DETAILED STRUCTURE AND SHARPNESS OF UPPER MANTLE DISCONTINUITIES IN THE TONGA SUBDUCTION ZONE

Rigobert Tibi, Douglas A. Wiens • Washington University

The Seismic Arrays in Fiji and Tonga (SAFT) experiment, which consisted of two arrays of broadband seismic stations in the Fiji and Tonga islands operating from July 2001 to August 2002, provides an ideal opportunity to perform a detailed local investigation of upper mantle discontinuities near one of the Earth’s coldest subduction zones. Recordings of deep Tonga earthquakes from the arrays are stacked and searched for reflections and conversions from upper mantle discontinuities in the Tonga subduction zone. In comparison with the commonly used teleseismic approaches, the short path lengths for the local data provide smaller Fresnel zones and high frequency content for precise mapping of discontinuity structure. This is particularly important for a subduction zone, where variations in temperature and water content are expected to cause small-scale changes in topography and sharpness of the discontinuities. To enhance the low-amplitude discontinuity phases s410p, P660p and S660p, deconvolved seismograms from each event/array pair are aligned on the maximum amplitude of the direct P wave and subsequently slant-stacked. For the 410-km discontinuity, the results show no systematic variations in depth with distance to the cold slab. The 660-km discontinuity varies between 656 and 714 km in depth. For the southern and central parts of the subduction zone, the largest depths occur in the core of the Tonga slab. For the northern part, two separate depressions of the 660 are observed. These anomalies are interpreted as being induced by the active, steeply subducting Tonga deep zone and a subhorizontaly lying remnant of subducted lithosphere from the fossil Vityaz trench, respectively (Chen and Brudzinski, 2001). Interpreting the deflections of the 660 in terms of local temperatures implies a thermal anomaly of −800oK to −1200oK at 660 km depth. Except for the southern region where it may thicken, the width of the depressed 660 region implies that the Tonga slab seems to penetrate the 660 with little deformation. Waveform modeling suggests that both the 410 and 660 discontinuities are sharp. The 660 km discontinuity is at most 2 km thick in many parts of the region, and a first order discontinuity cannot be precluded. The 410 thickness shows somewhat more variability and ranges from 2 km to 10 km outside the slab, and at most 10 km thick within the slab. This suggests that the subduction process does not produce dramatic effects on the sharpness of the discontinuities.


Map showing the locations (white triangles) for the Fiji and Tonga arrays. Crosses indicate the epicentral locations of the 25 earthquakes used. The locations of the bounce and piercing points at the upper mantle discontinuities for the different seismic phases investigated are shown. Pink hexagons are for s410p, green circles for P660p and red squares for S660p. Gray lines are contours of deep seismicity (Gudmundsson and Sambridge, 1998), with the numbers indicating the depth in km to the seismogenic zone. Line AA’ shows the location of the vertical cross section in Fig. 2.

(top) Vertical cross section along line A-A’ in Fig. 1 showing the bounce and piercing point locations for s410p (hexagons), P660p (circles) and S660p (squares). Thin lines indicate the nominal depths of 410 and 660 km for the discontinuities. Seismicity (dots) is from Engdahl et al. (1998). Width of the cross section is 240 km. (bottom) Enlargement showing the detailed topography of the 660-km discontinuity.