Summary

This thesis describes a distortion analysis and modeling of magnetotelluric (MT) and deep geomagnetic sounding (GDS) data of the Southern Central Andes. The data was collected during several field campaigns between 1995 and 1998, within the framework of the German Collaborative Research Programme SFB267 "Deformation Processes in the Andes". The measurements were carried out in the forearc and magmatic arc regions of the subduction zone, covering an area about 200 km long (W-E) and 60 km wide (N-S). The average penetration depths of the field data vary from 2 to 120 km in the Altiplano and exceed 200 km in the forearc.

Three dimensional (3-D) modeling was required to explain the induction arrows and the MT data, which were found to be strongly distorted by current channeling effects and also affected by anomalous magnetic fields. Conventional MT tensor decomposition methods to analyze dimensionality failed to determine a common regional strike of electrical conductivity. Understanding the source of the distortion was possible by applying a method of current channeling analysis developed in this thesis, allowing a qualitative recognition of the main 3-D high conductivity anomalies. This served as *a priori* information for the construction of the 3-D forward models.

The current channeling analysis is based on the hypothesis that telluric and magnetic distortion produced by local conductors of limited lateral extension and embedded in a resistive host affect the 2-D regional MT impedance tensor. The recognition of current channeling in the MT data stems from the property that the electric field fulfills; a stronger attenuation of the field intensity by higher conductivity contrast and by laterally longer conductors. The strike of the elongated conductors, which is different from the strike of the regional structure, can then be recovered. In addition, surface contour plots of particular distortion parameters as a function of site location, averaged over a selected period band, allow a qualitative recognition of the conductivity anomalies in the study area at the corresponding penetration depths.

The method developed here for recognizing current channeling and hence the existence of elongated conductors in the crust has been seen useful to apply in shear zones, especially when the strike of the faults is different from that of a regional conductivity structure.

Two mega-fault systems oriented sub-parallel to the coast line (N-S), composed of strike slip faults associated with the oblique subduction of the Nazca plate underneath the South American plate, are identified as highly conductive zones.

In the Coastal Cordillera the NNW-SSE Atacama mega-fault which also intersects the coast line is associated with highly conductive vertical crustal dikes of changing strike directions and widths of ∼7 km, stretching from the surface to at least 10 km depth. An electrical coupling between these dikes and the conductive ocean, together with the influence of a high resistivity zone in the ocean lithosphere, leads to strong current channeling distortion effects, impeding the resolution in depth of the conductive dikes. A severe change in the current flow direction producing anomalous magnetic fields causes the impedance phases of the coast-parallel (N-S) electric field component to leave the first quadrant (>90°).
Salinary and/or ore fluids circulating in the fractures is the best explanation for the conductivity enhancement detected in the Atacama fault, where widespread nitrate deposits possibly associated with metallogenetic events are found. Except for the vertical dike-like conductors, the whole crust has very high electrical resistivity values (>1000 Ωm), supporting the hypothesis that the lithosphere in this region has a brittle regime, given also the low geotherms (<300°C), the high seismic P-wave velocities and the evidence of crustal seismicity. Thus a long pathway down to the depths of the oceanic Moho (4-50 km) for the fluids circulating under hydrostatic pressure along fractures crossing the brittle crust, which is subject to shear stresses from an active subduction zone, is a possible explanation. The fluids trapped within the fractures are likely related to older metamorphic reactions which occurred during the emplacement of the Jurassic arc to the east. In addition, fluids in the upper crust could stem from meteoric waters.

Further inland, the eastern end of the forearc is conformed by the thrust-fold Precordillera fault system, where the strike-slip mega-fault ”West Fissure” is associated with the oblique subduction geometry. A 3-D high conductivity anomaly identifies this region. A coupling effect between upper crustal vertical dike-like conductors, oriented close to N-S and possibly of limited lateral extension, and a deeper high conductivity zone (HCZ) can explain the strong magnetic distortion observed in the data, where some sites have impedance phases out of the first quadrant (>90) for the electric field component tangential to the orientation of the conductive dikes (∼N-S). A severe change in the current flow direction producing anomalous magnetic fields, leads the phases to be out of quadrant.
In the Precordillera, the highly conductive vertical dikes (<5 Ωm) with varying strike close to N-S reach depths of about 10 km. These correlate with the fault system, which is associated with the emplacement of a huge porphyry copper system (Chuquicamata) to the south. The conductivity enhancement could be due to saline and/or ore fluids circulating in the fractures of the brittle upper crust (temperatures <200°C). A larger high conductivity zone (HCZ) extends below the conductive dikes between 10 and 35 km depth, with a N-S gradient of conductivity decreasing from north (>0.2 S/m) to south (<0.1 S/m). The lower boundary can only be constrained by inserting another HCZ at the levels of the oceanic slab (70-90 km depth). Assuming this HCZ to be present, free fluids released from dehydration reactions in the slab would explain the conductivity enhancement at these depths.
The clearly higher conductivity values to the north of latitude 21°S than to the south at depths of 10-30 km beneath the Precordillera are suggested as being due to a distinct concentration of fluids which are produced by metamorphic reactions that may have evolved with different P-T conditions from north to south, considering the different age of volcanic activity known at these latitudes (21°S). An additional explanation is that in the north, where magmatism is

older (>25 Ma) than in the south (<10 Ma), the crust might be more fractured due to a cooler and more brittle regime than in the south, allowing the fluids to be better interconnected and hence the electrical conductivity to be enhanced.

In the Altiplano high-plateau a high conductivity zone (HCZ) is encountered below 20 km depth (<2 Ωm) extending to the west to the beginning of the Western Cordillera (WC; the recent magmatic arc), and is interpreted as partial melting. The HCZ strikes NNW-SSE, similar to the bending of the volcanic arc, which seems to be related to the distinctly different volcanic activity between the regions north and south of latitude 21°S. The existence of an electrically conductive asthenosphere beneath the Altiplano (>70 km depth) may also be possible, supported by the elevated temperatures estimated in this zone (≥1250°C; Springer, 1999) and the high seismic attenuations (Whitman et al., 1992). The extension in depth of the HCZ is, however, beyond the resolution of the MT data.

A connection between the Altiplano-HCZ and the mid-crustal conductor of the Precordillera (PC) fault system, i.e., a conductive zone beneath the magmatic arc, in the southern sector of the study area (21°S; Ancorp) remains a question. A more dense set of stations at these latitudes could give a higher resolution of conductivity distribution (especially along NS, given the detected 3-D effects). The new measurements could thus identify the presence or absence of a conductivity enhancement in connection with the seismic reflector Quebrada Blanca Bright Spot, located at ∼30 km depth between the Precordillera and Western Cordillera, and/or the modeled low seismic velocity layer at depths of about 30 km obtained from receiver functions. Such a conductive structure would support the hypothesis of partial melts in the crust of the recent magmatic arc (Western Cordillera). This was the interpretation of a 2-D MT model obtained south of the study area, at latitude 22°S (Schwarz and Krueger, 1997). North of 21°S (on the Pica Profile), in contrast, where volcanism ceased about 20 Ma ago, a model with a conductive zone beneath the magmatic arc is not detected. Hence the hypothesis of partial melts in this region can be excluded.