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3-D Velocity Structure and Seismotectonics prior to the 2010 Chile Earthquake (Mw 8.8) from an Amphibious Seismological Network

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The project SFB574 “Volatiles and Fluids in Subduction Zones” aims to better understand the processes involved in the exchange of fluids in convergent margins. The current phase concentrates on the accretionary margin of south-central Chile, a region that includes the rupture area of the great 2010 Maule Earthquake (Mw 8.8).

Within the project, an “amphibious” network of 15 ocean bottom seismometers and 27 land stations was operated from April to October 2008 along 350 km from the outer-rise to the magmatic arc. Additional readings from 11 permanent stations of the Chilean Seismological Service were included in the database improving onshore coverage. One of the main goals of the project is to gain a detailed image of the crustal and upper mantle structure and the seismogenic zone by analyzing earthquake distribution and combined, passive and active source seismic tomographic images.

To achieve precise earthquake locations and to serve as an initial model for local earthquake tomography, we derived a P- and S-wave minimum-1D model using a very high-quality subset of 340 events (GAP $\leq$ 180°, at least 10 P-wave and 5 S-wave arrivals) and velocity information from a wide-angle profile shot in the area. Most of the $\sim$1200 earthquakes recorded in our target area were originated within the subducting slab down to $\sim$140 km depth, with a higher concentration beneath the main cordillera, at depths of 80-110 km. We observe for the first time with a local network a double Benioff zone in this area. Fewer events were generated at the outer-rise, at depths of $\sim$20-40 km, closely following the NE-SW trend of the oceanic plate faulting.

The database was relocated using the minimum 1-D model and a subset of 400 events (GAP $\leq$ 180°, at least 8 P-wave arrivals) with $\sim$7000 observations was selected to perform a P-wave tomography. Our first results confirm the strong, lateral velocity gradient in the forearc seen in previous works along the margin, interpreted as the transition between a paleoaccretionary complex and the seaward edge of the Paleozoic continental framework. The downdip limit of the interplate microseismicity previous to the great earthquake was aparently controlled by a low-velocity anomaly at $\sim$40 km depth, shallower than the deeper extent estimated by recent geodetic modeling for the Maule earthquake rupture. The interplate microseismicity nucleated from $\sim$40 up to $\sim$20 km depth, and did not extend up to the 100°C isotherm. It was sparse except for a cluster of $\sim$1200 km2 offshore and SW of Pichilemu town, within an area where a locking $\geq$ 75 % before the great earthquake has been recently estimated. The deep outer-rise seismicity and the low velocities on top suggest considerable hydration of the downgoing plate.