Correlation of a 410-km discontinuity low velocity layer with velocity tomograms along the RISTRA line array sampling across Utah, New Mexico and west Texas

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ABSTRACT

The transition zone water filter model (Bercovici and Karato, 2003) predicts that a hydroxyl melt fluid is produced in upwelling regions. The production is thought of being reached by P-wave receiver function studies using the combined IRIS-PASSCAL, RISTRA, and 1.5 line arrays that cross western Texas, New Mexico and Utah. A total of 1352 radial component receiver functions are calculated from 96 radially disposed P-wave data with Mw > 5.5 at a distance of 20°–40°. The receiver functions are generated by various orientation-time-migration special treatment method with a Gaussian 0.2 Hz low-pass frequency. The receiver functions are binned into the NW, SE, SW, and NE quadrants and rotated to produce two low-amplitude images of the 410-km and 660-km discontinuities. The disconnections of the two primary discontinuities vary from 395–442 km for the 410-km and from 649–678 km for the 660-km. With respect to the vertical component, the average amplitudes of the discontinuities are 3.0% (410) and 2.8% (660). Where observed, the 410 km low velocity layer (410-LVL) arrival has a < 0.5% amplitude which is ever twice as large as the side-lobe of the positive amplitude 60° arrival. The three receiver function quadrant plots have a correlation between the 410-km low velocity layer and kinematic body wave velocity tomography (Schmandt and Humphreys, in review). The 410-LVL arrival is absent where the velocities about the 410 km discontinuity are high and the 410-LVL is present where the velocities are low. Our finding is consistent with the transition zone water filter model which predicts for the production of a hydrous melt layer only where uplifts of significant hydrated transition zone mantle occurs. Additional efforts on the multi-layer ascertainment and validation due to potential noise floor by the slightly lower layer divided by 410-LVL topography complements the correlation of the 410-LVL with respect to the mantle flow structure inferred from the velocity tomography. Also, the long-range melt flow thickness depends on first order on the site which Karato and Bercovici call ‘vertical attenuation’ due to downwelling across the 410-km (Fig. 1).

INTRODUCTION

The seismic velocity discontinuities at 410-km and 660-km depth are due to phase change from olivine (Mg,Fe)2SiO4 to wadsleyite, and from ringwoodite to perovskite/magnesiowustite respectively. A 410-km low velocity layer (410-LVL) atop the 410-km discontinuity is found in teleseismic body-wave tomograms beneath western Utah and northeastern mantle filters off incompatible elements into the melt phase as it ascends from high-water-solubility transition zone into the upper mantle. Bercovici and Karato (2003) proposed a hypothesis termed the transition-zone water-filter model, which predicts in the upwelling region that ambient water is entrained into the melt phase, thus increasing melt fraction and the production of a hydrous melt flux due to a decrease in melt fraction. This hypothesis is tested via stacking of P-wave receiver function using the combined IRIS-PASSCAL RISTRA 1.0 and 1.5 line arrays in 185-km wide bins with 50% bin overlap (Fig. 6).

METHOD AND DATA

The combination of the RISTRA 1.0 and 1.5 seismic arrays (Fig. 5) forms a 1000-km linear array of 72 broadband seismometers with 2-km station spacing. 96 events with Mw > 5.5 and 20°–40° distance are collected for P-S receiver function analysis (Fig. 4). P-S waveform offsets are estimated using the Extended-Time Multi-Taper estimation (Helffrich, 2006). A low cut-off frequency-dominant ratio of 0.2 Hz is applied to the spectral estimation. After calculation, a 3-D filter is applied to the receiver functions. The radial components of receiver functions are stacked from time to depth based on average vertical velocity profile in study region from P wave model (Schmandt, et al., 2008). The S-wave speed model is calculated by sonic Vp/Vs ratio at 1.76 Hz for the crust and 1.82 Hz for the mantle. A total of 1352 radial receiver functions are calculated. The density of receiver functions is called as RMSK (Rz07), cross-correlation curve, and visual inspection. The total radial receiver functions are filtered and cleaned to create a set of NW, SE, SW, and NE quadrants stack traces with 4 Rosenbluth bins with a width of 185 km and 30 km bin overlap (Fig. 6). Given the previous seismic observations of 410-LVL, we propose a hypothesis that high velocity anomalies above the 410-km discontinuity manifest the upward transport shuffling of dynamic from the 410-LVL.

RESULT

We find that the velocity anomalies are correlated with the occurrence of 410-LVL. For the NW and SW quadrants, the amplitudes of 410-LVL discontinuities have a negative melt flow direction. For NW quadrants, the 410-LVL discontinuity is pronounced on both Z and Dz components. This finding supports the hypothesis that the water filter model is produced in downwelling high velocity region. This correlation between the amplitude of 410-LVL and Vp perturbation at the 410-km discontinuity is shown in the scatter plot of integral amplitudes of 410-LVL versus Vp perturbation at the 410-km discontinuity (Fig. 7). The high velocity anomaly without 410-LVL arrival indicates the lack of melt fluid.

CONCLUSION

A stack of all receiver functions shows two positive polarity arrivals at the depth of 410-km and 660-km, respectively (Fig. 3). The main phases of both discontinuities are 231–235 km, which is 4 km thicker than the 245-km global average (Dziewonski and Dziewonski, 2001). The 410-LVL negative polarity arrival has an amplitude of 1.8% with respect to the zero-lag P wave arrival. The two components and amplitude correlation of the 410-LVL arrival is 3.1% and 3.8% of that component, respectively. Phasing analysis is used to identify the arrival direction (Fig. 5). A 3-D slice of topography on 410-km discontinuity is measured from 395–442 km, and a 29-km range of topography on the 660-km discontinuity is measured from 649–678 km (Fig. 6).