GROUND MOTIONS EXCITED BY DEEP TERTIARY DEPOSIT

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SUMMARY

The influence of deep Tertiary deposit on earthquake ground motions was discussed using observed seismograms and the result from seismic prospectings. The deep subsurface ground structure in the south-western Kanto district, Japan, was investigated by means of seismic prospecting using explosions. And the propagations and amplification of seismic waves by deep Tertiary deposit were studied using seismograms obtained by array observation of earthquake ground motions. As results, the later phases, frequently including rather-long period ground motions, were known to be extremely modified by deep Tertiary deposit.

INTRODUCTION

The Kanto district is one of the most densely populated area in Japan (see Fig.1). Moreover, there are many huge structures as skyscrapers, long-spanned buildings and bridges, oil strages and submurged tunnels, as well as common buildings. Therefore, a total planning for prevention from earthquake disasters should be strongly required. For that purpose, it would be much important to make clear the deep subsurface ground structure and the characteristics of rather-long period earthquake ground motions in this area.

As for the deep subsurface ground structure, seismic prospectings using the Yumenoshima, Tokyo, Explosion are being performed twice a year since 1975 (see Fig.2). Using these data, the outline of deep subsurface ground structure in the middle part of Kanto plain was investigated and three layered structure at Yumenoshima was obtained as follows(1). The thickness of the uppermost layer having Vp=1.8km/s and Vs=0.68km/s was about 1.8km, the intermediate layer having Vp=2.8km/s and Vs=1.5km/s was about 0.8km in thick. And the bottom layer having Vp=5.6km/s and Vs=3.0 km/s was located in 2.3km depth. Now, the bottom layer is regarded as the seismic bedrock of the Kanto plain. In this paper, the subsurface ground structure in the south-western Kanto district was investigated through the data of the Yumenoshima Explosions.

On the other hand, for the purpose to investigate characteristics of earthquake ground motions and propagation of seismic waves, the array observation of earthquake ground motion is being performed in this area at several stations using wide-band velocity type seismometers. And the subsurface ground structures of these ststions are considered to be quite

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different each other.

In the seismograms obtained by the array observation, the later phases, including rather-long period groud motions, were often found out at stations on deep Tertiary deposit, but seldom or never at a station on the bedrock(2). After the studies, those ground motions should be considered to be excited by deep Tertiary deposit not only near the station but also along the propagation path.

DEEP SUBSURFACE GROUND STRUCTURE IN THE SOUTH-WESTERN KANTO DISTRICT

Seismic Prospecting Using Explosion

Seismic prospectings in the south-western Kanto district is being performed using the Yumenoshima Explosions. Temporary stations are distributed along several lines as shown in Fig.2. The dotted line indicates Bouguer anomaly and Line A(Yumenoshima-Takao Line) is introduced from Shima et al.(3) to compare the result with those of other lines. Here, travel time T at each station can be described as

$$T = t_s + \Delta / V + t_o ,$$

where Δ means epicentral distance, V is P-wave velocity in the bedrock, t_s and t_o show time-terms(delay time due to the existence of Tertiary deposit) at shot point and observation station, respectively. Among these parameters, V and t_o are the unknowns. Comparing the travel time at each station along Line D(Yumenoshima-Enoshima Line) with those of Line A, apparent velocity of P-wave, Vp=5.3km/s, is dominant within 20km of epicentral ditance along Line D as shown in Fig.3.

Then, if the true velocity of P-wave in the bedrock could be assumed as 5.3km/s in this area, the time-term at each station along Line A, D and B(Yumenoshima-Ohyama Line, see Fig.2) will be shown as solid circles in Figs.4. Moreover, if the thickness of deposit could be proportional to the time-term at each station, the outline of ground structure can be known as the size of solid circle in Fig.2. Solid line in this figure suggests the existence of vertical discontinuity beneath the Tertiary deposit. Although the interface between the deposit and the bedrock is almost flat in the north-eastern side from this line, it changes the depth irregularly in the opposite side. The thickness of the deposit is regarded as 2 to 2.5km in Tokyo, 3 to 4km in Yokohama and almost null in the surrounding mountainous area. But some uncertainty still remains in P-wave velocity in the bedrock because of lacking explosion from reverse side.

To cover this disadvantage, other informations from geological studies and seismic prospectings using deep well logging were taken into account. As results, there is a possibility that Vp in the bedrock should be 4.7km/s in the western area along Line D and Line B. Using Vp=4.7km/s, the time-term at each station along Line D and B was calculated as shown in Figs.4b, 4c by solid triangle. So, the thickness of the deposit might be not so large.

Time-Distance Relation of Seismic Wave During Earthquake

Array observation of earthquake ground motions is being performed at several stations in the south-western Kanto district using the wide-band velocity type seismometers. These stations are indicated as solid squares in Fig.1, with geological conditions(4). Among these stations, ASK is located almost directly on the firm Pre-Neogene basement, which is regarded as the seismic bedrock in this area. The other stations are located on deep Tertiary deposit, but the thicknesses are considered to be quite different each other. Stations AZM and AOB were closed at Apr. 1983.

Figs.5 show observed seismograms of transverse components at these stations during the Kangawa-Yamanashi Border Earthquake of Aug. 8, 1983(M=6.0, D=20km, EQ-3 in Fig.1), the Southern Off Kanto Earthquake of Aug. 12, 1982 (M=5.7, D=30km, EQ-2 in Fig.1) and the Near Miyake-jima Earthquake of Oct. 3, 1983(M=6.2, D=20km, EQ-5 in Fig.1). The broken line in these figures show time -distance curve of S-wave[$t=\Delta/V+t_s$]. Where, Δ indicates epicentral distance, V shows propagation velocity of S-wave and t_s means intercept time at the source. As for the EQ-3, V=3.9km/s, which is considered to S-wave velocity in intermediate layer of the Earth's crust, and t_s=1.7s from result during the Eastern Yamanashi Pref. of 1976(5). Because the souce locations of these earthquakes are quite identical. Now, as the clock of ASK was indistinct, the arrival time of S-wave was adjusted to this curve. The delay time of initial S-wave at each station should be mainly caused by the existence of deposit of each site, and almost invariable during other earthquakes. As for the EQ-2 and the EQ-5, V should be 4.3km/s because they are deep or far earthquakes. And t_s was defined as variable so that the error of the delay time at each station might be minimum during the EQ-3 and other earthquakes. From these figures, the largeness of the delay times at these ststions except ASK and ENS should be regarded as follows.

TKH > OKY > AZM > OFN > NGT > KWS.

Assuming that the crustal structure beneath the deep Tertiary deposit should be uniform in this area, the thickness of the deposit might correspond with the largeness of the delay time. Then, this result should be comparable with the result from explosion using Vp=4.7km/s. But, this assumption may be difficult to exist.

However, after confirming the deep Tertiary deposit structure, this method might be useful to investigate the deeper crustal structure and the propagation mechanism of seismic waves.

EARTHQUAKE GROUND MOTIONS EXCITED BY DEEP DEPOSIT

Seismograms Obtained by Array Observation

In Figs.5, remarkable later phases can be seen at almost all stations after the first arrival of S-wave. The features will be summerized as follows.

1. In case of the Kangawa-Yamanashi Border Earthquake of 1983.(EQ-3, EQ-4 in Fig.1)

   Propagation diagram of seismic waves for the EQ-3 is shown in Fig.5a. Wave form of each seismogram can be known quite different for each station. The most significant later phases would be those at KWS. They appears impulsively and systematically at a time interval of 6 to 7 seconds. These kinds of later phases are not so clear at other stations. Most of all, they cannot be found entirely at ASK. These tendencies are almost same for the EQ-4, which is one of aftershocks of EQ-3.
2. In case of the South Off Kanto Earthquake of 1982.(EQ-2 in Fig.1)

Propagation diagram of seismic waves is shown in Fig.5b. Impulsive later phases grow well at all stations except ASK. Phase velocity of these phases through NGT, AZM and OKY can be considered as 1.3km/s, and which may correspond with average S-wave velocity in Tertiary deposit. In this case also, seismogram at ASK is very simple and impulsive.

3. In case of the Near Miyake-jima Earthquake of 1983.(EQ-5 in Fig.1) Propagation diagram of seismic waves is given in Fig.5c. In this case, the rather-long period components of 8 to 10 seconds are fairly predominant. These phases show normal dispersion, and whose velocity can be recognized in the range of 4.3km/s through 3.0km/s. Unfortunately, seismogram has not been obtained at ASK.

From these facts, it can be pointed out that these later phases appear remarkably on Tertiary deposit, but never on outcrop of rocks like ASK. In case of impulsive and simple sources such as the EQ-3 and EQ-2, later phases can also be seen in the form impulse. And if there are some rather-long period components in the source, they must be enlarged in Tertiary deposit. Anyway, later phases mensioned above will provide useful means to understand the mechanism of wave propagation in Tertiary deposit in this area.

Amplification of Earthquake Ground Motions due to Deep Tertiary Deposit

Figs.6 show two-dimensional response spectra of ground motions at ASK, NGT and OKY during the South-eastern Off Kanto Earthquake of Feb. 21, 1982 (M=6.4, D=40km, EQ-1 in Fig.1) and the EQ-2. The spectral ratios of NGT and OKY against ASK during each earthquake are shown in Figs.7. In case of the EQ-1, the rather-long period ground motions were also found out in the seismograms at NGT and OKY, but scarcely anything at ASK.

If these components might be caused by the same mechanism near the site, the spectral ratios of each station would be expected to fairly similar through both earthquakes. But the spectral ratios are quite different as shown in Figs.7, especially in case of OKY. Consequently, it would be excited by the deposit not only near the site but also along propagation path, and it should be neccesary to elucidate how the rather-long period ground motions are excited by Tertiary deposit.

CONCLUDING REMARKS

The deep subsurface ground structure in the south-western Kanto district was investigated by means of seismic prospecting using explosions and two kinds of interpretations for deep subsurface structure were presented. However, it has still remained as the most important problem that P-wave velocity in the seismic bedrock could not be defined because of lacking reverse explosion. By using delay times of initial motions for S-wave during earthquakes, the thickness of Tertiary deposit was also estimated. These delay times would be useful to investigate the deeper crustal structure after the Tertiary deposit has just been confirmed clearly. The later phases, including rather-long period ground motions, were considered to be excited and enlarged by deep Tertiary deposit. And the farther consideration of these later phases can be expected to provide useful means to understand the mechanism of wave propagation in Tertiary deposit.

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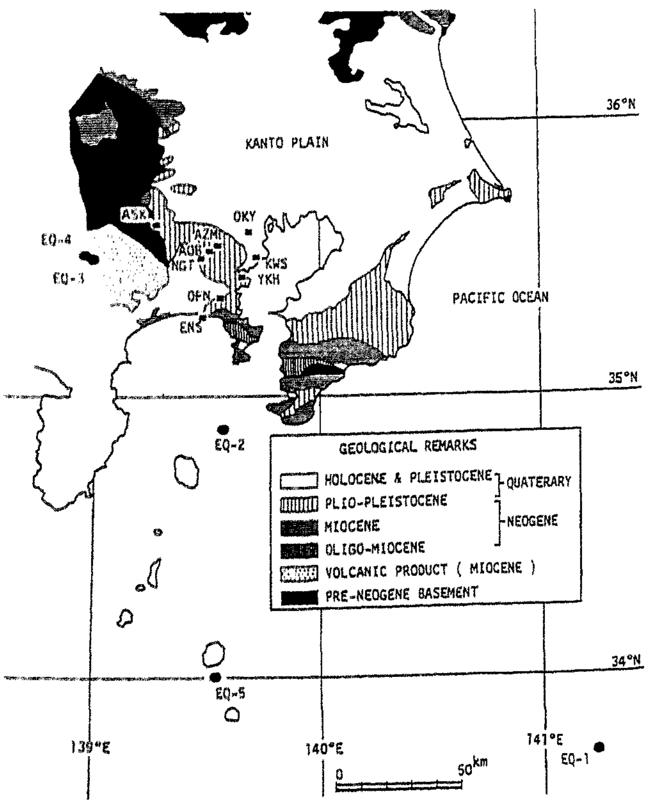


Fig.1 Map of the Kanto Region, Japan
Observation stations for earthquakes and epicenters are indicated with geological conditions..

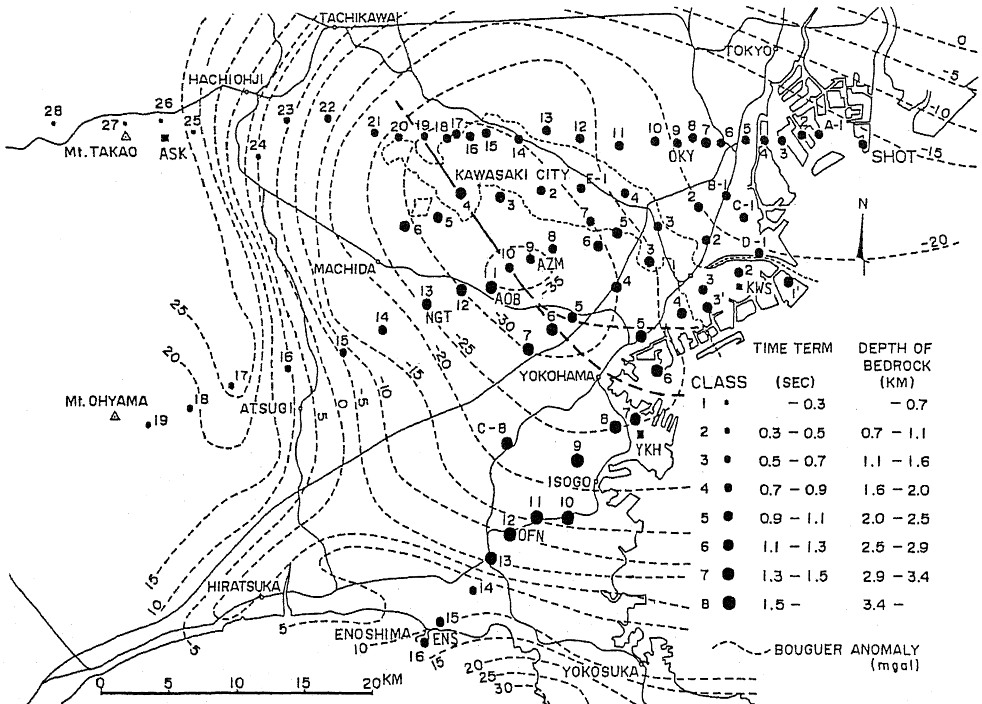


Fig.2 Distribution of observation stations for Yumenoshima explosions and obtained time terms.

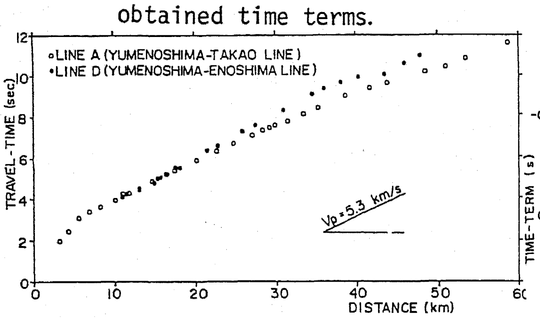
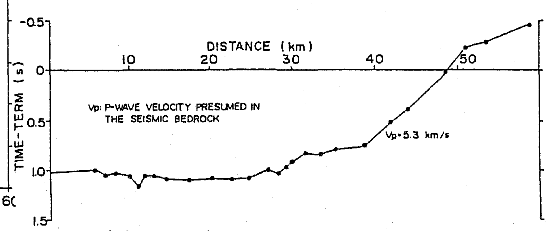
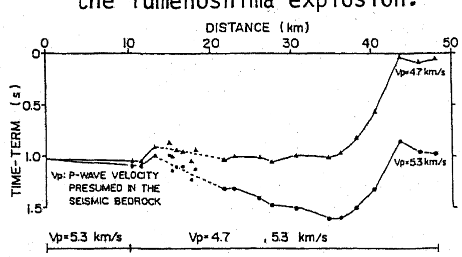


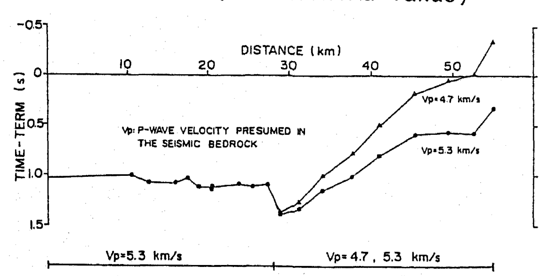
Fig.3 Travel time diagram obtained from the Yumenoshima explosion.



a. Line A (Yumenoshima-Takao)



b. Line D (Yumenoshima-Enoshima)



c. Line B (Yumenoshima-Ohyama)

Fig.4 Distribution of the time terms derived from the Yumenoshima explosions.

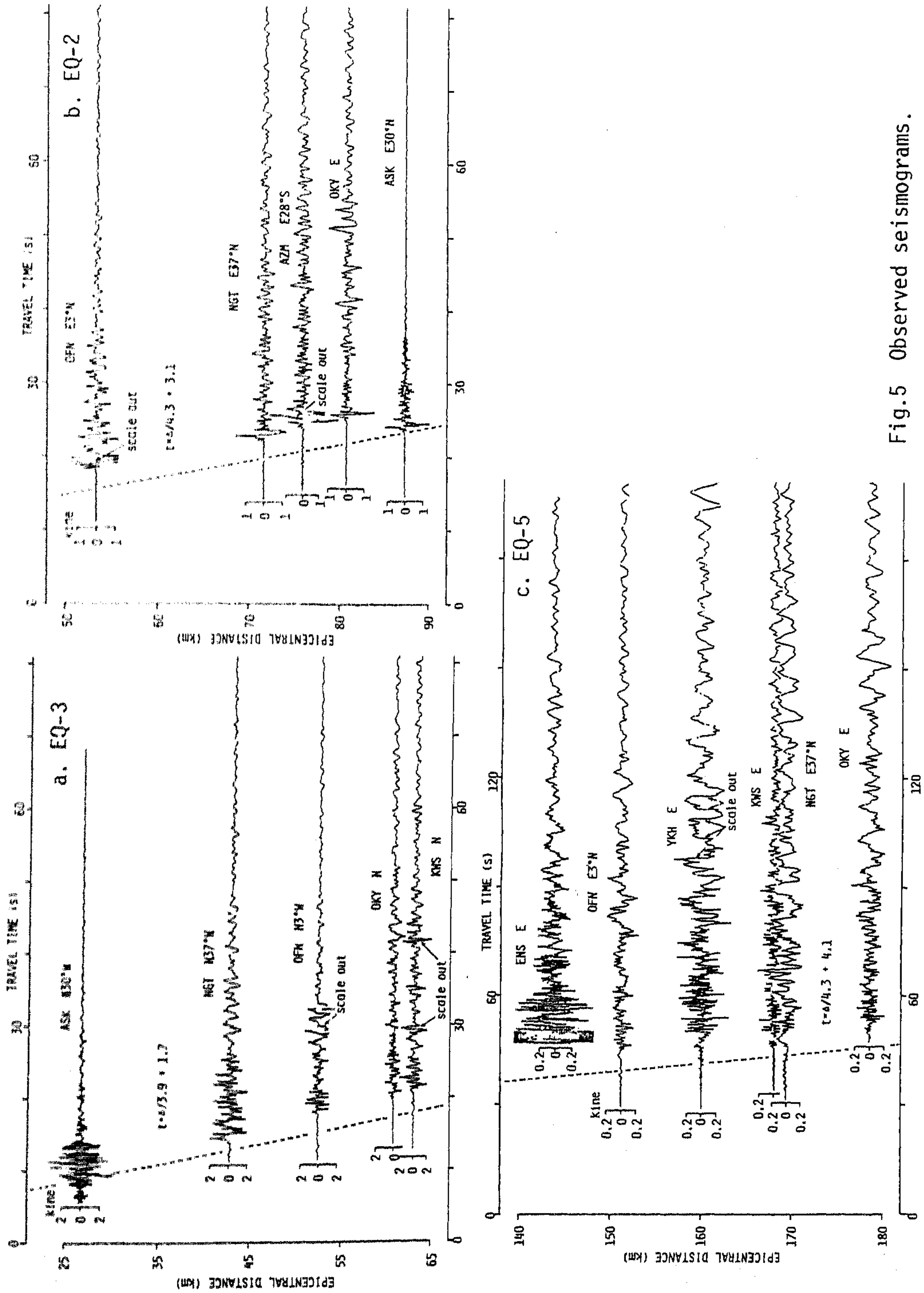
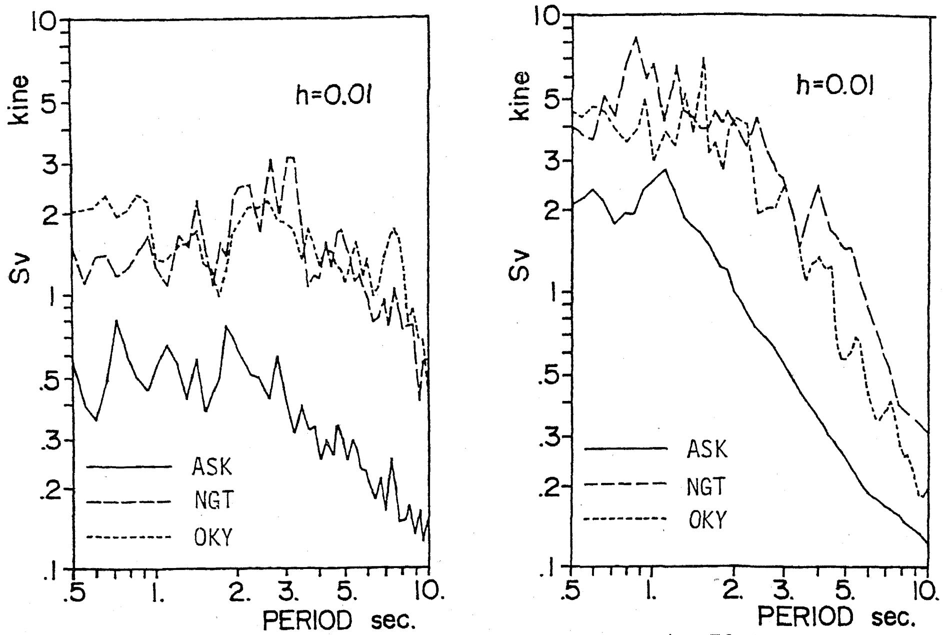
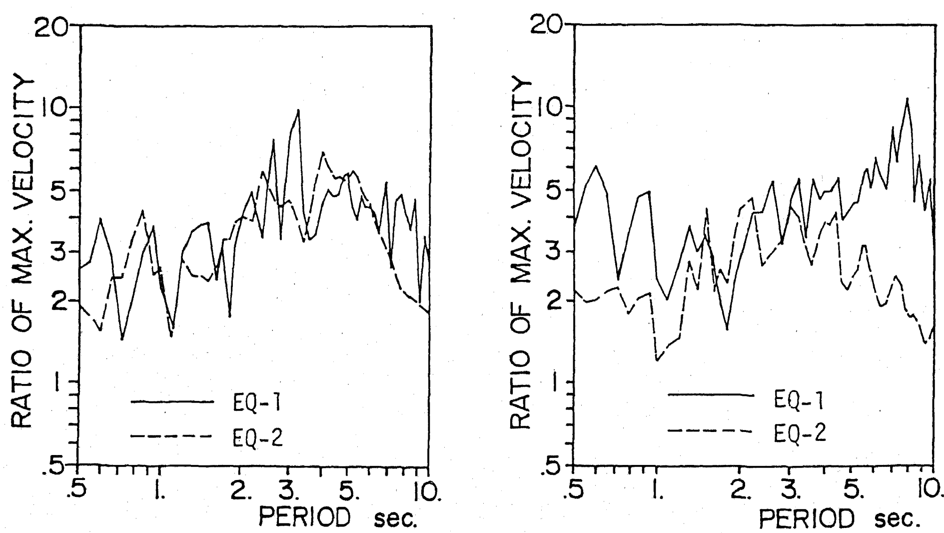


Fig.5 Observed seismograms.



a. EQ-1 b. EQ-2

Fig.6 Two-dimensional response spectra.



a. NGT/ASK b. OKY/ASK

Fig.7 Spectral ratios.