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CHARACTERISTICS OF SEISMIC S-WAVE PROPAGATION AT THE EDGE OF SEDIMENTARY PLAIN

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ABSTRACT

In observed ground motion, effects of propagation path is often very difficult to identify from source and site effects, since the effect of each factor do not appear separately both in frequency or time domain. But some seismograms have very simple wave form in which the propagation characteristics appear distinctively and clearly. In this paper, the propagation characteristics are discussed at the edge of sedimentary plain using seismograms recorded at ASK(Asakawa) on rock site and FCN(Fuchinobe) on sediment site due to the August 5, 1990 earthquake that occurred at the west part of Kanagawa prefecture(M=5.1, H=13.6 km). It was found that the first later phase that appeared as S-wave at FCN is not produced by multiple reflections of SH-wave at the upper boundary of dipping basement around the edge. Rather it was generated at the edge of sedimentary plain or structural line about 6.3 km away from FCN, in the south-west direction. This enable us to understand the contribution of path on ground motion when simple records are available.

KEYWORDS

path effects; first S-wave; first later phase; multiple reflection of SH-wave; polarization; time difference

INTRODUCTION

Strong ground motion prediction is one of important items for earthquake disaster prevention. Generally, ground motion is expressed as product of seismic source characteristics, path and site effects. If it is possible to understand these factors exactly, earthquake ground motion prediction with good accuracy will be possible. But it is difficult to identify and to estimate these factors since they are related to each other in a complex way. So it is important to estimate each characteristic using observed seismograms which show each factor clearly.

Sometimes small magnitude earthquake seismograms, which have simple wave form, showing the path effects between source and observation point are recorded. When the characteristics of seismic S-wave propagation was paid attention for instance, they will give useful information to investigate the path effects since it is difficult to identify later phases using big earthquake seismograms.

The objective of this paper is to investigate the characteristics of seismic S-wave propagation at the edge of sedimentary plain in the south west part of Kanto area using one of the simple seismograms recorded during the August 5, 1990 earthquake that occurred at the west part of Kanagawa prefecture(M=5.1, H=13.6 km).

OBSERVATION

The Kanto plain is one of the largest plains in Japan. Its south west-part is depicted in Fig. 1 with the observation points and the surface geology conditions. Velocity type strong motion seismometers and velocity type seismometers with three orthogonal components each were installed at ASK and FCN, respectively. The station ASK is located at the west part of the plain on a hard rock. FCN is located around the same area at the edge of the plain in the sediment. According to survey of deep structure by seismic explosion experiment done in the south Kanto area, the shape of upper basement leans to the east around FCN. The thickness of sediment to the basement is about 1,500-2,000 m. And going towards the west area, the thickness decreases drastically(Higashi *et al*, 1989).

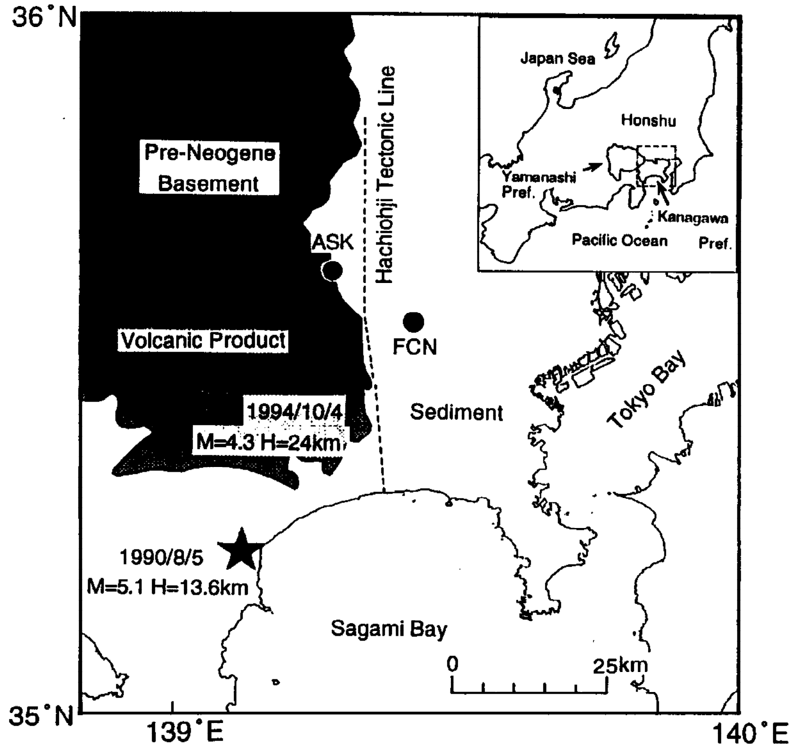

Fig. 1. Map of the south-west part of Kanto plain with surface geological conditions. The solid circles indicate observation sites. The stars show the epicenters of earthquakes.

CHARACTERISTICS OF WAVE FORM

Figure 2 shows an example of the three component seismograms recorded at FCN. Train of impulsive later phases appears after 2-3 seconds of first S-wave arrival in horizontal components. A such phenomena can be seen only in seismograms of earthquakes that occurred between the west part of Kanagawa prefecture and the east Yamanashi prefecture areas. The focal depth of these earthquakes is comparatively sallow(less than about 35 km). This type of seismograms has the following common characteristics;

(1) The time interval between the successive train of impulsive later phases becomes shorter and shorter towards the later duration.

(2) The pulse width of later phases in horizontal components are wider than that of first S-wave.

Kinoshita(1985) and Yamanaka *et al.* (1988) found seismograms observed during earthquake and explosion with the same shape from records at Fuchu array observation on the Kanto plain, in Tokyo. As the results of analyses of characteristics of seismograms, by using apparent velocity method and Hilbert transform method. It was observed that the train of impulsive later phases was produced by multiple reflections of SH-wave at the upper boundary of dipping basement around the edge.

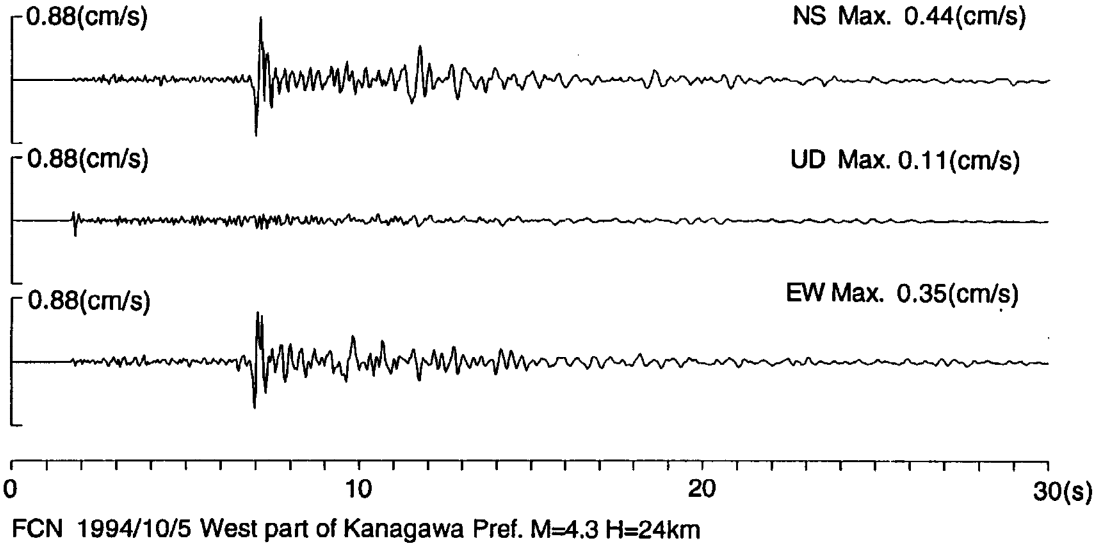

Fig. 2. An example of seismograms with later phases recorded at FCN.

Most of seismograms with similar wave shape, recorded at FCN, can be explain by their approach. But there are seismograms which can not be explain by the above method. The three component seismograms recorded at FCN shown in Fig. 3 is one of them. This earthquake occurred in the west part of Kanagawa prefecture area, on August 5, 1990, M=5.1, H=13.6 km. Though this seismogram has same characters described before, it seems that the phenomena that appeared in this seismogram can be explained by their conclusion. But after analyzing this seismograms in detail, a big difference was found. Somewhat big amplitude appeared as impulsive first later phase in vertical component. Generally on sedimentary plain, rays are refracted to vertical incidence gradually, as they pass through sedimentary layers. Only little part of the S-wave can appear in vertical component. So in this case, it is difficult to explain the later phase produced by multiple reflections of SH-wave at the upper boundary of dipping basement.

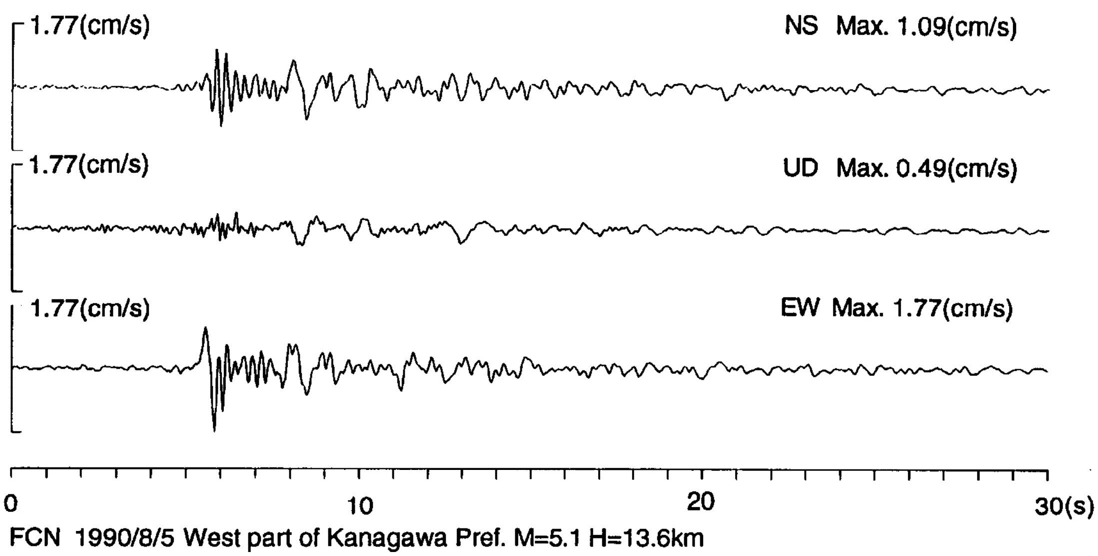

Fig. 3. An example of seismograms of different type of later phase recorded at FCN.

Next, seismograms observed at ASK and FCN, on August 5, 1990, were compared. Figure 4 shows the seismograms for each site, low pass filtered with 1 Hz cut off. When the first S-wave at ASK is overlapped on the first later phase of FCN in the vertical component, the other later phases in both seismograms are in agreement in both the vertical and horizontal components. Therefore it is difficult for the above characters to be explained by multiple reflections of SH-wave at the upper boundary of dipping basement. So it is necessary to investigate other possible effects.

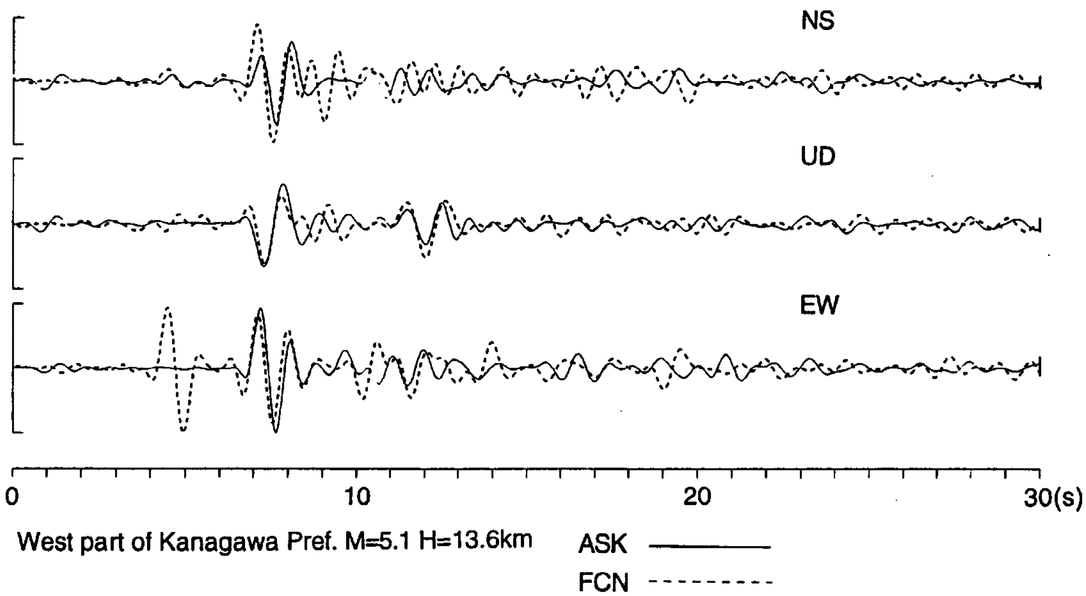

Fig. 4. Seismograms when the first S-wave at ASK is overlapped on the first later phase of FCN in the vertical component. Solid line is for ASK. Broken line is for FCN. Amplitude was normalized at each site by the maximum amplitude of the three components.

POLARIZATION ANALYSIS

To further investigate the cause and nature of these later phases, polarization analysis was made for recorded ground motion of the August 5, 1990 at each site using complex polarization analysis method proposed by Vidale(1986). The results are shown in Fig. 5.

The dip angle, which expresses inclination of orbit for horizontal plain, indicates negative value and there is big amplitude around the first S-wave motion in vertical component at ASK.This mean that the first S-wave is SV-wave. The elliptical polarization parameter, which is 0 for linearly polarized motion and is 1 for circularly polarized motion, is about 0.5, in this case, indicating elliptically polarized motion. It means that at the first S-wave arrival a Rayleigh wave characteristics is exhibited. So it indicates that part of first S-wave is not only body wave but also a wave with Rayleigh wave character, which propagated from south-west to north-east direction, as the principal axis of particle orbit on the plain shows.

On the other hand, in the part of first S-wave ground motion at FCN, the values of dip angle and elliptical polarization parameter gave almost 0, indicating that the seismic wave propagated vertically in the sedimentary plain. In the first later phase ground motion, the dip angle is almost 0, but the elliptical polarization parameter is about 0.5. It means that the first later phase has the characteristics of Rayleigh wave. So it is difficult to explain the first later phase to be produced by multiple reflections of SH-wave at the upper boundary of dipping basement. It is necessary to recognize the first later phase as surface wave. As the principal axis of particle orbit in the plain shows, this wave propagated from south-west to north-east direction.

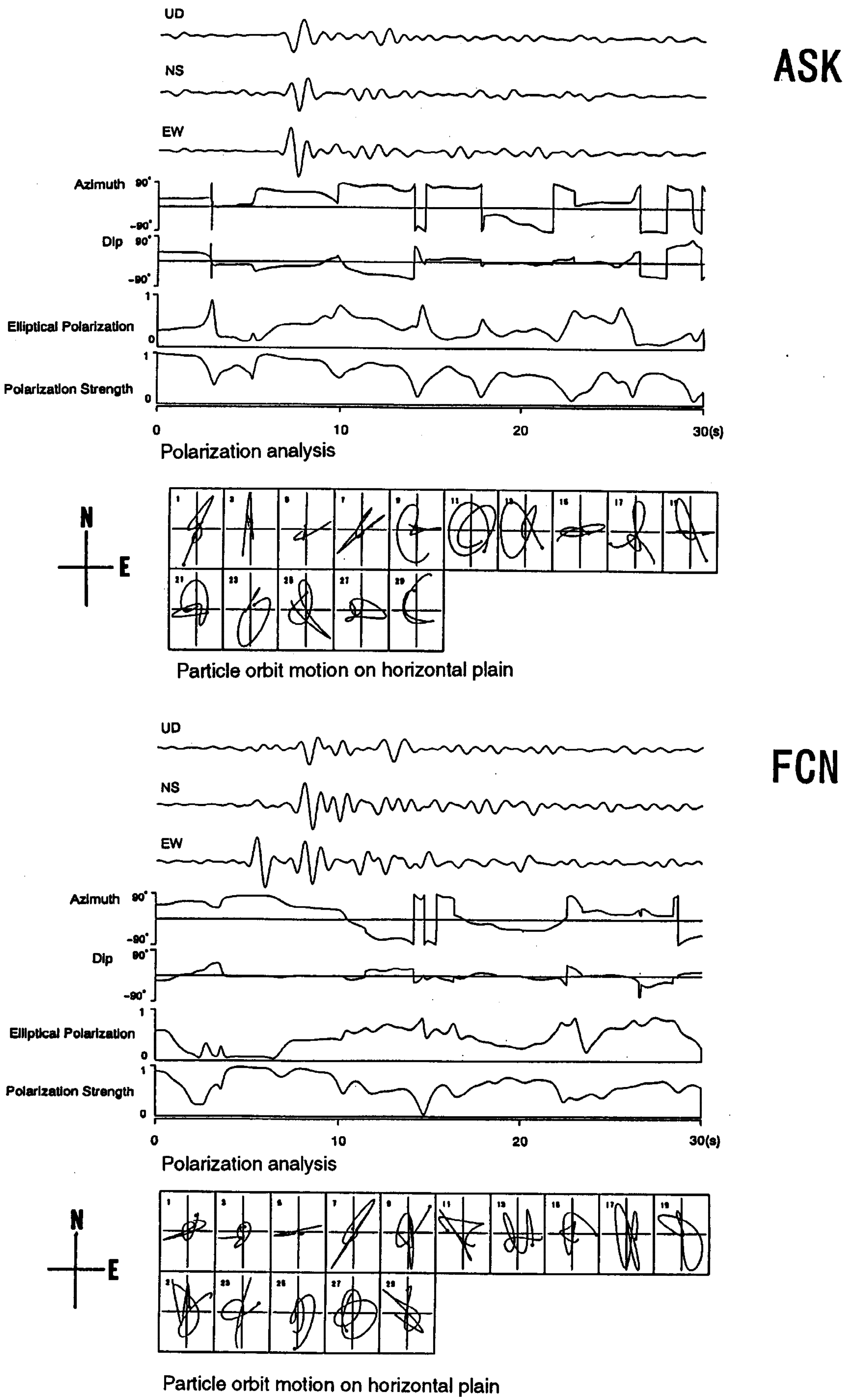

Fig. 5. Polarization analysis and particle orbits on horizontal plain of the velocity records from ASK and FCN. The numbers in the box at the right upper corner are the time in sec.

TRAVEL TIME ANALYSIS

Figure 6 is seismograms which shows the location of onset of first S-wave and first later phase detected by AIC (the Akaike's Information Criterion) and standard travel time table(Hamada, 1984), indicated by small and big arrows respectively.

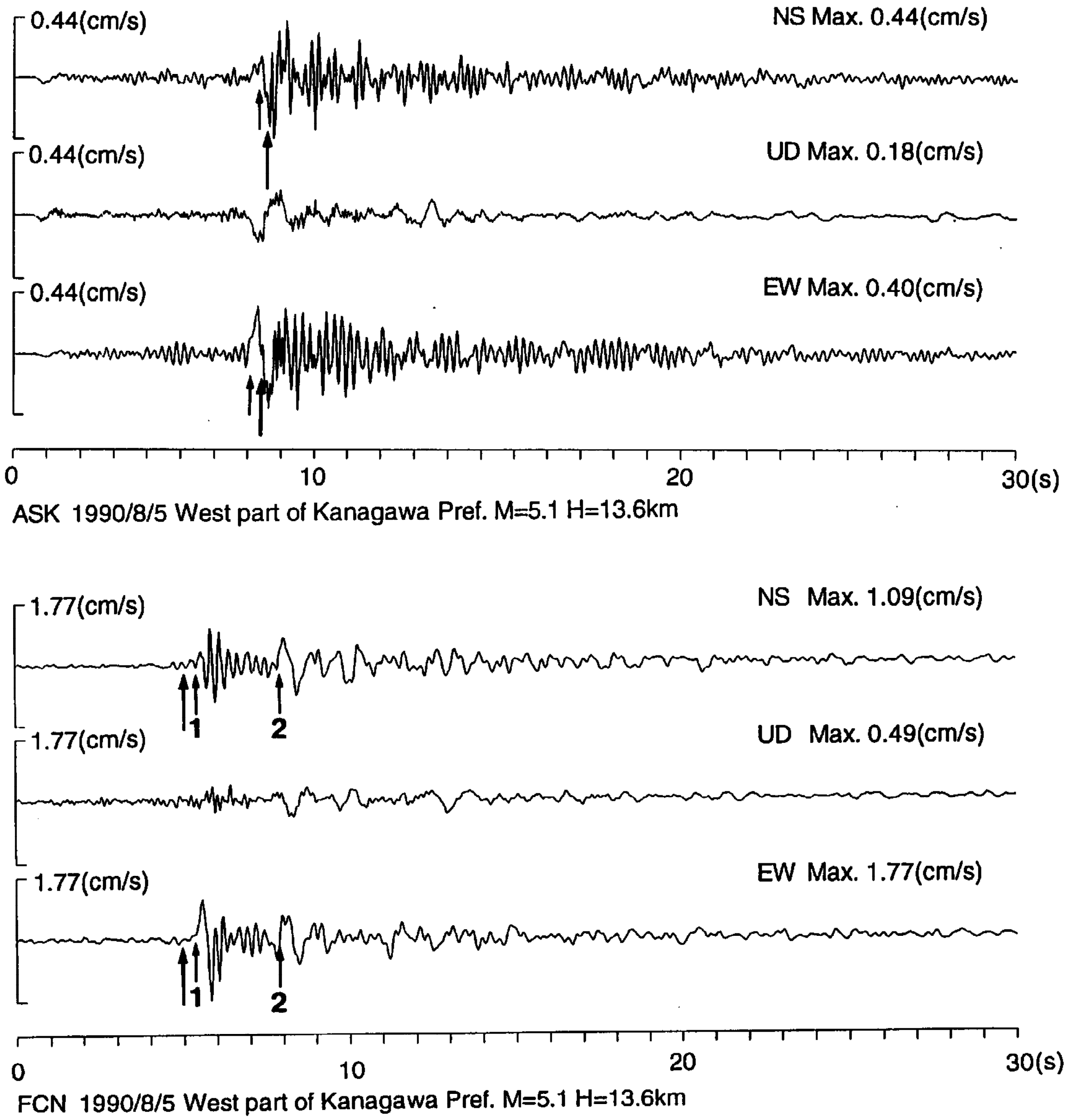

Fig. 6. Seismograms at ASK and FCN for the August 5, 1990 earthquake that occurred at west part of Kanagawa prefecture. The big arrows show the location of inference arrival time by standard travel time table. The small arrows indicate onset of first S and first later phase detected by AIC. No. 1 is located on S-wave onset. No. 2 is located on first later phase onset.

The arrival time of first S-wave is faster than the inference arrival time by standard travel time table. Because the ray of S-wave may have passed though high velocity structure area faster than average velocity structure which was assumed in standard travel time table. In spite of longer epicentral distance about 1.9 km as compared to ASK, the arrival time at FCN was delayed 0.98 sec as compared to ASK. Because the ray passes into sedimentary layer with low velocity structure. Assuming that the basement S-wave velocity is 3.1 km/sec and the average S-wave velocity in sedimentary layer is 1 km/sec, the thickness of sediment on FCN was estimated to be about 1.5 km by time term method using time difference between the first S-wave and the first later phase. This is in agreement with the result of seismic explosion survey(Higashi *et al.*, 1989).

Next, the relation between the first S-wave and the first later phase was considered. At FCN the time difference is 2.66 sec. If the time delay at FCN due to the sedimentary layers is corrected by assuming the same site condition as ASK, the arrival time at FCN will be faster by 1.59 sec. On the other hand, it was assumed that the first later phase propagated in sedimentary layers since it has the characteristics of Rayleigh wave. After correcting the time difference which removes the delay time, it is possible to detect the location of the later phases generation area using the corrected time difference and propagation direction estimated by principal axis of the particle orbit. As a result, the later phases observed at FCN during this earthquake was generated around the area between Hachiohji tectonic line and boundary of sedimentary plain, which is about 6.3 km away from FCN in the south-west direction(Fig. 7).

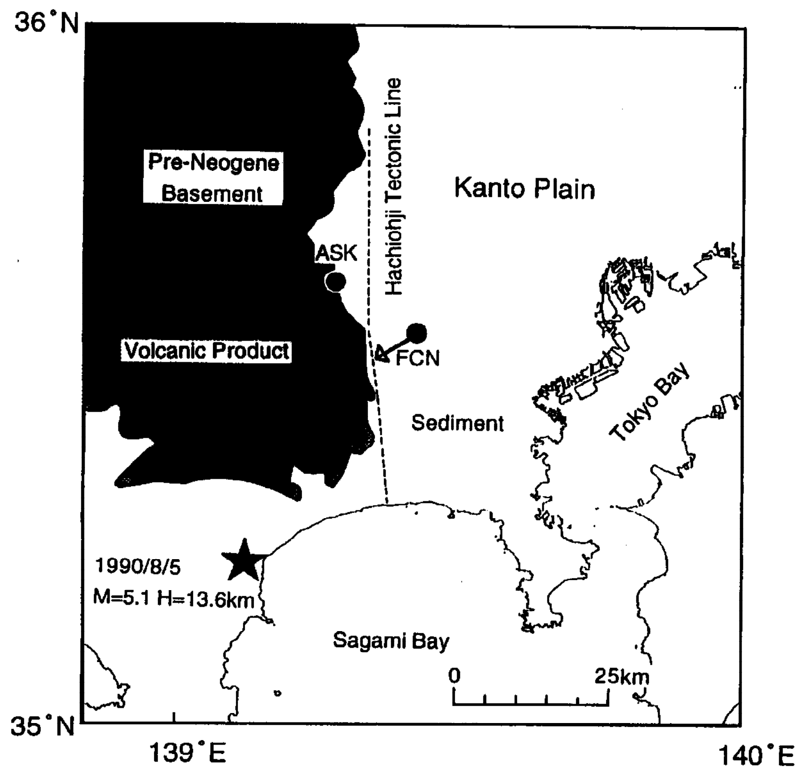

Fig. 7. Region of later phase generation indicated by arrow.

CONCLUSION

The characteristics of the seismograms observed at ASK and FCN due to the earthquake which occurred at the west part of Kanagawa prefecture on August 5 1990 (M=5.1, H=13.6 km) may be summarized as follows;

(1) As the result of polarization analysis, the first S-wave has the characteristics of both SV and Rayleigh wave, and propagates from south-west to north-east direction. On the other hand, It has SH-wave characteristics at FCN. And the first later phase that can be seen only at FCN has characteristics of a Rayleigh wave, and propagate from south west to north-east direction. It is difficult to explain later phases at FCN to be generated as multiple reflections of SH-waves at the upper boundary of the dipping basement around the edge area.

(2) Since the arrival time of first S-wave at ASK is faster than the inference arrival time obtained by standard travel time table, it was understood that the ray of S-wave passes though high velocity structure area faster

than the average velocity structure which was assumed in standard travel time table. And the delay of first S-wave arrival time at FCN can be explain by the depth of sediment at this site.

(3) The later phases observed at FCN was generated at the edge of sedimentary plain because of time difference between onset of first S-wave and first later phase.

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