ANOMALOUS DEEPER CRUST BENEATH THE CENTRAL ANDEAN FOREARC AND ARC REGIONS (21°-23°S)

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INTRODUCTION

The central segment of the Andean mountain chain is characterised by active volcanism in the magmatic arc, the Western Cordillera, located on the western margin of a the 2.000 km long and 300 km broad Altiplano plateau with an average height of 3.700 m, uplifted during late Cainozoic (e.g. Isacks, 1988). During the last 200 Ma. the magmatic arc of the central Andes has been displaced eastwards from the Coastal Cordillera to the actual position in the Western Cordillera (Coira et al., 1982; Scheuber et al., 1994), affecting considerably the crustal structure and evolution of the forearc region. Together with the magmatic arc the related forearc and backarc features shifted eastwards into their actual position.

In continuation of previous projects, within the SFB 267 seismic refraction investigations as well as seismological studies (Asch et al., 1994; Schmitz et al., 1994) have been realised in the forearc and arc region (PISCO 94 - Proyecto de Investigación Sismológica de la Cordillera Occidental) in order to improve the results of earlier seismic refraction studies in the area (e.g. Wigger et al., 1994). Whereas the genesis of the thickened backarc crust can be explained by crustal stacking, the evolution of the thick forearc crust is still under discussion. Information about the velocity structure including observations from the crustal base should help to clarify the nature of the deeper crust.

GROSS CRUSTAL STRUCTURES OF THE FOREARC AND ARC REGIONS

The field work was realised in northern Chile by scientists from the Freie Universität Berlin and the GeoForschungsZentrum Potsdam in co-operation with the Universidad de Chile, Santiago and the Universidad Católica del Norte, Antofagasta. The main seismic refraction profile was located along the western border of the Western Cordillera, the recent magmatic arc (Fig. 1). In addition, in the Precordillera and the Western Cordillera, fan observations were realised. In 1995, complementive profile observations during the CINCA 95 experiment (Crustal Investigations Off- and On-shore Nazca Central Andes) were realised to obtain additional information on the deep stucture of the forearc.

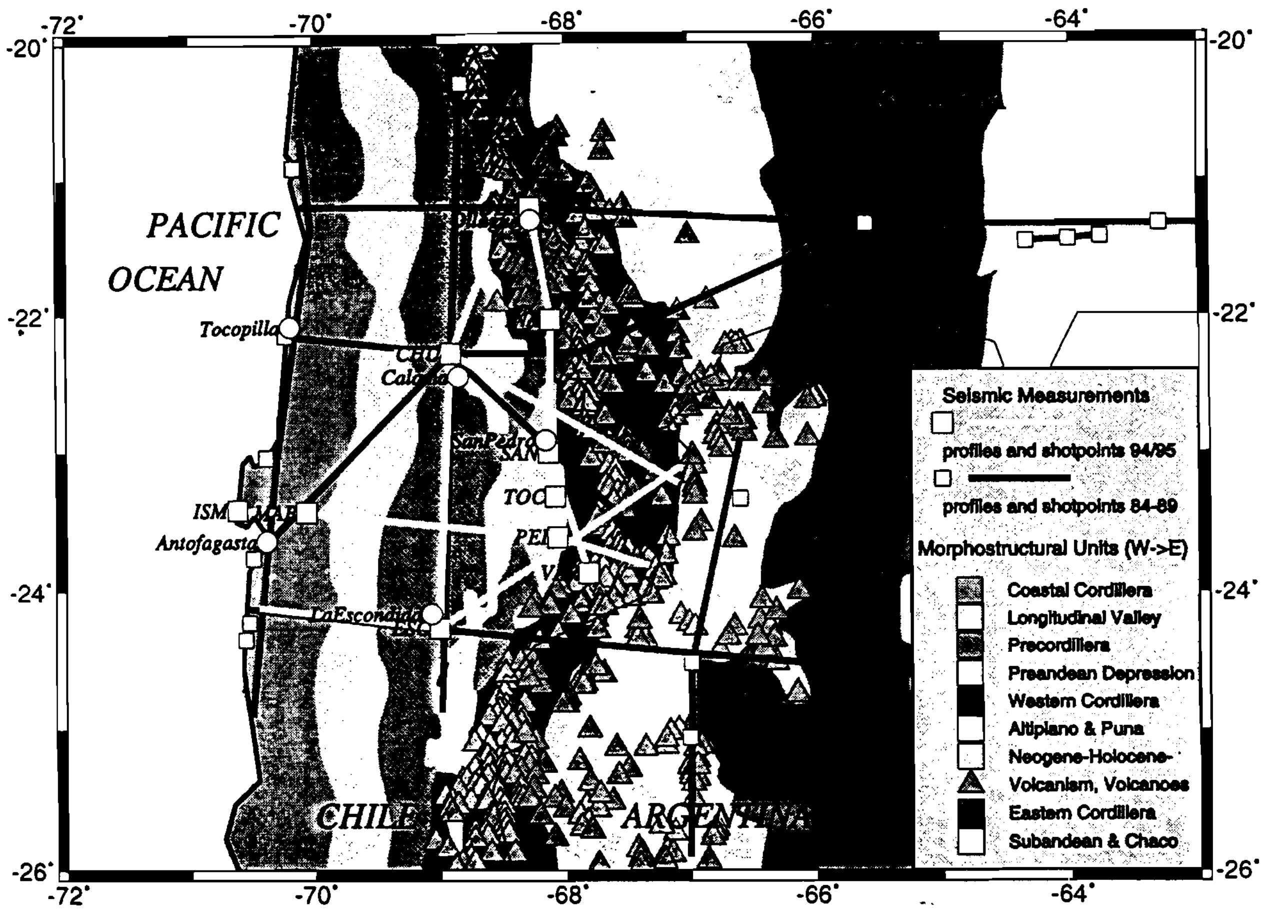

Figure 1. Location of the seismic refraction profiles and the main morphostructural units in the central Andes. The N-S profile on the western margin of the Western Cordillera penetrates the zone of active volcanism (grey triangles indicate volcanoes) in the northern part, while it descends to the Preandean Depression in the southern part. Here, the magmatic arc shows a significant retreat towards the east. Shotpoin locations are: ISM = Isla Santa Maria; MAB = Mantos Blancos; CHU = Chuquicamata; ESC = La Escondida; OLL = Ollagüe; INA = Inacaliri; SAN = San Pedro; TOC = Toconao; PEI = Peine; VAR = Pampa Varela.

Lower crustal material is exposed in the Coastal Cordillera south of Antofagasta (e.g. Lucassen and Franz, 1994). From seismic refraction data between 21° and 24°S, the top of the lower crust is located between 7 and 12 km depth, reaching down to 20-22 km, proven by prograde phases. The most prominent discontinuity at 40 km depth is interpreted as Moho of the subducted Nazca Plate. The average crustal velocity of the Coastal Cordillera is 6.6 km/s, increasing towards the south (Wigger et al., 1994). In the Precordillera, the upper crust increases to 20 km thickness and the lower crust extends down to approximately 40-45 km. The depth range 50 and 70 km is composed of high (6.9 - 8.0 km/s) and low (6.4 - 7.0 km/s) velocity layers. The 70 km-discontinuity may be associated with mantle material or the top of the downgoing oceanic crust (eclogite ?). The upper crustal units can be followed into the Western Cordillera; however, the crustal velocity decreases to 5.9-6.0 km/s. The most striking feature in the record sections of the Western Cordillera, a discontinuity at 20 km depth beneath Ollagüe, is interpreted from structural point of view as the top of the lower crust, although the crustal units below are characterised by partly reduced velocities. Locally limited high-velocity discontinuities in this crustal unit are observed down to approximately 45-50 km depth. Assuming this depth range as the base of the lower crust, a 25-30 km thick lower crust results with low average velocities of 6.0-6.2 km/s. No clear signals from depth levels beneath 50 km could be recorded in the Western Cordillera.

WHAT IS THE NATURE OF THE DEEP CRUST?

There are numerous geophysical indications for a thick crust in the forearc and arc regions (e.g. James, 1971; Götze et al., 1994; Wigger et al., 1994; Zandt et al., 1994), e.g. material with physical properties characterizing crustal material (low density, low seismic velocity), to about 70 km depth beneath the magmatic arc and the Precordillera. In contradiction, from tectonic point of view, no considerable thickening must be assumed for the forearc and arc regions, as Cainozoic crustal shortening is restricted mainly to the backarc (e.g. Kley, 1996). Therefore, with the actual state of knowledge, the origin of the material in deeper levels is under discussion and several solutions have been proposed.

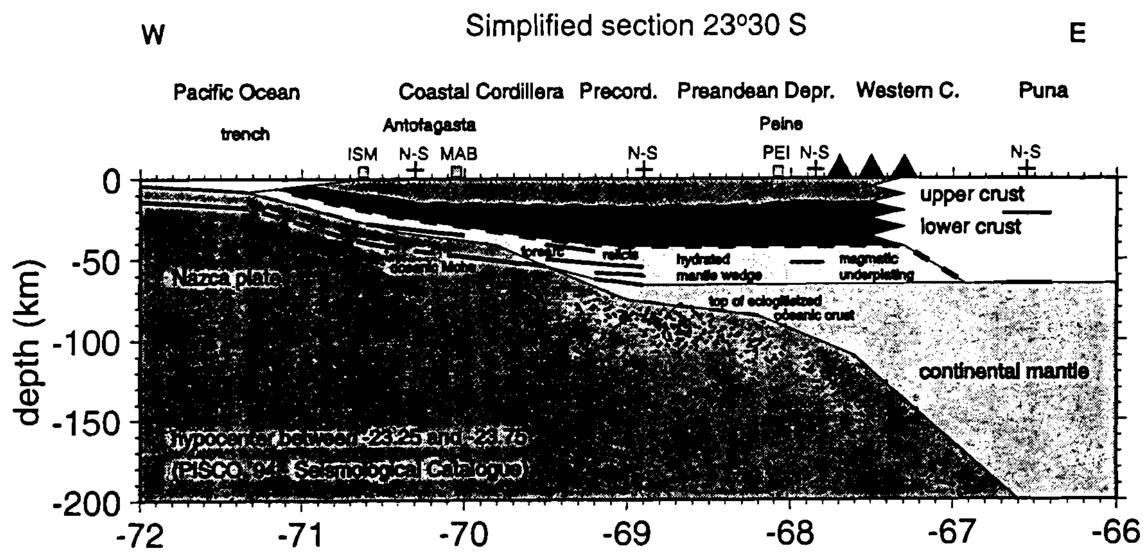

Figure 2. Simplified section across the central Andes in northern Chile (23°30' S). Crustal structrures can be traced from the Coastal Cordillera towards the Western Cordillera with increasing thickness of upper and lower crust. The shape of the subducted Nazca plate can be inferred from profile- and fan observations in the forearc, and from locations of the earthquake hypocenters derived from the PISCO 94 - seismological catalogue (Asch, Rudloff and Graeber, pers. comm., 1995). The deepermost crust is very inhomogeneous and may be composed of underplated crustal components (eroded from the continental margin) as well as of mantle material, strongly hydrated by fluids from the descending slab or differentiated by magmatic processes. Squares = shot point locations; crosses = position of N-S crolling profiles; black triangles = position of the magmatic arc.

The question arises, if the depth range 20 to 45 km is interpreted as continental lower crust, what are the consequences for the deeper horizons? Beneath the Precordillera, the top of the downgoing Nazca plate is given by deep reflections and the earthquake hypocenters. For the depth range between the slab and the base of the lower crust alternating high and low velocities are displayed. The seismic nature of the deeper crust and the transition to the mantle is still unclear due to ambiguous data for this depth range. One explanation for the low velocity material in the deeper forearc crust could be hydrated material of the peridotitic mantle wedge showing reduced seismic velocities (Fig. 2). Eroded material from the edge of the continent that has been emplaced in the deeper forearc crust within the subduction process, may contribute to thicken the crust in this depth range as well. Towards the Western Cordillera, partly molten rocks may be responsible for the strongly reduced seismic velocities and the observed high attenuation of the seismic waves.

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