MAGMATIC ARC TECTONICS AND THEIR APPEARENCE AT DIFFERENT STRUCTURAL LEVELS: EXAMPLES FROM NORTHERN CHILE

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Resumen

Los movimientos entre placas convergentes controlan la tectónica del arco magmatático. Se producen estructuras de acortamiento sin vergencia o con vergencias bilaterales junto con fallas transcurrentes paralelas. Se describen estas estructuras para diferentes pisos tectónicos.

Key Words: Magmatic arc tectonics, Central Andes, northern Chile

Introduction

Plate convergence has played a major role in the structural and magmatic evolution of the Central Andes of northern Chile since the beginning of the Jurassic (Andean Cycle, Coira et al. 1982). In a system of converging plates the greatest amount of deformation is probably accommodated in the shear zone between the two plates. However, the crust of the upper plate may also be deformed. Besides the backarc area and the subduction complex of the forearc, the magmatic arc is one realm that, contemporaneously to arc magmatism, may suffer very strong deformation including structures of orogen-normal shortening and/or orogen-parallel strike-slip (Reutter et al. 1988, Reutter & Scheuber 1988). In northern Chile and adjacent areas, this interrelation can be studied effectively as the magmatic arc shifted towards the interior of the continent during the Andean Cycle. This eastward shift resulted in four arc stages: (1) a Jurassic - Early Cretaceous arc in the Coastal Cordillera, (2) a Mid Cretaceous arc, not well documented, in the Longitudinal Valley, (3) a Late Cretaceous - Paleogene arc in the Chilean Precordillera (Sierra de Moreno, Cordillera Domeyko), and (4) the Miocene - Holocene arc in the Western Cordillera, with extensions of magmatic activity reaching into the Eastern Cordillera. The termination of the fossil arc stages was connected with an uplift of the arc's crust in the order of several km. This uplift allows the investigation of different structural levels of the magmatic arc's crust. The Jurassic - Early Cretaceous arc was upplifted up to 12 km, the Late Cretaceous - Paleogene arc up to 5 km, whereas the Miocene - Holocene arc shows near-surface structures. According to the tectonic level an infrastructure where ductile flow is the prevailing deformational mechanism can be distinguished from a suprastructure with folds and brittle faults.

The infrastructure

In the infrastructure a fully ductile level can be distinguished from a semiductile level. The criterion for this distinction is the occurrence of S-C fabrics which are absent under fully ductile conditions (Shimamoto 1989).

a) the fully ductile level

The deepest structural level crops out in the North Chilean Coastal Cordillera NW and S of Antofagasta. Its lithology is built up by basic to intermediate igneous rocks, to a minor amount also Paleozoic to Lower Jurassic sediments are involved. The structures are characterized by more or less distinct vertical foliations parallel to the orogen. The foliated area reaches a width of some 15 km. Deformation took place under amphibolite facies conditions at low pressures (500-600°C, <300 MPa, Scheuber & Andriessen 1989), there are, however, also granulitic portions (Rößling 1989). Vertical folds and bending of foliation in shear zones indicate that left-lateral strike-slip movement caused the deformation in this deep level.

b) the semiductile level

Here the deformed zone is narrower than in the fully ductile level. Deformation occurred in a mylonitic zone up to 2 km wide which is characterized by a strong strain partitioning on the mesoscopic and microspopic scales. Mesoscopically large strains are accommodated by mylonitic to ultramylonitic bands which are separated by moderately deformed protomylonites. On the microspopic scale C- and S-bands accommodated a major amount of strain. The semiductile shear zones are clearly related to orogen-parallel fault systems such as the Atacama Fault Zone of the Coastal Cordillera (Scheuber & Andriessen 1989) or the West Fissure in the Precordillera (Reutter & Scheuber 1988). The mylonitic rocks were formed at a depth of 5-7 km. In contrast to the fully ductile rocks, they contain several indicators for the sense of shear which can be related to the reconstructed direction of the motion of the subducting oceanic plate relative to S America. In the mylonites of the Coastal Cordillera the generally observed left-lateral sense of shear corresponds with the great obliqueness of the (oceanic) Phoenix plate's motion (Zonenshayn et al. 1984). The fabric patterns of the Precordilleran mylonites are generally more symmetrical or show a dextral sense of shear, they reflect a smaller convergence obliqueness during the Paleogene.

The suprasstructure

This level is structurally characterized by orogen-parallel anticlines and steep faults which developed contemporaneously to the igneous activity of the particular arc. Anticlines, in the core of which the pre-Andean basement is always involved are characteristic of the Late-Cretaceous - Paleogene arc of the Precordillera; usually the anticlines are compressed to such a degree that the limbs are steep or overturned and the core is upthrust with respect to the limbs. Vergencies are developed to the W and to the E. The flanks and especially the cores are frequently intruded by shallow plutons which can in part be considered as synkinematic. Structures of orogen-normal shortening are also found in the modern magmatic arc of the Western Cordillera and Puna. Here conjugate reverse fault systems with vergencies to the W as well as to the E are developed (Schwab 1970). Structures of Neogene to Quarternary folding are also frequent. Orogen-parallel strike-slip is revealed by en echelon fault arrays (e.g. Riedel shears), vertical folds or stratigraphic discontinuities in the suprastructure of the Late Cretaceous-Paleogene and in the modern arcs. The sense of shear is dextral in the Paleogene, sinistral during the Miocene-Quaternary.

Conclusions

The most characteristic feature of magmatic arc tectonics is the coincidence in time and space between deformation and arc magmatism. Each of the the four arc stages had a duration of several tens of million years so that a pervasive heating of the crust and a corresponding high geothermal gradient of about 60°/km could develop. Deformations in the magmatic arc are a response by the crust of the upper plate to the forces generated by plate convergence. Due to the heating of the crust the deformations are focussed to the magmatic arc. Liquid bodies contained in a crust which is subject to deformation reduce the differential stress to zero and thus perturbate the regional stress field. In the heated crust the brittle-ductile transition, which in quartz-rich rocks corresponds to the 300°C-isotherm (Sibson 1977), takes place at a higher level than it does under normal crustal conditions. In the arc stages of northern Chile this transition was located at a depth of about 5 km. Creep processes and the lack of strain hardening which can be assumed for the fully ductile level also gain significance at the rather shallow depth of about 8-10 km. A significant drop in differential stress and an increase in strain rate of the magmatic arc can thus be assumed. Magmatism also plays an important role in the relation between infrastructure and suprastructure. Chong & Reutter (1985) proposed a model in which the deformations in the suprastructure were thought to be triggered by intrusions that destabilized the crust to such a degree that continuous compressive stresses led the upper rigid level of the crust to shear off from its infrastructure.

Magmatic arc tectonics reflect the relative motion of the converging plates. In case of oblique motion the vector is resolved into two components, one acting perpendicularily and one parallel to the plate boundary. The first leads to structures of orogen-normal shortening, the second to orogen-parallel strike-slip motion (trench-linked strike-slip faults Woodcock 1986). If both types of structures occur together, the tectonic regime may be described as transpressive. There is no evidence that the structures of crustal shortening are a result of far reaching intracrustal overthrusting. It can be interpreted as distributed pure shear crustal thickening.

A long time span for magmatism is necessary for a large-scale heating of the crust. Deformation, however does not seem to be continous but it is accelerated during phases of increased spreading rates (Pilger 1984). This suggests that at low convergence rates the major amount of stress is absorbed in the subduction zone and that only at high plate velocities stresses are produced that are sufficent to generate deformations in the upper plate. If such high stresses are produced, they are preferably absorbed in the magmatic arc.

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