

MESOZOIC EXTENSIONAL AND STRIKE-SLIP FAULT SYSTEMS IN MAGMATIC ARC ROCKS OF THE ANDEAN PLATE BOUNDARY ZONE, NORTHERN CHILE

John GROCOTT⁽¹⁾, Graeme K. TAYLOR⁽²⁾ and Peter J. TRELOAR⁽¹⁾

(1) School of Geological Sciences, University of Kingston, Kingston-upon-Thames, Surrey KT1 2EE, U.K.

(2) Department of Geological Sciences, University of Plymouth, Drake Circus, Plymouth, Devon PL4 8AA, U.K.

SUMMARY

Middle Jurassic to Early Cretaceous plutonic rocks were emplaced in an extensional magmatic arc between 25°S and 27°S in the Andean convergent plate boundary zone of northern Chile. Abandonment of the magmatic arc in the Early Cretaceous was accompanied by a change from an extensional to a strike-slip regime in the plate boundary zone. Sinistral strike-slip displacements on the Atacama fault system are part of this regime.

KEY WORDS: Magmatic arc, Mesozoic, Extension, Strike-slip, Atacama, Chile

INTRODUCTION

The mechanisms of magma emplacement in continental magmatic arcs differ according to whether the plate boundary zone is in extension or compression. Studies which attempt to relate displacements in the arc to emplacement mechanisms often focus on displacements associated with emplacement of plutonic igneous rocks. In fact, the ductile and brittle fault systems which accompany magma emplacement are often linked to fault systems affecting the fore-arc, back-arc and the volcanic sequences at higher structural levels within the arc.

In extensional continental magmatic arcs, the arc and back-arc are often thought of as distinct tectonic units. Indeed, the back-arc is typically characterized by a marine marginal basin, whereas the arc remains at or largely above sea level because of the addition of arc magmas to the crust. This conventional subdivision of tectonic units at convergent plate margins tends to obscure an important unifying aspect of the arc/back-arc couplet, namely the linked fault system responsible for the overall extension of the convergent plate boundary zone.

We have studied deformation and magma emplacement in a Middle Jurassic to Early Cretaceous magmatic arc exposed between 25°S and 27°S in the Coast Ranges of northern Chile. We focus on the displacement history of arc-parallel fault systems, including the Atacama fault system, and point to the likely relationship between fault systems developed in the arc and those in the adjacent back-arc.

DUCTILE EXTENSIONAL DEFORMATION IN THE MAGMATIC ARC

Plutonic rocks now exposed in the Middle Jurassic to Early Cretaceous magmatic arc of northern Chile were emplaced between c.153 Ma and c.126 Ma at high levels in the crust - above the regional ductile-brittle transition. This is known because of the concordance of mineral and whole-rock cooling ages obtained for individual plutons by a range of isotope systems (Brown and others, 1991; 1993). However, ductile deformation is present in the wall rocks of individual intrusions and has been shown by field relations (Brown and others, 1993) and $^{40}\text{Ar}/^{39}\text{Ar}$ geochronology (Brown and others, 1992) to be related to emplacement of the intrusions. Therefore the magmas must have carried sufficient heat to high structural levels to allow ductile deformation of their wall rocks at temperatures as high as the upper amphibolite facies.

Steeply-dipping, ductile shear zones in the wall rocks of arc plutons are up to 800m wide, exhibit intense mylonitic fabric and contain steeply-plunging stretching fabrics. This implies kilometers of vertical displacement on these shear zones yet there is no evidence for such large changes in structural level across these zones. Therefore the shear zones probably reach a low-angle detachment at shallow depth beneath the plutons. That this is probably an extensional detachment is implied by: (a) passive emplacement mechanisms; (b) general lack of pre-main crystallization fabrics in the intrusions; (c) lack of contractional structures in the arc and (d) emplacement of conjugate dyke swarms indicative of east-west extension throughout the period of pluton emplacement and ductile shear zone formation.

BRITTLE EXTENSIONAL FAULT SYSTEM

Middle Jurassic (post Sinemurian, pre Kimmeridgian) shallow-water limestones (Pan de Azucar Formation) are exposed in the magmatic arc overlain by coarse conglomerates and a very thick sequence of lavas and volcanoclastic sediments (La Negra Formation). Both formations are cut by west-dipping, listric normal faults associated with rollover anticlines. The hangingwall of the faults was displaced to the west and the fault system accommodated east-west extension. Given that the exposed Middle Jurassic plutons were emplaced in an extensional regime also involving east-west extension, and are probably slightly younger than the La Negra Formation, it is likely that the extensional faults in the plutonic and volcanic rocks of the arc belong to the same (linked) fault system.

ATACAMA FAULT SYSTEM

Arc plutons become consistently younger from west to east across the arc towards a major arc-parallel fault system: the Atacama fault system (Brown and others, 1992). The fault system is characterized by sinistral strike-slip displacement, first in the ductile mode and subsequently in the brittle mode. The brittle sinistral strike-slip deformation is associated with intense Cu-Fe mineralization.

Ductile deformation under greenschist facies conditions in the Atacama fault system resulted in the formation of a belt of mylonitic rocks up to 1 km wide characterized by sinistral strike-slip displacements. An $^{40}\text{Ar}/^{39}\text{Ar}$ isotope correlation age from recrystallized hornblende in the mylonite gives a cooling age of 126 Ma - similar to the cooling age of the intrusion in which the mylonitic rocks were developed. Subsequent sinistral strike-slip deformation is ductile/brittle and later brittle and implies progressively declining temperature during continued displacement. Structures characteristic of the ductile/brittle transition include brittle faults with flexural-slip folds in their sidewalls which could indicate that the tectonic regime is transpressional. Mineralization is associated with the latest, most brittle, displacements.

ROTATION OF THE MAGMATIC ARC

Recent palaeomagnetic work by Taylor and others (1993) has shown that the rocks of the La Negra Formation exhibit a primary remanence indicating a net local block rotation of c.35°, west of the Atacama fault system between 25°S and 27°S. This rotation could be due to a combination of:

- (a) rotation on linked extensional faults associated with development of the magmatic arc;
- (b) dilation of wedge-shaped plutons;
- (c) antithetic rotation in sidewall ripout structures associated with sinistral displacement on the Atacama fault system.

EXTENSIONAL FAULT SYSTEM IN THE BACK-ARC AREA

Recent work by Mpodozis and Allmendinger (1993) has identified major extension on low-angle detachments in the back-arc area. This extensional deformation is between Aptian and Cenomanian in age. The major displacements involved displacement of the hangingwall to the northeast and the development of basin and range-type structures. They also identify an earlier phase of extensional deformation with displacement of the hangingwall to the northwest.

Mpodozis and Allmendinger (1993) propose that northeast extension could be related to sinistral strike-slip on the nearby La Ternera-Domeyko fault system (and on the Atacama fault system) in a transpressional regime. Further, they suggest that northwest extension may be related to an earlier extensional regime in the plate boundary zone. Our work in the magmatic arc relates well to the conclusions of Mpodozis and Allmendinger (1993) and this allows important generalizations to be made about linkage of the arc/back-arc fault systems.

CONCLUSIONS

- (1) Emplacement of arc magmas between c.153 Ma and c.126 Ma in the MJ-LC arc was associated with east-west extension. Strike-slip displacements did not occur in the overriding plate at this stage despite the probability that oblique convergence characterized the plate boundary zone at this time. Extension in the arc was likely linked to northwest-southeast extension in the back arc.
- (2) Linked extensional fault systems are probably present across both the magmatic arc and the back-arc basin in extensional margins. Emplacement of magmas in the arc counteracts extension so that the arc remains at or above sea level.
- (3) Ductile strike-slip displacement on the Atacama fault system was initiated at c.126 Ma. Subsequent transition from ductile to brittle sinistral strike-slip suggests that the arc was abandoned at this time. Initiation of transpression in the margin and migration of magmatic activity to the east is linked to the start of opening of the South Atlantic in the mid-Cretaceous.
- (4) A second phase of extensional deformation in the back-arc may be linked with sinistral strike-slip on the La Ternera/ Domeyko and Atacama fault systems.

REFERENCES

- Brown, M., Dallmeyer, R.D. Diaz, F. and Grocott, J. 1991. EOS Transactions American Geophysical Union v. 72/17, p. 263.

Brown, M., Diaz, F. and Grocott, J. 1993. Bulletin Geological Society of America v. 105 (In press).

Brown, M., Dallmeyer, R.D. and Grocott, J. 1992. Geological Society of America Annual Meeting (Cincinnati) Program and Abstracts A63-A64.

Mpodozis, C. and Allmendinger, R.W. 1993. Bulletin Geological Society of America v. 105 (In press)

Taylor, G.K., Randall, D., Grocott, J. and Treloar, P.J. 1993. 2nd International Symposium on Andean Geodynamics (Oxford) Program and Abstracts (In press).