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Crustal thickness and mantle wedge structure from receiver functions in the Chilean Maule region at 35°S

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ABSTRACT

A temporary passive seismic network of 21 broad-band stations was deployed in Central Chile between 35°S to 36°S. The network recorded data prior to the magnitude Mw = 8.8 2010 Maule earthquake at a latitude of the major slip and surface deformation. The experiment was conducted to survey crustal and mantle structures and to assess the state of hydration of the mantle wedge. We present results of a teleseismic P receiver function study, supporting a continental Moho at approx. 38 km depth. Phase conversion at this boundary could be observed continuously from the intersection of the subducting slab with the continental Moho towards the Andes. The character of receiver functions indicated little evidence for infiltration of water from the subducting plate into the overlying mantle wedge, suggesting that only a small amount of water is released from the subducting plate. Aftershocks of the Maule earthquake and post-seismic slip reached depths of 50 km and hence slip spread down-dip of the continental Moho in the post-seismic phase. Co-seismic rupture, however, occurred updip of the continental Moho. Spare aftershock seismicity is observed at the intersection of the continental Moho with the subducting slab.

1. Introduction

Central Chile is one of the most seismically active areas in the world caused by the subduction of the Nazca plate beneath the South American plate. Recently, the Maule region was hit by a moment magnitude Mw = 8.8 earthquake on February 28, 2010, causing profound destruction of the infrastructure. South-central Chile has been subject to a number of active and passive source experiments (e.g., Bohm et al., 2002; Gilbert et al., 2006; Heit et al., 2008; Krawczyk et al., 2006; Moscoso et al., 2011) investigating the structure of the continental and oceanic crust. Seaward of the trench, swath-mapping bathymetry of the incoming plate (Grevemeyer et al., 2005; Moscoso et al., 2011) suggested that the outer rise is strongly fractured. Further, active source seismic profiling showed profound velocity anomalies in the oceanic lithosphere, indicating that bending-related faults may reach the mantle, facilitating water migration down to mantle depth and hence causing serpentinisation (Contreras-Reyes et al., 2008; Grevemeyer et al., 2005; Moscoso et al., 2011). From those observations it is reasonable to conclude that large amounts of water are stored in the subducting plate and are transported into the subduction system. Water released from the subducting plate may cause mantle wedge serpentinisation (e.g., Bostock et al., 2002). Serpentinite and associated alteration products soften the rocks and are believed to facilitate the sliding behaviour along the inter-plate boundary (Bostock et al., 2002; Reinen, 2000). This would in turn affect the inter-plate coupling, earthquake rupture propagation, rupture stresses, and thus, would govern the down-dip limit of the mega-thrust fault (e.g., Hyndman and Peacock, 2003).

However, seismic wide-angle data (Moscoso et al., 2011) could not provide information on the continental Moho beneath the coastal area. Previous receiver function analysis in this area (within the CHARGE experiment) had a rather limited resolution below the Coastal Cordillera and in the forearc (Gilbert et al., 2006; Heit et al., 2008). Our new dataset recovered high quality waveform data, providing detailed structural information on the forearc crust and forearc Moho (crust-mantle boundary). Along with the distribution of aftershocks from the 2010 Maule earthquake (Lange et al., 2012), previously conducted micro-seismicity studies (Anderson et al., 2007; Kraft, 2011), and results from GPS measurements (Moreno et al., 2012; Vigny et al., 2011), we were able to reveal the structure of the forearc, assess the state of hydration of the mantle wedge, and gain information about the structure of the continental crust. We applied a P-wave receiver function analysis using P-to-S (compressional-to-shear) converted teleseismic waves. Data were collected from a seismic network deployed in 2008 in the Maule region prior to the Maule earthquake.

2. Methodology and data

The Talca Seismic Network was deployed in the region around the towns of Talca and Constitución between 35°S to 36°S latitude and 71°W to 72.5°W longitude (Fig. 1). The network consists of 21 three-component broad-band stations (CMG-3TESP/60 sensors) and 10

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short period stations (total of 31 land stations), which were operated between April and October 2008 and recorded continuously with a sampling rate of 100 Hz. The short period stations were deployed for the active part of the experiment, while we only use the three-component broad-band stations for our receiver function analysis. Only 11 out of the remaining 21 stations recorded enough data with a high signal-to-noise ratio that we could use for our studies. These are marked with red triangles.

A few percent of the incident P-wave energy from a teleseismic event will be converted into S-wave (Ps) at significant and relatively sharp discontinuities. Those small converted S phases arrive within the coda directly after the first P-wave arrival and they might be separated by deconvolving the vertical P-wave energy from the horizontal components, yielding P-wave receiver functions.

We use large teleseismic earthquakes with magnitudes mb > 5.9 at epicentral distances between 30° and 95° from different backazimuths (from NEIC). Teleseismic events with a fairly high signal-to-noise ratio (> 2) have been selected at each station. A time window of 150 s, starting 60 s before the P-onset arrival time was chosen. High-frequency signals are suppressed using a simple integration to retrieve the displacement resulting in enhanced data quality and filtering in the frequency range of 0.05 Hz to 5 Hz was applied to reduce the background noise level of the single traces. By using the theoretical backazimuth and incidence angle the ZNE components were then rotated into the local LQT ray-based coordinate system (L in the direction of P-wave incident to the surface, Q is perpendicular to L, and T is perpendicular to both). The converted energy should be concentrated in the Q component. To isolate the P-to-S conversions on the Q component, the

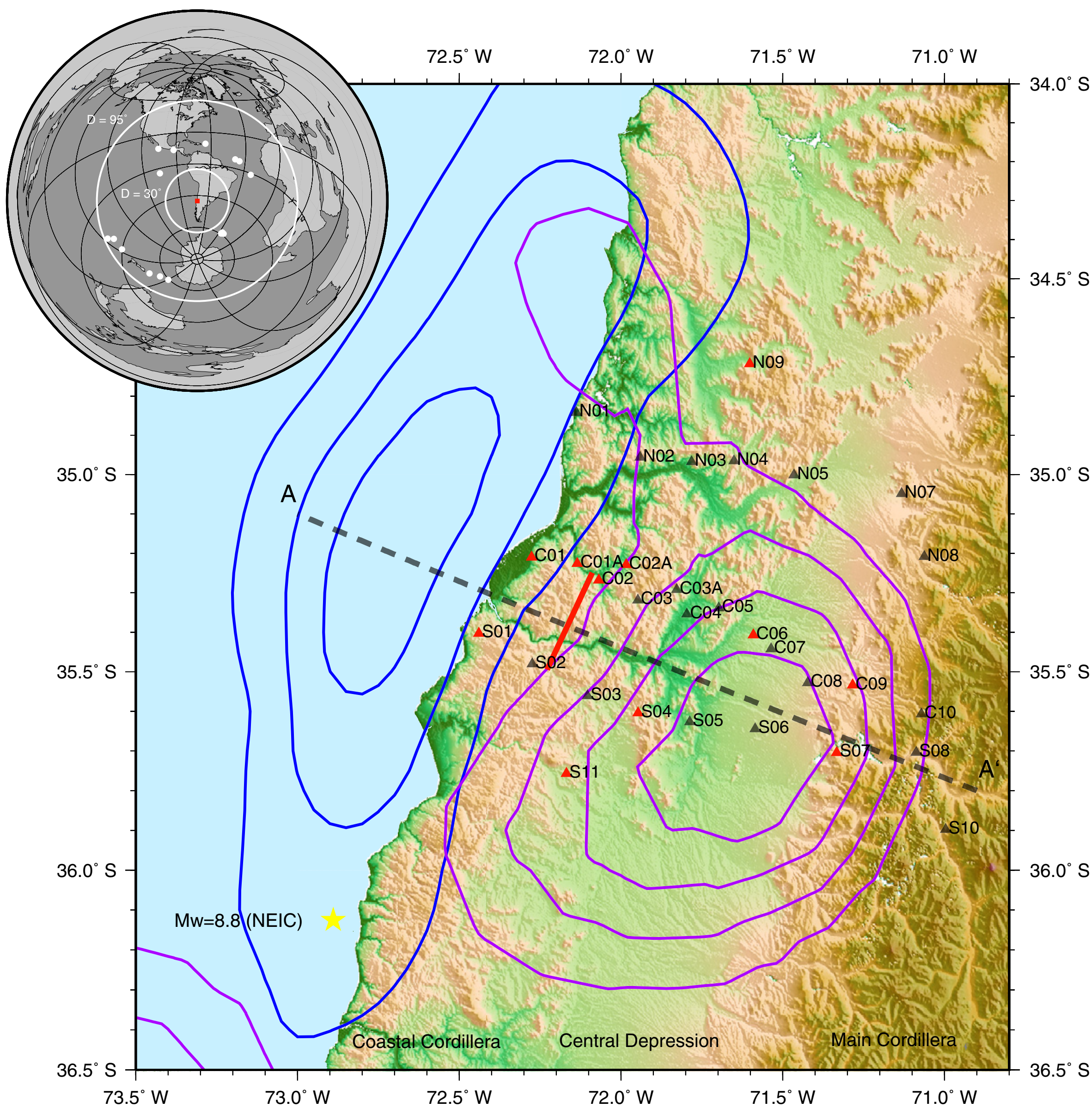

Fig. 1. Location map of the short-period and broadband stations. The red triangles mark stations used in our study. Along profile A-A′ (grey dashed line) the results and hypocentres in Fig. 3 were projected. The yellow star marks the USGS epicentre of the great Mw = 8.8 Maule earthquake. Blue contour lines show the co-seismic slip (Lorito et al., 2011) and the purple contour lines image the 12-days post-seismic slip (Vigny et al., 2011). The red solid line marks the intersection of the continental Moho with the subducting slab. The azimuthal equidistant plot of the Earth (upper left corner) shows the distribution of teleseismic events (white dots) recorded by the Talca Seismic Network between April and October 2008 that were used to calculate P-receiver functions. The red rectangle indicates the position of the network. The white large solid circles mark the 30° and 95° epicentral distances.