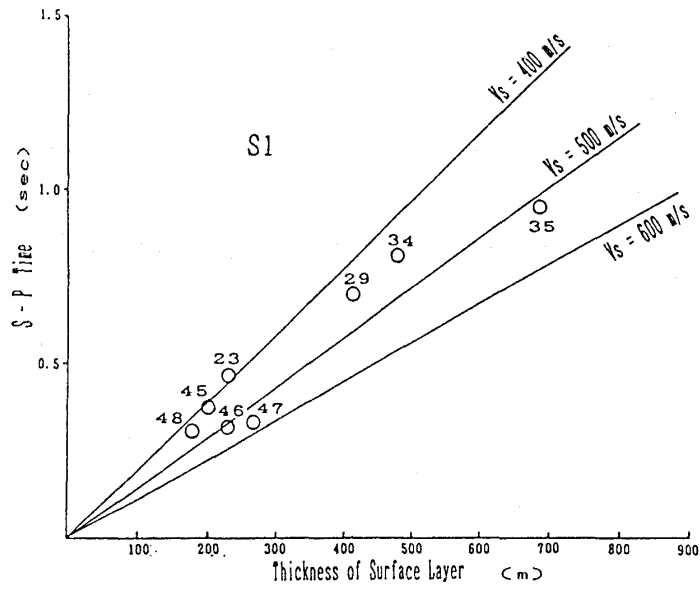
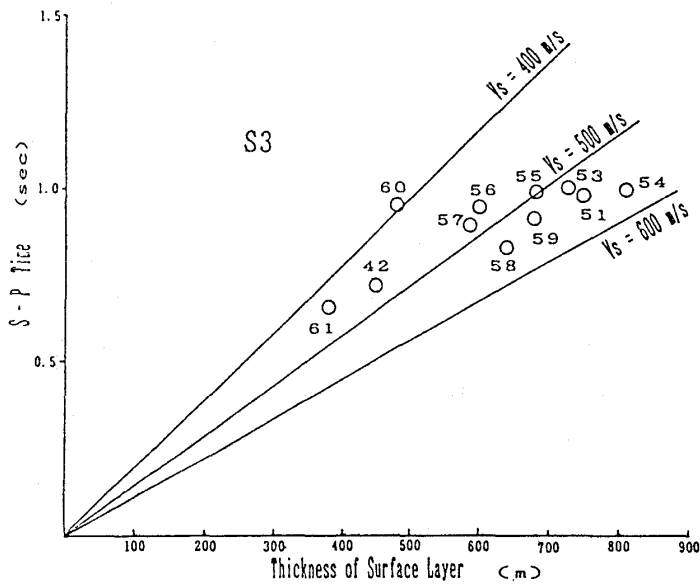


Reference

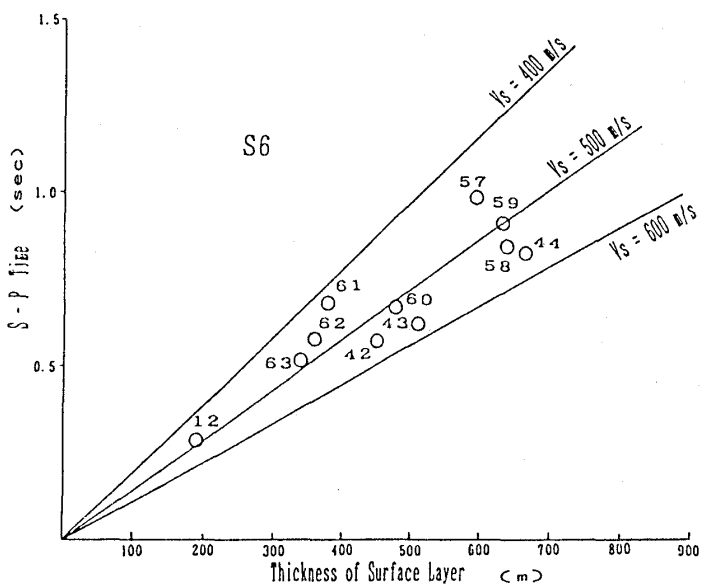
Shima, E., M. Yanagisawa and K. Kudo, Deep Underground Structure of Yutian Area, 1990, 72-85, Fundamental Research on Microzonation Methodology by Japan China Cooperative Research Team.



(a)



(b)



(c)

Fig 6.

Relation between arrival time difference between converted SV and refracted P waves from the base rock and thickness of the surface layer at each station. Numerals shown in the figures indicate the shot points and station numbers.

case, traveling waves from source to receiver is called diving waves. Then, the incident angle of such waves to the base rock becomes less than 90 degree, and we may expect appreciable energy for P to SV conversion. If the velocity gradients in the layers are small, the travel times from shot to receiver become almost the same in both models. Thus, we identified that the appreciable phases found in the seismograms of radial components will be the SV waves converted from P to SV at the boundary of base rock.

In the former analysis, we considered only one possible SV arrivals, which propagated from source as P down to base rock, then as P in the base rock and as converted SV from base rock up to the receiver. If we denote this arrivals as P-P-SV, other possible SV arrivals from source to receiver will be P-SV-SV, SV-P-SV and SV-SV-SV. Travel times in these cases will be longer than the analysed case. Even if these arrivals may have the appreciable energy, they will be contaminated by the earlier arrivals and may be hard to discriminate. Furthermore, the phases which experienced twice the conversion may not have the enough energy to be recorded. That is why we treated only the phases of P-P-SV.

4. Concluding Remarks

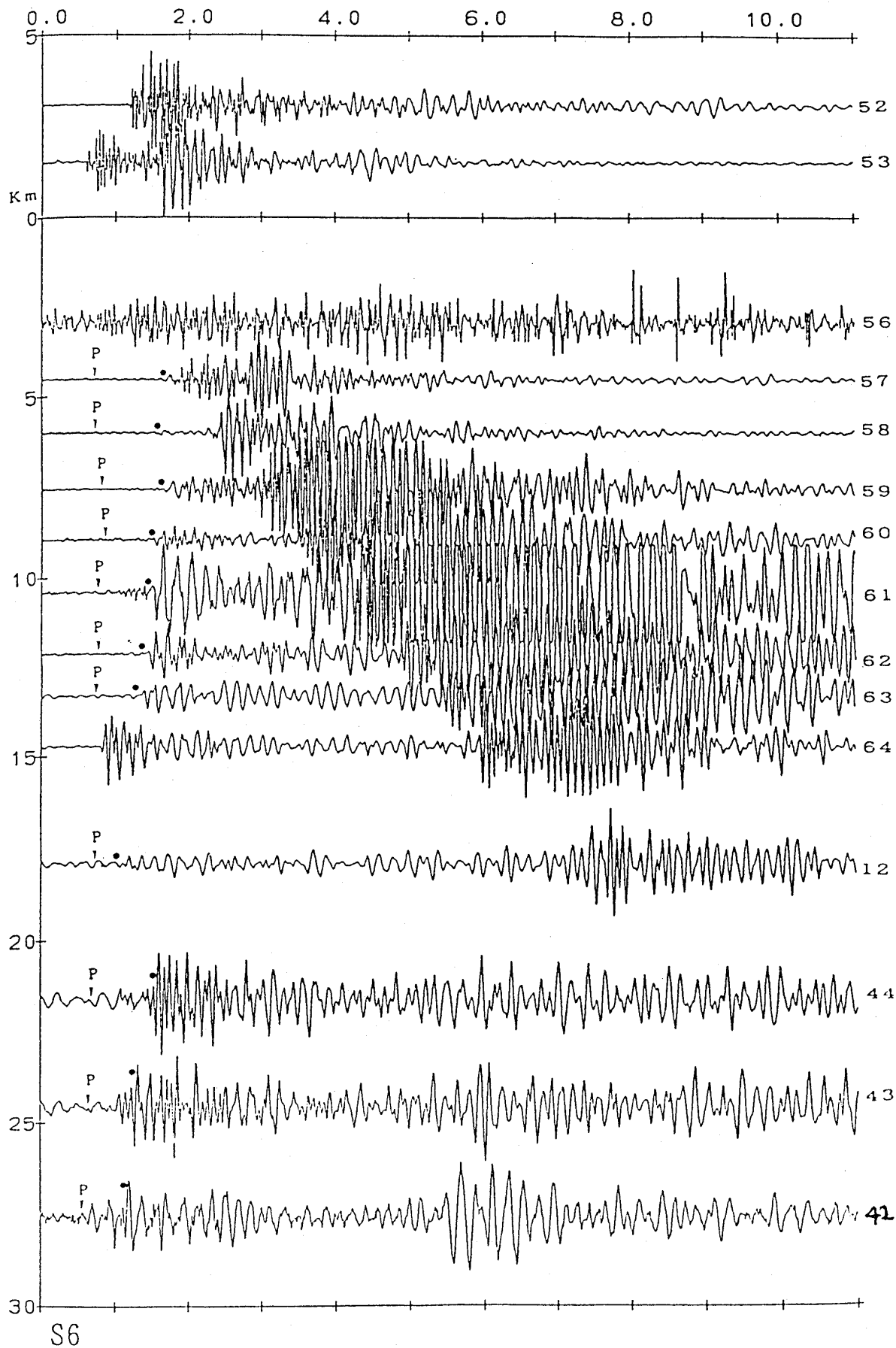
The refraction survey was carried out by Japan-China joint research team on microzonation methodology near Yutian, China. The main objective of this expedition was to study if the deep underground structure down to the basement rock play an important role in explaining the abnormal seismic intensity distribution due to 1976 Tangshan earthquake. During the experiment, radial components of the ground motion were also observed in addition to the conventional vertical ground motion observation if we could detect any shear arrivals.

In some of the seismograms, we found clear late phases in the radial components but not in the vertical ones at same travel times. It was thought that these arrivals may be explained as the SV arrivals which were converted from P to SV at the base rock under the receiver. To prove the hypothesis, travel time differences between first P and those arrivals were plotted against the depths of the surface layer at the receivers. We found good correlation between them. From this comparison, the SV wave velocity in the surface layer was found to be approximately 500 m/s.

Finally, the authors express their hearty thanks to those colleagues who joined the experiment and provided us with useful data.

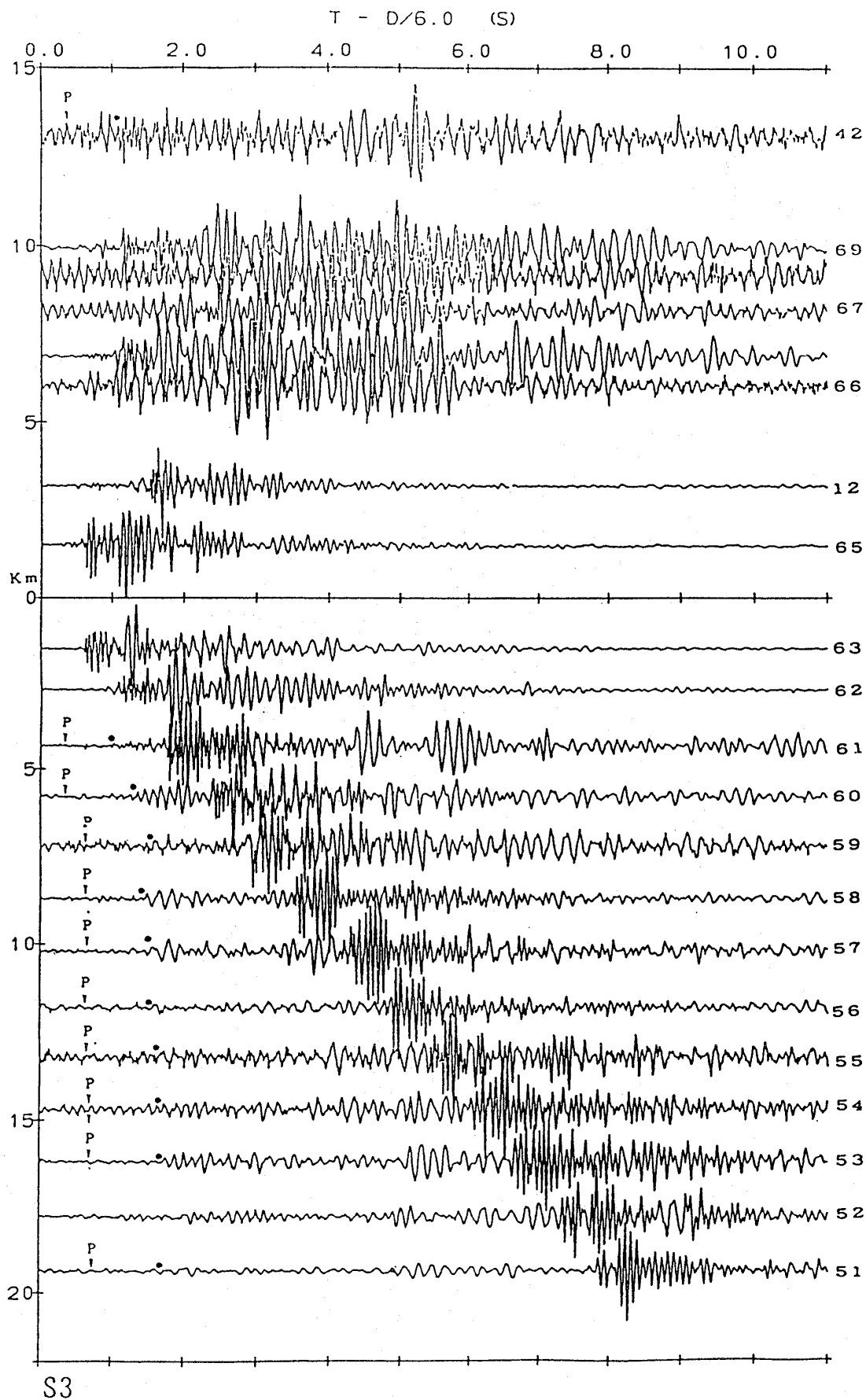
研究紀要第13号

T - D/6.0 (S)



(c)

地震記象に見られる変換S波



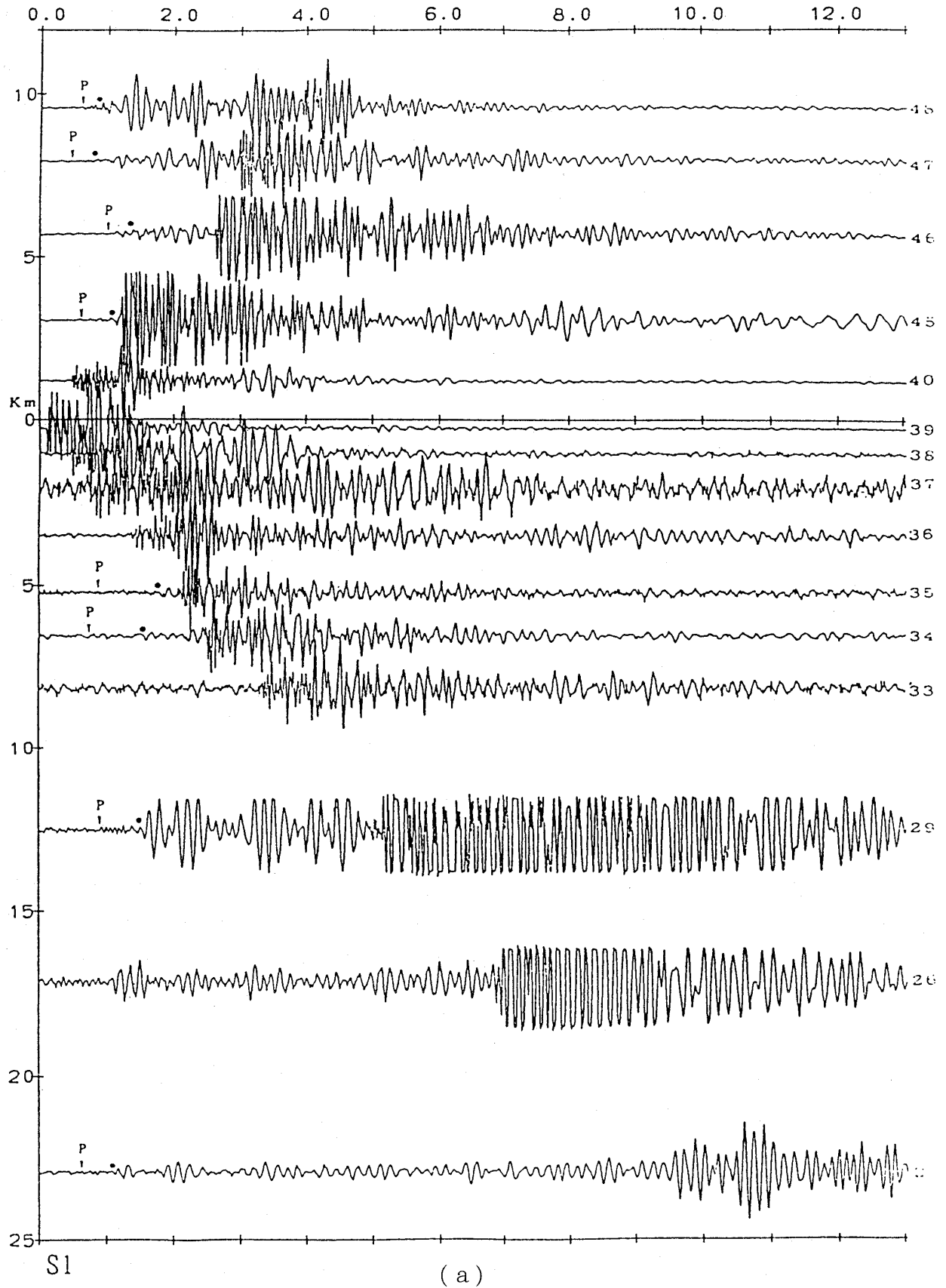


Fig. 5. Pasted up seismograms of radial components showing SV arrivals. They are marked by symbol •. P arrivals which were detected clearly in vertical component seismograms are also shown in the figure for reference.

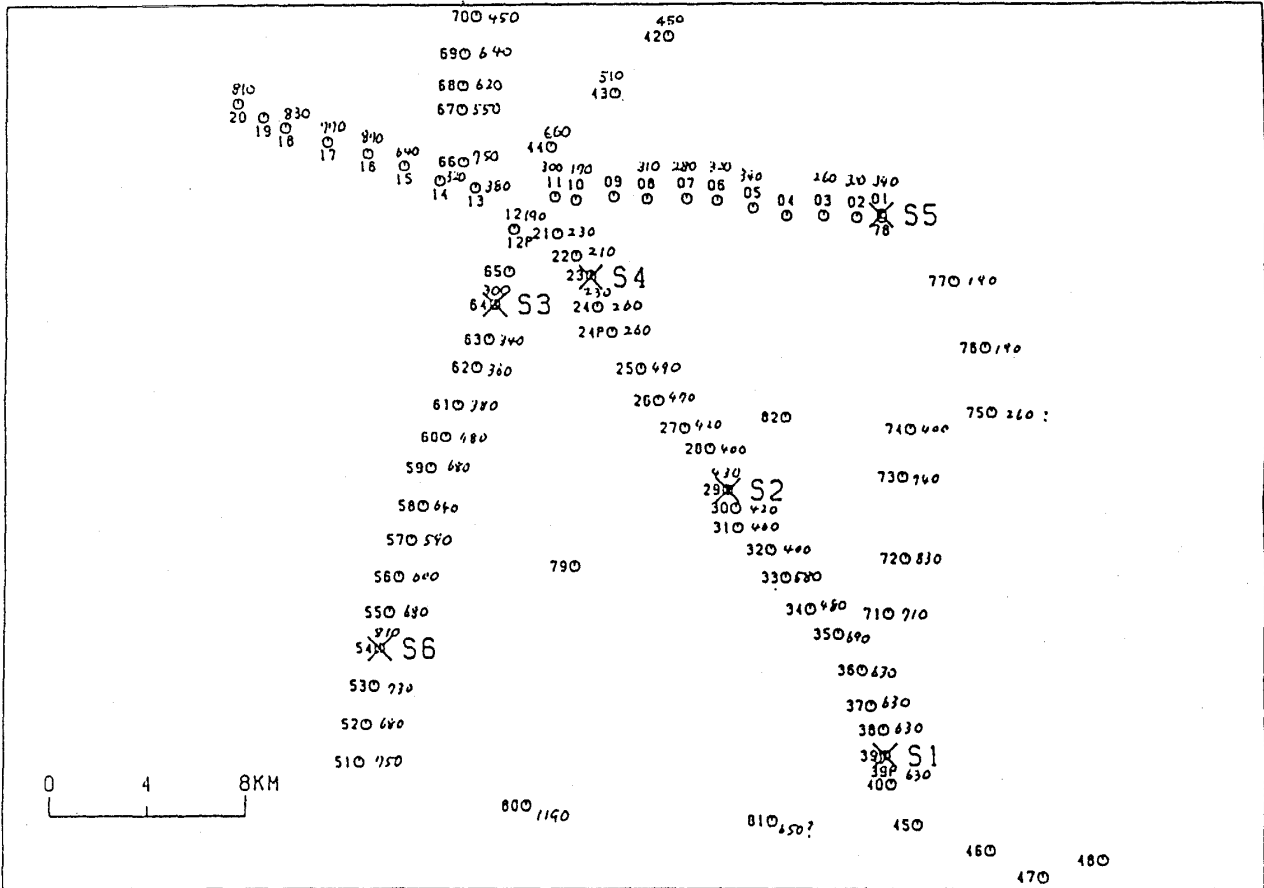


Fig. 4. Thickness of the surface layer at each station. Unit in m.

Fig. 5 shows the pasted up seismograms of radial components observed along two spreads. Both P and SV arrivals are shown in the figure. First P arrivals are clearly seen in vertical components, but not in radial components. So, P arrivals shown in Fig. 5 were marked consulting the vertical components. We read off all time differences available, and plotted them against the depths of surface layer at the observation points found in Fig. 4 and they are shown in Fig. 6. Straight lines found in the figures are corresponding SV velocities. From the figure we may conclude that the SV wave velocity in the surface layer is around 500 m/s.

3. Discussions

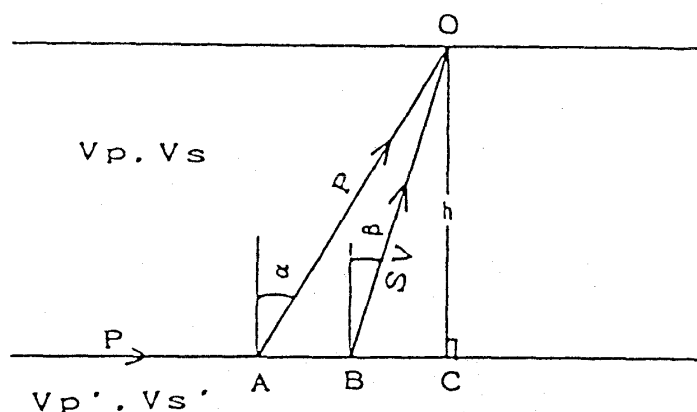
In the former analysis, we assumed the underground structure model as shown in Fig. 4. Namely, we assumed the constant velocities in the layers. If this is the case, from the theoretical point of view, the energy of critically refracted converted SV wave is expected to be very small. In the real earth, however, we may expect that the velocity in the layer increase with depth, although the velocity gradient may be small. In such a

2. Data and Analysis

Fig. 1 shows the shot and observation points carried out in this experiment. They are shown by "×" and "○" respectively. Shot and station numbers are also shown in the figure. Seismograms of both P and radial components obtained along two main NS spreads, S1 to NW and S6 to NE, were analysed. Fig. 2 shows examples of simultaneous comparison of vertical and radial ground motion. Seeing the figure, one will easily notice the clear late phases in radial component shown by arrows. It is extremely interesting to note that at the corresponding arrival times of such phases no significant phases are found in the vertical component. The plausible explanation of late phases found in the horizontal component is that these phases are converted SV waves generated at the layer boundary. P to SV conversion may take place at the existing discontinuities on the way of propagation path. For simplicity, we considered the case when P to SV conversion took place at the base rock boundary under the observation points. In this special case, as shown in Fig. 3, arrival time difference t between first P and SV phases will be

$$t = h (\cos \beta / V_s - \cos \alpha / V_p),$$

where, $\alpha = \sin^{-1}(V_p/V_p')$, $\beta = \sin^{-1}(V_s/V_p')$, and, V_p , V_s and V_p' , V_s' are the P and SV wave velocities in surface and basement layers respectively. h is the thickness of surface layer. Shima et al. (1990) obtained the thicknesses of surface layer at the stations and shown in Fig. 4. Therefore, an unknown variable in above equation is only V_s .



$$\alpha = \sin^{-1}\left(\frac{V_p}{V_p'}\right), \quad \beta = \sin^{-1}\left(\frac{V_s}{V_p'}\right)$$

Fig. 3. Paths of P and converted SV waves.

地震記象に見られる変換S波

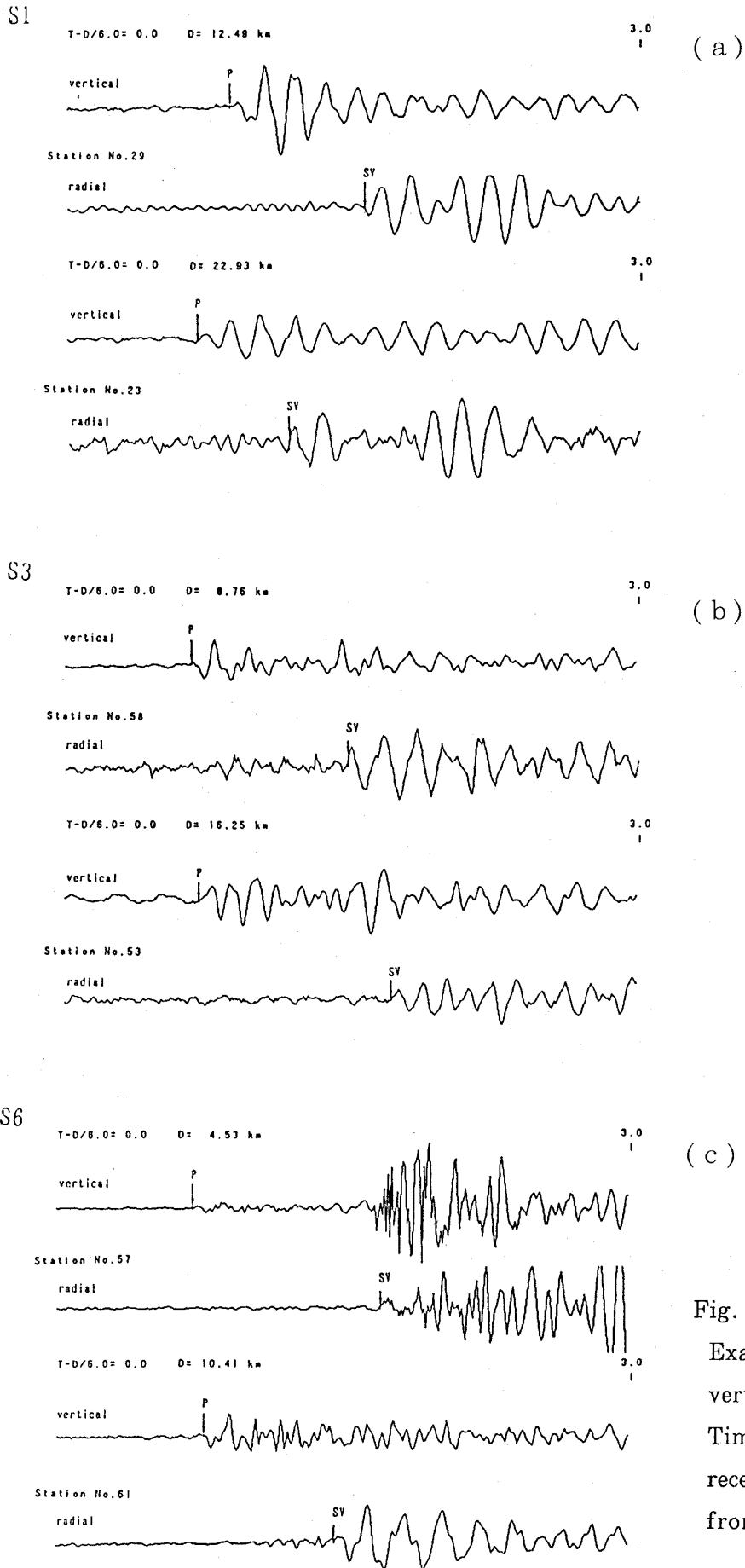


Fig. 2.

Examples of comparisons between vertical and radial seismograms. Time axis is reduced by source to receiver distance $D/6.0\text{km/s}$ from observed time.

brought the severe damage to the city and took more than 240,000 human lives. Due to this earthquake, the seismic intensity in Yutian area was VI in Chinese scale, while in the surrounding area that was VII. Yutian is situated on the alluvial deposits mainly composed of clay and sand. The shallow structure down to 20-30m depths in this area was studied in an attempt to interpret the abnormality, but no convincing explanation has been made yet. Thus, the joint study was aimed to clarify if the underground structure down to the Pre-Tertiary base rock at this area plays an important role to explain the observed intensity distribution or not. It was decided to utilize the refraction method to obtain the information of deeper underground structure at the site. It was extremely interesting to note that, we could observe P to SV converted waves during the experiment. This type of observation is quite seldom during the conventional refraction survey. Thus, in the following, we will mention briefly an effort to analyse P to SV converted waves.

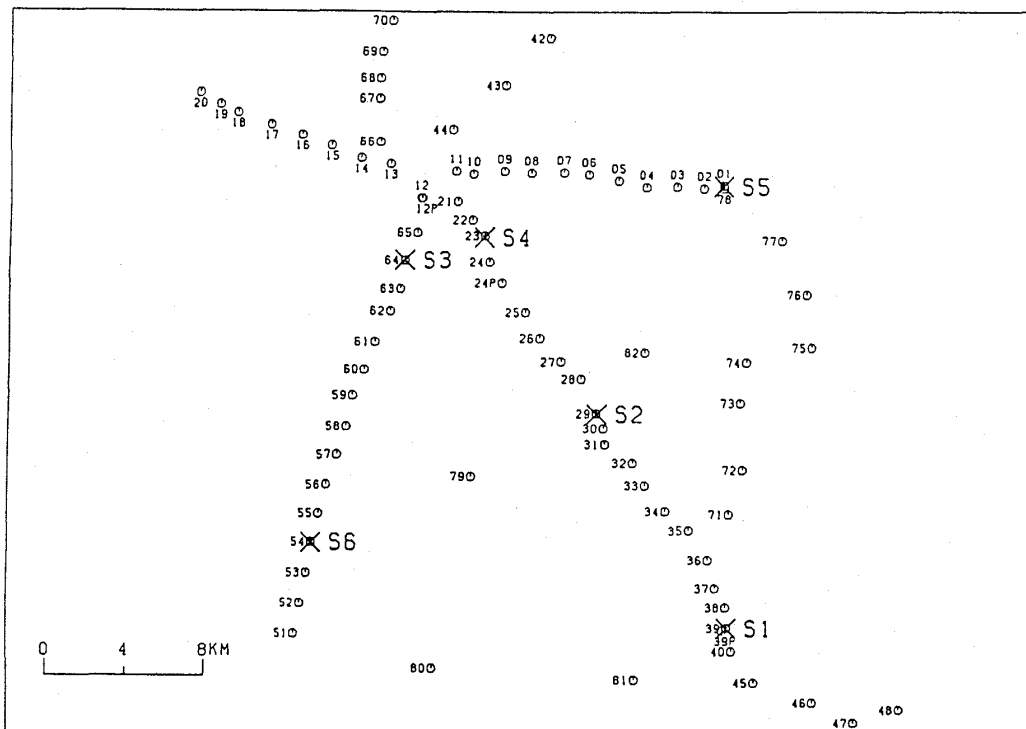


Fig. 1. Shot (crosses denoted by S1 to S6) and observation (small circles with station numbers) points of Yutian experiment.

Converted Shear Wave Arrivals detected in the Seismograms

By Etsuzo Shima¹⁾ and Tutomu Hoshino²⁾

Chiba Keiai Junior College¹⁾ and Tokyo Metropolitan Government²⁾

1. Introduction

In the field of engineering seismology, it is widely realized that the shear wave underground structure at the site plays an important role to explain the characteristics of seismic ground motion observed at the site. Thus the shear wave velocity logging down to the depth of few hundred meters is becoming quite popular at the site where the important facilities are being constructed.

Recently, the number of structures such as high rise buildings, huge oiltanks having long natural periods is increasing rapidly because of the needs of the times. For the aseismatic design of such structures, it is most desirable if the shear wave information down to the basement rock having the S wave velocity of around 3 km/s which is the topmost layer of the earth's crust is given. That is because, the seismic ground motion of long period range is affected very much by such a deep structure.

The refraction survey by means of explosive source is useful to obtain the P wave underground structure down to the base rock. Unfortunately, no shear wave source as powerful as the explosion source is used practically. Thus, we unavoidably convert the P wave underground structure into that of S wave by utilizing various assumptions.

The explosive source generates P and SV waves in the earth. Furthermore, P to SV conversion may take place everywhere at the velocity discontinuities which may exist along the wave path. Therefore, seismograms contain both P and SV information. However, we pay much attention on first P arrivals in conventional refraction survey. To pick the first arrivals accurately, signals are amplified very much and later arrivals which may contain SV phases are hard to discriminate because of the saturation. It is well known that the P wave predominates in the vertical component. On the contrary, SV wave predominates in the horizontal component of radial direction. So, if we compare the both components simultaneously, we may discriminate the arrivals of SV waves.

In 1987, the cooperative research on microzonation methodology has been started between Japan and China. The test field was selected in Yutian area, about 40km NW of Tangshan, China. In 1976, Tangshan area was attacked by M7.8 huge earthquake which