The mantle wedge in the Bolivian orocline in the view of deep electromagnetic soundings

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THE MT EXPERIMENT

Motivated by earlier findings of a large zone of high electrical conductivity below the southern Altiplano (Ancorp profile, cf. Brasse et al. 2002) a comparative magnetotelluric (MT) study was performed in 2002 (continued in 2004) along a profile extending from the Eastern Cordillera over the central Altiplano and the Western Cordillera until the forearc in North Chile (Fig. 1). Spacing between stations was on the average 10 km and data were recorded in a period range from 10-20.000 s, yielding approximate penetration depths from 5-200 km, depending on subsoil conductivity. The profile direction is approx. 45° and thus roughly perpendicular to the strike of main structural features in this area of the Bolivian orocline as well as to the contour lines of the Wadati-Benioff zone, inferred from Cahill and Isacks (1992). Topography and unaccessibility prohibited the continuation of the profile further into the Eastern Cordillera; in addition the sharp rise of the Western Cordillera Escarpment led to a, although minimal, gap in the profile. Distortion effects and deviations from two-dimensionality are low for most stations with the exception of sites PAT and OBS (near Patacamaya geomagnetic observatory), where the Coniri fault connects with the Laurani fault, and the forearc sites in North Chile.

PRELIMINARY 2-D MODELING AND FIRST INTERPRETATION ATTEMPTS

It is a lucky and not often encountered circumstance that induction vectors, derived from purely magnetic transfer functions (the ratio of vertical to horizontal field variations B_z/B_h), point in the direction of the profile over much of the study area (again with exception of North Chile), permitting a 2-D interpretation of the data set at least over the whole Altiplano. This direction is also corroborated by a multi-site, multi-frequency strike analysis of MT transfer functions, employing a code by McNeice and Jones (2001). A 2-D inversion code (Rodi and Mackie 2001) was applied using a homogeneous halfspace as a starting model, incorporating also the well conducting Pacific Ocean as a-priori structure. The data inverted for were the magnetic transfer functions with addition of magnetotelluric responses sensu strictu (apparent resistivities and phases). By adapting respective error bounds the weight of phase data (reflecting the actual induction process) was enhanced during inversion; effects due to static distortion of apparent resistivity curves could thus be minimized. Numerous inversion tests were performed, including variation of starting models, inversion of TE, TM mode and B_z data separately and jointly, calculation of trade-off curves, sensitivity studies, etc.

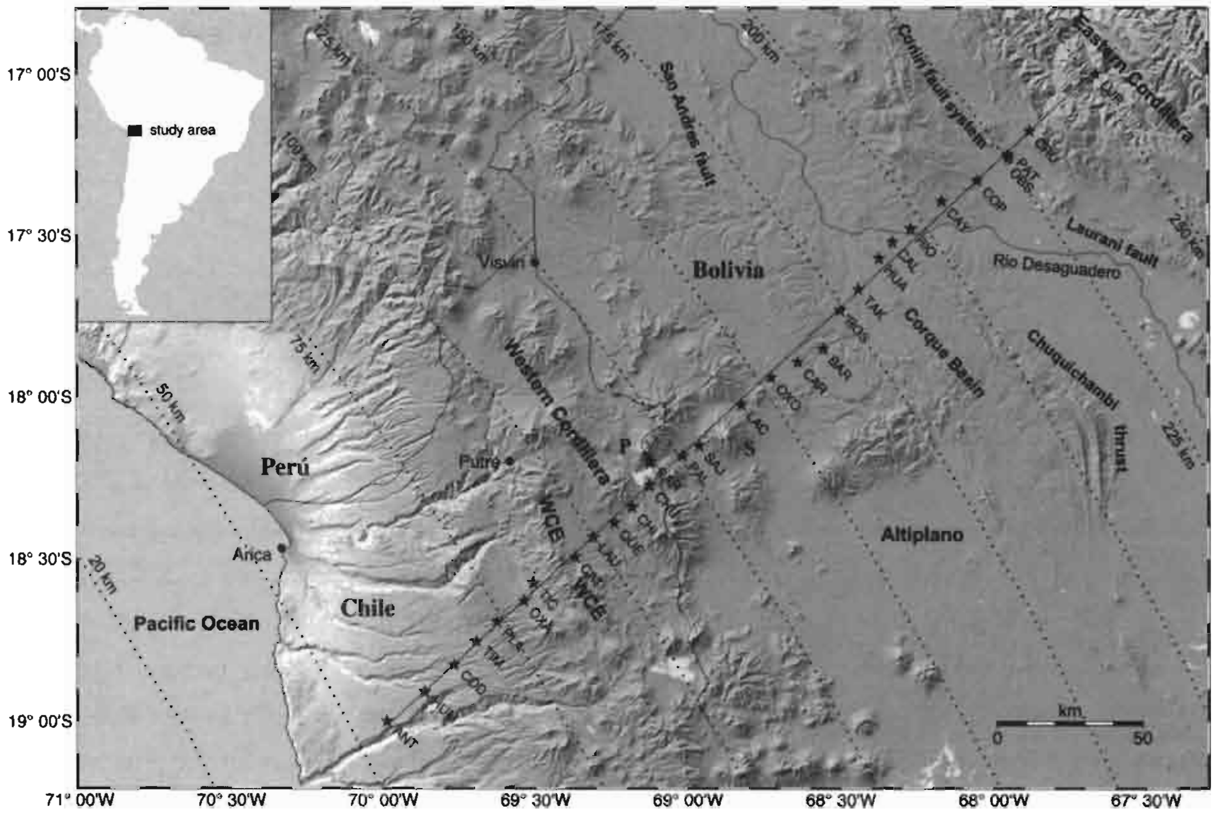

Fig. 1: Shaded relief map of the western central Andes (based on SRTM data) showing locations of recently measured MT sites in the Bolivian Orocline. The profile line is a great circle projection of the sites, while dotted lines mark the depth to the Wadati-Benioff zone after Cahill and Isacks (1992). WCE is the Western Cordillera Escarpment, the sharp rise to the high plateau in the study area. P, S are Parinacota and Sajama volcanoes.

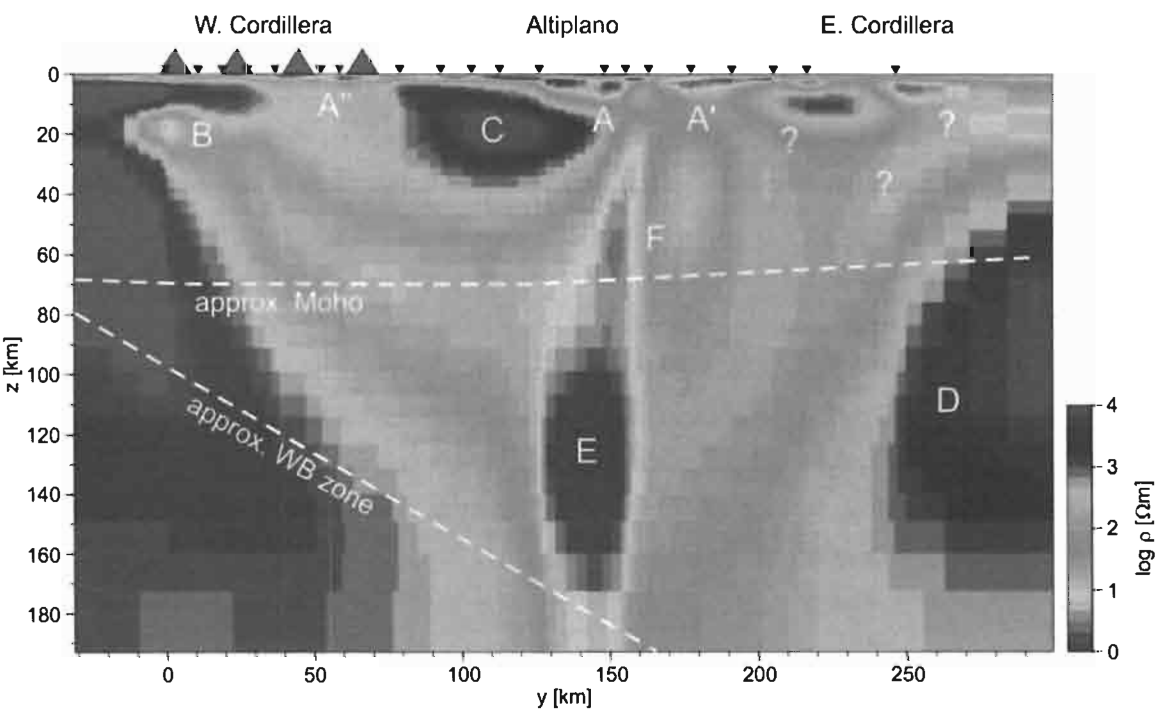

Fig. 2: Resistivity model from 2-D inversion. A - A' - A": Corque and minor basins, B: deep crustal magma chamber below W. Cordillera?, C: imperpeable upper crustal block, D: Eastern Cordillera block (analog to Dorbath et al. 1993, Dorbath and Granet 1996), E: mantle wedge, F: rise of fluids/melts. Question marks refer to areas of low resolution and/or three-dimensionality. Data from the forearc were not taken into account.

The expectation concerning conductive structures below the Altiplano was to find a similar HCZ in the deeper crust as below the Ancorp profile at 21°S. The resulting model, however, looks strikingly different (Fig. 2). Near the surface the Cenozoic Corque Basin appears as a highly conductive, asymmetric structure (e.g., Hérail et al. 1997) together with adjacent minor basins. This was already reported by Ritz et al. (1991) who carried out a similar experiment; the depth range of their interpretation was limited to the crust, however, owing to the limited frequency range and the unavailability of vertical field transfer functions.

The most spectacular feature of the model is a very good conductor in the upper mantle below the Altiplano at depths of approx. 120 km. From there a slightly less conductive structure is observed, rising to middle crust. A similar, but oblique and even less conductive branch reaches and underlies the western margin of the volcanic arc. A resistive block is modelled in the upper crust; also the margins of the model are resistive (i.e., below the forearc and the Eastern Cordillera), but naturally these resistivities are not well resolved due to lacking data coverage.

Although one might expect to image the mantle wedge as a good conductor, several of its features are surprising:

a) Conductivities are so high (in the order of 1 S/m) that a melt rate of at least 5% is needed. This contradicts many assumptions based, e.g., on seismological studies. Perhaps more saline fluids (usually thought to be more conductive then partial melt itself) then previously thought are involved. These high conductivies could, however, also be an effect caused by the 2-D approximation.

b) The shape resembles a dyke-like structure; this is, however, not well resolved and other geometries are possible, leaving the general characteristics concerning depth and position untouched.

c) The position of the conductor (in course agreement with a low-velocity zone detected by Dorbath and Granet 1996) well to the east of the volcanic arc is not in accordance with standard subduction scenarios. It must be taken into account, however, that we observe a momentary image only and that volcanism in this particular study area has recently been much less active then elsewhere in the Andes. One may speculate that we observe the initiazation of a new magmatic event or the feeding of a deep crustal magma reservoir similar to the one detected below the southern Altiplano.

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