A JOINT RESEARCH ON MICROTREMORS IN FUKUI BASIN, JAPAN - FOR SITE EFFECTS EVALUATION DURING THE 1948 FUKUI (JAPAN) EARTHQUAKE

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SUMMARY

A joint research project on application of microtremors has been promoted since 1997 with the support from the Ministry of Education, Science and Culture, Japan. One of principal research activities in 1997 was to have made joint microtremor measurements in the Fukui basin, Japan. Because the 1948 Fukui earthquake was really a catastrophic disaster including 3,769 deaths and 36,200 totally collapsed houses, but there was only a few information about seismic, geological and geotechnical data in the area. The joint microtremor measurements provided additional information such as the distribution of predominant period, the distribution of amplification characteristics due to local soil conditions, although we must be very careful about the fundamental characteristics of microtremors. Such results enabled us to discuss the site effects comparing them with the damage distribution during the 1948 Fukui earthquake.

INTRODUCTION

Fundamental characteristics of microtremors and the manner of their application to earthquake engineering have been discussed quite often since the 1985 Mexico earthquake [Kobayashi et al., 1986, Lermo et al., 1988, e.g.]. In case of the Mexico basin during the 1985 Mexico earthquake, the characteristics of microtremors seemed very clear so that the comparison between strong motion records and measured microtremors at the same places showed good agreement each other [Kobayashi et al., 1986]. But in general, microtremors should not be expected so well because local soil conditions are not so simple. For this reason, several trials have been made in different conditions with different approaches after a pioneering study by Kanai and Tanaka(1961). Kagami et al.(1986), for example, evaluated a two-dimensional site effect in the San Fernando valley with long-period microtremors taking spectral ratios between a referencial rock site and sediment sites. Nakamura (1989) proposed to take horizontal over vertical spectral ratios (H/V) of microtremors as a substitute for the transfer function of subsurface ground, although there were so many opinions that the physical meaning of taking H/V ratio had not been made clear. This method has been examined by Lachet and Bard (1994) with numerical and theoretical investigations. A joint measurement of microtremors has been examined in the Ashigara valley, Kanagawa prefecture of Japan, to confirm fundamental characteristics of microtremors and to discuss the results among the participants, as one of research activities on the effects of surface geology on seismic motion (ESG)[Seo, 1992]. The similar examinations were also attempted in the Kushiro area, Hokkaido of Japan, after the 1993 Kushiro-oki earthquake [Seo, 1994a, 1994b and 1995], and in the Kobe-Hanshin region after the 1995 Hyogoken-Nanbu earthquake [Seo et al., 1996, e.g.].

In this paper, the further trials will be made in and around the Fukui basin, Japan. First of all, the 1948 Fukui earthquake should be reviewed very quickly. Secondly, fundamental characteristics of microtremors will be made clear with a continuous measurement. Thirdly local site effects will be discussed with the results of mobile

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measurements of microtremors. And finally such local site effects obtained from microtremors will be compared with the damage distribution during the 1948 earthquake.

THE 1948 FUKUI EARTHQUAKE

The 1948 Fukui earthquake is often compared with the 1995 Hyogoken-Nanbu (Kobe) earthquake, because it brought a tremendously heavy damage including 3,769 deaths and 36,200 totally collapsed houses in Fukui city and its surrounding basin area. It was really a typical case that a very near and very shallow earthquake with magnitude 7 hit a local society. The damage concentrated within the basin, then local site conditions might be very effective to amplify the earthquake ground motion. Unfortunately there was no strong motion record in the Fukui basin at that time. Moreover geological and geotechnical data are not enough up to now. According to a few technical reports [General Surveys Branch, 1949, Tsuya, 1950, e.g.] which described the detail about damage degrees and their distribution, the totally collapsed ratio of houses distributed from 60% to almost 100% in the most of areas in the basin. As we can see the damage distribution and the geological condition in Fig.1, a sudden decrease of the totally collapsed ratio appeared just on the border between the basin and surrounding mountains, then there was no totally collapsed house outside of the basin.

JOINT MEASUREMENT OF MICROTREMORS

In such condition, we have planned a joint microtremors measurement in and around the Fukui basin with the cooperation by the research members for this purpose. The urgent subject of this measurement was to make clear the underlaying basin topography, P- and S-wave velocity profiles in the sediments, and the distribution of predominant period in the district. Then after getting such basic information, the final goal must be to estimate the characteristics of seismic motions and to explain the damage degrees and their distribution during the 1948 earthquake. The joint measurement was carried out from August to October in 1997 by taking into account the following research subjects.

1) Microtremors array measurements and the inversion analysis should be made at several sites to estimate P- and S-wave velocity profiles of the basin structure. The thickness of the soft sediments was expected from 100m to 400m over the basement rock.

2) Continuous measurements of microtremors and microseisms should be made at a rock site and at a sediment site to confirm the source characteristics and the stability (reliability) of microtremors.

3) Measurements of long-period microtremors should be made to understand the basin effect on the long-period earthquake motions including the mechanism of surface wave excitation.

4) Temporal measurements of short-period microtremors at about 400 to 500 points should be made to cover every towns and villages in order to explain the damage distribution during the 1948 earthquake.

5) Very dense measurements of short-period microtremors should also be planned in several towns to explain the different damage rates during the 1948 earthquake, and to propose seismic microzoning procedures for the future city planning.

6) Array measurements of microtremors should be made across the basin and the estimated fault area of the 1948 earthquake to discuss the underlaying topography and to confirm the quick decrease of the damage ratio on the border between inside and outside of the basin.

7) Comparison between measured microtremors and observed seismic motions should be carried out, because there are several strong motion stations recently prepared by the national and the local governments such as the K-NET.

After the joint measurements, a technical meeting was held to discuss the preliminary results. Although the final results about individual subjects listed above should be made open in the near future, the following items in this paper were considered to be the most fundamental ones through the discussion in the meeting. They are 1) Stability of microtremors, 2) Identification of microtremors from microseisms, 3) Evaluation of site effects from microtremors, and 4) Comparison of the characteristics of microtremors with other information.

STABILITY OF MICROTREMORS

The stability of microtremors was examined by means of continuous measurements every hour for about one week and every four hours for about one month at reference stations. One of the reference stations was installed at Fukui University (FKU, see Fig.1) on a sediment site within the Fukui basin, where the comparison between microtremors and earthquake ground motions can be expected. The other one was installed at Mikuni High School (MKH, see Fig.1) on an edge of the Fukui basin near the Japan sea. A set of 3-component velocity-type long-period seismometers with 10s in natural period was used at each station. Some of examples about measured microtremors at FKU and MKH are shown in Figs.2a and 2b, respectively. In each figure, 2-D horizontal spectra are shown every four hours to show their daily variation. It should be noted that the daily variation due to human activities could be eliminated when we take horizontal over vertical (H/V) spectral ratio as shown in Figs.3a and 3b. But in this case, we must be careful because the shape of these spectra is different between 2-D horizontal components (Fig.2) and H/V spectral ratios (Fig.3).

If we want to obtain amplification characteristics of sedimentary basin, we may take spectral ratios between FKU inside the basin and MKH outside the basin with horizontal components as shown in Fig.4. In this case also, it looks very difficult to find out a physical meaning in it. Because the resultant spectral ratio (this is regarded as amplification ratio in the sediments) shows very high value compared with Fig.5. Actually Fig.5 is providing a helpful information as a reference. The calculated transfer function in the figure was evaluated with a S-wave velocity profile which had been estimated by the inversion analysis of Rayleigh waves through a microtremor array measurement [Yamanaka et al., 1998]. It fits very well with the spectral ratio of observed seismic motions on the ground surface and the Tertiary basement, 175m in depth, during the 1995 Hyogoken-Nanbu earthquake. As we have discussed the similar problem before [Seo, 1992], the quite different characteristics of microtremors between inside and outside the basin will make something like a condition dividing by zero.

For further details, the variation of a) spectral amplitudes and b) predominant periods in the shorter period range (shorter than 1s) is shown for FKU in Fig.6. From these figures, very systematic daily variation in amplitude and very stable predominant period might be pointed out at FKU. Even at MKH, although we omitted the figure to save the space, the similar tendency can be noticed. On the contrary, another component of microtremors in the period range longer than one second has no such daily variation in its amplitude as shown in Fig.7a. It seems to have a correlation with the sea wave height. Such component is no longer microtremors but some kind of microseisms. The sea wave height in these figures was measured in Mikuni Harbor only a few kilometers away from MKH and about 15km away from FKU.

From these fundamental works, microtremors due to human activities, with daily variation in amplitude but very stable characteristics in predominant period, were identified from microseisms. Microseisms are independent from human activities and probably due to sea wave, although it was not so clear because the sea wave was quite calm during the measurements. We also compared such variation of microseisms with those of atmospheric pressure and wind velocity as shown in Figs.8 and 9, respectively. But we could not find any relationship between them, although the variation of atmospheric pressure and wind velocity tended to fit each other very well.

SITE EFFECTS FOUND IN MICROTREMORS

Mobile measurements of microtremors were carried out parallel to the continuous measurements with the similar instruments. Measuring points are distributed along the lines A, B, C and D as shown in Fig.1. Figure 10 shows the distribution of predominant period in measured microtremors as the most fundamental information. It looks very clear that the longer period predominates always in the sedimentary basin, and it does not appear outside of the basin (MKH, B01, C06, for example). The measuring points B07 and D03 were located on the local outcrop of the Tertiary basement, and such local condition made their predominant period very short. In relation to above, the distribution of Fourier amplitude corresponding to each predominant period was shown in Fig.11. The distribution of the highest H/V spectral ratios can also be drawn in Fig.12. But in this case we have a serious problem that the values of the points C06 and D03 on the stiff soil condition are equal or more compared with those on the soft sediments. Distribution of microseisms due to sea wave can be obtained as shown in Fig.13 by taking the average of Fourier amplitude between 1s and 10s in period range. We are sure that the figure is providing some important information about the deeper underground structure although we cannot explain the physical meaning so well.

DISCUSSION AND CONCLUDING REMARKS

As we have just accomplished the preliminary analyses, we cannot conclude every result at this moment. But we are finding several interesting facts from the preliminary analyses as follows.

Microtremors due to human activities were successfully identified from microseisms due to a natural phenomenon. The daily variation of amplitudes, getting larger in daytime and getting smaller in nighttime, and very stable predominant periods were found in microtremors those had been pointed out by Kanai and Tanaka (1961). Such characteristics were significant only in the sedimentary basin area. On the other hand, microseisms were compared with sea wave height, and they showed good correlation each other. But in general speaking, the activity of microseisms was not clear everywhere in these measurements. As one of reasons, it should be noted that sea wave was rather calm during the measurements. It means that there was almost no excitation in the period range longer than one or two seconds. Therefore we are not sure about the longer period characteristics of the basin. To solve this problem, we will need further measurements in the worse weather condition.

The reference station FKU is very important for us because we can expect simultaneous seismic data between the ground surface and the Tertiary basement, 175m in depth. The problem at this station is that we have not obtained a good agreement between Fig.2a and Fig.5. The predominant period around 0.6s in Fig.2a should be related with the second peak in Fig.5. But strangely enough, the most fundamental period around 2s in Fig.2a looks longer than the first peak in Fig.5. As we have already discussed above, the component around 2s in Fig.2a is no longer microtremors but microseisms, and the human activity around the area was not enough to excite whole of the sedimentary layers up to 175m in depth. The component with 2s in period looks very sensitive to the activity of distant sea wave. We are also hesitating to take horizontal over vertical (H/V) spectral ratio of microtremors as shown in Figs.3, and 12. It may be true that the daily variation of amplitude can be eliminated like Fig.3 and that we find some kind of similarity between Fig.11 and Fig.12. The problem is whether we can find a physical meaning of this fact or not.

We can expect measured microtremors to explain the damage distribution during the 1948 Fukui earthquake, because they showed higher amplitude and clear predominant period only in the sedimentary basin area. Results from the dense measurements of microtremors will be very helpful to do this work more precisely. Comparison of such results with geotechnical data and seismic motion records will be also expected. Some of observed seismic records was already made open by Fukui University for this purpose. As one of examples is shown in Fig.5, they have been observed during the 1995 Hyogoken-Nanbu earthquake and its aftershock on the ground surface and the Tertiary basement of -175m in depth. At this moment we only point out the similarity of the characteristics between observed seismic motions and estimated underground structure by means of microtremors array measurement (Yanmanaka et al., 1998) as shown in Fig.5.

In the near future after solving the problems mentioned above, we need to compare such results with those in the Kobe-Hanshin district. Because the features of the 1995 Hyogoken-Nanbu (Kobe) earthquake are used to be compared with those of the 1948 Fukui earthquake quite often. It may be true there are some common factors in both earthquake disasters that a very near and shallow earthquake with magnitude 7 brought a heavy damage in the neighboring area. But we must be very careful to confirm local site effects and vulnerabilities of the society for evaluating the damage during an earthquake.

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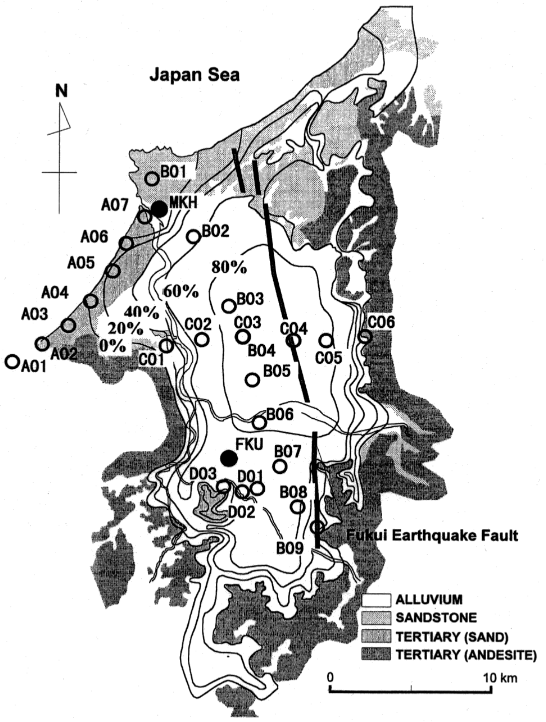

Fig.1 Surface geology and totally collapsed damage ratio in percent during the 1948 Fukui earthquake. Microtremors station is indicated with solid circle for continuous measurement and with Open circle for mobile measurement.

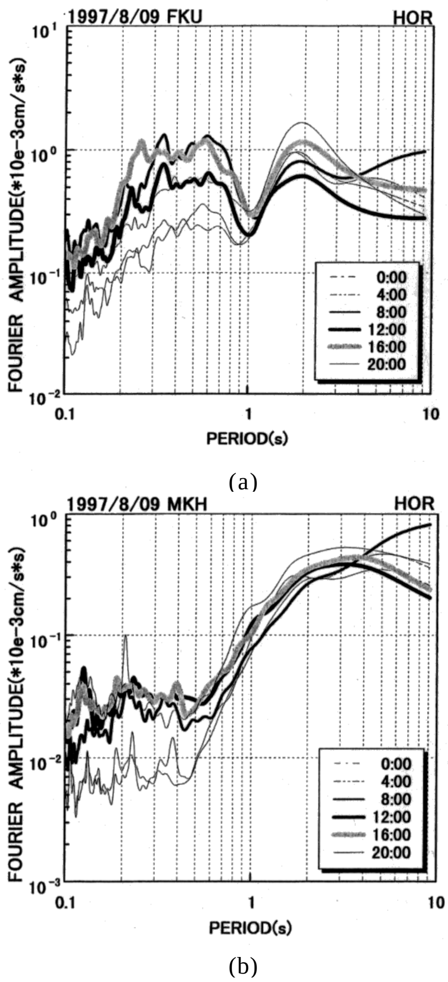

Fig.2 2-D horizontal Fourier spectra of microtremors with a continuous measurement at FKU(a) and at MKH(b).

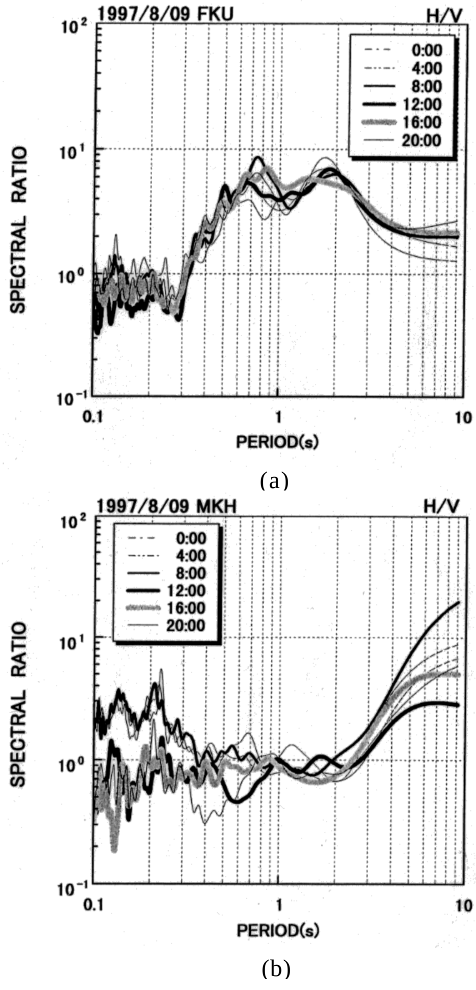

Fig.3 Horizontal over vertical (H/V) spectral ratios of measured microtremors at FKU(a) and at MKH(b).

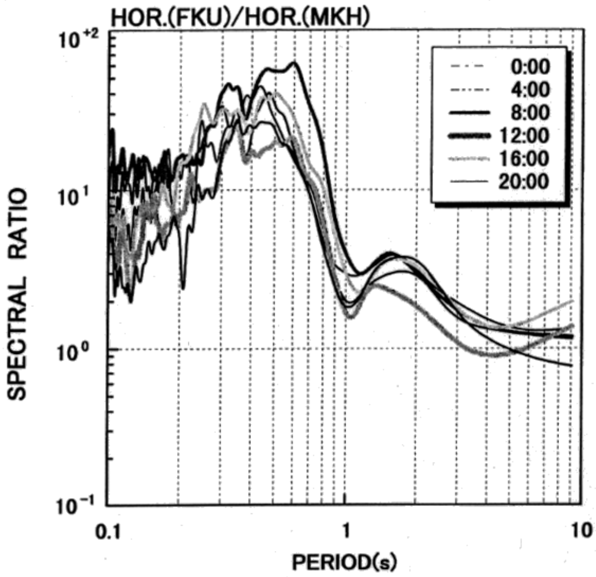

Fig.4 Spectral ratios of 2-D horizontal microtremors between FKU and MKH.

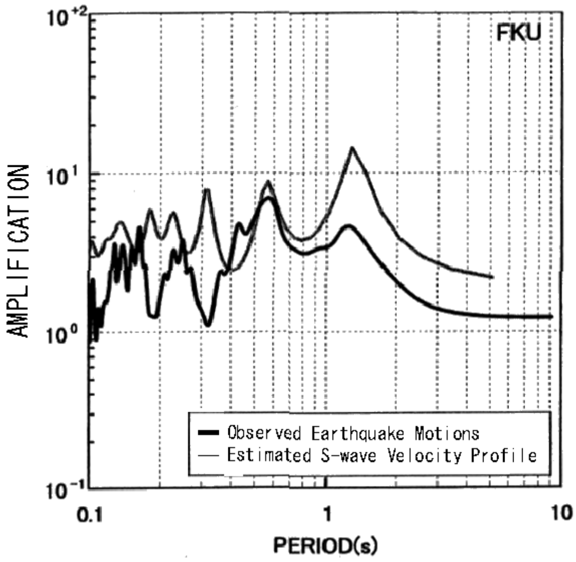

Fig.5 Spectral ratio of observed seismic motions on the ground surface and the Tertiary basement during the 1995 Hyogoken-Nanbu earthquake, and calculated transfer function based on S-wave velocity profile through a microtremor array measurement.

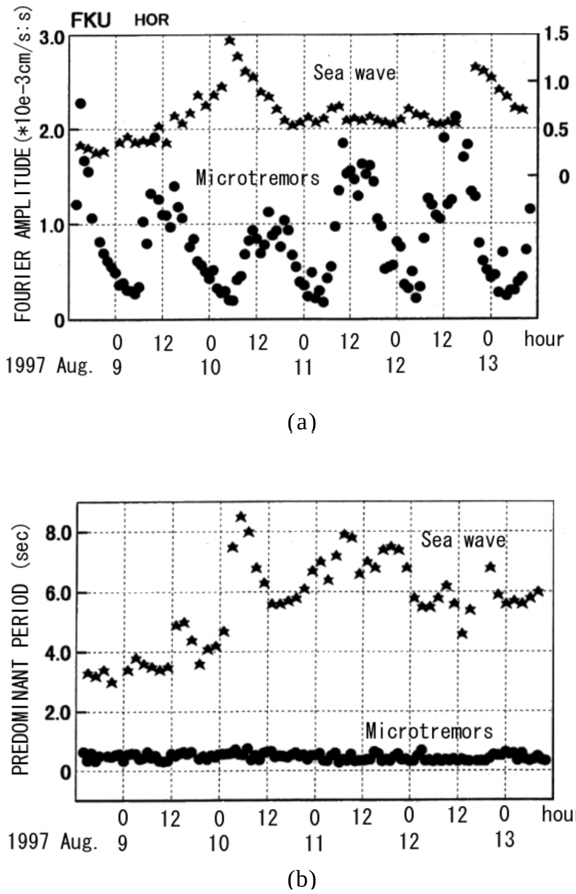

Fig.6 Variation of Fourier amplitude(a) and predominant period(b) in short period microtremors at FKU, those were compared with sea wave height in Mikuni harvor.

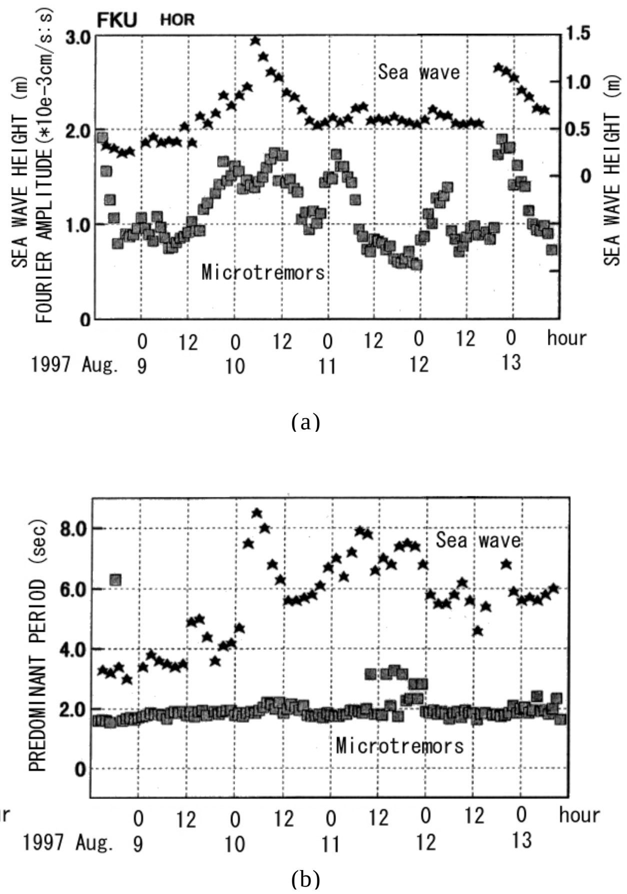

Fig.7 Variation of Fourier amplitude(a) and predominant period(b) in long period microtremors (microseisms) at FKU, those were compared with sea wave height in Mikuni harvor.

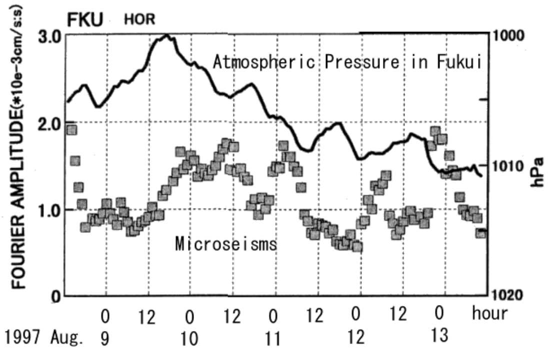

Fig.8 Variation of microseisms at FKU compared with those of atmospheric pressure.

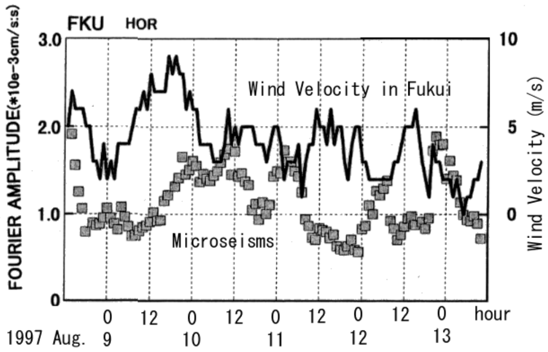

Fig.9 Variation of microseisms at FKU compared with those of wind velocity.

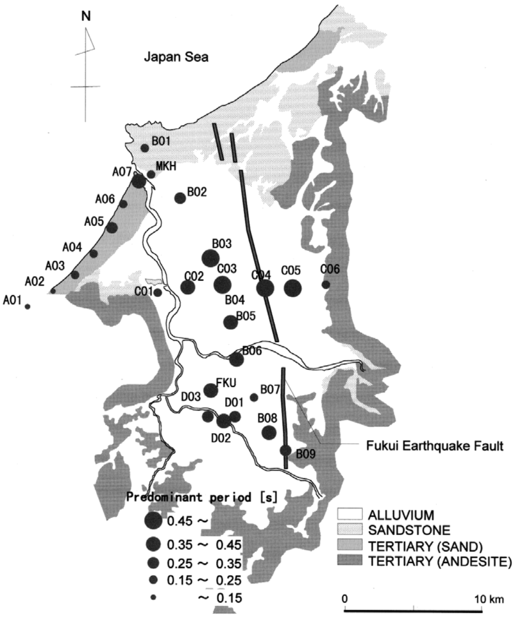

Fig.10 Distribution of predominant period in short period microtremors.

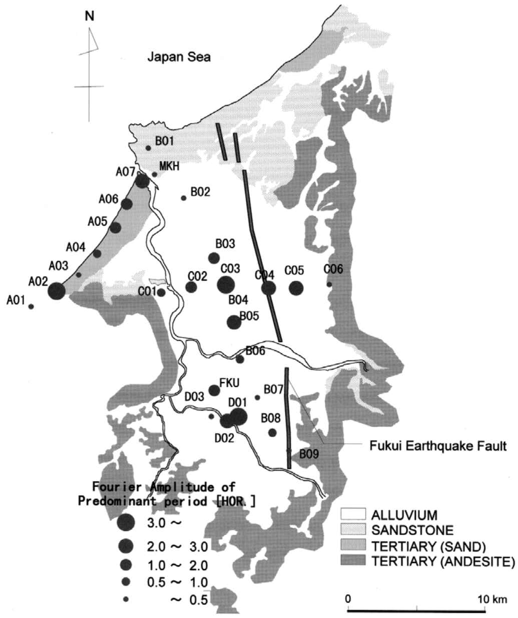

Fig.11 Distribution of Fourier amplitude corresponding to each predominant period in Fig.10.

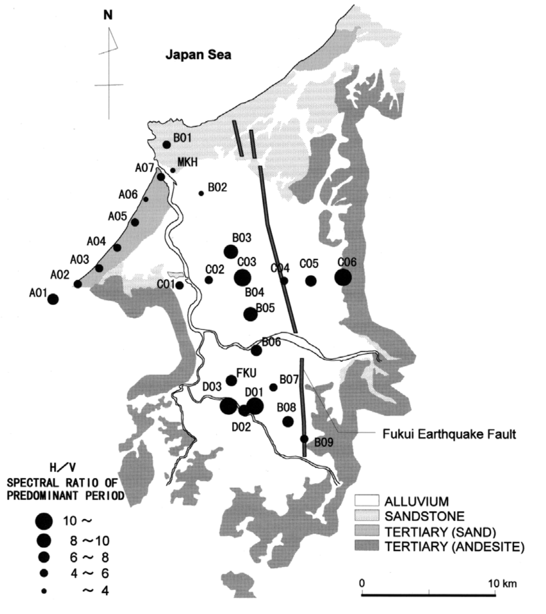

Fig.12 Distribution of highest H/V spectral ratios in short period microtremors.

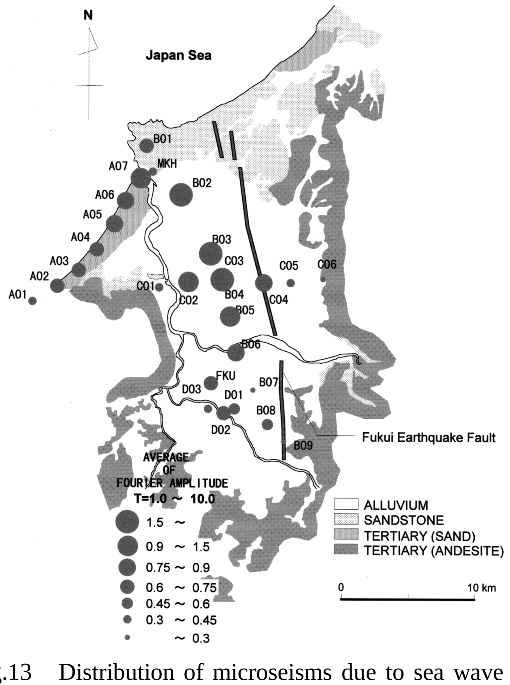

Fig.13 Distribution of microseisms due to sea wave by taking the average of Fourier amplitude between 1s and 10s in period range.