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# Polarization anomalies of Love waves observed in and around Japan

Reiji Kobayashi*

*Department of Geophysics, Kyoto University, Kyoto 606-8502, Japan*

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Polarization anomalies of Love waves, sometimes called quasi-Love waves, are likely to be caused by lateral variations of azimuthal anisotropy in the upper mantle. Polarization anomalies of Love waves from the 9 October 1995 earthquake near the coast of Jalisco, Mexico, have been recorded by the Pacific21, IRIS, and Japan Meteorological Agency networks of broadband seismometers in and around Japan. The Love-to-Rayleigh conversion areas for the clearly detected quasi-Love waves are located by using the group velocities of the observed surface waves. In the cases of the stations in the northern part of Japan and Philippine, the locations of the Love-to-Rayleigh conversions mostly concentrate near the trenches, and suggest that the properties of the azimuthal anisotropies in the upper mantle have lateral variations across the trenches. We infer that the lateral variations of the azimuthal anisotropies may reflect the changes of the mantle flow due to the subducting slabs. The Love-to-Rayleigh conversion areas for the other stations mainly concentrate near the Emperor seamounts and the Mid-Pacific mountains. Several results of surface wave tomographic studies show that the azimuthal anisotropies in these regions are much weaker than those in the central part of the Pacific along the paths. The lateral variation in azimuthal anisotropy may cause the Love-to-Rayleigh conversions.

## 1. Introduction

Love and Rayleigh waves are coupled by the rotational Coriolis force, ellipticity, lateral heterogeneities, and azimuthal anisotropies in the Earth (e.g., Woodhouse and Dahlen, 1978). As a result of the coupling, polarization anomalies of Love and Rayleigh waves, which are sometimes called quasi-Love and quasi-Rayleigh waves, respectively, can be seen in the records (e.g., Park and Yu, 1992; Yu and Park, 1993). However, the effects of the rotational Coriolis force and ellipticity on the coupling are negligible at frequencies higher than 4.2 mHz (Park, 1986).

The quasi-Love waves, arriving simultaneously with or slightly behind the Love waves, appear in the vertical and radial components, and the quasi-Rayleigh waves, arriving simultaneously with or slightly before the Rayleigh waves, appear in the transverse component. Since the refracted Love waves do not appear in the vertical component, the quasi-Love waves can be easily distinguished from the refracted Love waves. On the other hand, it is difficult to distinguish the quasi-Rayleigh waves from the refracted Rayleigh waves, because not only the quasi-Rayleigh waves but also the refracted Rayleigh waves appear in the transverse component. Furthermore, the quasi-Rayleigh waves can be contaminated by the Love wave coda. The quasi-Love waves are useful to investigate the coupling between Love and Rayleigh waves. However, since higher-mode Rayleigh waves are similar to quasi-Love waves, we should distinguish between them by comparison of observed seismograms with the synthetic ones for a spherically symmetric Earth model.

Park and Yu (1992) and Yu and Park (1993) calculate coupled free oscillations at periods longer than 67 s in laterally heterogeneous or azimuthally anisotropic structures. They show that plausible levels (e.g., 3%) of the lateral heterogeneities in the upper mantle cannot generate clear quasi-Love waves, while the lateral variations of a few percent in azimuthal anisotropic media effectively generate quasi-Love waves. By means of the 2.5-D finite difference method with point sources developed by Okamoto (1994), Kobayashi (1998) calculates surface waves propagating across the Pacific from California to Hokkaido, Japan, in a model which has a velocity contrast in the crust and uppermost mantle across the Kuril trench. He shows that an unlikely velocity contrast of 20% at the Kuril trench is required to obtain clear quasi-Love waves in Hokkaido as observed by Kobayashi *et al.* (1997). The most possible cause of quasi-Love waves observed in Hokkaido is, therefore, lateral variations of azimuthal anisotropies. The quasi-Love waves can be used to detect lateral variations of azimuthal anisotropies in the upper mantle.

Shear wave splitting and surface wave tomography have been mainly used to investigate azimuthal anisotropies in the crust and upper mantle. Shear wave splitting provides us with local information of azimuthal anisotropies at stations, sources, or bounce points. On the other hand, surface wave tomography provides us with global distribution of azimuthal anisotropy, but its resolution usually is poor because of the small azimuthal coverage of the paths. Quasi-Love waves can provide us with regional information on azimuthal anisotropy and add constraints on results obtained

*Present address: Geodynamics Research Center, Ehime University, Ehime 790-8577, Japan.

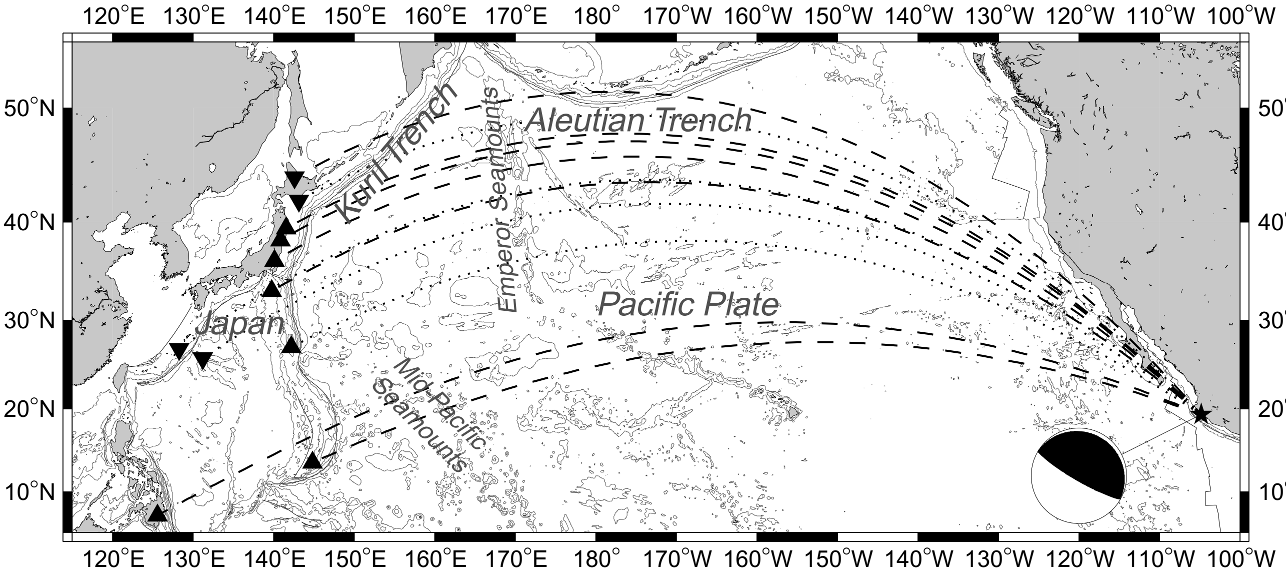


Fig. 1. Great-circle paths connecting the epicenter (star) of the 9 October 1995 earthquake near the coast of Jalisco, Mexico, and stations. The focal mechanism is taken from Dziewonski *et al.* (1997) (Table 1). The lower hemisphere of focal sphere is shown by equal area projection. The thin lines show the bathymetry contoured at 2000 m intervals. Dashed lines are for the paths with detected quasi-Love waves, and dotted lines for the paths with very weak or no quasi-Love waves.

by shear wave splitting and surface wave tomography.

Kobayashi *et al.* (1997), Kobayashi and Nakanishi (1998), and Kobayashi (1998) analyze the quasi-Love waves from the 17 August 1991 earthquakes located near Oregon and California, USA, recorded in Hokkaido, Japan. They conclude that the quasi-Love waves are caused by the lateral variation of azimuthal anisotropy across the Kuril trench, and infer that the mantle flow may change at the Kuril trench due to the subducting slab.

In this paper we extend the databases by analyzing the surface waves recorded by networks of broadband seismometers in Japan, Guam, and Philippine, which propagate across the northern Pacific and the Philippine Sea. The Love-to-Rayleigh conversion areas for the detected quasi-Love waves are located by using the group velocities of the observed surface waves, and we discuss the lateral variations of the azimuthal anisotropies in the northern Pacific and the Philippine Sea.

## 2. Data

The 17 August 1991 earthquake off the coast of the northwestern California that we mainly analyzed in our previous papers (Kobayashi *et al.*, 1997; Kobayashi and Nakanishi, 1998; Kobayashi, 1998) is very suitable to investigate the quasi-Love waves recorded in Japan, because the stations in Japan are close to the Rayleigh-wave radiation node, and the small quasi-Love waves can be easily detected. When the 17 August 1991 earthquake occurred, however, network of broadband seismometers in Japan was sparse. Yu and Park (1994) also detect quasi-Love waves propagating the Pacific, but only two stations in Japan were used.

Recently many broadband seismometers STS-1 and STS-2 have been installed in Japan. The data are managed by Pacific21 (formerly POSEIDON) and Japan Meteorological Agency (JMA), respectively.

Table 1. Source parameters (Dziewonski *et al.*, 1997).

| | |
|---|---|
| Origin time (UTC) | 1995/10/9 15:36:28.8 |
| Location | 19.34°N, 104.80°W |
| Depth | 15 km |
| Magnitude | $M_0$ 1.1 × $10^{28}$ dyne cm, $M_W$ 8.0 |
| Moment tensor | $M_{rr}$ 3.62, $M_{\theta\theta}$ −2.53, $M_{\phi\phi}$ −1.09, |
| | $M_{r\theta}$ 9.44, $M_{r\phi}$ −5.49, $M_{\theta\phi}$ 1.40 |
| Best double-couple | (302°, 9°, 92°), |
| (strike, dip, slip) | (120°, 81°, 90°) |

Table 2. Stations sorted by latitude (north to south).

| Code | Network | Lat. (°N) | Lon. (°E) |
|---|---|---|---|
| ASHI | JMA | 44.117 | 142.597 |
| ERIM | JMA | 42.016 | 143.157 |
| KGJ | Pacific21 | 39.388 | 141.565 |
| AOB | Pacific21 | 38.248 | 140.850 |
| TSK | Pacific21 | 36.211 | 140.110 |
| HCH | Pacific21 | 33.120 | 139.800 |
| OGS | Pacific21 | 27.050 | 142.200 |
| KUNK | JMA | 26.832 | 128.275 |
| MINA | JMA | 25.819 | 131.221 |
| GUMO | IRIS | 13.588 | 144.866 |
| DAV | IRIS | 7.0878 | 125.574 |

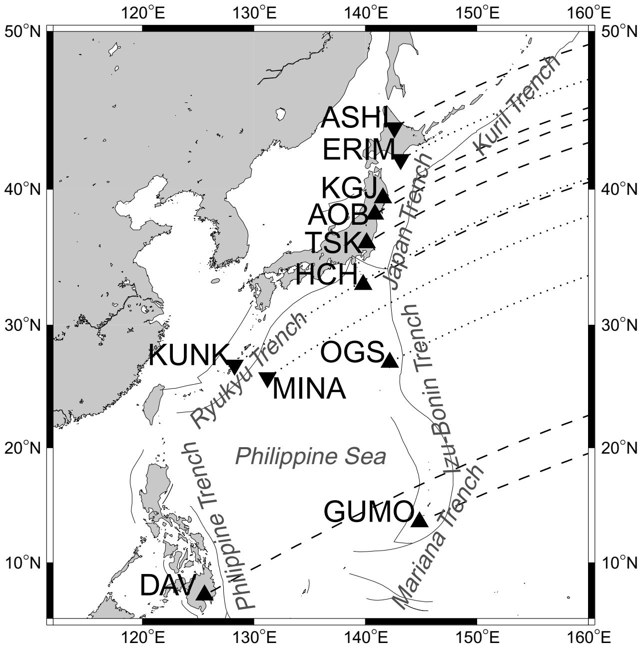


Fig. 2. Distribution of the stations. Triangles and inverted triangles indicate the STS-1 (Pacific21 and IRIS) and STS-2 (JMA) stations, respectively.

Surface waves propagating from the 9 October 1995 earthquake (Ms 7.4) near the coast of Jalisco, Mexico (Table 1), are clearly recorded by the Pacific21 and JMA stations in Japan and IRIS stations in Guam and Philippine (Fig. 1). We use eleven stations facing Pacific or Philippine Sea to prevent the effect of continental crust and mantle on quasi-Love waves (Table 2, Fig. 2). Figure 3 shows the transverse and vertical components recorded at all stations.

The focal mechanism of the 17 August 1991 is better than that of the 9 October 1995 earthquake, because all the stations recorded small Rayleigh waves which help us to recognize quasi-Love waves. Although the Rayleigh waves from the 9 October 1995 earthquake recorded at KGJ, HCH, and TSK are comparable with the Love waves, quasi-Love waves are observed at these stations clearly enough to analyze.

## 3. Detection of Quasi-Love Waves

The waveforms recorded at station HCH in southern Japan are shown in Fig. 4(a). A quasi-Love wave, arriving slightly behind the Love wave and before the Rayleigh wave, appears to be present in the vertical and radial components. Generally quasi-Love waves resemble to higher-mode Rayleigh waves. We calculate synthetic seismograms by summing all of the modes of spheroidal oscillations with periods $T \geq 31.4$ s, and compare the synthetic seismograms with the observed ones. The spherically symmetric and transversely isotropic Earth model PREM (Dziewonski and Anderson, 1981) is used for the synthetic waveform. The source parameters are taken from Dziewonski *et al.* (1997) (Table 1). The amplitudes of the fundamental-mode Rayleigh waves calculated were approximately 3 times as large as those of the observed waves. These discrepancies of amplitudes may be due to the uncertainties of the source parameters and the difference of shallow structure along the paths from that in the model.

The synthetic seismogram of the vertical component at HCH lowpass filtered at 60 s is also shown in Fig. 4(a). No higher-mode Rayleigh wave, arriving simultaneously with or slightly after the fundamental Love wave, appears in the synthetic seismogram. The source depth estimated by Dziewonski *et al.* (1997) is shallower than 24 km depth estimated by the detail analysis of the source process (Escobedo *et al.*, 1998). We also synthesize the seismograms with the depths changed to 30 and 50 km, which are deeper than the depth estimated by Escobedo *et al.* (1998), and with the best double-couple of the moment tensor. The higher-mode Rayleigh wave still does not appear. Thus we can recognize the quasi-Love waves in the observed seismograms.

We attempt to detect quasi-Love waves in the records at all the stations (Fig. 3). The observation of the quasi-Love waves in and around Japan is summarized in Fig. 1.

At station ERIM, quasi-Love wave cannot be seen in the seismograms. At stations OGS, MINA, and KUNK (Fig. 4(b)), small waves arrive before the Rayleigh waves, but have several peaks or a continuous wavepacket. These small waves may be quasi-Love waves. However, we cannot use them to locate the conversion area in the next section. The causes of very small or no quasi-Love waves are discussed in Section 5.

## 4. Locations of Love-to-Rayleigh Conversions

A quasi-Love wave propagates as a Love wave with the Love group velocity before the Love-to-Rayleigh conversion, and propagates as a Rayleigh wave with the Rayleigh group velocity after the conversion. We can locate Love-to-Rayleigh conversion areas by using the group velocities of the observed Love, Rayleigh, and quasi-Love waves (Kobayashi and Nakanishi, 1998). If a Love-to-Rayleigh conversion occurs gradually, the quasi-Love wave can have a long wavepacket. Most of the quasi-Love waves that we detected in this study have short wavepackets, suggesting that the conversions occur sharply. Thus, we assume that the conversion occurs at a point on the great-circle path. We also assume no bend of surface wave paths due to conversion and refraction, and constant group velocities along the two paths before and after the conversion. The distance $\delta\Delta$ between the conversion point and station is represented by

$$\delta\Delta = \frac{U_{qL}^{-1} - U_L^{-1}}{U_R^{-1} - U_L^{-1}}\Delta,$$

where $U_L$ and $U_R$ are the observed group velocities of the Love and Rayleigh waves, respectively, and $U_{qL}$ the apparent group velocity of the quasi-Love wave for the epicentral distance $\Delta$.

The group velocities are measured by means of the multiple filter technique (Dziewonski *et al.*, 1969). This method involves a systematic error from the distribution of the input spectrum amplitude (Cara, 1978; Levshin and Lander, 1989; Shapiro and Singh, 1999). When the spectrum amplitude is larger at higher frequencies, the maximum amplitude of the gaussian-filtered spectrum shift to a higher frequency than the central frequency of the gaussian filter. Shapiro

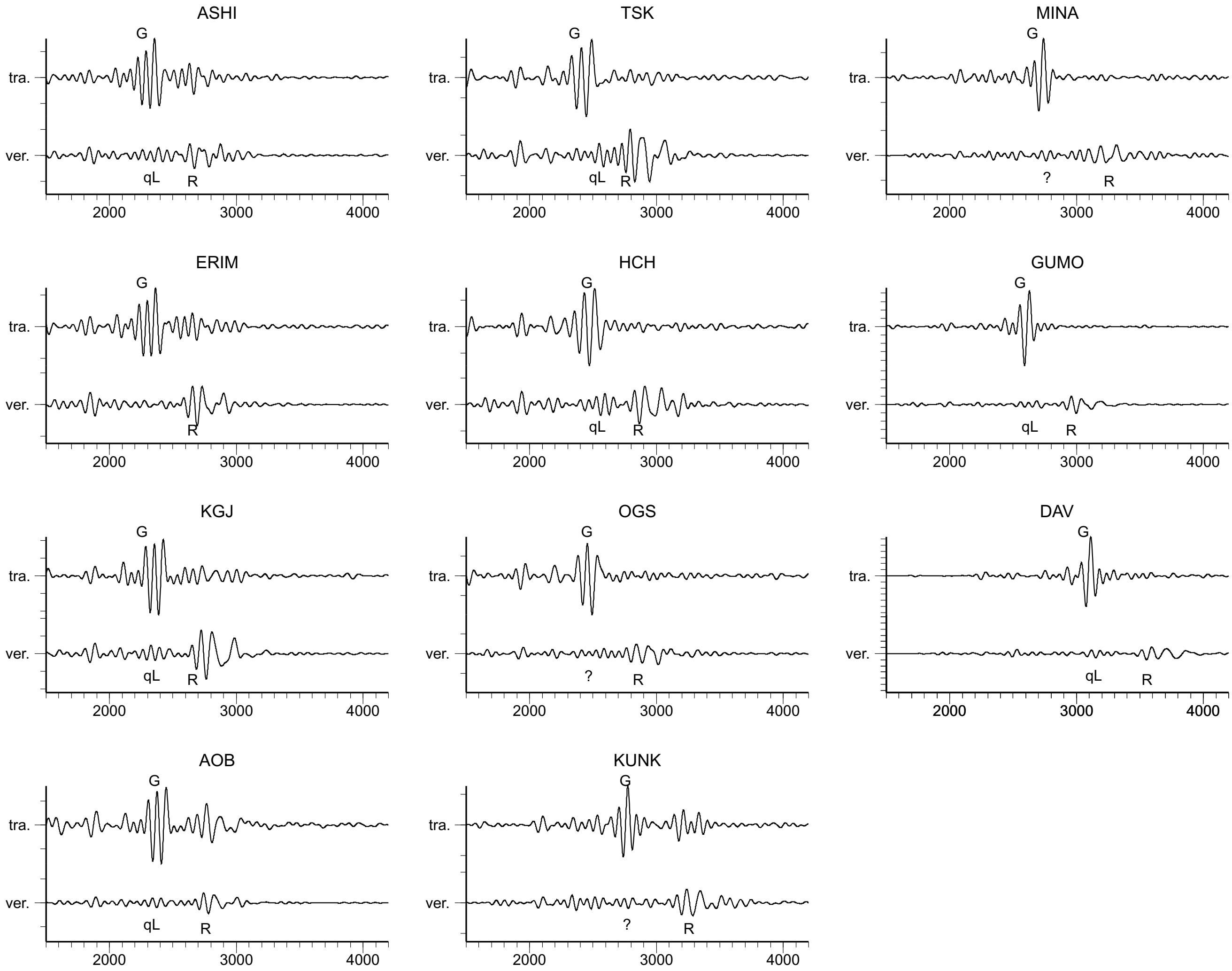


Fig. 3. Transverse and vertical components recorded at all stations for the 9 October 1995 earthquake. Seismograms are lowpass filtered at 60 s. Tickmark intervals are 100 s for travel time and 10 $\mu$m/s for amplitude. G, R, and qL mark Love, Rayleigh, and quasi-Love waves, respectively.

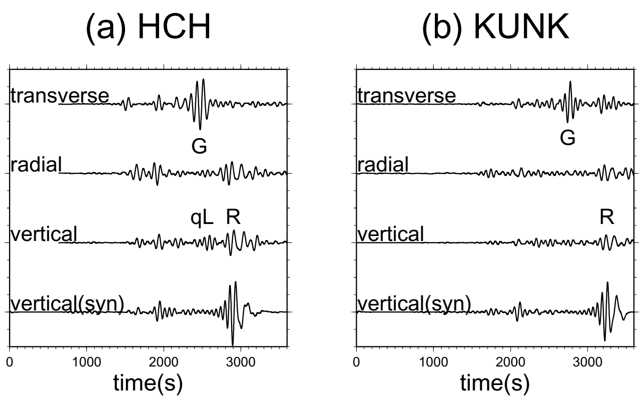


Fig. 4. Observed and synthetic seismograms (syn) of the vertical component lowpass filtered at 60 s. (a) HCH, (b) KUNK.

and Singh (1999) propose that the central frequency of the gaussian filter should be replaced by the centroid frequency of the filtered spectrum in order to correct the systematic error. A filtered spectrum $y(\omega_0, \omega)$ is made by a multiplication of the spectrum of a seismogram $x(\omega)$ in frequency domain by a gaussian filter,

$$y(\omega_0, \omega) = e^{-\alpha[(\omega-\omega_0)/\omega_0]^2} x(\omega),$$

where $\omega_0$ and $\alpha$ are the central frequency and a parameter of the bandwidth of the filter, respectively. In this study, $\alpha$ is equal to 12.6. The bandwidth is slightly broad so that the quasi-Love waves are clearly separated from the Rayleigh waves in time domain. The centroid frequency $\omega_c(\omega_0)$ of the filtered spectrum is calculated by

$$\omega_c(\omega_0) = \frac{\int \omega |y(\omega_0, \omega)|^2 d\omega}{\int |y(\omega_0, \omega)|^2 d\omega}.$$

In order to estimate the error from the multiple filter technique, waveforms for PREM are synthesized. The source depth is set to 0 km to avoid having a group time delay caused by the focal mechanism. The other parameters, station and epicenter locations, are equal to the ones used in Section 3.

Table 3 lists the errors from the multiple filter technique with and without the correction for systematic errors as de-

Table 3. Errors in group velocity (km/s) due to the multiple filter technique.

| frequency | with correction | | | without correction | | |
|---|---|---|---|---|---|---|
| (mHz) | average | min. | max. | average | min. | max. |
| 8 | 0.045 | 0.044 | 0.047 | 0.061 | 0.057 | 0.075 |
| 10 | 0.056 | 0.054 | 0.057 | 0.065 | 0.063 | 0.067 |
| 12 | 0.035 | 0.034 | 0.036 | 0.041 | 0.040 | 0.042 |
| 15 | 0.008 | 0.006 | 0.009 | 0.009 | 0.008 | 0.010 |
| 18 | −0.003 | −0.004 | −0.002 | −0.006 | −0.007 | −0.005 |

scribed above. The correction reduces the errors, but the errors at frequencies of 8, 10, 12 mHz are not negligible. These errors may be caused by the broadband width of the filter, which is needed to obtain clear records of quasi-Love waves.

Errors in the group velocities are also caused by interferences between the quasi-Love and Rayleigh waves. However, it is difficult to accurately estimate errors from interferences between the quasi-Love and Rayleigh waves, because the properties of the quasi-Love and Rayleigh waves for each station and frequency are different. In all cases, therefore, we apply the errors, which have been roughly estimated from a numerical experiment of interferences between two sinusoids with the change of 0 to $2\pi$ in the phase difference of the sinusoids (Kobayashi and Nakanishi, 1998). The errors in group velocity due to the interferences are 0.00 to 0.02.

The contour maps of the amplitude envelopes as functions of frequencies and velocities (Fig. 5) show the group velocity dispersion curves. Strong maxima in the contour maps of the transverse and vertical components show the dispersion curves of the fundamental Love and Rayleigh wave group velocities, respectively. The maximum energy corresponding to the quasi-Love waves can be seen at group velocities around 4.2–4.5 km/s in the contour maps of the vertical components.

At frequencies lower than 10 mHz, the velocities of the quasi-Love waves do not increase as rapidly as the theoretical group velocity of the higher-mode Rayleigh wave. This indicates that the quasi-Love waves may not have a property of the higher-mode Rayleigh waves.

All the detected quasi-Love waves are very weak or cannot be seen at frequencies lower than 8 mHz (125 s), and several Rayleigh and Love waves show multiple arrivals at frequencies higher than 18 mHz (55.6 s). We thus use the group velocities at frequencies of 8, 10, 12, 15, and 18 mHz, and locate the conversion areas for clearly observed quasi-Love waves with short wavepackets.

The group velocities vary in the Pacific with the age of the plate. When the errors of the conversion areas are estimated, we consider that the Love wave group velocities before the conversion can vary 0–2% lower than $U_L$, and that the Rayleigh wave group velocities after the conversion can vary 0–2% higher than $U_R$. This consideration results in the large errors before the conversion.

The Love-to-Rayleigh conversion points and the error bars are shown in Fig. 6. In the case of stations ASHI, KGJ, and DAV, the conversion points are mostly located near the Kuril, Japan, Mariana, and Philippine trenches. Since the error bar for ASHI also reaches the Aleutian trench, the conversion possibly also occur near the Aleutian trench. In the other case, the conversion points are located near the Emperor seamounts and the Mid-Pacific mountains. Figure 6 shows the conversion points at every frequency, but we cannot find the dependence of the locations on frequency in both cases. Therefore crust and upper mantle structures beneath the trenches and seamounts are sensitive to Love-to-Rayleigh conversions at 8–18 mHz.

## 5. Discussion

The stations along the Ryukyu trench, MINA and KUNK, record very weak quasi-Love waves. The great-circle path between the epicenter and the Izu-Bonin trench for KUNK is very similar to that for HCH (Fig. 1). HCH, however, records clear quasi-Love waves. Since large lateral heterogeneities in seismic velocity exist across the trench, the path for KUNK can deviate from their great-circle paths. The deviations, however, may be smaller than the wavelength of the surface waves (200–600 km) that we consider, and the effects on the surface waves may be small. Therefore, the very weak quasi-Love waves at MINA and KUNK imply that the quasi-Love waves decay in the northern part of the Philippine Sea.

We can consider two following possible causes of the decay of the quasi-Love waves: 1) the quasi-Love waves can be also generated in the Philippine Sea, and can interfere with the quasi-Love waves generated in the Pacific, and 2) the quasi-Love waves could mainly contain higher-mode Rayleigh waves converted from the fundamental Love waves, and might decay in the low-Q upper mantle, where the energy of higher-mode Rayleigh waves concentrate, beneath the Philippine Sea and the volcanic zones along the back arc. The first is more possible than the second, because the dispersion curve of the quasi-Love wave recorded at HCH does not behave like higher-mode Rayleigh waves at lower frequencies. However, we cannot determine the decisive mechanism of the decay of the quasi-Love waves. Calculations of waveforms with models of seismic structure beneath the Philippine Sea and the volcanic zone may provide us with the answer.

The station ERIM, which records no quasi-Love wave in this study (Fig. 3), is very close to station ERM, which records weak quasi-Love waves in our previous studies. Kobayashi and Nakanishi (1998) conclude that the Love-

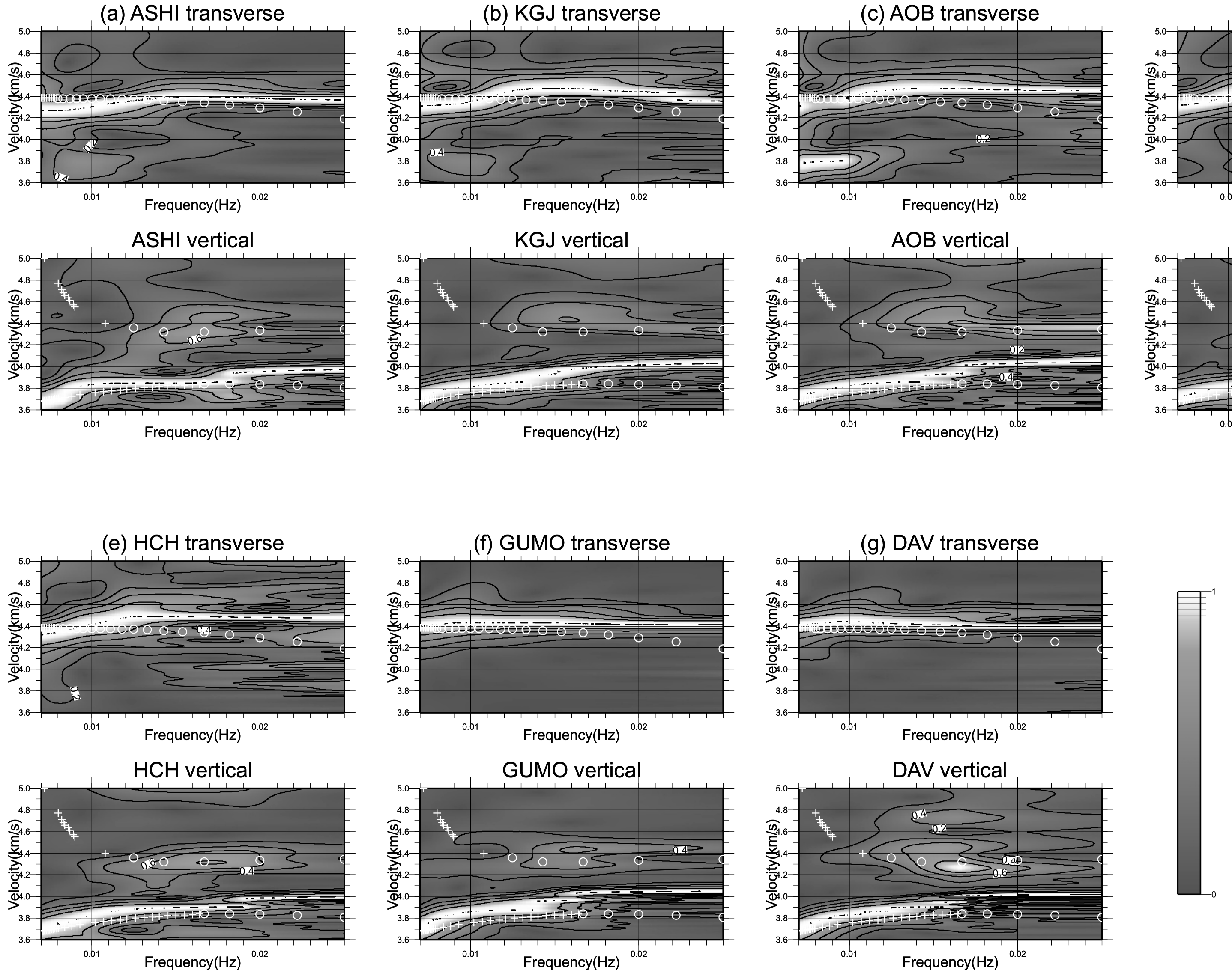


Fig. 5. Contour maps of the amplitude envelopes as functions of frequency and group velocity with correction of systematic errors. (a) ASHI, (b) KGJ, (c) AOB, (d) TSK, (e) HCH, (f) GUMO, (e) DAV. The top and bottom of each figure show the transverse component for the Love wave and the vertical component for the Rayleigh and quasi-Love waves, respectively. They are normalized with respect to the maximum value of the envelope for each frequency. Crosses and circles represent the theoretical group velocities of fundamental Love (top) and fundamental and first higher-mode Rayleigh waves (bottom) for PREM. The crosses are taken from the tables in Dziewonski and Anderson (1981) and the circles are calculated by the generalized y-method (Kawasaki and Koketsu, 1990).

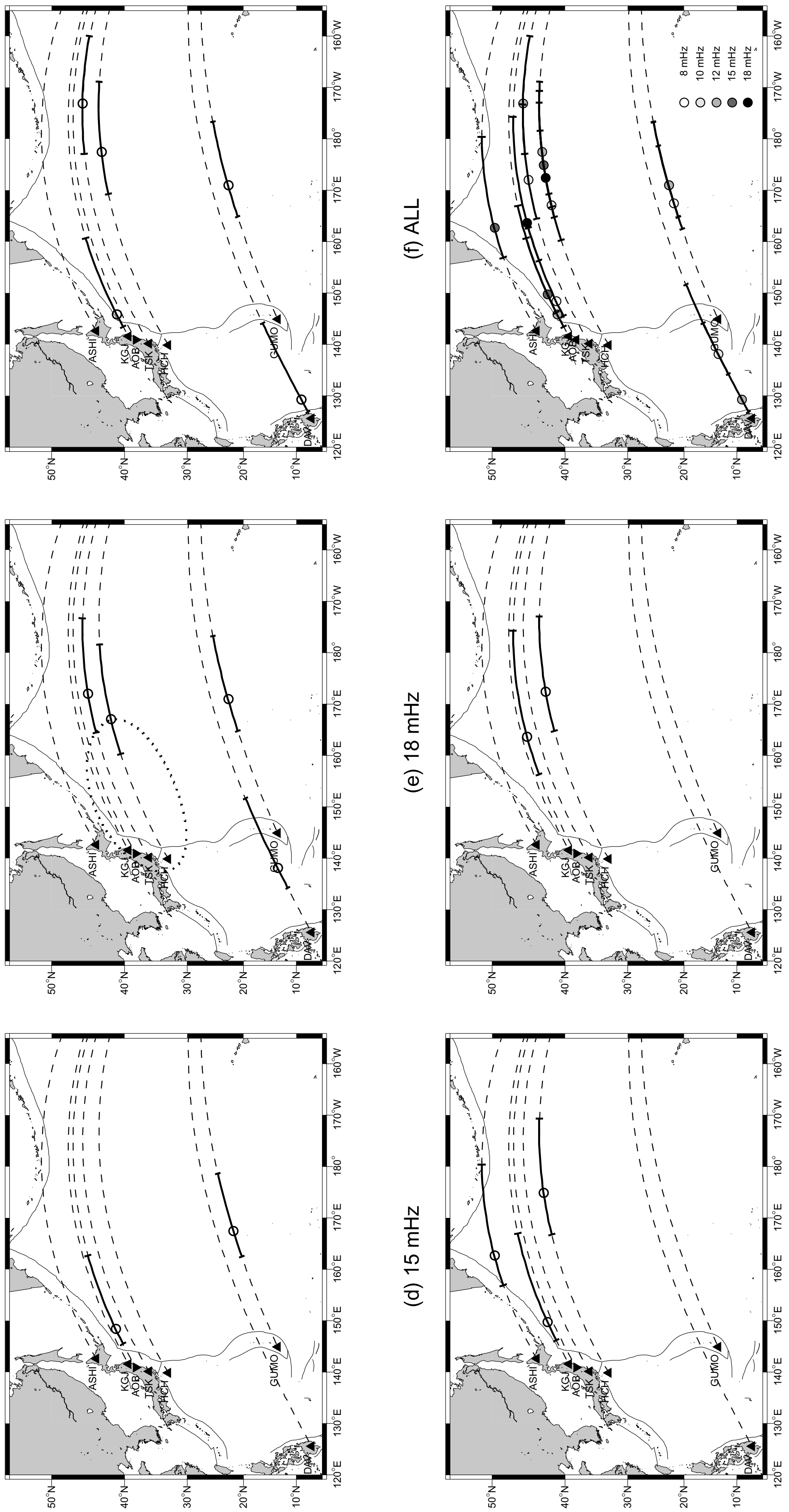


Fig. 6. Love-to-Rayleigh conversion points with error bars at (a) 8 mHz, (b) 10 mHz, (c) 12 mHz, (d) 15 mHz, (e) 18 mHz, and (f) all frequencies. A dotted line in (b) connects the possible scattering points for HCH without the assumption that the conversion occurs along the great-circle path.

to-Rayleigh conversions occur around the Kuril trench. Yu *et al.* (1995) demonstrate that quasi-Love waves become stronger in a zone with lateral variation in anisotropy. The path between the Kuril trench and ERIM, which could be in the zone with laterally variation in anisotropy, for the 9 October 1995 earthquake is shorter than the path between the Kuril trench and ERM for the 17 August 1991 earthquake. Therefore the quasi-Love wave for the 9 October 1995 earthquake may be weaker than that for the 17 August 1991 earthquake.

The Love-to-Rayleigh conversions located near the trenches in the cases of ASHI, KGJ, AOB, and DAV suggest that the properties of azimuthal anisotropies in upper mantle vary laterally between the trench regions and the Pacific. Such lateral variations of azimuthal anisotropies are consistent with Nataf *et al.* (1986), which shows that property of transverse isotropy (the simplest anisotropy) at depth above 220 km in trench regions differs from that in oceanic regions. The lateral contrasts of azimuthal anisotropies suggest that the mantle flow may change in the trench regions induced by the subducting slabs.

Lateral heterogeneities along subduction zones, which cannot be considered in the calculation of the 2.5-D finite difference method with the 2-D trench model in our previous study (Kobayashi, 1998), can also cause quasi-Love waves. In the case of ASHI, the error bar reaches the Aleutian trench, and the incident angles of the path with respect to the Kuril and Aleutian trenches are very shallow. In the case of KGJ and AOB, the paths run near the junction of the Kuril and Japan trenches, which make three-dimensionally lateral heterogeneities. The effect of these lateral heterogeneities may not be ruled out. Numerical experiments should be required to estimate the effect of the lateral heterogeneities.

The Love-to-Rayleigh conversions for AOB, TSK, HCH, and GUMO are mainly located near or around the Emperor seamounts and the Mid-Pacific mountains. In these regions, the lateral heterogeneities are at most 3% in the uppermost mantle (e.g., Suetsugu and Nakanishi, 1987a; Montagner and Tanimoto, 1990). It is unlikely that this level of lateral heterogeneity generates clear quasi-Love waves (Park and Yu, 1992; Yu and Park, 1993; Kobayashi, 1998). Therefore we cannot attribute the conversions to the lateral heterogeneity in the northwestern part of the Pacific.

Azimuthal anisotropy patterns in the Pacific have been presented by several studies of surface wave tomography (Tanimoto and Anderson, 1985; Suetsugu and Nakanishi, 1987b; Nishimura and Forsyth, 1988; Montagner and Tanimoto, 1990). The azimuthal anisotropy patterns for Rayleigh waves at the periods of 60.9 s and 82.6 s presented by Suetsugu and Nakanishi (1987b) and at the period of 91 s by Montagner and Tanimoto (1990) show that the strengths of the azimuthal anisotropies in the northwestern Pacific are weak, while those in the central part of the Pacific are strong. The Love-to-Rayleigh conversion locations suggest the lateral variations of the azimuthal anisotropies across the central and northwestern part of the Pacific, and support the results of Suetsugu and Nakanishi (1987b) and Montagner and Tanimoto (1990). The very weak quasi-Love wave recorded at OGS is, however, inconsistent with the lateral variation in azimuthal anisotropy. The lateral variation of the azimuthal anisotropy in the south part of the Emperor seamounts might not be large enough to generate quasi-Love waves.

The Emperor seamounts and the Mid-Pacific mountains are considered to be produced by hotspots. Partial melting beneath hotspot regions can weaken the anisotropy in the upppermost mantle. However, since the Emperor seamounts is narrow, the effect on the surface waves at the periods that we consider may not be large.

In this study, it is assumed that the Love-to-Rayleigh conversion occurs quickly at a point along the great-circle path, because the peaks of the quasi-Love waves can be clearly seen in the records. Therefore the conversion points are mostly distributed within the error bars. However, the broad distribution of the conversion points for AOB and DAV might suggest the limitation of the assumption. It is possible that the conversions occur gradually or occur several times. The multiple conversions are suggested by the contour maps, showing broad widths of the peaks corresponding to the quasi-Love waves for AOB and DAV. The broad peaks can be caused by interferences between the quasi-Love wave and multipathing of the quasi-Love waves or quasi-Love waves generated in other region.

Surface waves can be scattered by lateral contrast in isotropy and anisotropy (e.g., Maupin, 2001). A line connecting possible scattering points for HCH at 10 mHz is also shown in Fig. 6(b). The points located near the Kuril and Izu-Bonin trenches, where lateral contrast in isotropy and anisotropy exists, are the most possible candidates. Three-dimensional numerical experiments, in which scattering due to lateral contrast in isotropy and anisotropy is considered, should be needed in the next stage of our study.

## 6. Conclusion

We investigate the quasi-Love waves from the 9 October 1995 earthquake near the coast of Jalisco, Mexico, recorded in Japan, Guam, and Philippine. Very weak or no quasi-Love waves are detected at ERIM, OGS, MINA, and KUNK. For the stations along the Ryukyu trench, MINA and KUNK, it seems that the quasi-Love waves decay in the northern part of the Philippine Sea. The decays of the quasi-Love waves are possibly caused by the interference among the quasi-Love waves generated in the Pacific and the Philippine Sea or by the low-Q upper mantle beneath the Philippine Sea and volcanic zones.

We attempt to locate the Love-to-Rayleigh conversion areas for the detected quasi-Love waves by using the group velocities of the observed surface waves. In the cases of ASHI, KGJ, AOB, and DAV, the conversion areas mostly concentrate near the Kuril, Japan, Mariana, and Philippine trenches, and suggest that the lateral changes of the fast axis or strength of the azimuthal anisotropy reflect the changes of the mantle flow induced by the subducting slabs. The Love-to-Rayleigh conversions for the other stations are mainly located around the Emperor seamounts and near the Mid-Pacific mountains in the northwestern part of the Pacific. This result is consistent with the distribution of azimuthal anisotropy determined from surface wave tomography by Suetsugu and Nakanishi (1987b) and Montagner and Tanimoto (1990), which show the smaller azimuthal anisotropies in the northwestern part of the Pacific than those in the central part of the Pacific.

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R. Kobayashi (e-mail: reiji@sci.ehime-u.ac.jp)