CHAPTER 9
CONCLUSIONS AND GEODYNAMIC IMPLICATIONS

Structural, geomorphical, and geochronological studies in the Southern Andean intra-arc zone targeted endogene and exogene Prozesses active in the Southern Andes. The results place constraints on the long-lasting tectonic, magmatic, and morphologic history of this segment of the Andes improving the understanding of the dynamics of active margin systems. Specifically, my work has implications for the following: (1) the significance of climatic and tectonic control on Neogene uplift and exhumation, (2) active margin deformation, (3) partitioning of oblique convergence between the Nazca and South American plates, (4) orocline formation, and (5) strain partitioning during transpression.

Below I summarize these implications.

Tectonic and climatic control on uplift and exhumation

Neogene uplift, exhumation, and topography of the Southern Andes is governed by the interplay between erosion and tectonic processes. The topography of the Main Cordillera basically reflects the southward increasing Neogene efficiency of erosion on the western, windward side of the orogen. More specifically, a southward decrease of maximum, minimum, mean, and modal elevations concurrent with an increase of local relief, mean and modal slopes, and surface ratio and a change from V-shaped valleys to U-shaped valleys are consistent with a change from dominantly fluvial erosion in the north to dominantly glacial erosion in the south. Accordingly, the level of exhumation of the North Patagonian Batholith increases southward from shallow (< 3 km) to mid-crustal (10 – 15 km) levels. Erosional unloading, heavily partitioned spatially into the south of the study area and temporarily into the glacials, accounts for at least one third of the observed differential rock uplift and exhumation since the Miocene. Pre-Pliocene tectonic rock uplift, localized within mid-crustal orogen-parallel transpression zones, was complementary less than two third of rock uplift.

To further investigate the interplay of endogene and exogene processes and their imprint on the landscape more regionally, detailed topographic analysis based on high-resolution DEMs (as it was performed in this work) of the Main Cordilleran parts north and south of the study area together with thermochronologic, geobarmotric studies, and analysis of long-river profiles (Hack, 1973, Kirby and Whipple, 2001) seem a successful approach for the future.

Trigger of active margin deformation

The tectonic history of the Southern Andes shows longlasting periods (tens to hundreds of millions of years) of extension and basin formation during the Mesozoic (e.g. the Neuquén basin) and Oligocene - Miocene (e.g. the Cura-Mallín basin) alternating with relatively short (several million years) intervals of transpression and mountain building during the mid-Cretaceous and Late Miocene. There is no clear temporal relationship between plate kinematic parameters and regional deformation of the overriding plate. This implies that active margin deformation is controlled primarily by other factors than plate kinematics. More specifically, increments of cross-arc shortening (with minor amounts of arc-parallel shear) has been shown to follow increments of crustal extension and to be late-synmagmatic with respect to emplacement of granitoids of the North Patagonian Batholith implying that subduction orogeny may be triggered by magmatic weakening and crustal thinning. Initiation of the Liquiñe-Ofqui Fault Zone during the Late Miocene/Early Pliocene was concurrent with collision of the Chile Ridge at the southern end of the Southern Volcanic Zone of the Andes implying that, under favorable mechanical conditions (i.e. presence of a lithospheric scale weak zone), extensional forces associated with subduction of an active spreading center may have a primary control on fore-arc sliver formation.

Partitioning of plate convergence

The youngest increment of intra-arc deformation in the Southern Andes is represented by the Liquiñe-Ofqui Fault Zone (LOFZ) which has been active as a brittle SC-like simple shear zone between latitudes 38° and 42°S since the Pliocene. Fault kinematic data show a bimodal distribution due to kinematic partitioning of deformation into arc-parallel synthetic and arc-oblique antithetic fault zones. A two-dimensional kinematic model suggests that the LOFZ has accommodated ca. 84 km (+66, -28) of dextral shear resulting in the northward translation of a fore-arc sliver, the Chiloé block. This displacement is consistent with offset of regional geological markers, vertical axis rotations, and the space provided in the fore-arc by Neogene Central Andean plateau formation. The resulting displacement rate suggests that about half of the margin-parallel component of oblique convergence between the Nazca and South American plates has been partitioned into the intra-arc zone. The remaining half of margin-parallel slip is most probably accommodated by oblique thrusting in the accretionary wedge and to a minor amount by internal deformation of the fore-arc.

A paleomagnetic survey would be suitable to improve the existing paleomagnetic database and to test the validity of the here proposed correlation of clockwise and anticlockwise vertical axis rotations with, respectively, synthetic and antithetic faults of the LOFZ. Due to the hydrothermal active setting it seems not a successful approach to date brittle LOFZ deformation, for example by dating syntectonic veins, posttectonic nodules, or cement of fault brecciae, illite (e.g. Franzke et al., 1996) or fine fractions (e.g. Wemmer and Ahrendt, 1997) of fault gauges and cataclasites, or hydrothermal alterations (e.g., Blisniuk et al., 2001, Tanaka et al., 1995).

Orocline formation due to differential shortening

During the Late Miocene, the Southern Andes experienced significant regional cross-arc (E-W) shortening which led to basin inversion, mid-crustal transpression, and building of the Main Cordillera. This increment correlates with the main mountain building Andean "Quechua phase". A two-dimensional kinematic model suggests that upper crustal cross-arc (E-W) shortening during this increment had magnitudes of ca. 10 – 40 km in the Southern Andes. This is one order of magnitude smaller than back-arc shortening in the Central Andes and is consistent with the widely accepted model of formation of the Central Andean plateau and the Bolivian orocline by differential shortening (Isacks, 1988).

To improve this semi-quantitative kinematic model, balanced cross sections based on seismic data and including detailed analysis of outcrop scale structures and evaluation of ductile microstrain comparable to those existing for the Central Andes are necessary..

Strain partitioning during transpression

Petrologic analysis of exposed structures of the Late Miocene increment of deformation indicates a southward increase of syntectonic metamorphic conditions ranging from non-metamorphic at 38 – 39°S to greenschist facies at 41 – 42°S. This metamorphic gradient correlates with the exposed level of intrusion of granitoid rocks of the North Patagonian Batholith (Seifert et al., in press). Tectonics varies also systematically from broad zones of basin inversion in the north to narrow brittle-ductile transpressional shear zones in the south. Geometric restoration of these differentially exhumed structures and two-dimensional kinematic modeling suggest that the component of pure shear decreases systematically with crustal depth within the deformation zone by an order of magnitude from shallow to mid-crustal levels (tens of kilometers versus several kilometers). The observed geometry and kinematics of the deformation zone is accordant with empirical models of crustal scale shear zones and flower structures (e.g. Handy et al., 2001, Robin and Cruden, 1994). The larger amounts of cross-arc shortening and mountain building at upper crustal levels required by this model are probably accommodated by lower crustal lateral low.