Special Contributions, Geophysical Institute, Kyoto University, No. 4, 1964, 51-62

SOME PROPERTIES OF MICROEARTHQUAKES IN THE WESTERN PART OF KINKI DISTRICT (PRELIMINARIES)

By

Yoshimichi KISHIMOTO, Michio HASHIZUME, Kazuo OIKE, and Kazuo MINO

(Received November 10, 1964)

Abstract

Properties of microearthquakes in the western part of Kinki District were investigated. The analysis was mainly made as to about 30 earthquakes observed simultaneously at three stations. Distributions of epicenter and focal depth seem to have some particular characteristics in the area concerned. Some phenomena suggesting the future development were described as to the magnitude and focal mechanism. Also, the distributions of P-S time and maximum amplitude at three stations were mentioned.

1. Introduction

Properties of the so-called "microearthquake" regarding their occurrence and relations to other phenomena have not been fully clarified yet, except some special cases such as the aftershock and volcanic earthquake. This fact seems to be due to various causes. Main reason for this fact may be a practical difficulty to carry out such an observation for pretty long period which needs extremely high sensitivity and precision. Recently, however, the microearthquake has been believed by many seismologists to possibly give an efficient method to predict the occurrence of large earthquakes. Namely, the occurrence of large earthquake is thought to have some relationships to the occurrence of minor earthquakes. Gutenberg and Richter [1949], for instance, stated many interesting results as for the magnitudes and numbers of large and small earthquakes. Also, it is a fact well-known that the large earthquake usually accompanies some foreshocks. These facts strongly suggest that observation of the microearthquake, which is thought to occur so often in most places in Japan, will become an effective clue to investigate the properties of large earthquakes and, finally, to bring about a method to predict their occurrences.

The Tottori Microearthquake Observatory was set up in April 1964, attached to the Disaster Prevention Research Institute, Kyoto University, in order to strongly carry out the investigation of microearthquakes from the point of view mentioned above. At the Tottori Observatory, the management of observation work, collection of data and research work are made. Three stations, at present, are attached to the Observatory, where practical observations are carried out. They are situated in western part of the Kinki District, as shown in Fig. 1.

We have had an opportunity to analyse seismograms obtained at these stations, and it has been possible to mention about some natures of microearthquakes in the area concerned. Although the number of station and period of observation is never sufficient to do detailed investigation, various interesting phenomena on seismicity, origin mechanism and others were found out, suggesting further developments in near future on these problems. In the followings, the results and suggestions to the future researches will briefly be described, and the detailed treatment of various research items will be reported in the succeeding papers.

2. Obervation system

The Tottori Microearthquake Observatory and three observation stations, Funaoka, Mikazuki and Hikami, are shown in Fig. 1, and some data about these stations are listed in Table 1.

The electromagnetic, moving-coil seismograph with a period of one sec. is set up at each observation station. An amplifier of vacuum tube type and pen-writing galvanometer are used for recording. The seismogram is written on the paper by

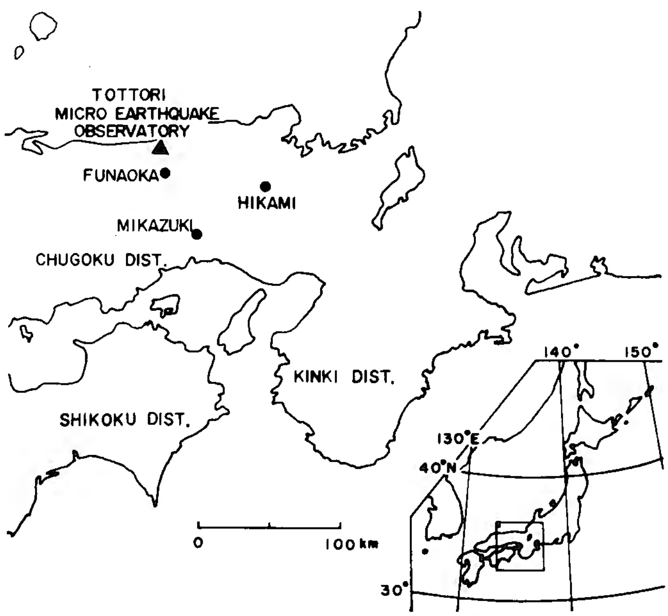


Fig. 1. Positions of the Tottori Microearthquake Observatory and three observation stations.

Table 1.

	Tottori	Funaoka	Mikazuki	Hikami
Latitude (N)	35°30′48.″8	35°19′59.″3	34°59′01.″3	35°13′35.″5
Longitude (E)	134°14′13.″2	134°16′18.″4	134°26′44.″6	135°02′36.″6
Elevation (m)	45	140	200	250
Seismograph	—	2H, 1V	2H, 1V	1V
Beginning date	Apr. 1964	May 1964	Nov. 1963	Aug. 1964

2H: 2 components of horizontal seismograph
1V: 1 component of vertical seismograph

ink, which is changed once a day. The overall sensitivity of this seismograph system including the seismograph, amplifier and galvanometer is shown in Fig. 2. The time mark is given by a crystal clock every second, the length of which is 4 mm on the seismogram. The detailed description of this observation system will be reported in a publication of the Disaster Prevention Research Institute, issued in near future. As will be stated in the later section, the lower limit of magnitude of microearthquake observable by this system is approximately estimated as $M = -0.5$.

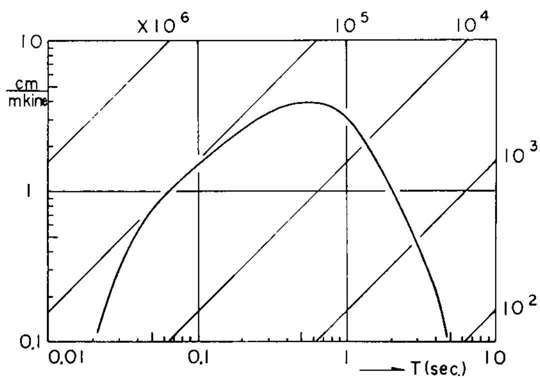


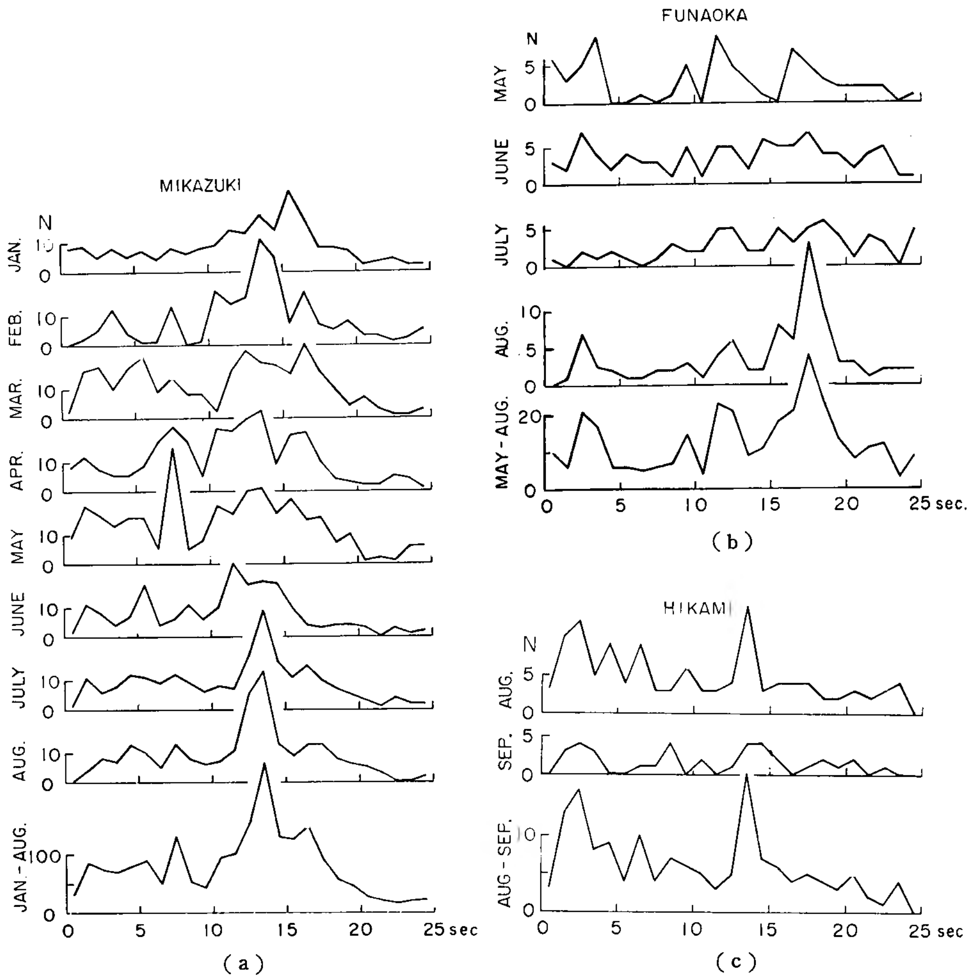
Fig. 2. Overall velocity sensitivity of instruments used.

3. Distributions of P-S time and maximum amplitude

(i) Distribution of P-S time

The observation was commenced at Mikazuki early in November 1963. It seems, therefore, possible, to some extent, to estimate the seismicity and its time variation near Mikazuki. Periods of observation at Funaoka and Hikami are so short that it is impossible to discuss, in detail, the exact aspect of seismic activity near these two stations. However, it seems still interesting to try a comparison of P-S time distributions at three stations, the result being shown in Figs. 3a, b and c.

At Mikazuki, some characteristics are recognized on this graph. Generally



Figs. 3a~3c. P-S time distributions at three stations.

speaking, P-S time distribution in each month from January to August is considered to have nearly the same form, when P-S time distribution is treated with in a range less than 25 sec. It is remarkable that a large number of earthquakes is distributed in a P-S time range of 10 to 18 sec. This group of earthquakes probably corresponds to several areas in which the seismicity is very high. Namely, it is a well-known fact that the seismicity of the earthquakes comparatively larger than the microearthquake is high in such areas as, for instance, Wakayama City area, Tokushima Pref., central part of Chugoku District, Tango Peninsula, Wakasa Bay and Lake Biwa area. These areas are all in a distance range corresponding to P-S time of about 15 sec. In a later section, it will be shown that pretty large number of earthquakes is really distributed in these areas, particularly in Wakayama City area.

Besides, we may recognize some more characteristic features, if we examine in more detail. The distribution graph has especially high peak at 7~8 sec. in May, while at 13 sec. in July and August. This shows that sometimes seismicity is particularly high in a certain area. The latter peak in July and August is also recognized at 17 sec. at Funaoka, and at 14 sec. at Hikami, so that these earthquakes are thought to have occurred in Wakayama City area. Our main interest consists in a range of P-S time less than 10 sec., because these earthquakes are inferred to be generated close to our network. The general form of the graph in this P-S time range also resembles to each other in respective months with two or three peaks, although there may be some difference from month to month. Some considerations on distribution of these earthquakes will be made in the next section. At two stations, Funaoka and Hikami, the form of distribution looks to have their own forms which somewhat differ from each other and also from that of Mikazuki station. Detailed discussion about mutual comparison and change of P-S time distribution is postponed to a succeeding paper.

(ii) Distribution of maximum amplitude

The value "*m*" in Ishimoto-Iida's formula [1939]

$$N(a)da = ka^{-m}da ,$$

was examined at each station. As well-known, the value of m is considered to be 1.9 or so for usual cases, except some special cases such as the volcanic earthquake. Fig. 4 shows the results at three stations. These results are considered to agree with those obtained so far by many authors. It is to be noted that this relation about

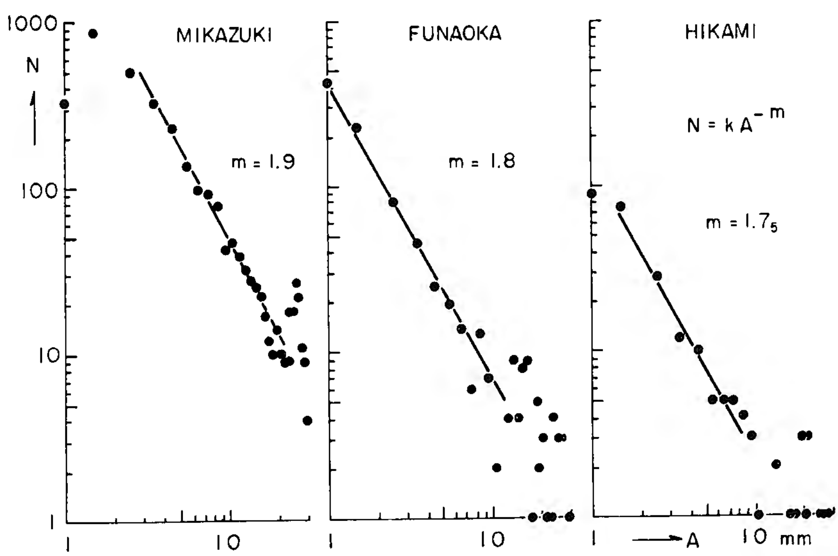


Fig. 4. Maximum trace amplitude distributions at three stations.

the maximum amplitude is also valid for a range of microearthquakes whose magnitudes are between, say, 3 and 0.

4. Distribution of near earthquakes observed at three stations

Numbers of earthquakes observed at three stations are very large, as shown in Table 2. As recognized from P-S time distribution, however, most earthquakes have their origins outside our observation network. Therefore, in the following treatment, we shall tentatively confine ourselves to the earthquake P-S time of which is shorter than 20 sec. at every station, and moreover, we shall pick up only the earthquake observed simultaneously at all of three stations.

Table 2.

	Mikazuki	Funaoka	Hikami
Jan. 1964	498		
Feb.	348		
Mar.	430		
Apr.	425		
May	465	196 (23 days)	
June	326	289	
July	367	245	
Aug.	416	295	159 (20 days)
Sept.	412	225	102 (13 days)

We shall first determine positions of their foci. Various methods are used to determine the hypocenter, but, needless to say, we have no general method to be applicable for all cases. We must adopt any method which is considered best for respective case, taking into consideration the span of network and the crustal structure in the area concerned. The crustal structure in this area was investigated by some authors (Kishimoto, [1955]; Mikumo et al., [1961]). Researches on the crustal structure in this district are planned to be made using the seismograms from our network, but here we shall provisionally assume the structure in Fig. 5, proposed by the Research Group for Explosion Seismology, cited above (Mikumo et al., [1961]). Theoretical

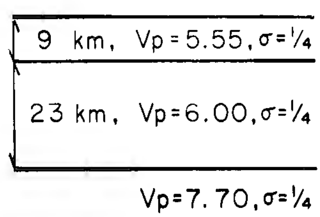


Fig. 5. Structure assumed. (after Mikumo et al., [1961])

P-S times being calculated from this structure for various focal depths, then we can determine the position of epicenter and focal depth from the observed P-S time by the trial and error method. The result is shown in Fig. 6, in which circle, semi-black circle, and dot correspond to focal depths of 0∼10, 10∼20, and 20∼30 km, respectively. Some systematic tendency seems to be recognized in Fig. 6. First, relatively

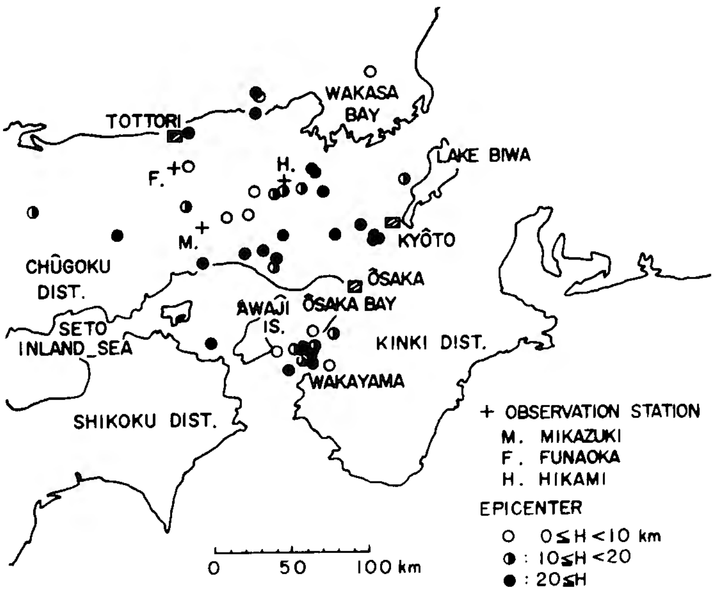


Fig. 6. Distribution of hypocenters.

many earthquakes occur along a line connecting both Hikami and Mikazuki stations. Another line along which earthquakes frequently occur is that connecting the Lake Biwa and Osaka Bay, and probably extending westward. The latter was already stated by Okano and Hirano.*) There seems to be a relatively aseismic belt-like area between the two lines above. Along the former line, distribution of focal depth seems to have a certain interesting aspect. Near Hikami, foci are rather deep-seated, mainly in the second layer. On the other hand, the focal depth is shallow on the western half of this line, mainly in the first layer. As to whether this result about focal depths is real or not, we must await accumulation of more data, but, anyway, this is an interesting phenomenon which is to be investigated, particularly in relation to the crustal and geological structures.

Focal depths of earthquakes along the latter line above-mentioned were estimated relatively deep in the second layer. However, this result may be partly due to

*) A lecture at the meeting of the Seismological Society of Japan, May 1964.

the unsuitableness of assumed structure, namely, the assumed horizontally layered structure of constant thickness may be unreasonable to apply to such a wide area. Also, another possibility for explanation may be a mixing of the direct and refracted waves. In order to make these points clear, it is necessary to take the observation at closer stations together into consideration, and to analyse their wave forms carefully. Besides those, there are several spots where earthquakes occur in a group, for instance, Wakayama City area and the northern region of Hyogo Pref. It is interesting to note that the latter spot corresponds to an area where the aftershocks of the great Kita Tango earthquake in 1927 prevailingly occurred. On the other hand, it is also interesting to see that there are relatively aseismic areas neighbouring with active areas. The most remarkable ones are the belt-like area mentioned above, and a triangular region inside our network.

We shall next estimate approximate magnitudes of these earthquakes. Since only the vertical seismograph is used at Hikami station, the maximum amplitude was read on the vertical seismogram at two other stations, too. The period of the phase of maximum amplitude is, with no exception, in the range of 0.3 to 0.4 sec., so that we could safely assume the velocity sensitivity of observation system was constant. Fig. 7*) shows a relation between epicentral distance and maximum trace amplitude in mm, in which all earthquakes and stations are plotted on the same graph without considering their origin mechanisms and magnitudes. Therefore, this graph is expected to give approximate upper and lower limits of observed maximum amplitude, and their general tendency of attenuation with distance. Two dotted lines show the upper and lower limits, respectively. Taking the sensitivity of instrument used and the original definition of magnitude into consideration, the upper and lower boundaries of magnitude of earthquakes analysed here are estimated from Fig. 7 as 2.3 and 0.7, respectively. If we assume that an earthquake occurs very close to any one station and its maximum trace amplitude is 0.3 mm which is lower limit of reliably observable amplitude on our seismogram, its magnitude corresponds to −0.5. This means that we can observe by the present observation system as small earthquakes as $M = -0.5$. It is to be noted here that the present seismicity map in Fig. 6 corresponds to some magnitude range, say, 0.7 to 2.3. Earthquakes with magnitude between 0.7 and −0.5 which are to be plotted in a position between the lower dotted line and the broken one, occupy large part of earthquakes observed at any one station. Therefore, it is necessary to simultaneously investigate the distribution of smaller earthquakes by a denser observation network, in order to obtain the more precise seismicity map.

---

*) This graph was also shown by Okano and Hirano at the meeting of the Seismological Society of Japan, May 1964.

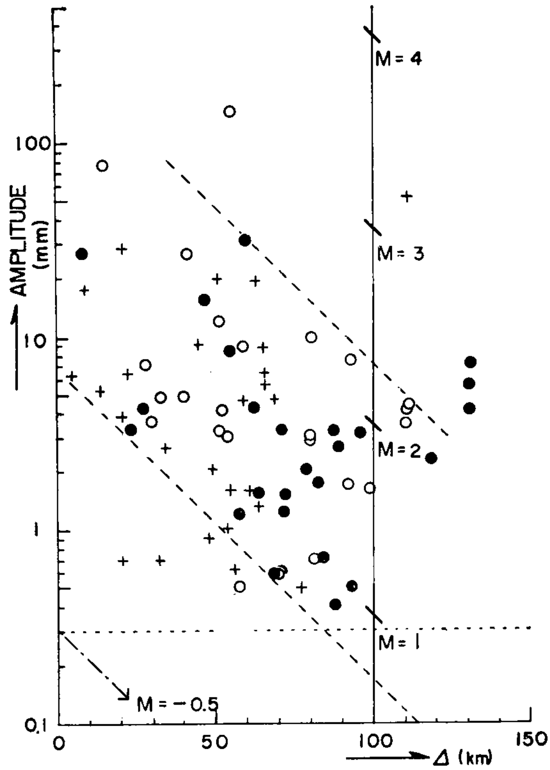


Fig. 7. Relation between the epicentral distance and maximum trace amplitude.

5. Some other results

(i) Attenuation of maximum amplitude with distance

As stated in the previous section, all data were plotted on the same graph regardless of the difference in their focal mechanism, in order to obtain the approximate

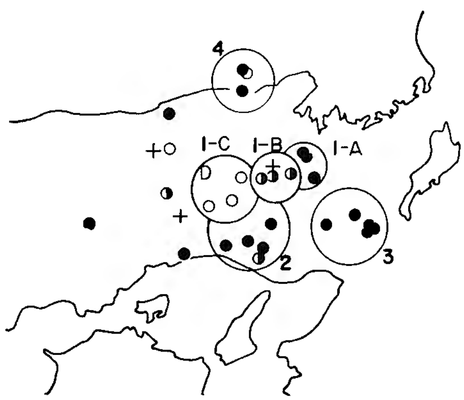
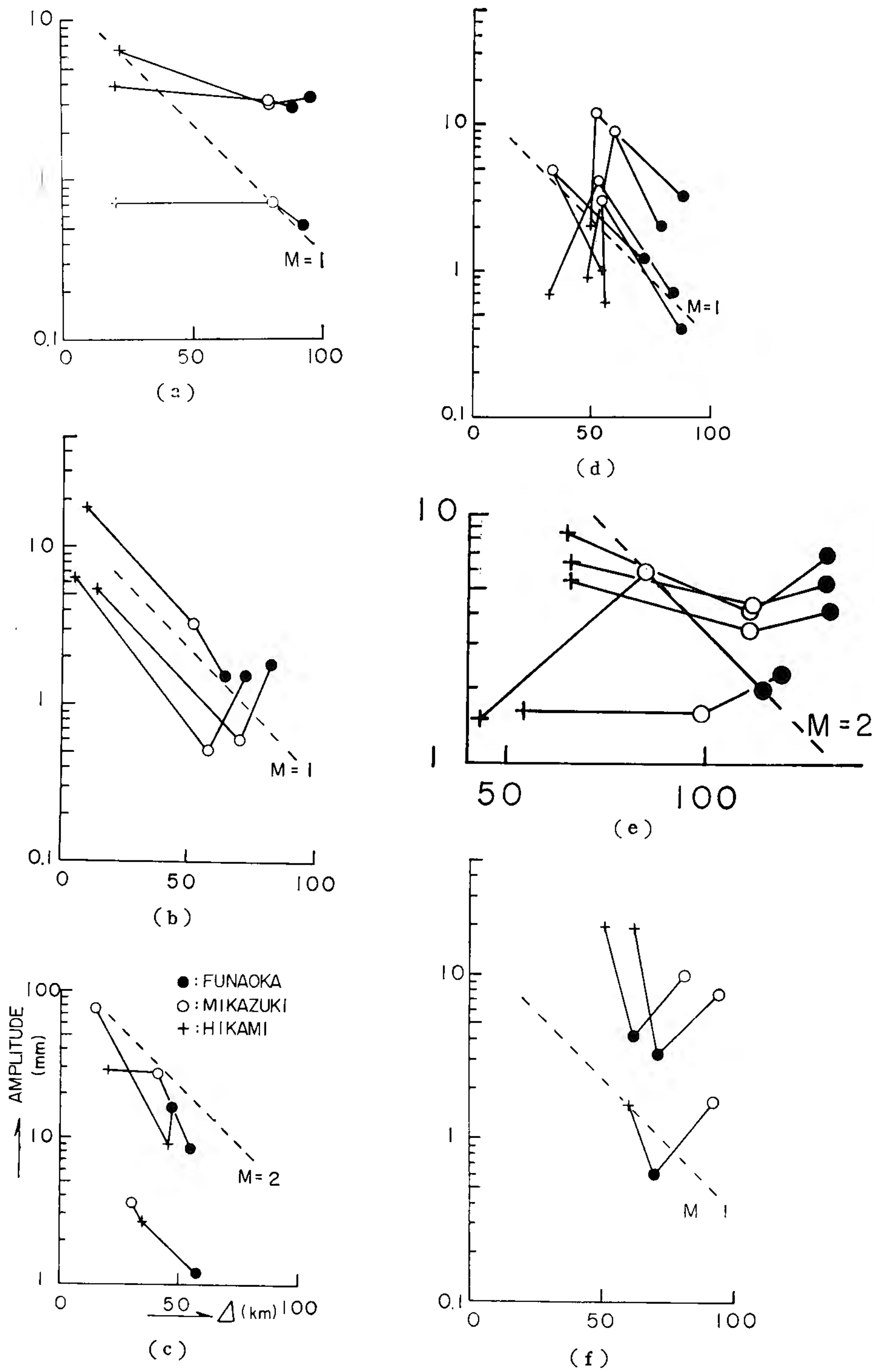


Fig. 8. Classification of epicentral area.



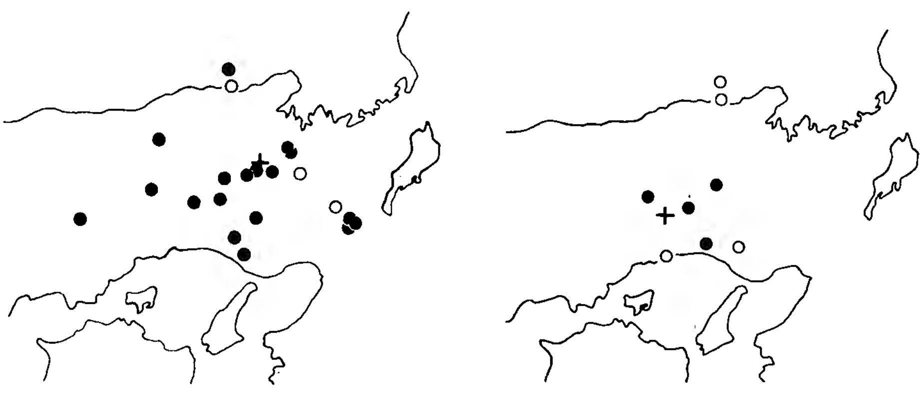
Figs. 9a~9f. Relation between the epicentral distance and maximum trace amplitude in respective groups.

magnitude of earthquakes analysed. It is necessary, however, to examine this problem in more detail, for example, as to their focal depths, magnitude, and epicentral regions, if we wish to know an exact aspect of attenuation and to estimate an exact magnitude. Data are too little to do such a detailed examination, so that we shall give some preliminary treatments in the followings.

Earthquakes used were classified into 6 groups (1A, 1B, 1C, 2, 3, and 4), as shown in Fig. 8, corresponding to their epicentral regions. In each group, focal depths are considered nearly the same. A relation between the maximum amplitude and epicentral distance was given for each group in Figs. 9a to 9f, in the same manner as that in Fig. 7. As for group 1A (Fig. 9a), situated on east of Hikami, the attenuation of amplitude is small for 3 earthquakes the focal depth of which is rather deep. In groups 1B and 1C (Figs. 9b and 9c), the attenuation seems relatively rapid. In three groups 2, 3 and 4 (Figs. 9d, e, f), we can see that each group has respective characteristics which are different from each other. If this similarity between earthquakes belonging to the same group is not occasional but real, it may be due to the fact that the focal mechanism and the wave path are nearly the same for each group.

(ii) Push-pull distribution of the initial P motion

The focal mechanism of microearthquakes is one of the main interests of this project. One of the most effective methods to approach the focal mechanism is to estimate the movement at the origin by analysing the so-called push-pull distributions of P and S waves. Application of this method to microearthquakes of enormous number will greatly contribute to this problem. For this reason, the following trial was made as a first approximation. As shown in Figs. 10a and 10b, directions of the initial P motion of earthquakes shown in Fig. 6 were mostly push (dot) at Hikami, with only 3 pull motions (circle) which were distributed on a line passing through



(a) (b)

Figs. 10a~10b. Push-pull distribution of the initial P motion.

Hikami from NW to SE. On the other hand, at Mikazuki, some earthquakes gave push-direction and some others pull-direction as shown in the figure, although the data are insufficient compared with at Hikami.

This result is considered to suggest some systematic, tectonic force acting at these epicentral regions. This problem is to be examined in more detail, and should be treated with in relation to other quantities, such as magnitude, focal depth, crustal structure and crustal deformation.

6. Concluding remarks

A preliminary report was described regarding microearthquakes observed at three stations of the Tottori Microearthquake Observatory.

P-S time distributions at three stations show respective characteristics which seem somewhat different from each other. Seismicity of microearthquakes is considered nearly the same as that of a little larger earthquakes which have been observed by the network of the Japan Meteorological Agency.

Distribution of the maximum amplitude at any one station is also the same as those having been mentioned by many authors.

Distribution of hypocenters of earthquakes observed simultaneously at three stations showed that there are some areas with particularly high seismicity, and, on the other hand, some aseismic regions neighbouring with the former active areas. This distribution is considered a seismicity map of earthquakes whose magnitude is in between 0.7 and 2.3.

The "push-pull distribution" of the initial P motion showed some special pattern of tectonic force acting in this area.

References

Gutenberg, B. and C. F. Richter, 1949; Seismicity of the earth and associated phenomena, Princeton Univ. Press.

Ishimoto, M. and K. Iida, 1939; Observations sur les seisms energistre par le microseismograph construit dernierement (1), Bull. Earthq. Res. Inst., 17, 443.

Kishimoto, Y., 1955; Seismometric investigation of the earth's interior. Part II. On the structure of the earth's crust, Mem. Coll. Science, Kyoto Univ., A, 27, 243-288.

Mikumo, T. et al., 1961; Crustal structure in central Japan as derived from the Miboro explosion-seismic observations, Part 2, Bull. Earthq. Res. Inst., 39, 329-349.