Generation of Converted Love Waves in Irregular Crustal and Upper Mantle Structures

Mitsuru Yoshida[1]

[1] Fortran Plan Office
6-24-7 Yutaka-chou, Kasukabe-Shi,Saitama-Ken, 344-0066 Japan

1 Introduction

Seismic surface waves, which are excited by earthquakes or nuclear explosion test, are propagated along the Earth's surface of the ocean and continent. When the surface waves travel laterally inhomogeneous regions, the conversion from Rayleigh waves to Love waves is likely to occur. In the present study we numerically model the mountain root structure of the Tien Shan, which is located at the western part of Lop Nor nuclear test site in China. Seismic long-period Rayleigh waves are assumed to be propagated obliquely in the mountain root structure. The propagation of Rayleigh waves across the irregular crustal and upper mantle including double low velocity zones beneath the mountain root is simulated by the use of 3-D finite difference method [1, 2]. The generation of Love waves converted from Rayleigh waves can be observed through time series and wave motion fields. The eigenfunctions of converted Love waves are investigated on the basis of normal mode theory.

2 Mountain root structure and Rayleigh wave propagation

The oblique incidence of plane Rayleigh waves on the irregular front (t1) of the mountain root structure is schematically shown in Fig. 1. Waves are coming from the left (site 5) and are outgoing to the right. Waves travel towards site 15 (ϕ =0 deg.) and 15' (ϕ =60 deg.) for Models T and LB. The model LB has a double low velocity zone (LVZ) beneath the mountain root structure while the Model T does not include a LVZ. Physical parameters of velocities of compressional (Vp) and shear (Vs) waves, and density (ρ) for the eastern and western regions of the Tien Shan are used. When Rayleigh waves travel for the azimuthal angle of incidence of ϕ =0 deg., there is no surface wave interconversion [3]. Conversion from Rayleigh waves to Love waves increases with the increase of the azimuthal angle of incidence [4, 5]. Scattered waves for ϕ =60 deg. are shown in Fig. 2. Rayleigh waves of the W and U components are not so different between Models T and LB, while Love waves of the V component are significantly excited at site 5 for Model LB. The amplitudes of the V component are also greater at site 15' for Model LB than for Model T.

3 Wave motion field of the displacement

The displacement-depth profiles of the W, U, and V components for Model LB are shown in Fig. 3, in which the elaps time of the time series given in Fig. 2 is 270 sec. For both the W and U components the displacement distributions obliquely contoured downwards in the right direction are observed in a depth range from 150 km beneath site 5 to 300 km

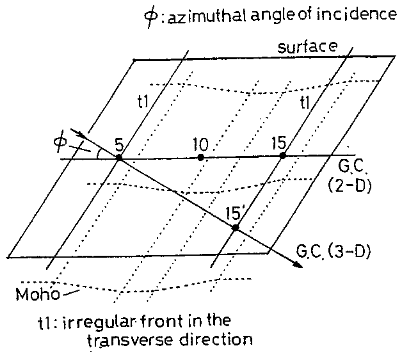

Fig. 1. A bird's eye view of the oblique incidence of Rayleigh waves. The distance between sites 5 and 15 is 250 km.

beneath site 10'. However, these pattern is not found in the V component. The oblique displacement distributions of the W and U components are extended in the upper mantle near the low velocity zone (LVZ4) at depths of 112.5 –162.5 km. They can be caused by reflections of Rayleigh waves travelling towards the wave's incoming direction. Parts of scattered waves are transmitted in inner parts of the Earth and might be converted to compressional waves (P waves) and shear waves (S waves) [6, 7]. In the crust and upper mantle between site 10' and 15', where the reflection is not significant the positive (solid line) and negative (dotted line) displacements of the W and U components are alternately distributed in the inner parts as well as on the ground surface.

The displacements of converted Love waves of the V component, as well as those of Rayleigh waves of the W and U components, decrease gradually with the increase of depth in the crust and upper mantle (Fig. 3). However, the maxima of the amplitudes of the V-component are not always located at the ground surface. The maximum amplitude of -207 ($x10^{-5}$) cm in the V-component, denoted in the depth of about 30 km in the right side of site 10', implies that the amplitude pattern is formed in the process of conversion from Rayleigh to Love waves beneath the mountain root structure.

4 Eigenfunctions of Rayleigh waves and converted Love waves

For the oblique incidence of Rayleigh waves on the mountain root structures the conversion from Rayleigh waves to Love waves is likely to occur owing to the slope of Moho discontinuity. The existence of a double LVZ in the crust and the mantle strengthens the scattering of the vertical and radial components, which leads to the generation of Love waves whose particle displacement consists of the transverse component. For both Models T and LB the conversion from

Rayleigh waves to Love waves is maximum near at periods of 20-25 s [4]. The eigenfunctions of Rayleigh waves and Love waves are shown in Fig. 4, along with the eigenvalues (c). The displacement function of Rayleigh waves of the W component y_1^R , which is maxmum near at the ground surface, is close to that of Love waves y_1^L .The stress function of Rayleigh waves of the W component y_2^R is relatively similar to that of Love waves y_2^L . The wave number (k) of converted Love waves is smaller than that of Rayleigh waves; the wavelength (λ) of converted Love waves is longer than that of Rayleigh waves. The phase velocity (c) of converted Love waves is faster than that of Rayleigh waves.

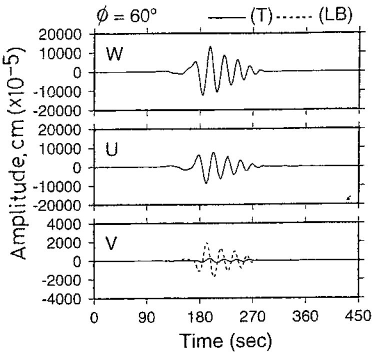

Fig. 2. Time series of scattered waves of the vertical (W), radial (U), and transverse (V) components at site 5 for angle of incidence of 60 deg.

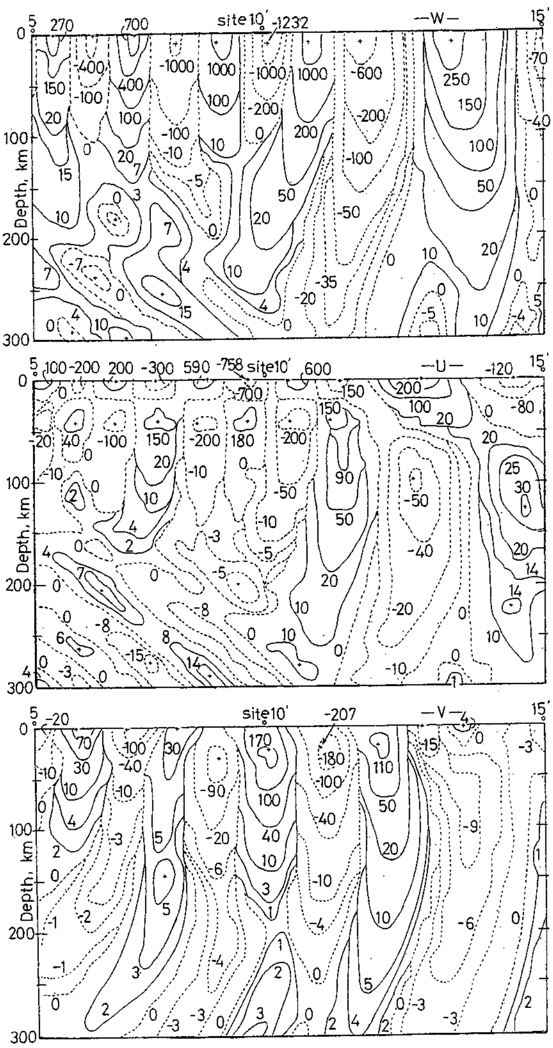

Fig. 3. Wave motion fields for the vertical (W), radial (U), and transverse (V) components at an elaps time of 270 s.

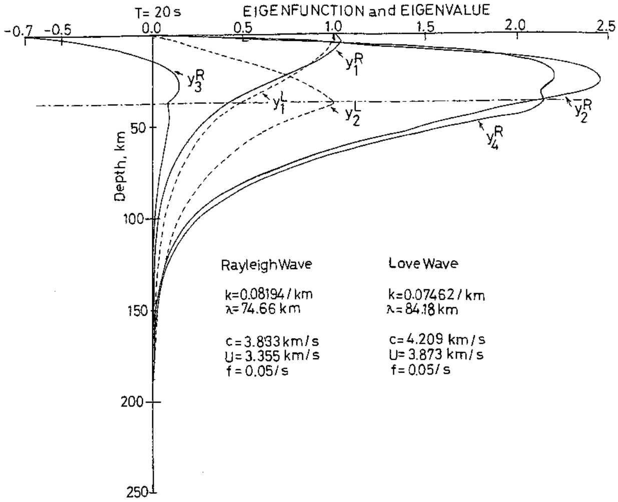

Fig. 4. Eigenfunctions of Rayleigh waves (y_1^R, y_2^R, y_3^R, y_4^R) and Love waves (y_1^L, y_2^L) for a period of 20 s . A dot-dash line denotes the depth 37.5 km of the Moho discontinuity. Eigenvalues are indicated by phase velocities (c).

5 Conclusion

Particle motion of Rayleigh waves consists of the displacements of the vertical (W) and radial (U) components. For Rayleigh wave propagation in irregular crustal and upper mantle structures, a part of Rayleigh wave energy converts to Love wave energy, the displacement of Love waves being the transverse component (V). The generation of converted Love waves due to an oblique incidence of Rayleigh waves with an azimuthal angle of 60 deg. on the front of the mountain root structure has been simulated by the use of 3-D finite difference method and the wave motion field of the displacement of converted Love waves has been depicted as well as those of incident Rayleigh waves. It is suggested from the eigenfunction analysis that the displacement-depth curve of converted Love waves is close to that of incident Rayleigh waves of the vertical component at periods of 20-25s.

References

[1] Yoshida, M., Shear wave splitting simulation in an anisotropic body, Proceedings of the 27th Japan Simulation Conference, Japan Society for Simulation Technology, 273/276, 2008.

[2] Yoshida, M., qP-wave anisotropy due to lattice preffered orientation, Proceedings of the 28th Japan Simulation Conference, Japan Society for Simulation Technology, 253/256, 2009.

[3] Yoshida, M., Oscillation of a mountain root structure due to a Rayleigh wave incidence, Earth Planets Space, 53, 1099/1109, 2001.

[4] Yoshida, M., Rayleigh to Love wave conversion in a mountain root structure, Bull. Earthq. Res. Inst., Univ. Tokyo, 78, 1/18, 2003.

[5] Pedersen, H. A., J. P. Avouac and M. Campillo, Anomalous surface waves from Lop Nor nuclear explosions: Observations and numerical modelling, J. Geophys. Res., 103, 15051/15068, 1998.

[6]Yoshida, M. And H. Hagiwara, Inspections of the wave-fields of Rayleigh wave scattering, Japan Geoscience Union Meeting Abstract, S210-P007, 2006.

[7] Yoshida, M., Rayleigh wave scattering and resonant standing waves, Japan Geoscience Union Meeting Abstract, S210-P008, 2006.