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THE GROUND MOTION CHARACTERISTICS OF ASHIGARA VALLEY, JAPAN

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SUMMARY

Ashigara valley is a sediment filled valley located in the west of Kanagawa prefecture, central Japan. We analyzed the ground motion data sets from two moderate earthquakes (Mj5.4 and Mj4.5) occurring in the north of the valley. The input motions to the sedimentary layers from these events are so simple that we can clearly see the excitation of later arrivals. In frequency range between 0.2 and 0.5 Hz, distinctive later arrivals are found at the southern part stations of the valley. Using the semblance analysis we found that these later arrivals propagated with relatively low velocity. The results of seismic refraction survey suggest that depth to the basement increase near the center of the valley. In order to confirm the effects of this oblique basement structure, we modeled the underground structure and simulated the ground motion characteristics using pseudo spectral method. The results of calculation suggest that the later arrivals are the secondary generated surface wave due to the irregularity of basement structure.

INTRODUCTION

Successive later arrivals forming long duration of strong motion has been a great interest in the field of engineering seismology, since the 1985 Michoacan, Mexico earthquake. Many studies using array observation data have shown that the later arrivals are formed mainly from the secondary generated surface waves [e.g. Furumura and Sasatani, 1996, Hatayama et al., 1995, Yamanaka et al., 1992]. Ashigara valley is a middle sized sediment filled valley located in the west of Kanagawa prefecture, central Japan. Uetake and Kudo (1998a) studied the site response of Ashigara valley for wide frequency range (0.05-5.0Hz). Their results show that the spatial distribution of ground motions in low frequency range under 0.2 Hz is relatively simple, but it is very complex for high frequency range. Waveforms at the south of the valley are significantly different from those at the north area. These characteristics probably relate to complex geological conditions. In this paper, we discuss the seismic motion in Ashigara valley using the strong motion data from the events of local distances occurring in the border of Yamanashi-Kanagawa prefecture, Japan, focussing on the frequency range from 0.2 to 0.5 Hz.

DATA

Ashigara valley is a middle-sized dimension as the long axis of 12 km and the short one of 5 km. It is located in the west of Kanagawa prefecture, Japan, surrounded by Hakone Mountains, Tanzawa Mountains and Oiso hills. The valley is opened to the sea to the south. The data from the events that occurred near the border of Yamanashi and Kanagawa prefecture, Japan, are used in this study. The source parameters of the events are shown in Table 1. The location map of epicenters and observation stations is shown in Figure 1. A reverse fault type is indicated from both source mechanisms determined by National Research Institute of Earth Science and Disaster Prevention, Science and Technology Agency, Japan. The analyzed data sets consist of ground motion records obtained at seven rock sites and twenty-one sediment sites. Most stations are operated by Earthquake Research Institute, University of Tokyo (ERI) [Kudo et al., 1988, Uetake and Kudo, 1998a]. MMJ, SSY, PPL were temporally operated by ERI from October to December in 1996. YMK, ODK are stations of K-NET

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[Kinoshita 1998]. These stations are KNG014 and KNG013 in the K-net original code, respectively. AGC, SPA and GCC are operated by Kanagawa prefecture. NSG is operated by Tokyo Electric Power Company. Accelerometers are used at all stations. The sampling rates of observation systems are 50 Hz for Kanagawa prefecture and 100 Hz for other stations. The frequency responses of observation systems are almost equal in lower frequency than around 10 Hz.

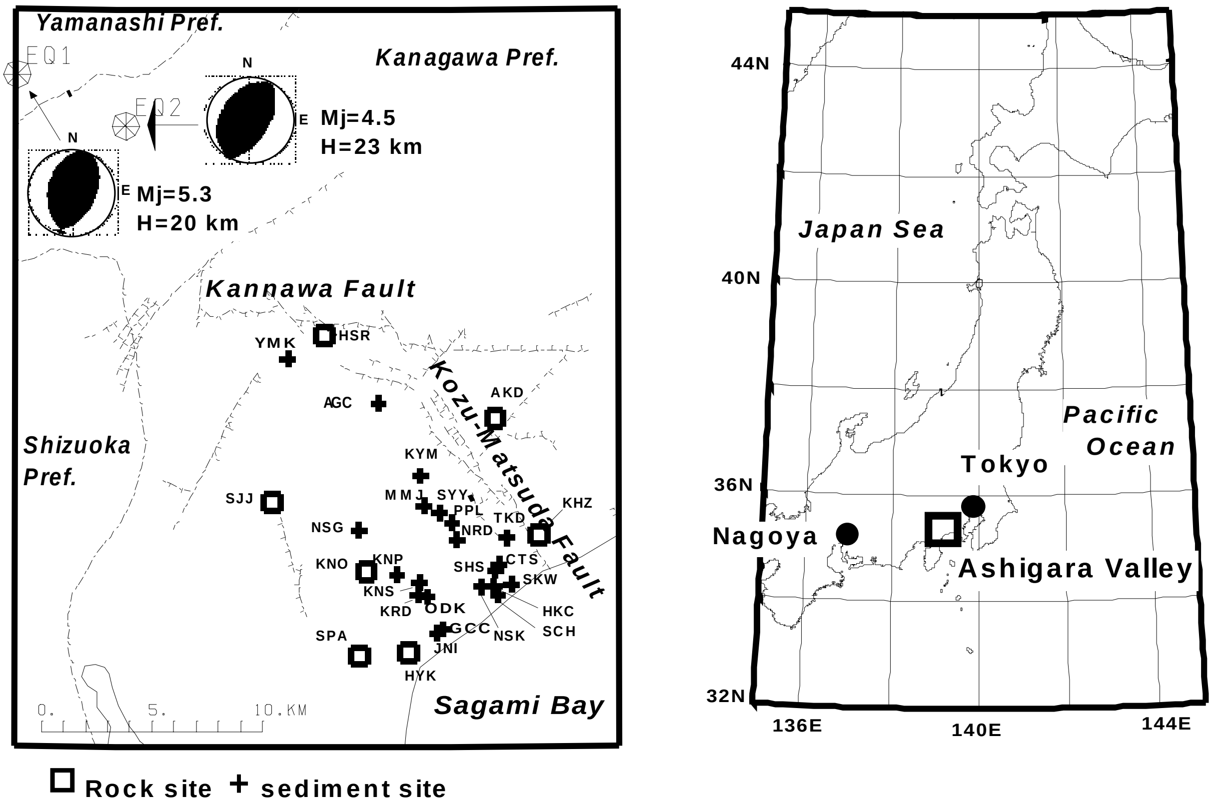


Figure 1: Location map showing epicenters and strong motion observation stations

Table 1: Earthquakes parameters (after Japan meteorological Agency).

	Origin Time(JST)	Latitude	Longitude	Depth(km)	Magnitude
EQ1	1996/03/06 23:35:28.7	35.473N	138.951E	20	5.3
EQ2	1996/10/25 12:25:17.6	35.452N	139.005E	23	4.5

CHARACTERISTICS OF GROUND MOTION

Band-Pass Filtered Wave Forms

The band-passed (0.2-0.5 Hz) velocity waveforms from EQ1 and EQ2 are shown in Figures 2 and 3, respectively. The bottom seven traces in each figure show the waveforms at rock sites and the others are those at sediment sites. We divide sediment site stations into two groups. The eight traces from AGC to SCH in Figure 2 and the fourteen traces from YMK to SCH in Figure 3 show the ground motions at sediment sites along the long axis (NNW-SSE) of the valley. The top six traces in Figure 2 and the top seven traces in Figure 3 show the ground motions along the west margin of the valley. It is clearly understood that the waveforms at rock sites are simple and the S-wave arrivals are predominantly polarized to radial direction for both events.

The later arrivals predominated at sediment sites have following distinctive features: (1) The ground motions at NRD and PPL, which are located on south center of the valley, are particularly large in amplitude and long in their duration. (2) The later arrivals are distinctive in the south of the valley but inferior in the north of the valley. (3) The other phases are also indicated in later arrivals for both events, especially in UD component [C in Figs 2 and 3]. (4) The later phases in horizontal components [B and B' in Figs 2 and 3] and in vertical component [C] arrived at different time and have different predominant periods. (5) The excitation of later arrivals in western margin of the valley is different from the nature found along the central axis of the valley. (6) The initial motion of S-wave arrival [A in Figs 2 and 3] is radially polarized, but the later arrivals significantly include transverse component.

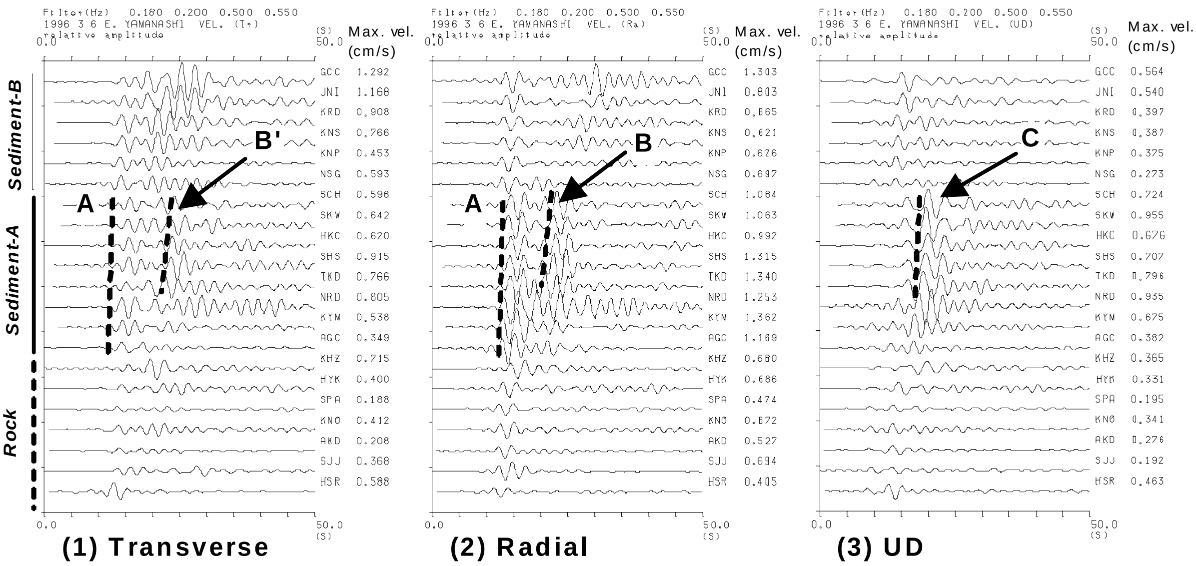


Figure 2: Band-pass (0.2-0.5 Hz) filtered velocity seismograms from EQ1 in Ashigara valley.

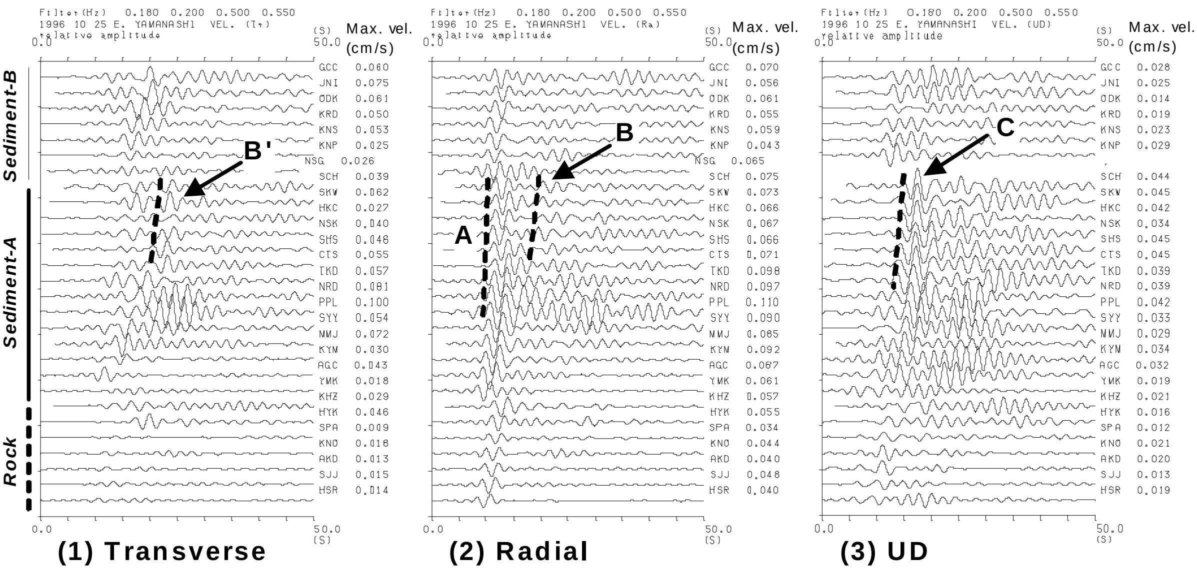


Figure 3: Band-pass (0.2-0.5 Hz) filtered velocity seismograms from EQ2 in Ashigara valley.

Propagation Characteristics of Later Arrivals

In order to determine the propagation velocity and azimuth of the later arrivals, a semblance analysis [Neidell and Taner, 1971] was applied to the data of small array which consist of SKW, NSK, SCH, HKC and SHS. Because the array size is relatively small to the epicentral distance, therefore, we can assume propagation of plane waves within the array. Because the record from EQ1at NSK was not obtained, we used the data of four stations in the semblance analysis. The propagation characteristics of both events are quite similar as followings. The wave group "A" propagates from a little west of epicenter with apparent velocity of 2.5-3.0 km/s. The wave group "B" propagates with apparent velocity of about 1.0 km/s coinciding with the source direction and "B'" propagates with about 1.0km/s from north of the array. The wave group “C” propagates from the source direction with the velocity of about 2 km/s in early part and about 1 km/s in later part. The phase velocity of B’ and C were re-estimated using more narrow band-pass filter. The cosine shaped band-pass filter which bandwidth is 20% of center frequency were used. The center frequencies are 0.38 Hz and 0.3 Hz for B’ and C, respectively. The re-estimated phase velocity of B’ (transverse component) is about 1 km/s. The re-estimated phase velocities of C are about 1.9 km/s in early part and about 1.5 km/s in later part. Uetake and Kudo (1998b) proposed a flat layered model and tried to interpret the propagation characteristics of later arrivals as surface wave propagation. We revise a new model as shown in Table 2 considering the observed Love wave dispersion in frequency range of 0.05–0.25 Hz [Uetake, 1999] and Rayleigh wave dispersion of microtremor in frequency range of 0.7-3.0 Hz [Kanno et al., 1999]. The dispersion curve of surface waves calculated from the model shown in Table 2 and the estimated phase velocity are shown in Figure 4. Two different phase velocities at the same frequency were estimated for the wave group C. The phase velocities from early part and later part of C correspond to the first higher and fundamental mode of Rayleigh waves, respectively. The phase velocity of B’ coincides with fundamental mode of Love waves.

Table 2: Underground structure model for the southern part of Ashigara Valley

No.	Vp(km/s)	Vs(km/s)	, qig/cm3 j	H(km)
1	1.7	0.3	1.8	0.08
2	2.0	0.6	1.9	0.20
3	2.4	1.0	2.0	0.28
4	2.8	1.3	2.1	0.55
5	3.0	1.5	2.2	1.00
6	4.3	2.4	2.5	1.20
7	5.5	3.0	2.6	10.00
8	6.8	3.9	3.0	

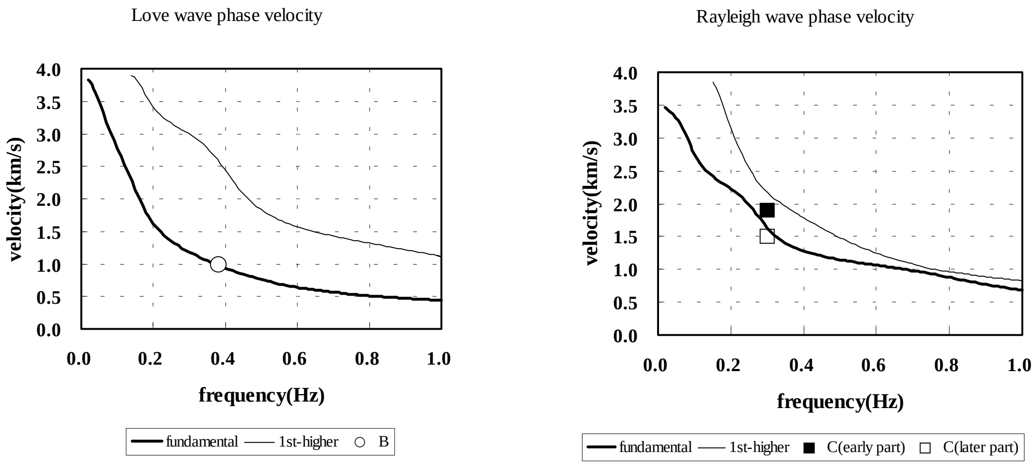
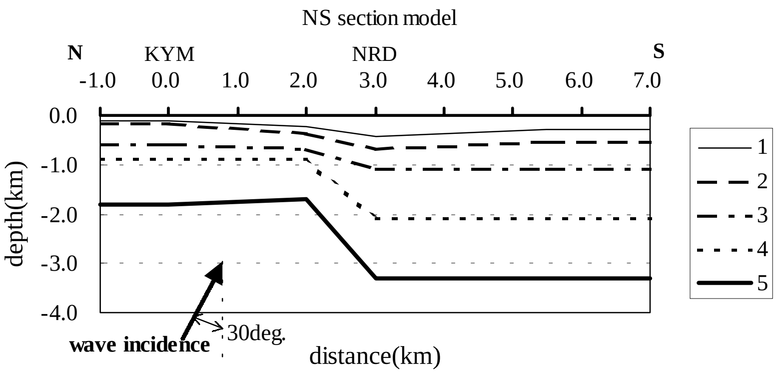


Figure 4: Phase velocities of surface waves calculated from the model shown in Table 2 and estimated phase velocities for later arrivals.

NUMERICAL SIMULATION

Higashi (1991) made a NS section model of Ashigara valley using travel time data of refraction surveys. The model consists of surface layer (Vp = 2.2 km/s) and basement layer (Vp = 3.0 km/s). The section line is corresponds to the line between KYM and NRD. Kanno et al. (1999) investigated the subsurface structure along the section line using the data of array microtremor observation. Taking into consideration these results, we made an NS section model shown in Figure 5. This model has a steep change of basement depth near NRD. We calculate the seismic response of the model to confirm the effects of this oblique basement structure. For numerical calculation, we use the pseudo spectral method [Furumura, 1992]. We assume plane SH and SV wave incidences as an input motion. A grid size of 0.1km is commonly used, however, the time intervals of 0.03 s for SV input and 0.06 s for SH input are used in the computation. A Ricker wavelet (*T*p=3s) is used as input motions. The results of calculation are shown in Figure 6. The later arrivals in southern part of the valley are well reproduced as followings: (1) Large amplitudes of horizontal component for the SV-wave incidence appear further around 2.9km point that are corresponding to NRD, (2) rather solitary waveforms of vertical component at points between 4.7km and 5.9km coincide with the observations, and (3) significant arrivals for the SH-wave incidence are found later than those of vertical component of SV-wave incidence. We may conclude that the later arrivals are secondary generated surface wave due to the steep oblique basement structure near the center of the valley.



	Vp(km/s)	Vs(km/s)	R(g/cm3)	Q
1	1.8	0.6	1.8	50
2	2.4	1.0	2.1	100
3	2.8	1.3	2.1	150
4	3.0	1.5	2.2	150
5	4.3	2.4	2.5	200
6	5.5	3.0	2.6	400

Figure 5: Structure model

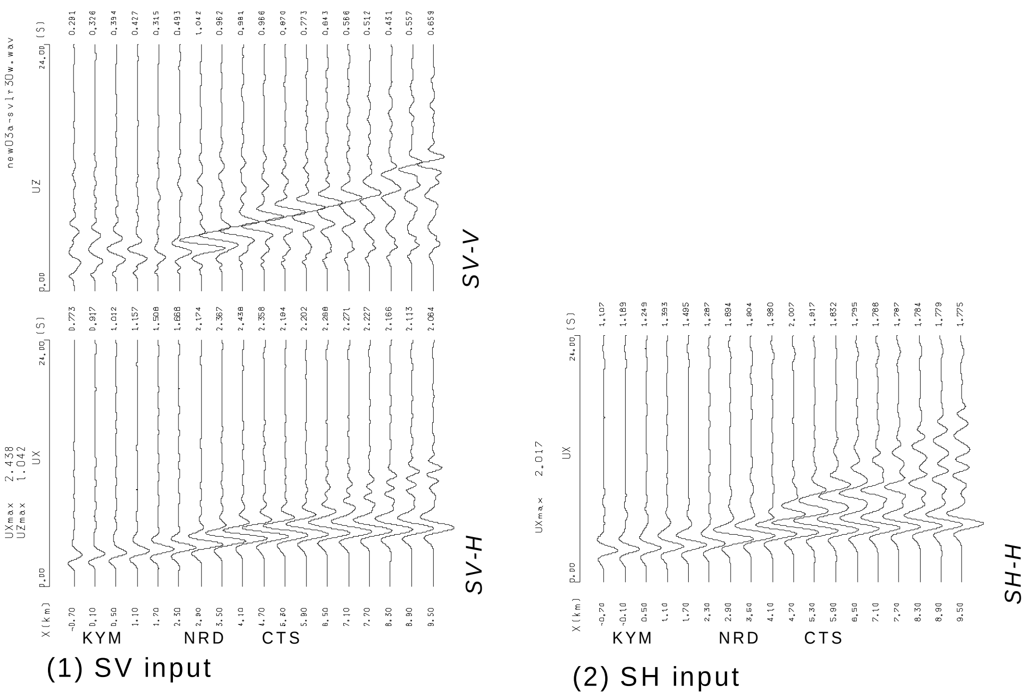


Figure 6: Numerical simulations for SV- and SH-wave inputs.

DISCUSSION

Figure 7(a) shows the spatial variation of amplitude ratios of transverse maximum velocity EQ2, referring to HSR and taking into account the effect of geometrical spreading. It is compared with the depth contour obtained by Higashi (1991) using the data of refraction surveys as shown in Figure 7(b). The pattern of amplitude ratios shows a similarity with the contour of basement depth. This indicates that a depth variation of basement in a basin induces secondly surface waves and contributes to amplification near the site of irregular basement structure. During the 1995 Hyogo-ken Nanbu earthquake, the constructive interference between direct S wave and diffracted waves propagated from basin edge or surface waves amplified ground motion at sediment sites in Kobe [e.g. Kawase, 1996, Motosaka and Nagano, 1996, Pitarka et al., 1996]. The large amplitudes at NRD , PPL may be a result of constructive interference between direct S-waves and secondary generated waves. At this moment, however, the mechanism of constructive interference and the reasons of large SH-motion at southern part of the valley even a less significant SH-incidence have not been clarified. The questions on larger excitation of basin induced Love waves than Rayleigh waves has also been indicated by Kawase and Sato (1992).

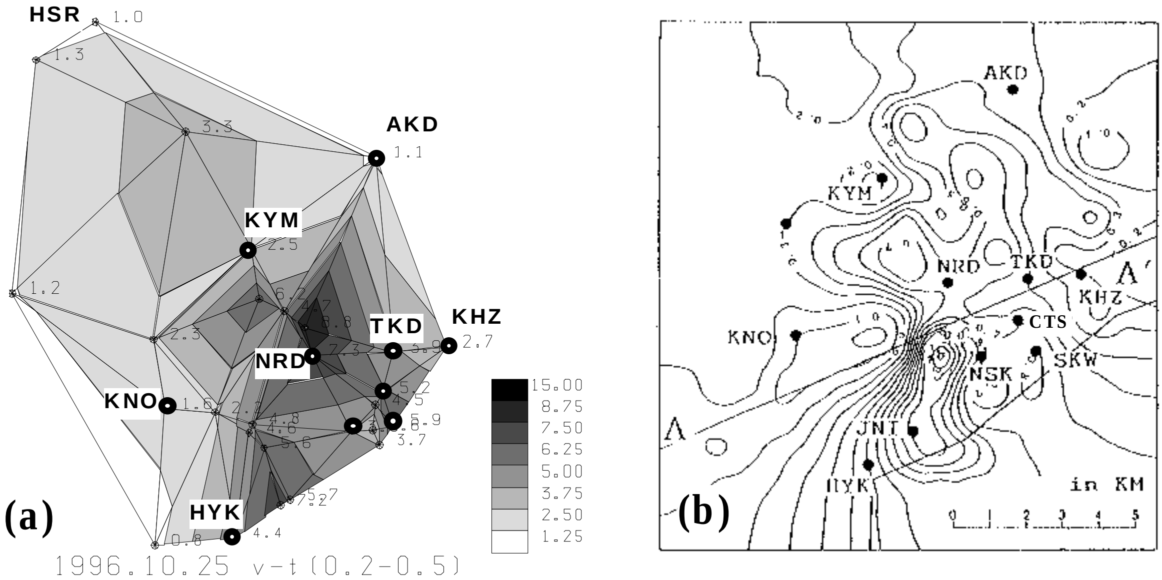


Figure 7: Comparison of transverse component excitation and basement layers' depth. (a) Spatial distribution of maximum amplitude ratios of transverse component to HSR for EQ2. (b) Contour map of upper boundary of Vp=3.0km/s layer after Higashi(1991).

CONCLUSIONS

We analyzed the strong motion data set obtained at Ashigara valley from two earthquakes (Mj5.3 and Mj4.5) of Yamanashi-Kanagawa border. Focusing on the frequency range between 0.2 and 0.5 Hz, we discussed on direct S-wave and two significant later arrivals. These later arrivals are predominated at sediment sites in the south of the valley, but they are inferior at the north of the valley and rock sites. The propagation velocities of later arrivals match with the ones of Love and Rayleigh waves calculated from the subsurface structure model. The results of seismic refraction surveys suggest that the depth to the basement is not uniform around the central area of the valley. We confirmed the effects of the steep oblique basement structure through numerical simulations by 2-D finite difference modeling using pseudo spectral method. An underground structure model was introduced considering the results of refraction survey and array observation of microtremors. The 2-D simulations indicate the strong excitation of surface waves near the irregularity of basement and further sites. This is in good agreement with the observations. We have learned the significant effects of basin edge to ground motion amplification during the 1995 Kobe earthquake. Similar to this, the irregularity of basement in a sedimentary basin also contributes to large amplification of ground motion. In order to understand the large excitation of SH-type even in SV-wave incidence, as found in the observation, it will be inevitable to construct 3-D simulation.

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