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30. *Investigations into Microseisms by the Observational Data of Many Stations (Part II).*

—Further Considerations on the Origin of Microseisms.—

By Tetsuo A. SANTÔ,

Earthquake Research Institute.

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1. Introduction

In the previous paper,[1] the writer investigated the features of occurrence of microseismic storms in the Japan Islands due to the passing of cyclones, typhoons and strong cold fronts. One of the most important features we found was that when a cyclone passed off the eastern coast of Japan with high speed, microseismic amplitudes at a certain district became maximum considerably later than the passing of the cyclonic center.

From this observational fact, and further, by comparing the data of microseisms and swells recorded at the two stations in the same district, the writer made a suggestion that the origin of microseisms* (the area where the energy of swell changes into that of microseismic waves) exists somewhere near the coast.

This suggestion is quite important in the study of microseisms. Therefore, the writer will, in this paper, try to re-examine this suggestion by using additional data of microseismic storms due to the passing of typhoons.

The data of microseisms being used in this paper were, as before, all obtained at many stations in the Japan Islands during I.G.Y. period.

2. Additional data of microseismic storms due to the passing of typhoons.

After the first paper was written, the writer was able to get plenty of data on microseismic storms due to the passing of typhoons. In September 1958 especially, three typhoons T5819, T5821 and T5822 pas-

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[1] T. A. SANTÔ, *Bull. Earthq. Res. Inst.*, **37** (1959), 307.

*) The microseisms treated in this paper are restricted to those which have the periods of approximately 3∼7 seconds.

sed near and across the Japan Islands. Fig. 1 shows the feature of the occurrence of microseismic storms at thirteen observation stations due to the passing of these typhoons.

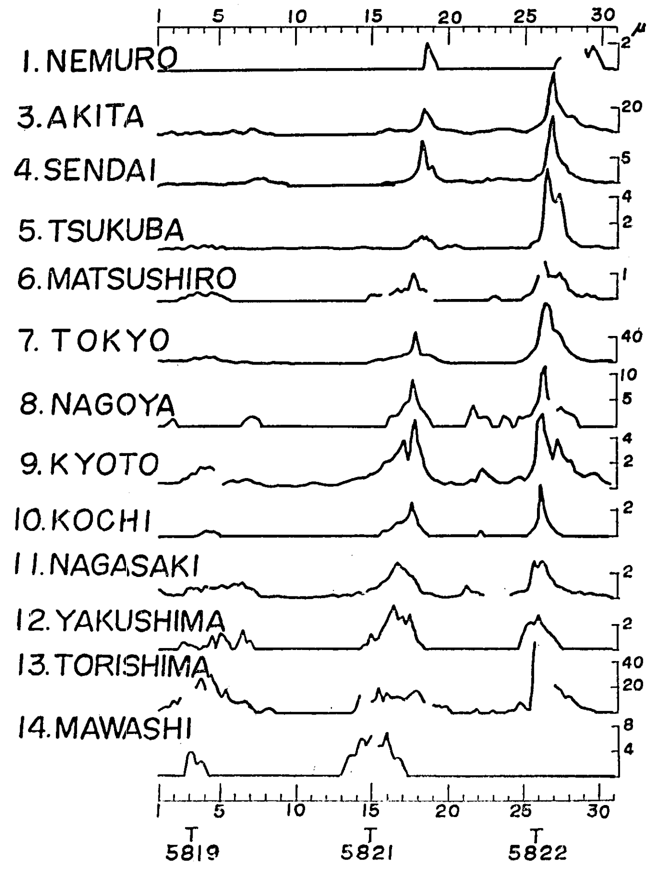

Fig. 1. Time variations of microseismic amplitudes (in μ) at many stations due to the passing of three typhoons on September 1958.

As was reported in the previous paper, it is clearly seen that the microseismic storms shift from the southern to northeastern stations. The relation between the positions of the centers of typhoons and the relative strengths of microseismic storms at many stations at given times are, for the case of T5821 and T5822, represented in Fig. 2. These two very strong ones passed across the central part of the Japan Islands and caused severe damage on their landing districts. In these cases, as can be seen in Fig. 2, the appearance of the microseismic storm is not after the passing of the centers of these typhoons but rather before it. Fig. 3 shows the time variations concerning the periods of microseismic storms due to the passing of these three typhoons given above. Except a few stations on which the responses of seismographs were not good for long periods, the periods of microseisms remarkably increased up to six or seven seconds due to the passing of these typhoons. Comparing one of these curves, for instance that of observation station 5 (Tsukuba), with the curve of the half periods of swells recorded at Naarai (about 80 km south-east of Tsukuba), a noticeable phenomenon can be found, i.e., these two curves coincide very well at around the time of the passing of these typhoons (See Fig. 4(a)). This phenomenon has also been

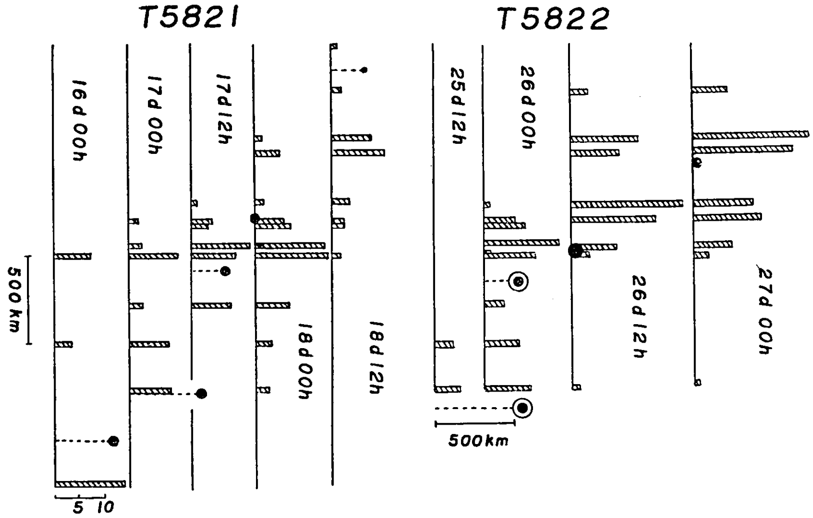

Fig. 2. Shifts of the region of microseismic storms due to the passing of two strong typhoons. The positions of the observation stations are taken along the ordinate. Station 1 and 14 correspond to the uppermost and lowermost edge. In the case of T5822, the data of station 14 was missed. The length of the hatched column at every station is the amplitude ratio of microseismic storm at a given time to the ordinary ones. Diameters of black (for $p>970$ mb) and inner black (for $p<970$ mb) circles are inversely proportional to the central pressures of typhoons.

found by J. E. Dinger and G. H. Fisher.[2] We cannot say, however, that the standing wave theory does not hold in the other ordinary case. For, in calm times, the wave form of microseisms recorded at Tsukuba at least is irregular (Fig. 5), having many components with nearly equal amplitudes, therefore, in calm times, we are apt to measure the periods for different waves which do not correspond to each other from these two kinds of records. Correspondence between the amplitude variation

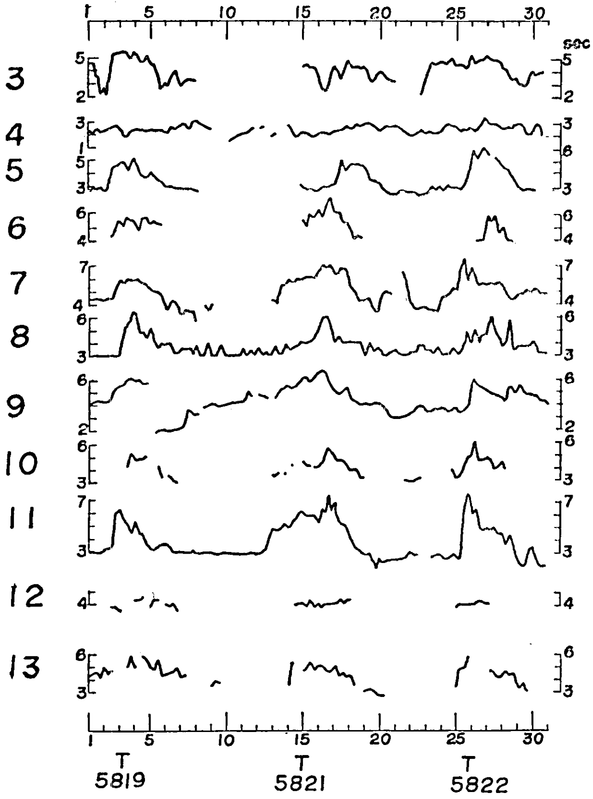

Fig. 3. Time variations of microseismic periods at many stations due to the passing of the same typhoons as in Fig. 1.

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[2] J. E. DINGER and G. H. FISHER, *Trans. Amer. Geophys. Union*, **36** (1955), 262.

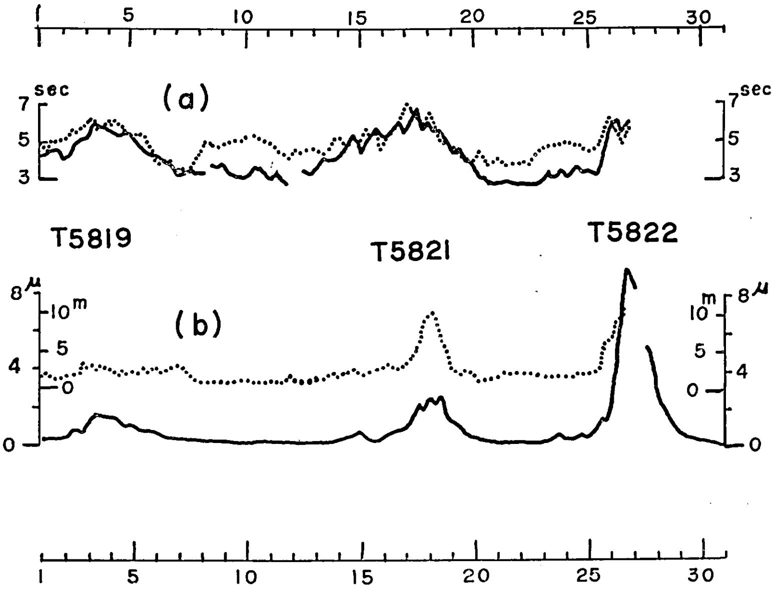

Fig. 4. (a) Relation between the variations of the periods of microseisms (solid line) at Tsukuba and half periods of swells (dotted line) at Naarai on September 1958.

(b) Relation between the variations of the amplitudes of microseisms (solid line) at Tsukuba and of swells (dotted line) at Naarai. Inside scale of ordinate is for the heights of swells.

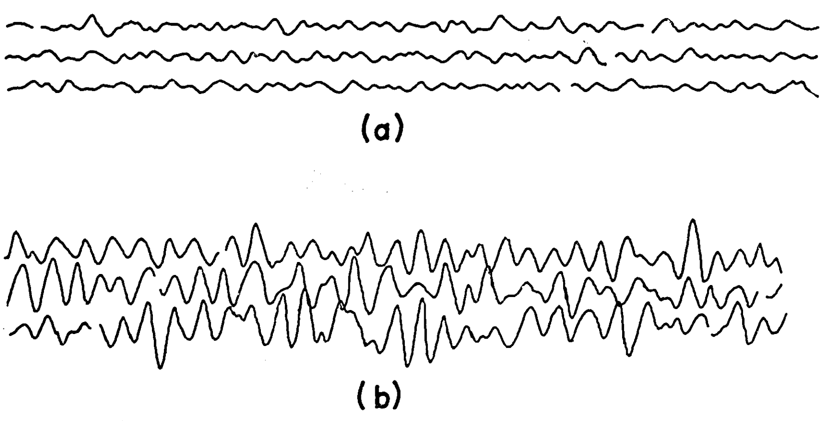

Fig. 5. Examples of microseismic wave forms recorded at Tsukuba in two cases. (a) Calm. (b) Stormy.

of microseisms recorded at Tsukuba and that of the swells at Naarai is shown in Fig. 4(b). As was noticed in the previous paper, the maxi-

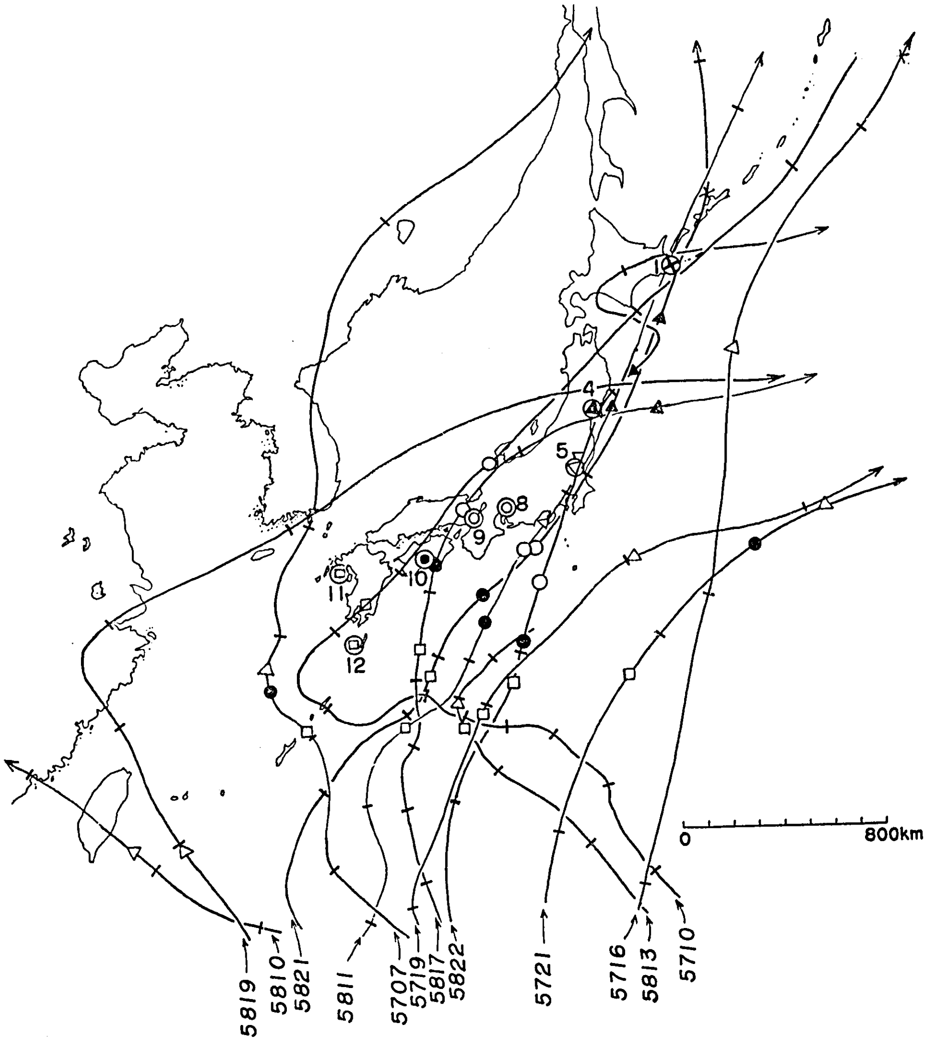

Fig. 6. Travelling paths of typhoons. The marks on the path show the positions of the center of every typhoon at the time when it caused the largest microseismic amplitudes at the corresponding stations (circles are added to the marks of center position). Intervals between short bars on the path represent the travelling distances of typhoons during one day.

mum amplitude of microseisms never occurs before that of swells which arrived at the coast in the same district.

Fig. 6 represents the travelling paths of typhoons which caused microseismic storms in the Japan Islands during I.G.Y. period. Several kinds of marks on each path mean the positions of the centers of typhoons when they caused the largest microseismic storms at the corresponding observation stations for microseisms. In this figure, we can see, especially at southern stations, that in the case of typhoons, the times when microseismic storms become largest at a certain station are not delayed so much as in the case of cyclones but rather coincide with the passing of their centers.

3. General features of the distribution for the positions of cyclonic centers when they cause the largest microseismic storm at a certain station.

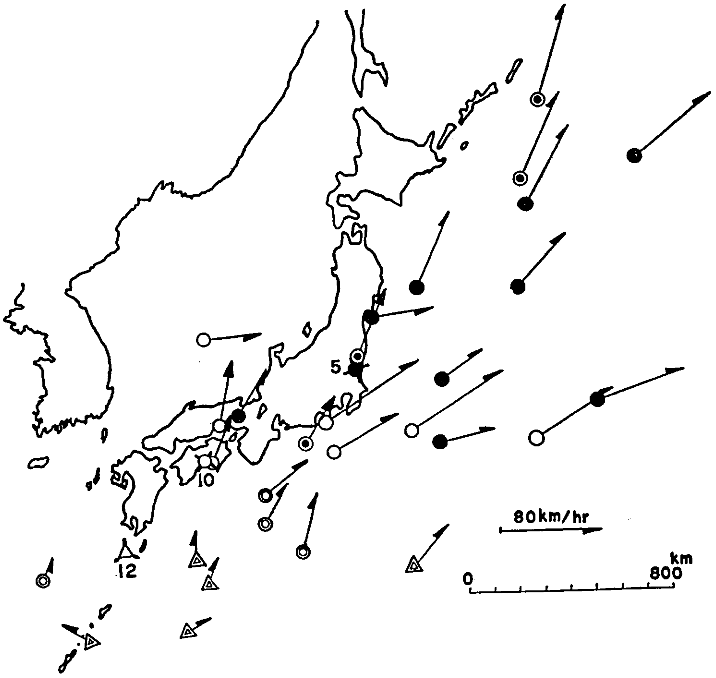

Fig. 7. Positions and travelling velocities of cyclonic centers when they caused the largest microseismic storms at a few observation stations. Double marks are those for $p<990$ mb and others are for $p>990$ mb.

Black and white circles, and triangles are those positions of cyclonic centers correspond to the station 5, 10 and 12 respectively.

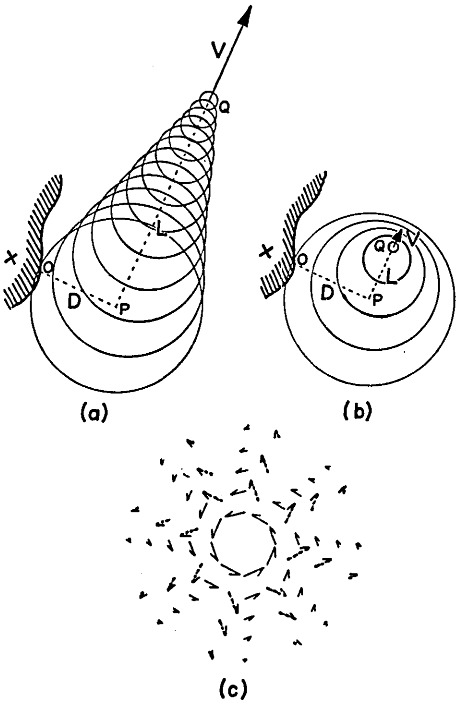

Fig. 8 (a and b). Schematical figures of wave distributions around and behind the center of a running point source. (a) When $V>v$. (b) When $V<v$. (c) Schematical figure of the directions of winds (solid arrows) and swells (dotted arrows) around a stationary cyclone.

In the previous paper, we found that microseismic storms at a certain station became largest remarkably later than the passing of a cyclonic center. As we have seen in the previous section of this paper, however, this phenomenon is not so noticeable in the case of typhoons. Furthermore, just the opposite relation could be found for the case of T5821 and T5822 which passed just above the observation station Tsukuba. Getting together, the positions of the centers of cyclones and typhoons when they caused the largest microseismic storm at a station were shown in Fig. 7 for a few representative stations (Tsukuba, Kochi and Yakushima).

Consider now a simple case when a vibrating point source is travelling straight with the velocity V on the water surface. In this case, when the wave front originated at P reaches a position O with a distance $D(=OP)$ from the travelling path, the wave source has covered the distance $L(=PQ)$. (Fig. 8(a) and 8(b)). In other words, the wave always arrives at the point O later than the passing of the wave source. In this case, the following relations must be satisfied.

$$D=vt, \qquad L=Vt,$$

in which, v is the wave velocity and t is the travel time of the wave covered the distance D. From these, the next relation easily follows.

$$V=vL/D \,. \tag{1}$$

Of course, in the actual case of a cyclone or a typhoon, the mechanism of wave generation around the center is much more complicated than this case of a point source (Fig. 8(c)). Winds and swells are being sent away in counter-clockwise directions around the center and their strength distributions depend upon those of the atmospheric pressure gradients around the center. Furthermore, when the center moves, the wind becomes stronger in the first and weaker in the third quadrant for the travelling direction of the center, and as a result so does the swell.

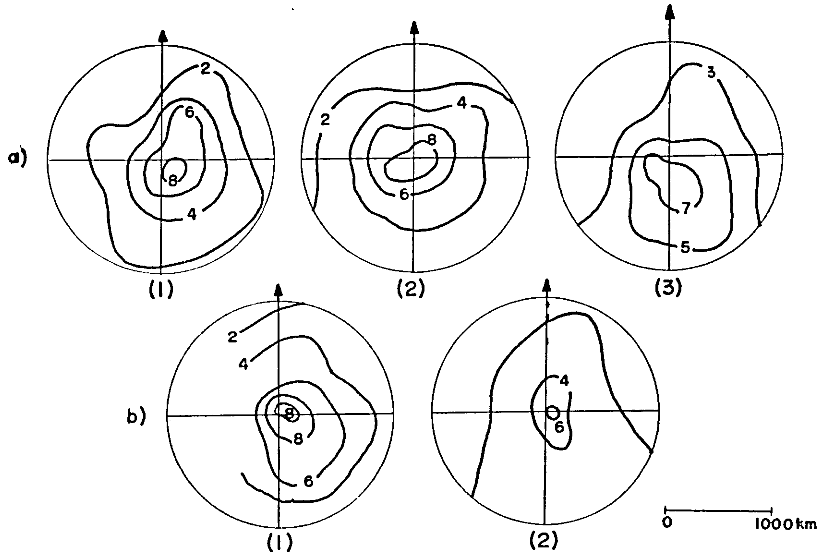

Fig. 9. (a) Mean distribution maps of wave heights (in meter) due to the typhoons with the same central pressures $960\sim980$ mb, but different travelling speeds. (1) $V<20$ km/hr. (2) 20 km/hr$<V<$40 km/hr. (3) $V>40$ km/hr.

(b) Mean distribution maps of wave heights (in meter) due to the typhoons with the same speed but different central pressures. (1) $p<940$ mb. (2) $p>980$ mb.

(After S. Unoki)

It is, as a matter of fact, very difficult to observe the distribution of swell height around the center of a cyclone or a typhoon. There is, however, a laborious work on this problem done by S. Unoki.3) He collected the data of swell heights due to forty seven typhoons being observed during 1949~1956 at the Ocean Weather Station "Tango" (29°N, 135°E), and made the averaged distribution maps concerning the heights of swells around the center of typhoon within a certain range of central pressure p and travelling speed V. His results are shown in Fig. 9(a) and 9(b). Regrettable to say, as the travelling speeds of typhoon are, in general, still low on the southern ocean around this ob-

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3) S. UNOKI, *Journ. of Met. Soc. Japan*, [ii], **35** (1957), 297.

servation point, he could not know the actual heights of wave distribution around the center of the typhoon with such high travelling speeds as 60~80 km/hr, which is needed for the present case. However, the following general tendency can be imagined by these maps concerning the distributions of swell heights:

i) When p or V becomes high, the wave distribution around the cyclonic center becomes similar to those due to a single running point source.

ii) When p is very low, on the contrary, the wave distribution becomes like (b) in Fig. 8, even when V is considerably high.

iii) When a disturbance source passes through the left side of a coast against its travelling direction, the wave front reaches the coast earlier than the other case. Furthermore, when p or V is small, it can happen that the wave reaches the coast earlier than the passing of the center.

4. Collation with the actual data of microseisms.

It is quite interesting to examine whether or not the "delay phenomenon" for the occurrence of microseismic storms can be explained by the above considerations of the wave distribution around the cyclonic center. For, if it is explained well, the writer's suggestion that the energy transformation from swells to microseisms occurs somewhere near the coast will be powerfully verified.

Based upon considerations i), ii) and iii) in the previous section, a test was made if the actual data satisfy the relation (1) in section 3. For this purpose, V, L and D were measured on maps only for those cyclones and typhoons which run approximately straight. The actual relation between V and L/D thus obtained are shown in Fig. 10, in which the marks of points have the same meaning as in Fig. 7. Further, in this figure, the two cases when the observation station is located on left or right side of a running cyclonic center are distinguished by the location of a short bar on every mark.

This result satisfies very well, beyond the writer's expectation, the relation between V and L/D which holds for waves generated around the running point source. That is:

i) Two kinds of marks (for $p>990$ mb and for $p<990$ mb) are scattered separately around two straight lines with different inclinations. From these inclinations, we can find two different travelling velocities of the swells due to the cyclones or typhoons. The results are: for $p>990$ mb, $v \doteqdot 17$ km/hr and for $p<990$ mb, $v \doteqdot 30$ km/hr. As almost all the central pressures of cyclones belong to the first class here used were higher than 1010 mb (only one of them were 990 mb) and those belong to the second class lower than 965 mb (only one of them were 985 mb), these values of v are quite reasonable ones as the velocity of swells due to the cyclones with such strengths.

It must also be noticed that the marks with short bars on their right side (meaning that these data correspond to the cases when the cyclones or typhoons passed through the left side of these stations) make another straight line approximately parallel to the line for $v \doteqdot 17$ km/hr. This fact can also satisfy the circumstances given in the third item of the previous section.

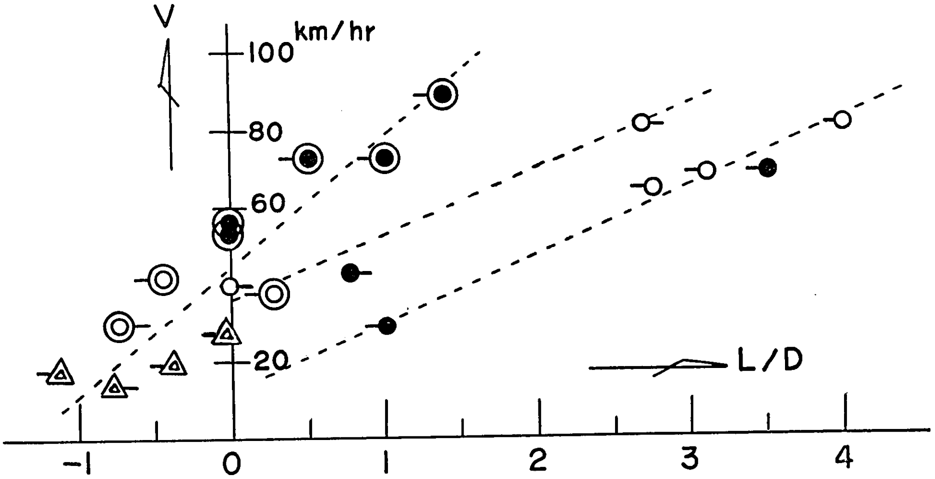

Fig. 10. Relation between V and L/D. V is the travelling speed of the center of cyclone or typhoon. L and D are the travel distances of wave source and wave itself respectively as are shown in Fig. 8 (a) or 8 (b).

ii) If the running wave source is a point, the straight line of $V \sim L/D$ must point to the origin of the coordinate. In the case of actual cyclones or typhoons, as we have found in section 3, the wave distribution becomes circular around the center only when V reaches a certain value V_0. In this case, the wave can reach the coast almost simultaneously at the time of the cyclone passing. The value of V_0 satisfying the above condition will become larger for the lower value of p. Seeing the cutting point of two straight lines in Fig. 10, the circumstance can also be very well recognized.

iii) When V is lower than V_0, wave pattern projects to the front of the running cyclonic center. In this case, it can happen that the wave reaches the coast earlier than the passing of the cyclonic center. Several points in Fig. 10 on minus side of the ordinate show the above circumstances.

5. Conclusions.

In the previous paper, the writer made an important suggestion for the origin of microseisms that the microseisms with periods of 3～7 seconds are caused somewhere near the coast. In this second paper, this suggestion was re-examined by using additional data on microseismic storms due to typhoons and the oceanographical results on the distribution of swells around the running center of typhoons. Through this re-examination, it was again and more clearly recognized that, in all cases of the passings of cyclonic center with various strengths and distances, microseisms at a certain district occur simultaneously with the arriving of swells at some coast on the same district. In other words, the re-examination in this paper lead us again to the conclusion that the energy transformation from swells to microseisms occurs somewhere near the coast.

6. Acknowledgments.

At the conclusion of this paper, the writer wishes to express his sincere thanks to Dr. K. Wadati and to Mr. S. Miyamura who encouraged him during the course of his investigations. The writer's hearty thanks are also due to Mr. T. Kizawa who gave him much help in collecting the data on swells.

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30. 多くの観測点の資料に基づく脈動の研究 (その二)

—脈動源に関する前推論への再検討—

地震研究所　三　東　哲　夫

前論文で，3 秒から 7～8 秒の周期をもつた脈動の発生源は，台風や低気圧の中心附近にはなくて，陸地のすぐ近くにある．という考え方を提出した．この推論は，大変重要なことと思われるので，更にその後の台風による脈動嵐の資料を加え，また台風の中心周囲の波高分布に関する海洋学上の観測事実をも考慮に入れた上で，この点をもう一度追究して見た．その結果，台風の通過に際して，脈動嵐はやはり波浪が陸地に到達した頃に起ることが示され，前論文の推論通り，波浪のエネルギーは陸地のすぐそばで脈動のエネルギーに変ると考えて差支えないことが分つた．