LONG-PERIOD GROUND MOTION SIMULATION IN FUKUOKA AREA, JAPAN USING A 3D MODEL BY MICROTREMOR ARRAY EXPLORATIONS AROUND SCHOOL SITES

Nobuyuki Yamada[1] and Hiroaki Yamanaka[2]

1 Assoc. Professor, Dept. of Science Education, Fukuoka University of Education, Japan
2 Assoc. Professor, Dept. of Environmental Science and Technology, Tokyo Institute of Technology, Japan
Email: nyamada@fukuoka-edu.ac.jp, yamanaka@depe.titech.ac.jp

ABSTRACT :

In this study we carried out long-period ground motion FD simulations during a middle magnitude earthquake using the 3D basin model by some previous studies in the Fukuoka area, Japan. Because the model has some interpolations in space, our purpose is a reconstruction of the model based on the comparison with synthetic records and observed one, and microtremor array explorations of the area around schools including a contribution to science education in near future. Although the long-period modeling indicated a reasonable reproduction of the observed records in generally, some disagreements of the records at the basin site existed. The microtremor explorations leaded some 1D S-wave velocity structures; the basin maximum depth with 2 layers of the Vs 0.8km/s and 1.6km/s is about from 0.6 to 0.8km. These results help us to reconstruct of the 3D basin model, we will be able to prepare the renewed model.

KEYWORDS: Long-period ground motion, 3D basin model, FD simulation, Fukuoka plain, Microtremor array measurement around school sites

1. INTRODUCTION

The 2005 west off Fukuoka Prefecture Earthquake (M_J 7.0) had heavy damaged in the area near the source fault. The earthquake struck a mega city more than one million population since 1995 Hyogoken Nanbu Earthquake. The source region of the 2005 earthquake located in an extension of Kego fault line under the Fukuoka city. The Headquarters for Earthquake Research Promotion published a long-term evaluation of the probability of the potential of earthquake for Kego active fault which has a little higher probability of earthquake occurrence more than the other active fault in Japan (e.g., Hashimoto, 2008). And strong ground motion prediction in Fukuoka area for scenario earthquakes of the fault have been experimented (e.g., Kawase *et al*, 2003; Morikawa *et al.*, 2008). Although the used 3D model has integrated subsurface structure information then, we need a more accurate 3D model for the evaluation of ground motion. Recently, the subsurface structure in the Fukuoka basin is surveyed by geophysical exploration (e.g., Mori *et al.*, 2007; Hirano *et al.*, 2007; Yamada, 2008), the case is increasing.

This article is described about basin structure and 3D model made by some previous studies in the Fukuoka area, Japan and ground motion simulation using the model. In addition, our results of subsurface structure exploration by microtremor array measurement in the area are reported.

2. 3D VELOCITY MODEL IN FUKUOKA AREA

Fukuoka area locates at the northern part of Kyushu Island in Japan Island. The location of target area is shown by Figure 1 with dotted square. The basin size of Fukuoka area is not so deep and large in comparison with Kanto basin and Osaka basin. There are some 3D models in this area, too (e.g., Morikawa *et al.*, 2008). Digital 3D model data used in this study is made by Fujiwara (personal communication) which is based on the model used by Morikawa *et al.* (2008). The model has mainly 2 velocity layers of the Vs (S-wave velocity) 0.6 and 2.1km/s in the basin framed by basement of Vs 3.1km/s. Figure 2a and 2b show the boundaries depth distribution of the each layer and figure 2c shows the model profile. A maximum depth is 0.12km and 1.60km respectively, and the point locates below at Meinohama near the central Fukuoka city and in the Hakata bay. Although one of the features of this model is the layer depth detailed data each about 1km mesh, the original information of subsurface structure survey of the model has some uncertainties. Because there are a few explorations of the deep sedimentary structure around the northern part of Kyushu Island (e.g., Morijiri *et al*., 2002), many space interpolations have been done in the 3D model in our guess. Even if there are some reports about the subsurface structure, almost the data or information is explored for mining coal around Fukuoka and Chikuhou coal mine away from the target basin area, now, these fields had been closed. Therefore, it is not too much to say that this area is a lack of underground information for ground motion estimation, especially the basin deep structure, in spite of more than one million people live in the area of Fukuoka city.

The other, the shallow sedimentary exploration data by boring exist at very many sites, there is a detail shallow part 3D model. Figure 3 shows a one of the thickness contour map of Quaternary sediment by Satoh and Kawase (2006). The maximum depth of surface sediment of under Vs 0.3km/s has about 50m around north-eastern part of Kego fault. Naturally, there is not only the layer but also some low velocity layers less than 0.3km/s. For example, the velocity structure at FKO006 by K-NET observation in Figure 1 and 3 has the Vs 0.10, 0.13, 0.15, 0.18 and 0.32km/s layers, the depth of the bottom of Vs 0.32km/s correspond to the top of the Vs 0.60km/s in the contour map of Figure 3.

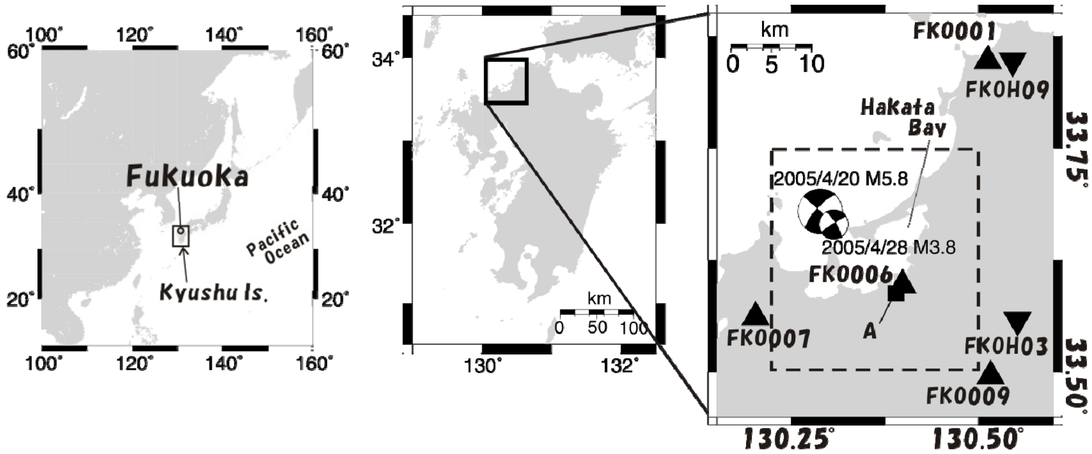

Figure 1. Map of the target area around Fukuoka. Dot square is ground motion simulation model area.

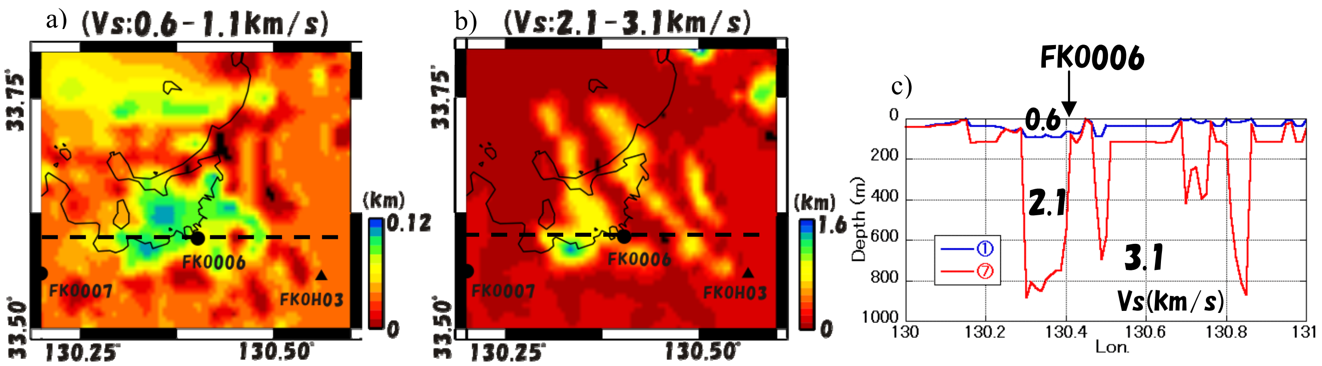

Figure 2. Boundary depth distributions and model profile of the dotted line in left figure by used 3D model data.

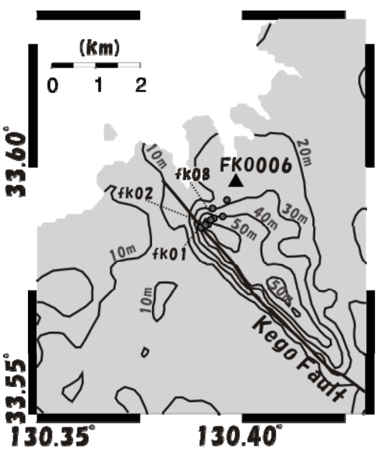

Figure 3. Contour of Quaternary-sediment thickness touched in figure by Satoh and Kawase, 2006. Dots show the location of aftershock observations of the 2005 west off Fukuoka Prefecture Earthquake by Yamanaka *et al.* (2005). Black triangle is a location of K-NET station (FKO006).

3. LONG-PERIO GROUND MOTION SIMULATION

To check a performance of the sedimentary 3D basin model digital data, the ground motion during one of the aftershocks of the 2005 Fukuoka earthquake simulated with finite difference method (FDM). The analysis region about 30km width shows in Figure 1 (right). The model has 6 velocity layers as Table 1 with physical parameters. The first surface layer of Vs 0.4km/s referring to Satoh and Kawase (2006) in figure 3 is set in the 3D model, although 1st layer depth is 30m because of the simulation restriction of free surface condition and grid size of FD model. The flat boundaries from the 4th to 6th layer of referring to Asano and Iwata (2006) are set in the model.

Simulation parameters for FDM and the source parameter are shown in the Tables 2 and 3, respectively. The minimum FD grid space is used in 60m with rectangular grids for z-direction. The lower period set 0.8s from the relation between minimum velocity and grid space. A target earthquake is M_J 3.8 event at the 28 April 2005. In addition, it is the maximum magnitude earthquake (M_J 5.7) at the 20 April 2005 of the aftershocks to check a performance for broadband range, unfortunately the record of only FKO006 exists in the model area. The M_J 5.7 earthquake's source location and mechanism are similar to M_J 3.8. The source models are assumed to be simple point source of smoothed source time function with duration of 1.0s at the location of drown the source mechanism of two earthquakes in Figure 1.

Figure 4a shows observed and synthesized ground motion waveforms resulting from the M_J 3.8 earthquake, as recorded by observation array of aftershock of the 2005 west off Fukuoka Prefecture Earthquake (M_J 7.0) by Yamanaka *et al.* (2005). The location of the observation array points of fk01, fk02, fk08 and FKO006 shown by Figure 3. Figure 4b's waveforms are for the earthquake of M_J 5.7. The stations array located across the surface layer step made by the Kego fault. The horizontal components velocity waveforms of band-pass filtered of period range from 0.8 to 5.0s and 20.0s shown by Figures 4a and 4b. A comparison with observed and synthesized waveforms indicate better reproduction in generally, although this simulation result is got from simplified point source model, and which the tuning of the model by simulations never done. However, there are some problems in the synthesized waveform by the detail comparison. The travel time of synthesized S-wave is earlier than the observed one at each observation. The cause looks like the problem of the deep structure in the 3D model. Otherwise, the amplitude of synthesized have about a half of observed in the each component at the fk02 and fk08. The small feature indicates inadequate for a lack of the reality of the 3D model, the shallower part particularly. In spite of these observations locate on the slop in the first layer, minimum FD grid space size has 30m at only surface grid, and there is not enough resolution for the configuration.

These results suggest that the differences between the real underground 3D structure and the modeled one for FD simulation exist. It is thought that it was not avoided because it was made these based on limited subsurface structure information in the Fukuoka area. Therefore, we need more the information for accurate 3D basin model, and we should explore the basin structure in the area. And besides, it needs the reconstruction of a new 3D model and the recheck by ground motion simulation.

Table 1. Physical parameters of density, Vp, Vs and the boundary depth for each layers of simulation.

No.	ρ (g/cm^3)	Vp(km/s)	Vs(km/s)	Depth(km)
1	1.80	1.70	0.40	variable
2	1.90	2.00	0.60	variable
3	2.40	4.00	2.10	variable
4	2.60	5.50	3.10	5.0km
5	2.70	6.00	3.46	18.0km
6	2.80	6.70	3.87	∞

Table 2. Simulation parameters for FDM.

Model dimension	369 × 386 × 83*
dx	0.06km, 0.25km*
Vs min	0.4km/s
T min	0.8s
	*Rectanguler Grid

Table 3. a) Source information and parameters for M_J 3.8.

date	2005/4/28
time	3h43m17.67s
epicenter	(33.67°, 130.30°)
depth	h=8.0km
	Mo =1.61*10^{14} N・m
strike, dip, rake	(328, 77, 4)

b) Source information and parameters for M_J 5.7.

date	2005/4/20
time	6h11m26.83s
epicenter	(33.68°, 130.29°)
depth	h=8.0km
	Mo =1.31*10^{17} N・m
strike, dip, rake	(312, 90, 14)

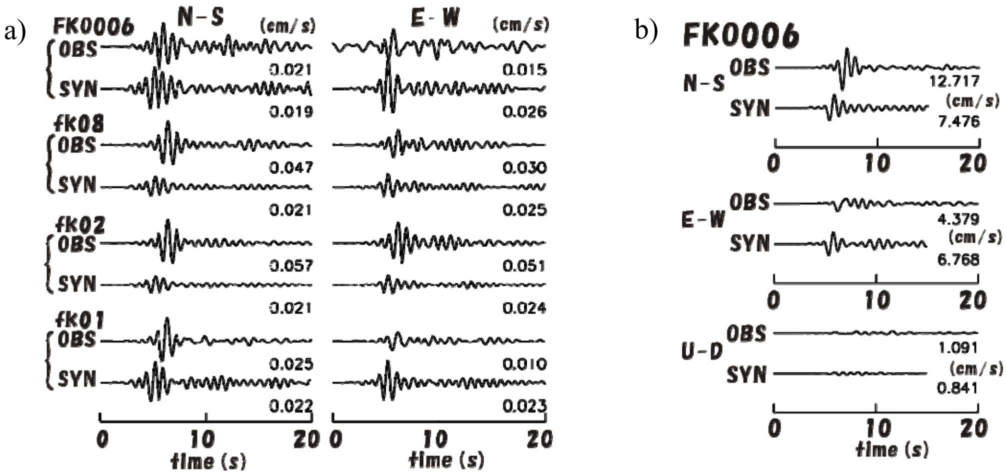

Figure 4. Comparison with observed and synthesized velocity waveform of period range of a) 0.8-5.0s during M_J 3.8 earthquake, b) 0.8-20s during M_J 5.7 earthquake.

4. MICROTREMOR ARRAY EXPLORATION

To increase the subsurface structure data, our group conducted microtremor array explorations in the Fukuoka area near school site to estimate 1D S-wave velocity profiles of deep sedimentary layers over the basement with a Vs 2.4-2.8km/s. Recently, the exploration in the area came to be curried out by ourselves and other groups, and the subsurface structure information increases, because of lack of data of the subsurface structure in Fukuoka area.

Figure 5 shows the locations of the finished or planned site of microtremor array measurement, the sites of except for black triangles have analyzed 1D profile. The details of the observation and analysis were described and discussed previous some papers (e.g., Yamanaka *et al.*, 2005). At each site, 2 arrays with different array sizes were deployed by installing 7 seismometers with station spacing of 0.1 to 1.2km. We can record 7 waveforms and estimate Rayleigh wave phase velocity from the f-k spectral analysis. The Rayleigh wave phase velocities observed in this study of 9 sites are shown Figure 6. The phase velocities at period range of 0.5 to 2.0s are different indicating variation of subsurface structure. The observed phase velocities suggest that the basin size is not so large, comparison with Kanto and Osaka basin. The phase velocity estimated at each site is inverted to an S-wave velocity profile by GA. In the inversion of all the phase velocities, we estimated a 3-layers model from previous study models, for example used 3D model data in this study. A 1D S-wave profile is determined with the GA inversion of phase velocity. Figure 7 shows the inverted S-wave profile and the comparison with a result of Mori *et al.* (2007) at the black square in Figure 5. The basement depth Vs about 2.5km/s changes from 0.5 to 0.8km, from west to east, the other the surface layer bottom depth of Vs 0.8km/s is not so change. Our results and Mori *et al.* (2007) are comparable. Figure 8 indicates each layer boundary depth for expression of 3D basin velocity structure, although the number of site is not enough to reconstruct. Compiling these data enable to make an accurate 3D basin model.

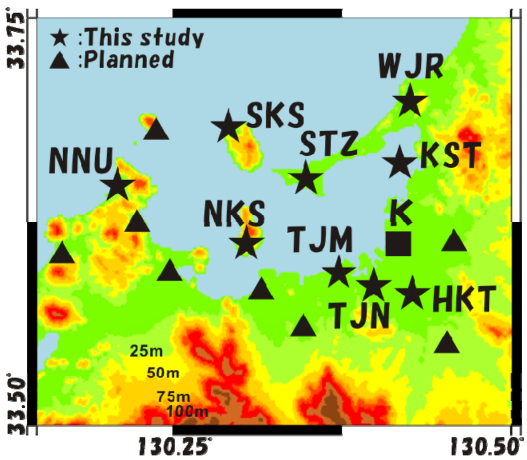

Figure 5. Location map of microtremor array observation. Stars show our observed sites.

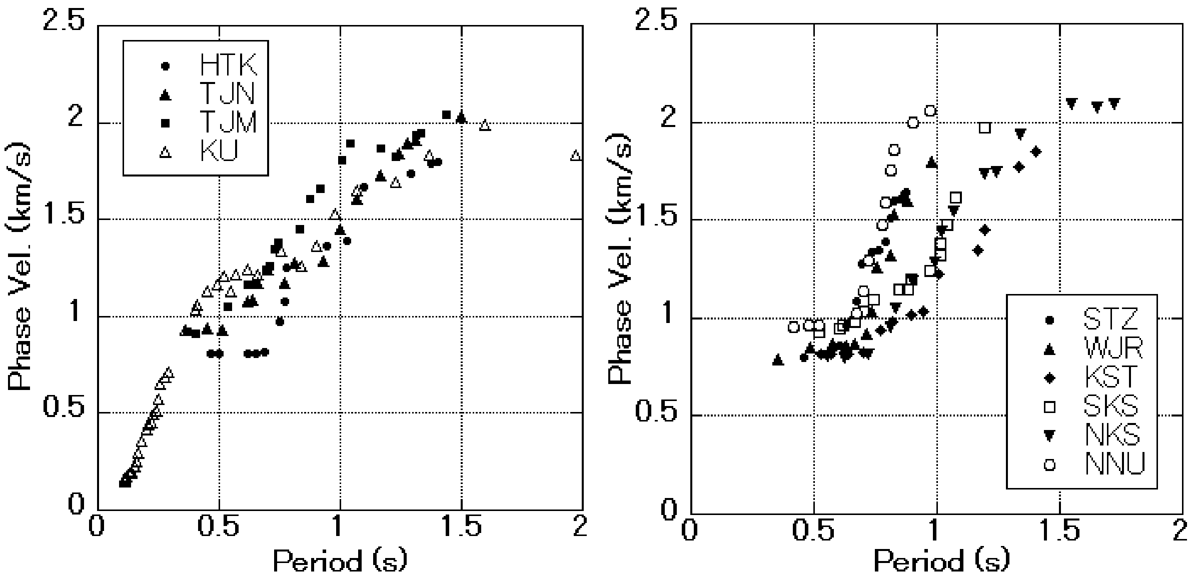

Figure 6. Observed Rayleigh wave phase velocities. KU data is quoted from Kinoshita *et al.* (2001).

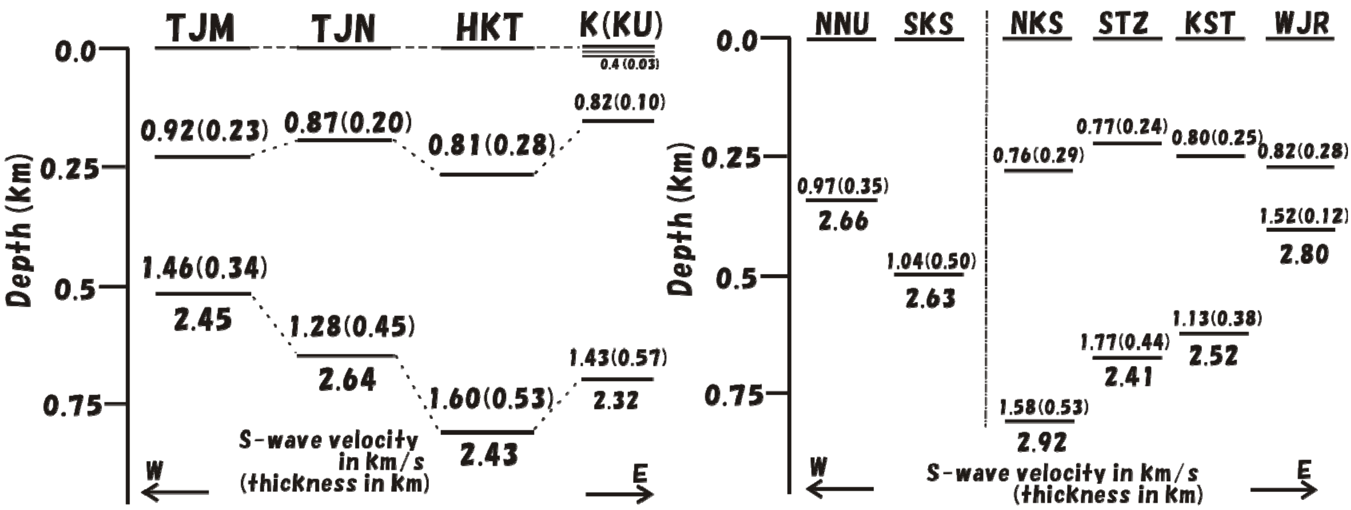

Figure 7. S-wave models from inversions for observed phase velocities at our 9 sites and at the mark of 'K' in figure 5 by Mori *et al.* (2007).

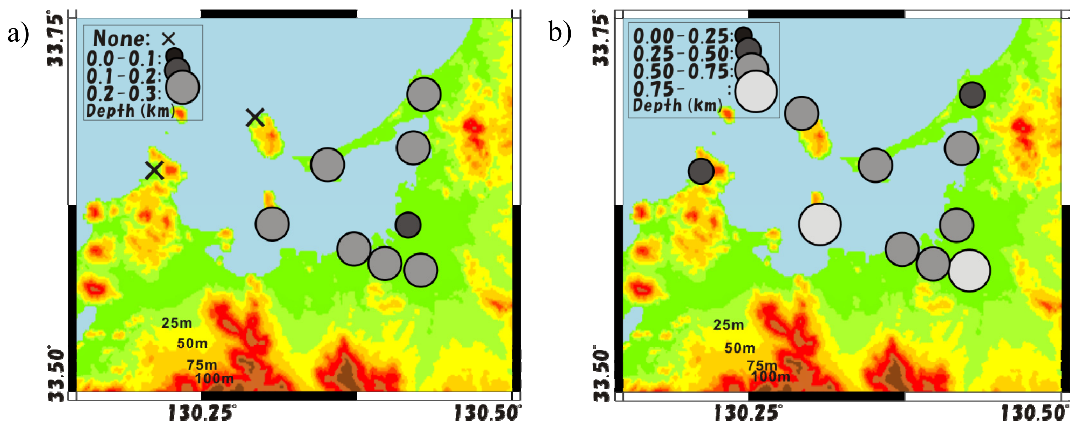

Figure 8. Top depth of Vs a) 1.2-1.8km/s and b) 2.4-2.8km/s layer of our 9 sites on topography map from our results of microtremor array measurements in this study and a result of Mori *et al.* (2007).

6. CONCLUSION

In this article, we showed results of long-period ground motion FD simulation during the aftershock of the 2005 Fukuoka Earthquake using an existent 3D model in the Fukuoka area, and results of the sedimentary basin explorations by microtremor array measurements. The ground motion simulation results indicate that we need more detail examination of subsurface structure of the whole basin. The basin structure explorations show that the boundary depth of Vs 2.4-2.8km/s is 0.3-0.8km and the depth of Vs 0.8-1.0km/s is about 0.3km with flat layer. These 1D S-wave velocity structures is comparable with other's recently results. Although we have to compile these data, it is not enough to make an accurate 3D basin model. Therefore, it is need that the expansion of subsurface structure exploration, the re-construction of the 3D basin model and the performance evaluation of the model by ground motion simulation for high resolution strong ground motion prediction. And also, we are planning to apply these results of subsurface structure explorations and ground motion simulations to practical use for earth science education. Therefore, all microtremor array measurement sites set near the elementary or junior high school.

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