ELECTRICAL CONDUCTIVITY STRUCTURES IN NORTHERN CHILE

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INTRODUCTION

During the last ten years, electromagnetic investigations have been carried out in the Central Andes to study the conductivity structure of the active subduction zone at the South American western margin (Schwarz et al. 1994). They are part of an integrated geological and geophysical project, which also comprises seismic refraction, reflection and gravity studies. The working area is located north and south of the tropic of Capricorn, between the Chilean town of Antofagasta to the Andean foreland in Bolivia and Argentina (Fig. 1).

While natural variations of the horizontal geomagnetic and geoelectric (telluric) field are measured in the magnetotelluric (MT) method, geomagnetic deep sounding (GDS) additionally utilizes the vertical component of the magnetic field. Both methods allow an estimation of conductivity distribution of the subsoil, with depth of penetration depending on period length. The results of data analysis and conductivity (resistivity) modelling for the magmatic arc and forearc regions will be presented in this contribution.

CONDUCTIVITY DISTRIBUTION IN THE ARC AND FOREARC

The earlier magnetotelluric measurements - carried out along two transects across the Andes (Schwarz et al. 1994, Schwarz & Krüger 1996) - revealed a prominent high conductivity zone (HCZ) beneath the Western Cordillera, which constitutes the present magmatic arc. Two-dimensional models were calculated for data on profiles A and B (Fig. 2, cf. Krüger 1994 and Massow 1994). Commencing at a depth of approx. 20 km, the depth extent of this anomaly is still remaining uncertain but is likely to execeed 60 km. Extremely long period measurements ($T > 1$ day) are necessary to penetrate through this conductor, since resistivity values - derived from 2-D modeling - are remarkably low (0.5 - 2 Ωm).

Recent developments led to completely new magnetotelluric instruments, which enable a broadband recording of electromagnetic variations in the period range from approx. 0.0001 s to more than 1 day and thus yield a resolution of very shallow as well a deep structures. Two field campaigns were carried out in 1993 and 1995 in the north of the previous measuring areas, covering two transversal profiles in Northern Chile, one through the Quebrada de Guatacondo, the other in the area of the town of Pica (profile C in Fig. 1). Again a distinct HCZ was detected, but instead of being located below the magmatic arc, it is surprisingly shifted to the west below the Precordillera. In this region - the so-called Pica gap - no recent volcanism has occured. The electromagnetic data thus hint at a N-S segmentation of the magmatic arc in accordance with geochemical results (Wörner 1994).

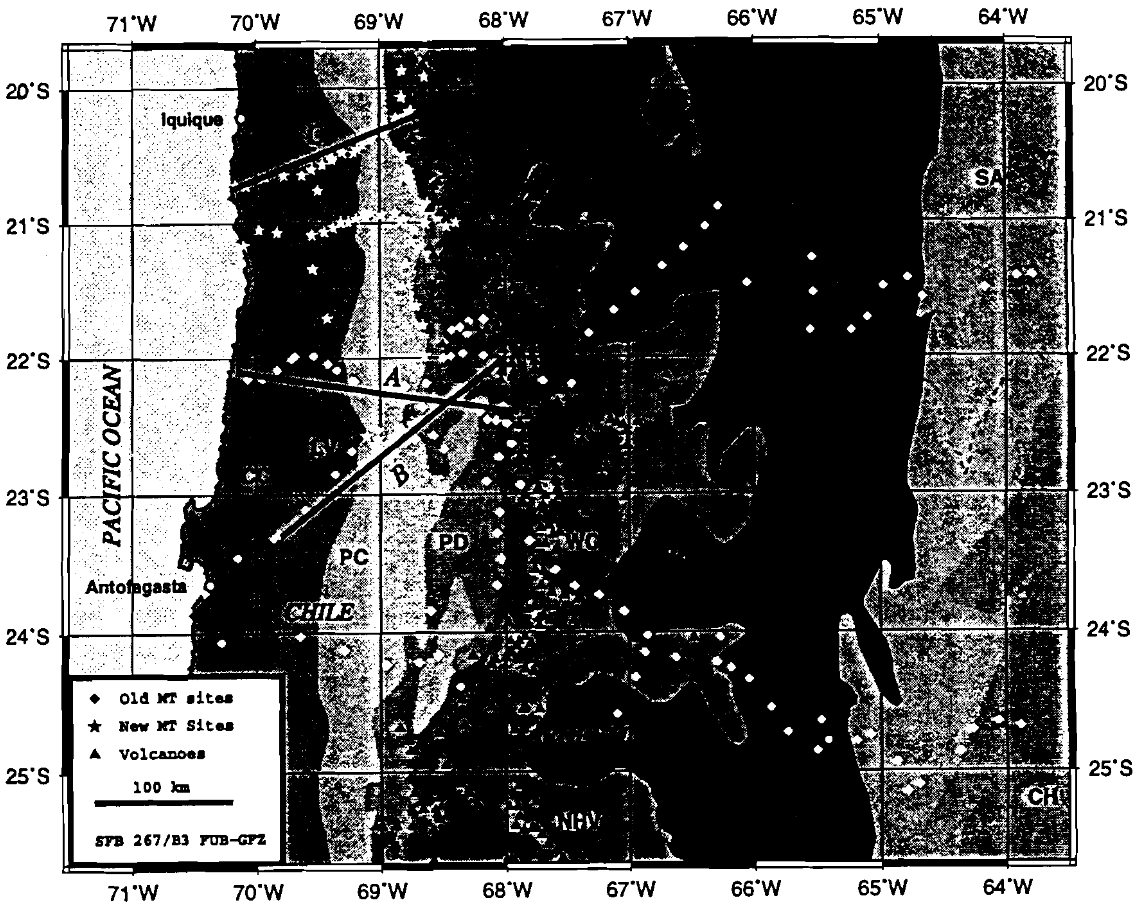

Fig. 1: Location of electromagnetic sites in the Central Andes. Two-dimensional models were calculated for profiles A-C (see Fig. 2).

Three fossil magmatic arcs constitute the area west of the Western Cordillera, which have evolved since the Jurassic. As the oldest of these arcs the Coastal Cordillera, with its occurence of vast batholites, is characterized by high resistivities, but also by anisotropic structures (modelled as dikes in Fig. 2A), which may be due to the influence of the large Atacama fault system, originating from oblique convergence of the former Farallon plate.

The actual slab of the subducted Nazca plate does not appear as a good conductor in model A, which may be explained by the complicated three-dimensional conductivity distribution in the forearc. Despite the highly resistive batholites near the coast, large parts of the forearc crust exhibit suprisingly low resistivities, which is unusual for a consolidated crust and may indicate a generally high amount of fluids, released from the subducted oceanic plate.

In the northern cross section C a diffuse conductive feature is modelled in the middle crust below the Coastal Cordillera. It is not yet clear, if this anomaly is due to released fluids from the slab or/and if there exists a connection to the possibly deep reaching Atacama fault system.

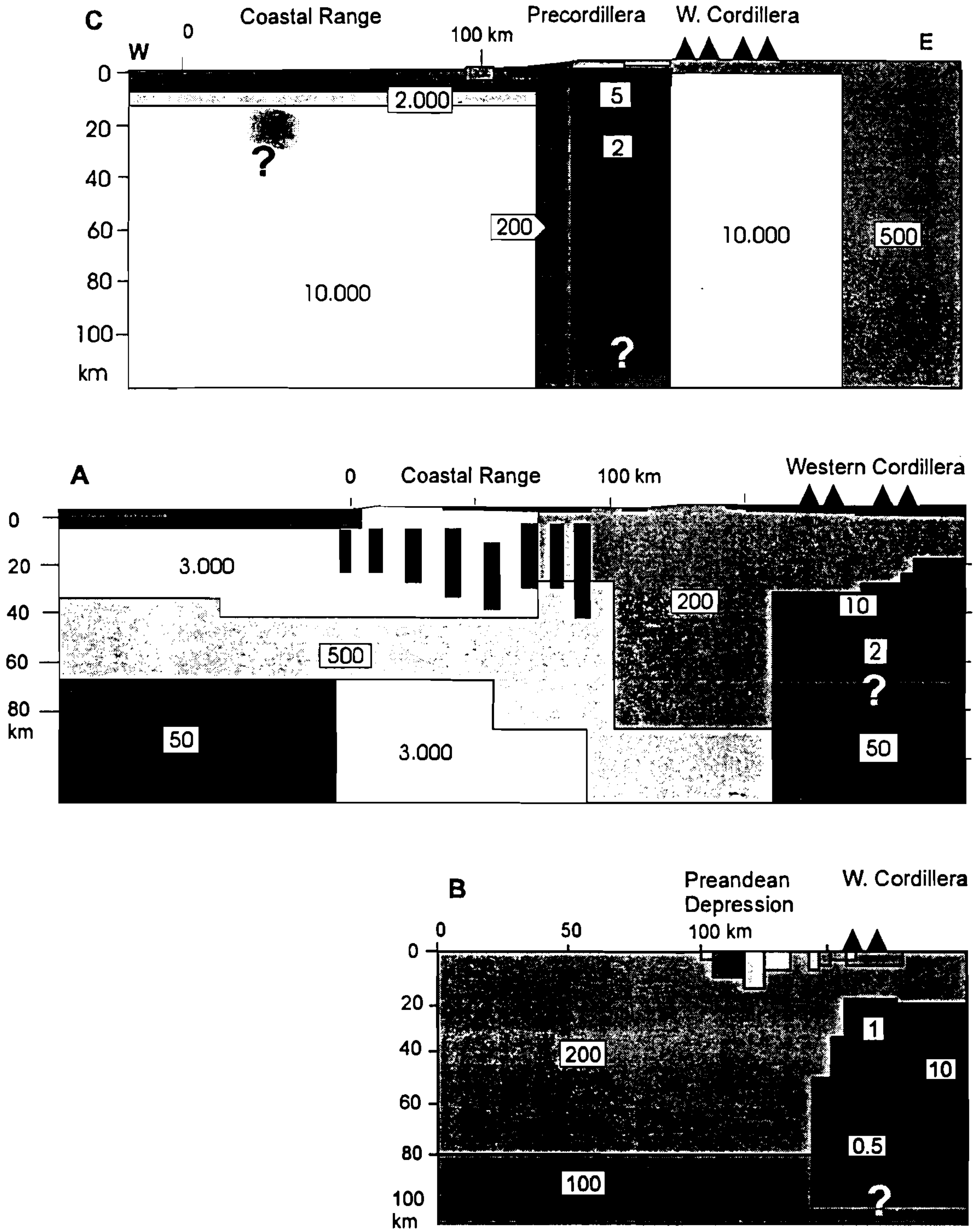

Fig. 2: 2-D models of electrical resistivity derived from electromagnetic measurements along profiles A-C in Northern Chile. Resistivity values in Ωm. Further explanation see text.

PARTIAL MELTS AS AN EXPLANATION OF THE HIGH CONDUCTIVITIES?

To understand the nature of the petrophysical processes leading to the dominant anomalies below the magmatic arc, the results of other geophysical investigations have to be taken into account. The subduction of the Nazca plate is relatively steep with an angle of 30°. Gravity and seismic investigations indicate a crustal thickness of about 70 km. Several low velocity zones were detected below the magmatic arc. In addition, a zone of high attenuation of seismic waves was deduced from measurements of a recent seismological network, coinciding with the region of high conductivity. There is a distinct correlation between a low of the residual gravity field (approx. -40 mGal) and the strike of the volcanic chain.

Although graphite and large amounts of saline fluids are often responsible for conductivity anomalies, the most likely explanation of the high conductivity values below the volcanic arc is the assumption of vast amounts of partial melts, originating in the release of water from the subducted oceanic plate at about 100 km depth. Laboratory measurements demand a temperature of at least 640 °C and a partial melting rate of at least 20% of silicic magmas to account for conductivities in the range of 1 Siemens/m. Although the actual thermal flow is not well known in this part of the Andes, this constrain should not constitute a major obstacle below a volcanic arc at a depth of >20 km. The existence of other fluid phases may not be excluded, however, and they may even play a substantial role in the explanation of the HCZ. It will be virtually impossible to distinguish between these two sources unless detailed temperature and heatflow data are available.

The large anomaly below the Precordillera in profile C does not necessarily oppose the assumption of this model, if the recent steepening of subduction is taken into account: the low resistivities would thus indicate a region of newly formed partial melts. On the other hand, the assumed prolongation of the Falla Oeste may also have to be taken into account.

CONLUSIONS

Electromagnetic investigations in the arc and forearc regions of Northern Chile revealed extensive highly conducting zones in a depth of approx. 20-60 km beneath the volcanic chain of the Western Cordillera. Partial melts are discussed as the most likely explanation of the anomalies, especially with regard to gravity and seismic results. The conductive zone is obviously correlated with recent vocanic activity, and is shifted towards the forearc in the so called Pica gap. Future work will concentrate on investigations on a profile in the forearc and Altiplano, where a seismic reflexion programme will also be carried out.

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