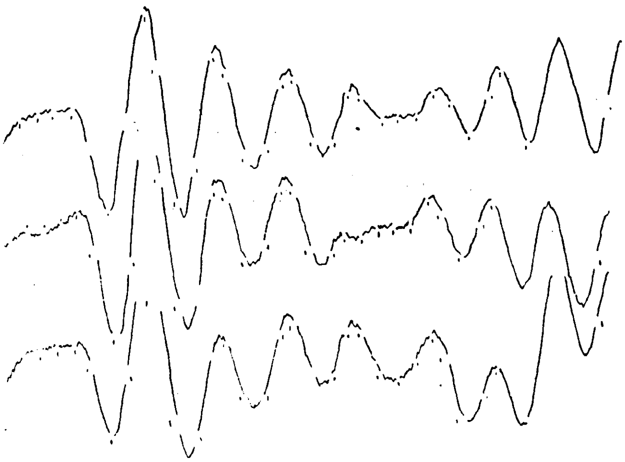

Fig. 3. The records of the tripartite observation.
The upper record shows microseisms at R-station.
The middle, at M-station.
The lower, at S-station.

Moreover, because we were doubtful of the phases at the underground of a certain depth, we set up two tromometers 7 m apart at the ground surface and the bottom of a pit, the depth of which is 1.3 m, and observed the microseisms simultaneously. These records showed also no phase difference at both positions as shown in Fig. 2.

3. The lay of the Koshikawa Botanical Garden, where we tried the observations, is divided into two parts, upland and lowland. It is neccessary to investigate the disparity of the microseismic phases between the two parts of the lay. We observed them at A and M in Fig. 4, simultaneously.

On these records the microseisms of 4 sec. periods were the same wave-forms at both positions, although there were phase differences in accordance with distances. But the wave-forms of the short periods (0.2–0.3 sec.), which might probably be caused by traffics, showed some differences. That is to say, the amplitude of the short period motion of the lowland was larger than the one of the upland, and also the phase did not exactly correspond to each other.

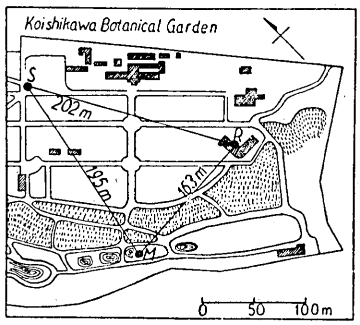

Fig. 4. A part of the Koishikawa Botanical Garden in Tokyo.

From these results, it is expected that the propagations of microseismic waves of 4 sec. periods may be ascertained, when the tripartite observation is tried more than 150 m apart.

4. Three tromometers were stationed at the three positions R, M and S in Fig. 4 in the same directions respectively, and the observations were held on Feb. 9th, 11th and 14th. The weather maps of those days are shown in Figs. 5, 6, 7 and 8. Fig. 3 shows parts of the records of these three tromometers on Feb. 9th.

The first step in the actual calculation of bearing is to measure the differences in times of arrival between the stations R and M, M and S, and S and R. For example, the linear distances (as shown in Fig. 9) from the time break of certain well-formed microseisms recorded at all the three stations are measured in millimeters to the nearest crests and troughs respectively, and these values are converted into seconds.

The values to the actual travel time between the stations R and M, M and S, and S and R were calculated from the expressions, $R-M=\{(R_1-M_1)+(M_2-R_2)\}/2$, $M-S=\{(M_1-S_1)+(S_2-M_2)\}/2$, and $R-S=$

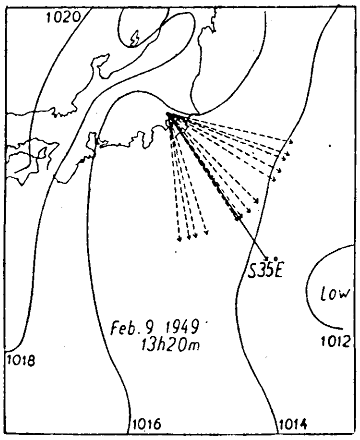

Fig. 5. The weather map of Feb. 9, 1949, 13 h 20 m, and the bearings obtained. An arrow in full line is the bearing obtained from the average travel time, and the dotted arrows are those obtained from the individual travel time.

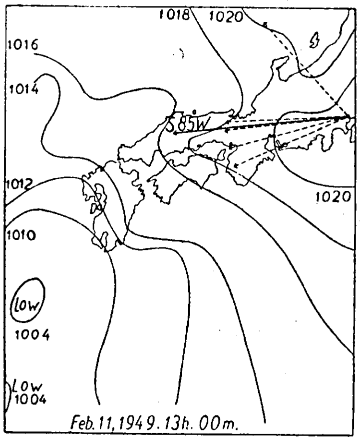

Fig. 6. The weather map of Feb. 11, 1949, 13 h 00 m. and the bearings obtained.

$\{(R_1-S_1)+(S_2-R_2)\}/2.$

The average travel times were obtained as follows, $T_{RM}=\Sigma(R-M)/n$, $T_{MS}=\Sigma(M-S)/n$, and $T_{RS}=\Sigma(R-S)/n$, where n was the numbers of measurements. These values are shown in Table I.

The method of the determination of the arrival direction of microseisms was similar to that derived by Gilmore[3].

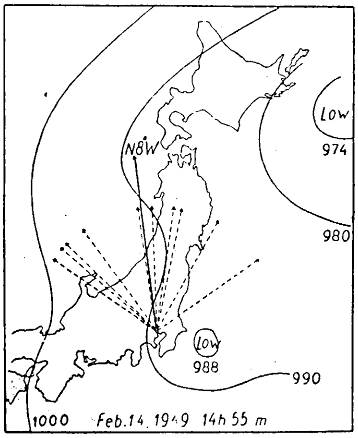

Fig. 7. The weather map of Feb. 14, 1949, 14 h 55 m, and the bearings obtained.

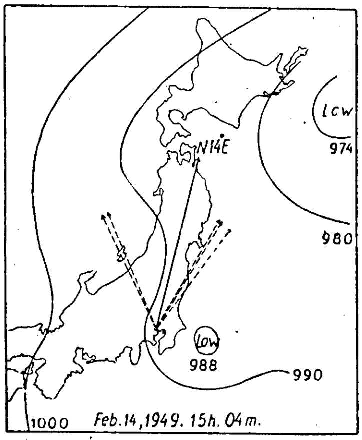

Fig. 8. The weather map of Feb. 14, 1949, 15 h 04 m, and the bearings obtained.

3) M. H. GILMORE: *Bull. Seism. Soc. Amr.*, 36 (1946), 95.

The bearings obtained from the average travel times by that method are shown in Figs. 5, 6, 7 and 8 by arrows in full line respectively. Much interest was aroused by the fact that each bearing was nearly in line with the position of an atmospheric depression at that time.

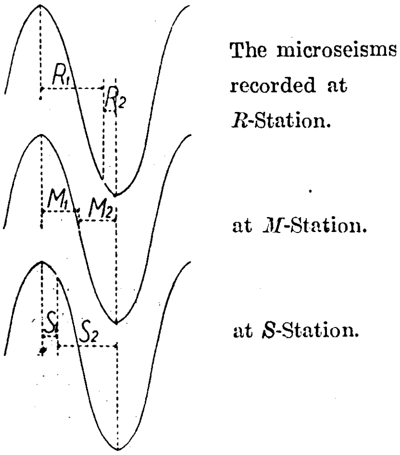

Fig. 9. The method to measure the linear distances from the time break to the nearest crest and trough.

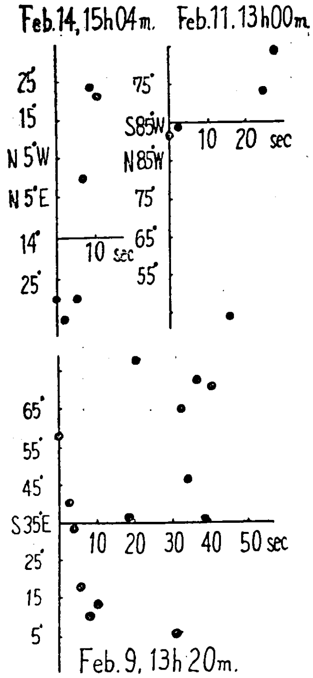

Fig. 10. The relations between the bearings and the measured time of these bearings.

The bearings calculated individually from the actual travel time are shown in those figures by dotted arrows, and they are scattered within the angular deviation of 30–40 degrees. These deviations might be attributed to observation errors, but in this case there might be some causes besides errors as referred to below. The relations between the bearings and the measured times of these bearings are shown in Fig. 10. According to this figure, the deviations of the bearings seem to have some systematical changes. When atomospheric depression extends over a wide area, it is possible to consider that the bearings may be deviated in variant directions. But in such a case it is difficult to expect the systematical changes of the bearings. These systematical changes of the bearings may be able to be elucidated by the consideration that these changes are caused by the resultant waves of the ones propagated from a depression and the ones caused by the free vibration of that ground. This subject must be established by future investigations.

The average velocity of microseisms obtained was 239±0.02 km/sec.

5. Acknowledgement.

We express our thanks to the staffs of the Koishikawa Botanical Garden, who offered facilities for our observations.

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Table I.

Feb. 9, 13 h 20 m.			
	R—M	*R—S*	*M—S*
1	.058	.068	.010
2	.079	.159	.080
3	.058	.158	.099
4	.007	.190	.182
5	−.023	.139	.162
6	−.011	.120	.131
7	.066	.049	−.017
8	−.004	.013	.017
9	.051	.051	.000
10	.048	.079	.031
11	.040	.033	−.007
12	.041	.102	.061
13	.054	.047	−.007
Mean	.036	.093	.057

Feb. 11, 13 h 00 m.			
	M—R	*S—R*	*M—S*
1	.066	.072	.017
2	.075	.051	.024
3	.020	.050	−.030
4	.069	.035	.034
5	.084	.028	.056
Mean	.063	.047	.020

Feb. 14, 15 h 04 m.			
	S—M	*S—R*	*R—M*
1	.080	.033	.047
2	.118	.039	.079
3	.113	.046	.066
4	.046	.039	.007
5	.052	.064	−.012
6	.082	.097	−.015
Mean	.082	.053	.029

Feb. 14, 14 h 55 m.			
	S—M	*S—R*	*R—M*
1	.030	.035	.045
2	.102	.080	−.020
3	.065	.087	−.065
4	.012	.075	−.063
5	.036	.067	−.031
6	.071	.033	.019
7	.046	.015	.061
8	.027	.029	.013
9	.047	.059	−.016
10	.077	.075	.002
Mean	.056	.056	.000