Geophysical Research Abstracts, Vol. 9, 09389, 2007
SRef-ID: 1607-7962/gra/EGU2007-A-09389

Depth-graded properties in the seismogenic zone at the South-Central Chilean margin from onshore geophysical observations

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The understanding of structural and petrophysical properties of seismogenic coupling zones is one of the major goals in subduction zone research. Seismogenic zones are governed by seismological activity, regionally and temporally diverse, and at their down-dip end mega-thrust earthquakes initiate.

In Chile, the project TIPTEQ (from The Incoming Plate to mega-Thrust EarthQuake processes) concentrated between 2005 and 2007 different onshore geophysical experiment components between 37˚-39˚ S. The surveys were designed to (1) yield a structural image, (2) reveal the vertical crustal zonation and map active faults, (3) determine the conductivity structure, and (4) result in a 3-D asperity mapping. This should give finally a high-resolution image of the seismogenic coupling zone in the area of the 1960 Chile earthquake hypocentre.

A controlled source seismic experiment at 38˚ S provides the structural characteristics and an image of the present state of the plate interface ruptured during the 1960 earthquake. Close to the coast the subducting oceanic crust is clearly visible and can be traced further inland down to about 50 km depth with variable reflectivity. A strongly structured forearc and accretionary wedge are identified. Between depths of 5 to 25 km several bright reflectivity spots can be seen in the upper plate, which may suggest fluid traps in the accretionary wedge. Strong reflective bands up to 3 km thick characterise the upper and middle crust of the overriding plate. These slightly upwardly convex, reflective structures are interpreted as representing the Permo-Triassic accretionary wedge above the subducting Nazca Plate. Two high-velocity bodies in the upper crust are found on either side of the Lanalhue fault zone, suggesting uplift of mantle material. However, they are presumably of different origin. A major structural element at the plate boundary lies between 18 and 50 km depth. It is interpreted as a subduction channel that is transporting sedimentary material from west to east below the overriding South American plate.

Local seismicity and teleseismic data, gathered with a temporary seismological network, show that most of the crustal seismicity is concentrated in clusters. Close to the coast line activity is concentrated in the subduction channel, and further inland at the Lanalhue fault zone. Evaluation of both offshore and onshore MT data reveals uniformly deflected induction vectors over the entire forearc (and even arc) between 38˚S and 41˚S. These are only interpretable by assuming a deeply fractured crust - in the view of modeling this is treated with a macro-ansiotropic approach. This anisotropy persists for the whole continental crust until the trench. The oceanic crust is characterised by relatively low resistivities, indicative for seawater penetrating perhaps into upper mantle depths. Finally, a combined seismological-magnetotelluric monitoring E-W profile was installed as a set of three stations, extending from the Atlantic Ocean to the Volcanic Arc. The overall goal is to detect transient events which are related to the subduction system. Synchronous recordings of seismic broadband data (periods up to hours) will allow us to examine a wide spectrum of earthquake styles with the recently acquired new data sets.

Thus, the Chilean subduction system at c. 38˚ S is characterised by a seismically active subduction channel at depth, and a recently more inactive part of the old Permo-Triassic accretionary wedge above. The onshore structural image and coastal uplift suggest that basal accretion of parts of this material controls the seismic architecture and growth of the south Chilean crust. Large, long-living fault zones may have been used repeatedly, with varying kinematics through time. Furthermore, high-velocity bodies at shallow depth suggest together with strong reflective bands that these reflectors could represent old shear zones along which continental mantle material may have been transported to upper crustal levels. The suggestion that the rheology of the forearc exerts an important control on where extensive rupture and great earthquakes can occur will be further examined based also on gravity data. An optimised filtering of the gravity anomalies along the continental margin also shows that coseismic slips associated with the 1960 Chile earthquake correlate with fore-arc gravity lows centered on sedimentary basins.