

MAIN CRUSTAL ANOMALIES OF THE CENTRAL ANDEAN LITHOSPHERE

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RESUMEN: Basadas en observaciones geofísicas obtenidas en la década de los 80 se derivan nuevas informaciones sobre la estructura de la corteza andina. Se revisa la estructura casi simétrica de la corteza con un espesor de alrededor de 70 km en la zona del arco magmático, disminuyendo hacia el antearco y el trasarco. Mientras hay un doblamiento cortical en el trasarco, la corteza continental en el antearco está compuesta por una corteza continental delgada con una zona de "mezcla" inferior. Resulta una estructura asimétrica con un antearco "delgado" y un trasarco grueso. El arco magmático actúa como amortiguador ductil entre los dos bloques más rígidos.

KEY WORDS: Central Andes; geophysical anomalies; crustal thickening; asymmetric crustal structure.

INTRODUCTION

Within the frame of the research group "Mobility of Active Continental Margins" at the Freie Universität and Technische Universität of Berlin, geological and geophysical investigations were carried out between 20° and 26°S. Geophysical anomalies not only give knowledge about the lithospheric structure but they also allow to make statements about the dynamic and evolution of the Andean orogene. Across a traverse through the Central Andes a set of geophysical data is available (figure 1.) which allows, together with tectonic and petrological observations, conclusions about the geodynamic processes in the convergence system of the oceanic Nazca plate and the continental South American plate.

THE DATA

In the 80th a considerable amount of geophysical data has been measured in the Central Andes. Seismic refraction lines cover all morphostructural units from the coast to the Andean foreland with a total length of the recording lines of more than 4000 km (Wigger et al. 1993). Magnetotelluric measurements were focussed on two profiles between 21° and 22°S and at 24°S, crossing the Andes in their whole width (Schwarz et al. 1993; figure 1.). The net of gravimetric datapoints covers a great part of the area between 20° and 26°S with varying distances between the recording sites (Götze et al. 1993).

THE CRUSTAL STRUCTURE

The Moho-discontinuity, at 40 km depth in the foreland, can be followed in the seismic observations down to about 70 km depth at the eastern border of the Altiplano (figure 2.). Here, in the backarc region, the

crustal thickening is interpreted as crustal doubling by stacking of different crustal units. The corresponding shortening is documented in the sedimentary cover of the Subandean Ranges by tectonic shortening of 140 km (Kley & Reinhardt 1993). High velocity zones at 20-25 km depth beneath the Eastern Cordillera are interpreted as overthrust lower crustal material to the east (Schmitz et al, this volume), corresponding to an A-subduction of the foreland-crust beneath the Andes.

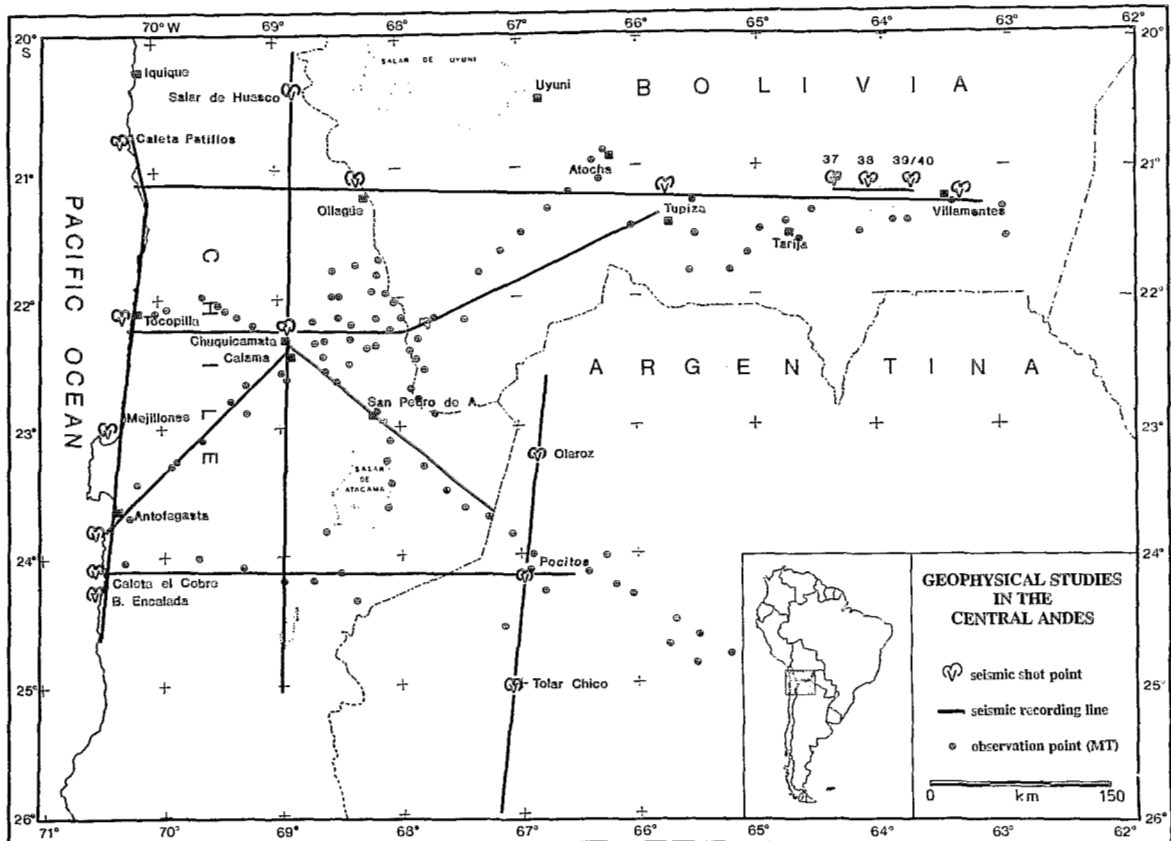


Figure 1. Map with the position of the seismic refraction lines and magnetotelluric (MT) recording sites (Schwarz et al. 1993). A gravimetric survey (Götze et al. 1993) covers almost the whole displayed area.

Beneath the Western Cordillera and the Altiplano no clear crust/mantle boundary can be detected from the seismic results, but intracrustal discontinuities are indicated. Based on the existence of a Bouguer anomaly of less than -400 mGal (Götze et al. 1993) about 70 km of material with crustal densities must be assumed. Zones of high electrical conductivity (HCZ) are observed at varying depths east of the magmatic arc, rising towards the surface in the Eastern Cordillera (Schwarz et al. 1993). In the Western Cordillera, the actual magmatic arc, the HCZ beginning at 10-15 km depth corresponds with low velocity zones (LVZ) in the same position.

A different structure is observed in the forearc. Here, high velocities (7.0-7.2 km/s) are observed at 20 km depth beneath the Coastal Cordillera, dipping to the east to about 35 km depth in the Precordillera. The deeper crust of the forearc is characterized by LVZs with an average velocity of 6.6 to 6.2 km/s down to 40 km depth beneath the Coastal Cordillera and 60-70 km depth beneath the Precordillera. The 40 km discontinuity beneath the Coastal Cordillera is interpreted as oceanic Moho. Its continuation to the east is not exactly known. Thus the forearc crust can be divided into a normal to thinned continental crust in the upper part and a lower part, consisting of a mixture of material characterized by lower, but also relatively high seismic velocities. A high in the residual anomaly in the Precordillera south of Calama is interpreted by an intracrustal inhomogeneity at 15-20 km depth.

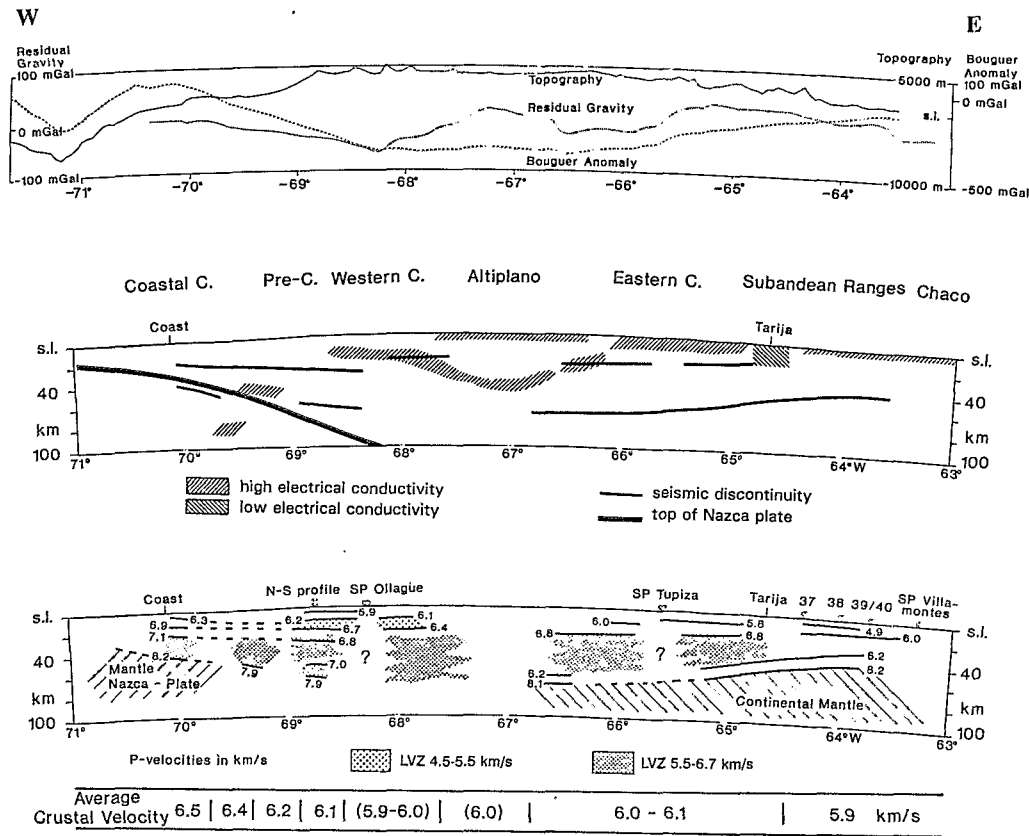


Figure 2. Above: Bouguer anomaly and residual gravity at 21°S (Götze et al. 1993). The topography is given for comparison. Center: Electrical conductivities between 21° and 22°S derived from magnetotelluric measurements (Schwarz et al. 1993). Below: Seismic discontinuities and P-wave velocities at 21°S in the parts which are proven by vertices (Wigger et al. 1993; Schmitz 1993). The average crustal velocities are given below.

CONCLUSIONS

The most outstanding anomaly of the Central Andes is the extreme thickening of the crust to about 70 km beneath the Western Cordillera and the Altiplano area derived from seismic and gravimetric data. Up to now, the thickening of the Andean crust was seen as a more or less symmetric phenomenon, but this picture must be revised. A pronounced asymmetric feature results from the interpretation of the existing geophysical data. Genetic aspects of the andine upper plate point to a "thinned" forearc crust and a tectonically thickened backarc crust.

The Andean crust shows a pronounced rheological structuration in vertical as well as horizontal direction. In the forearc, a normal to thinned continental crust is underlain by a pile of material, that possibly contains a thickened oceanic crust or remnants of that, continental material tectonically eroded from the continental margin and underplated in the forearc region, or remnants of the former continental mantle. From rheological point of view the upper plate shows a rigid behaviour whereas the lower part is probably ductile. The descending plate again shows a rigid behaviour.

The crust of the magmatic arc and the Altiplano is thickened, undifferentiated, without a clear Moho and it has relatively low average velocities and a spectacular high electrical conductivity anomaly (>10.000-20.000 Siemens) in 10-20 km depth (Schwarz et al. 1993) which must be characterized as "world

Rheological stratification of the Central Andean lithosphere

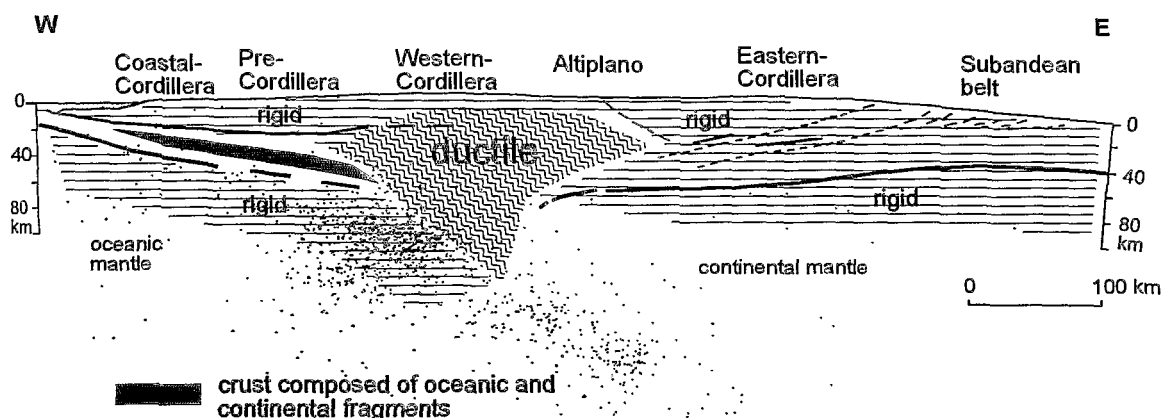


Figure 3. Rheological stratification of the Central Andean lithosphere. Hypocentral data are taken from ICS, USGS and PDE.

anomaly". Such extreme values of electrical conductivity can be explained only by fluids and/or partial melted zones. This crustal segment acts like a ductile buffer between forearc and backarc.

In the Eastern Cordillera and Subandean region of the backarc the crust is thickened with the development of a fold- and thrust belt. As the average crustal velocities increase again to the east, this crustal segment again is assumed to be rigid, but the distribution of high electrical conductivity areas in the sedimentary cover in the Subandean Belt and parts of the middle and lower crust of the backarc are ductile. In this sense the downgoing HCZ under the Eastern Cordillera - Altiplano border could indicate a deep reaching sole thrust.

REFERENCES

- Götze H-J, Lahmeyer B, Schmidt S & Strunk S 1993 The lithospheric structure of the Central Andes (20°-26°S) as inferred from interpretation of regional gravity. In: Reutter K-J, Scheuber E & Wigger P (eds) *Tectonics of the southern Central Andes: 7-22*, Springer, Berlin Heidelberg New York.
- Kley J & Reinhardt M 1993 Geothermal and tectonic evolution of the Eastern Cordillera and the Subandean Ranges of southern Bolivia. In: Reutter K-J, Scheuber E & Wigger P (eds) *Tectonics of the southern Central Andes: 155-170*, Springer, Berlin Heidelberg New York.
- Schmitz M 1993 *Kollisionsstrukturen in den Zentralen Anden: Ergebnisse refraktionsseismischer Messungen und Modellierung krustaler Deformationen*. Dissertation, Freie Universität Berlin.
- Schmitz M, Giese P & Wigger P 1993 *Crustal thickening in the Central Andes - results from seismic refraction and crustal balancing*. This volume.
- Schwarz G, Chong DG, Krüger D, Martínez E, Massow W, Rath V & Viramonte J 1993 Crustal high conductivity zones in the Central Andes. In: Reutter K-J, Scheuber E & Wigger P (eds) *Tectonics of the southern Central Andes: 49-68*, Springer, Berlin Heidelberg New York.
- Wigger P, Schmitz M, Araneda M, Asch G, Baldzuhn S, Giese P, Heinsohn W-D, Martínez E, Ricaldi E, Röwer P & Viramonte J 1993 Variation in the crustal structure of the southern Central Andes deduced from seismic refraction investigations. In: Reutter K-J, Scheuber E & Wigger P (eds) *Tectonics of the Southern Central Andes: 23-48*, Springer, Berlin Heidelberg New York.