DETERMINATION OF SUBSURFACE STRUCTURE OF IZUMO PLAIN, SOUTHWEST JAPAN USING MICROTREMORS AND GRAVITY ANOMALIES

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ABSTRACT :

Microtremors and gravity anomalies were observed in the Izumo plain, Southwest Japan. Microtremors were recorded by seismic arrays (4 sites) and 3-component single-site observation (400 sites). Gravity data were obtained at about 50 sites. The microtremor data were analyzed by the spatial auto correlation (SPAC) method and the horizontal-to-vertical spectral ratio (H/V). S-wave velocity in quaternary and the distribution of predominant periods were determined by the microtremor array observation and the H/V (horizontal-to-vertical) spectral ratios, respectively. It was found from the result that the average S-wave velocity in quaternary was 230m/s. The predominant periods of H/V spectral ratios indicate thicknesses of quaternary following to the quarter wavelength law. The thickness was determined to be about 10 to 100m with the predominant period of 0.2 to 1.8s. The subsurface structures was determined by followings:1) S-wave velocity structure models obtained at the array observation sites, 2) a 3D bedrock configuration based on H/V and the residual gravity anomaly, 3) 2D density structures determined using the gravity anomaly and the seismic refraction method.

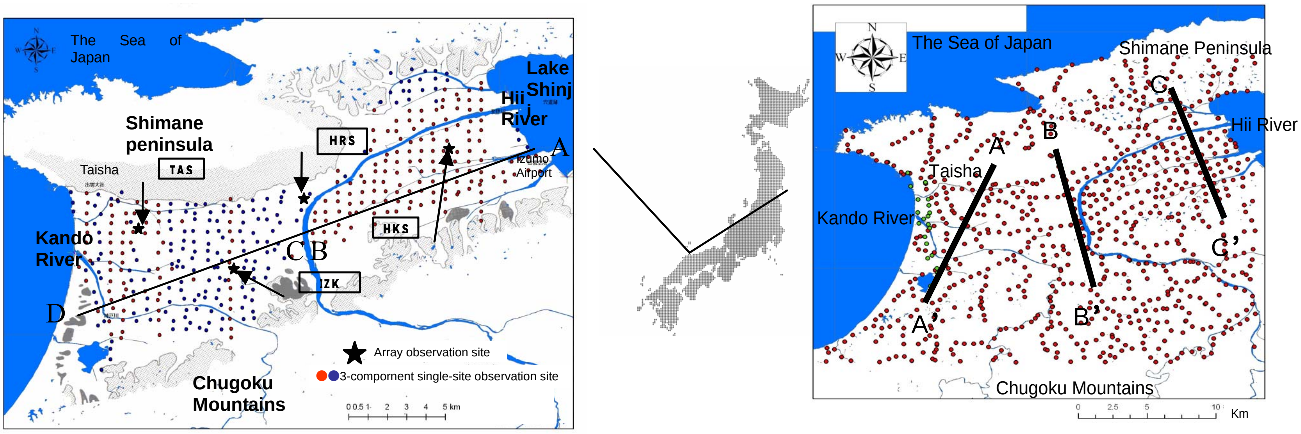
KEYWORDS: Izumo Plain, Microtremors, S-wave velocity, Gravity anomalies, Density structures

1. INTRODUCTION

The Izumo plain in the Sanin area of Japan, the target area of this study, was severely damaged by the 1872 Hamada earthquake (M7.1) etc., and it is an important area as a factor for the prevention or mitigation of earthquake disasters. The severely damaged area was concentrated on the western part of the Izumo plain, whereas there was less damage in the eastern and southern parts of the plain. It is thought that this concentration of the damage was caused by the characteristics of the strong earthquake motion, which is affected by the local subsurface structure of the Izumo plain. The observations of microtremors and gravity have been carried out in this area. The purpose of our study was to determine the subsurface and bedrock structures of the Izumo plain by microtremors and gravity observation records.

2. OBSERVATIONS

The observations of microtremor and gravity have been carried out in this area. 3-component single-site observations at 400 sites and array observations at 4 points were implemented to see the microtremors in the Izumo plain. A 3-component seismometer (T_0=5s) was used in the single site observation system. The array observation system consists of four vertical seismometers (T_0=1s), an amplifier, and a data-recorder. Locations of the 3-component single-site observation points are shown in Fig.1(a).Gravity observations at about 50 points were implemented in the Izumo plain. A Racoste Lon Berg's G type gravimeter was used for the observation. The precision of the altitude measurements was kept within 1m. The observational data was added to the existing data (Gravity Research Group, 2001 and AIST, 2004) and gravity was analyzed. The gravity observation points are shown in Fig.1(b)



(a) (b)

Figure 1 (a): Small circles: single-site observation sites, and stars: array observation sites. Line A-B corresponds with A-B of Figure 3. Line C-D corresponds with C-D of Figure 3.

(b): Small circles: gravity observation points. Line A-A', B-B', C-C' corresponds with A-A', B-B', C-C' of Figure 5.

3. DETERMINATIONS OF UNDERGROUND STRUCTURES

3.1 Determination of Subsurface Structure Using Microtremors

Horizontal-to-vertical ratio (H/V) was calculated by use of using the averaged Fourier spectra of the selected data. A contour map of the peak periods of H/V is shown in Fig. 2. A long period like a belt can been seen in the eastern area. There is area of the long period in the side of Shimane peninsula (north side of plain) and the western area.

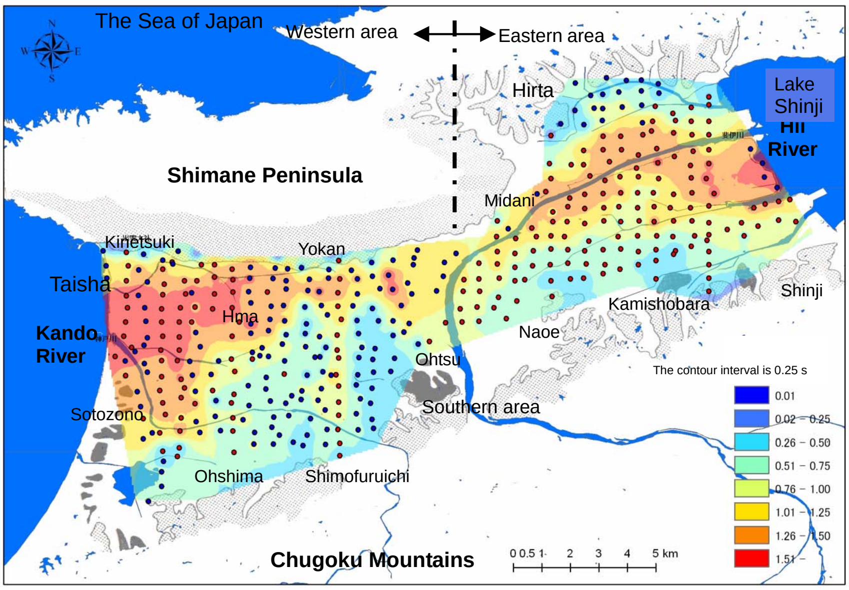


Figure 2 Contour map of the H/V peak period. The contour interval is 0.25s. Small circles; microtremor single-site observation sites.

The dispersion curve of the phase velocity was calculated by the SPAC method (Aki, 1957). Parameters (number of layers, density, P-wave velocity; [Vp] S-wave velocity; [Vs]) of the subsurface structure models are shown in Table 1. Vp was found by the formula Vp=1.11Vs+1290(m/s) (Kitsunezaki et al., 1990). By holding Vs, Vp and densities value and changing only the layer thickness, a subsurface model could be determined by trial and error. The final subsurface structure model is shown in Table 2.

Table 1 Parameters for the determination of the subsurface structural models at the microtremor array observation sites.

Density (g/cm^3)	Vp (m/s)	Vs (m/s)	Geological Age	Geology
	1420	120		
1.7	1460	150	Quaternary	Alluvium & Diluvium
	1510	200		
2.0	1620	300		
2.2	1900	600	Neogene	small consolidation
2.3	2900	1500		large consolidation

Table 2 Final subsurface structure models at the microtremor array observation sites.

$\rho(t/m^3)$	Vp (m/s)	Vs (m/s)	Thickness (m)			
			IZK	TAS	HRS	HKS
1.7	1420〜1510	120〜200	37	15	43	21
2.0	1620	300	26	50	26	17
2.2	1900	600	40	80	40	180
2.3	2900	1500	∞	∞	∞	∞

3.2 Determination of Quaternary Using Average S-wave Velocity and Predominant Periods of H/V Spectral Ratio

Thickness of the quaternary can be estimated by using the quarter wavelength law from the predominant period of the H/V spectral ratio and the average S-wave velocity (Vs=230 m/s). The estimated thickness and the geologic cross section at each point(●) are given below. It is clear that there is a big difference in some areas (HHI1004~HHI1011). As far as our limited observations, this difference seemed to have been influenced by softness of clay. To make it sure, we had another observation. Then we found the S-wave velocity of the average 120m/s, which was completely corresponded with our calculation (●).

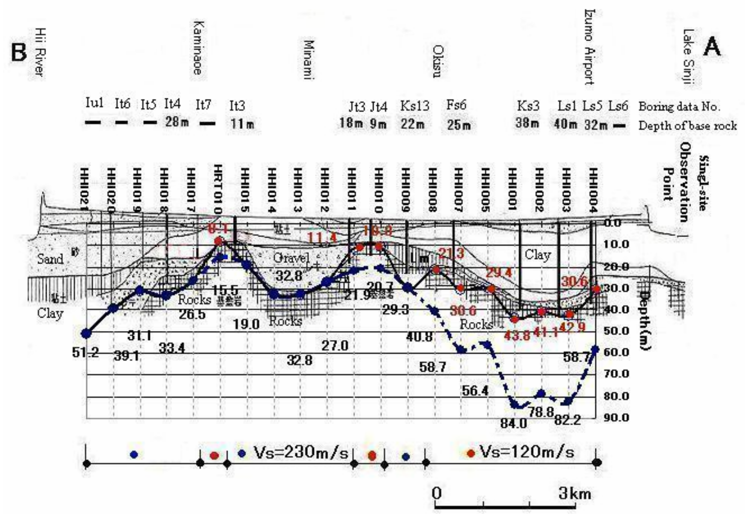


Figure 3 Comparison of estimated thickness and the geologic cross section (Line A-B). The locations of these sections are shown in Fig.1(a).

Figure 4 is the comparison of estimated thickness and the geologic cross section. The same difference as in Figure

3 came out in some area (HHI033~IZM027). As this area is composed of one-kind-thick clay, we calculated with a minimum of S-wave velocity (Vs=150m/s) of the observation. Then the difference was materially reduced.

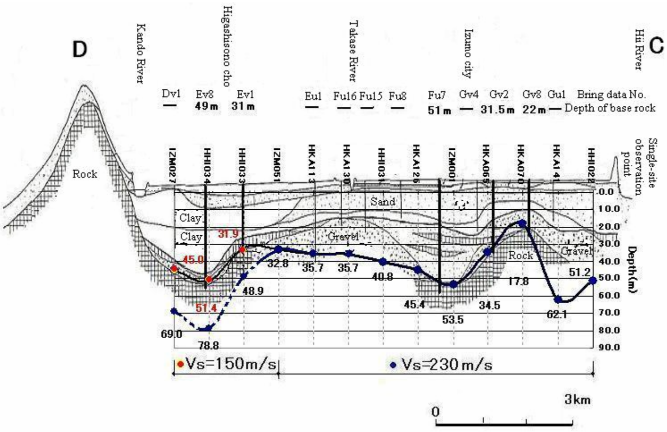


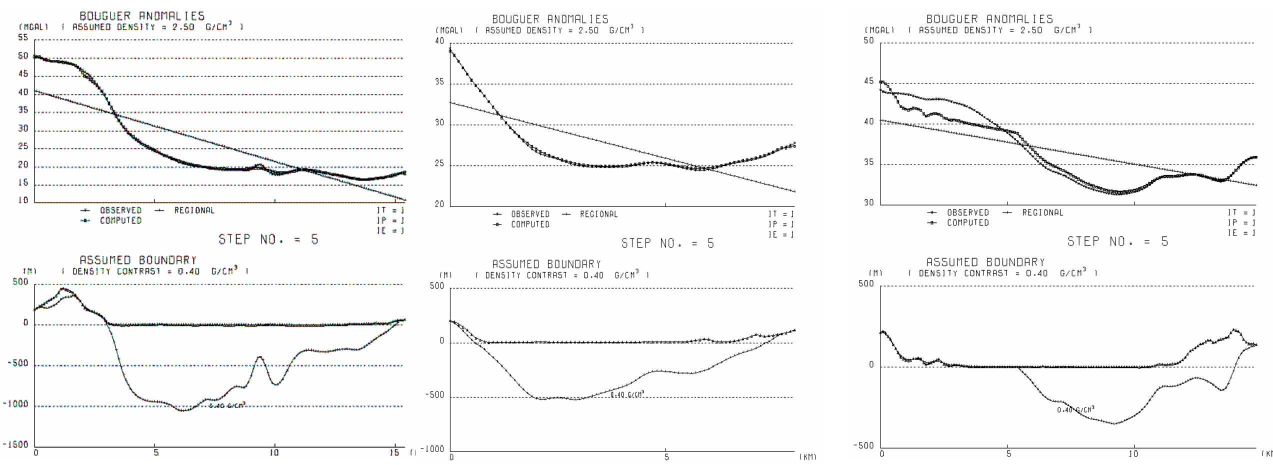
Figure 4 Comparison of estimated thickness and the geologic cross section (Line C-D). The locations of these sections are shown in Fig.1(a).

When a big difference appears, it is absolutely necessary to make array observations and to get velocity structures at the place.

3.3 Determination of 2D Bedrock Structure Using Gravity Anomalies

Terrain correction was made with a topographic 50m mesh and a 250m mesh digital data to obtain the Bouguer anomaly. G-H method (Rikitake et.al, 1965) and CVUR method (Komazawa, 1995) were used to determine a suitable density. Program codes of a 2D or 3D analysis method by Komazawa (Komazawa, 1995) were used to determine 2D or 3D density structures.

The 2D density structure models in 3 lines are shown in Fig.5. We thought the density difference between the surface (sedimentary) and the bedrock layer is 0.4g/cm^3, and the assumed density for the Bouguer anomaly was set to 2.5g/cm^3. We input 0 m of a bedrock depth is in the both edges of the sections (the border between a mountainous area and a plain) as control points. The control points are based on the result of P wave velocity structure by the seismic refraction method.



Line A-A' Line B-B' Line C-C'

Figure 5 2D density structure models. The upper panel shows the Bouguer gravity anomaly value where the measured and calculated values overlap. The lower panel gives the calculated density structure. The locations of these sections are shown in Fig.1(b).

3.4 Determination of 3D Bedrock Structure

We compared the gravity analysis results with the seismic refraction (Kano et.al, 1989). The results were superimposed each other. The configurations of both structure models are seemed to be almost same. Then, we inputted the bedrock depth from the refraction results as a control point in the 3D structure analysis by gravity, where Line A-A’, Line B-B’ and Line C-C’ were used for the analysis. And the 6 points a bedrock depth is 0m were also used as a control point. We thought the density different in the 2-layer is 0.4g/cm^3. And Bouguer anomalies were filtered with the band-pass range from 50m to 1000m to reduce an effect of the deep structure. The 3D bedrock structure is shown in Fig.6.

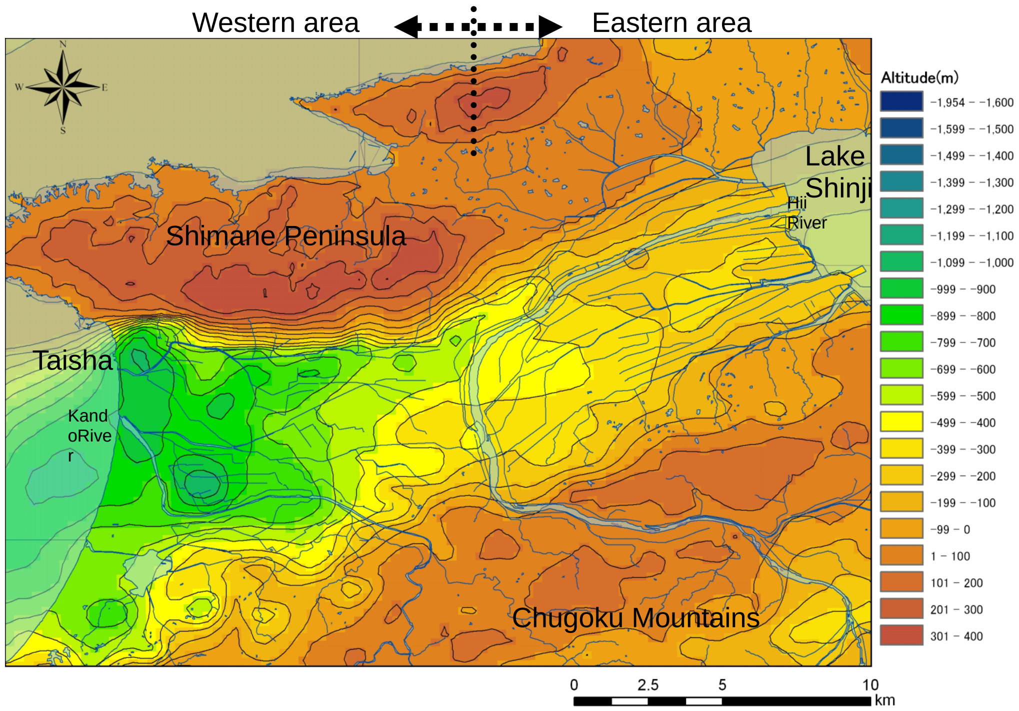


Figure 6 Contour map of the 3D density structure model. The interval of the contour lines is 100m.

4. CONCLUSIONS

Microtremor observations and gravity surveys were carried out in Izumo Plain to determine the subsurface structure. The result is as follows.

(1) The S wave velocity structure models were obtained on 4 points from the data of microtremor array observation (Table 2). The depth to the quaternary layer of average S-wave velocity 230m/s was found to be approx. 10-70 m.
(2) The H/V peak period data were obtained from the microtremor single site 3-component observations (Fig. 2).
(3) When a difference of thickness comes out, it is necessary to implement observations at the place (Fig.3, 4).
(4) The 2D-density structures (Fig.5) were determined from the gravity data by using a 2D gravity analysis.
(5) From the comparison of the seismic refraction and the gravity analysis results, the bedrock depth and the configuration were found to be almost same (Fig.5).
(6) The 3D bedrock model was obtained by a 3D gravity analysis using the results of seismic refraction for the bedrock depth as control points. The bedrock depth was found to be approx.1100m at most (Fig.6).

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