



## THE ATACAMA FAULT SYSTEM IN THE HUASCO PROVINCE, SOUTHERN ATACAMA DESERT, CHILE

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### INTRODUCTION

The Atacama Fault System (AFS) is a continental scale, trench-parallel strike-slip fault system that transects mainly Mesozoic plutonic and volcanic magmatic arc rocks along the axis of the Coastal Cordillera of Northern Chile (Brown *et al.*, 1993). From north to south, the AFS has been subdivided into three major segments of brittle and ductile faults: the Salar del Carmen, the Paposo and the El Salado segments (Naranjo, 1987). In the last 10 years systematic studies of the northern-most segments have produced considerable progress on the understanding of the chronology and flow regime of the displacements associated with the activity of the AFS (Brown *et al.*, 1993; Dallmeyer *et al.*, 1996, Wilson and Grocott, 1999; Bonson, 1998). In particular, in the El Salado segment it has been shown that the AFS was initiated about 130 Ma ago as a left-transensional strike-slip system and was active as a synplutonic fault to at least 106 Ma (Dallmeyer *et al.*, 1996). It was also established that heat advected from adjacent plutons softened country rocks allowing the formation of ductile segments along the fault traces and, as plutons cooled down, transitions to brittle-ductile and brittle deformation mechanisms took place. Despite these important results, the relationship between emplacement-related strain and regional deformation is still incompletely understood. This is because the presence of mainly isotropic plutonic rocks as host rocks, and the lack of well-stratified rocks preserved in the pluton roofs and walls, have limited this type of analysis in the northern segments. In contrast, in Huasco province, towards the southern termination of the AFS, important thickness of stratified rocks in the roof and walls of plutonic complexes were displaced and deformed by sets of major NS-trending faults. Detailed mapping and preliminary kinematic studies demonstrate that these high level rocks contain a complete record of emplacement-related and regional deformation that accompanied activity on the AFS activity in this region. In this contribution we describe the main structural systems of the AFS in Huasco province and characterise the deformation and chronology of each system.

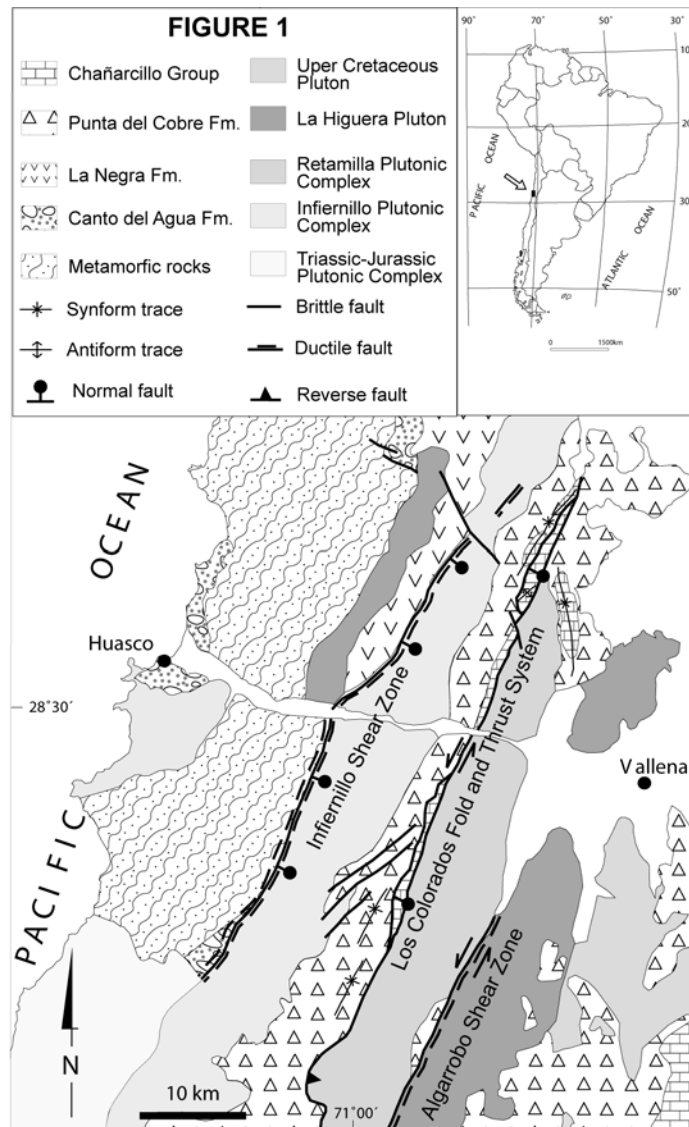
## **THE INFIERNILLO SHEAR ZONE**

The Infiernillo Shear Zone represents the western branch of the AFS in Huasco Province. It is a NNE-trending sinuous belt of synplutonic high-temperature shear zones formed under amphibolite to upper amphibolite facies conditions and including some migmatization. The shear zones mark the contact between plutonic rocks of the Infiernillo Plutonic Complex (ca. 130 Ma) and volcanics and volcanoclastic rocks of the Jurassic La Negra Formation (García, 1967), the Triassic Canto del Agua Formation (Moscoso and Covacevich, 1982) and Devonian-Carboniferous metamorphic rocks (Figure 1). A strong planar fabric is developed on both sides of the intrusive contact. Toward the east the foliation intensity gradually decreases into undeformed granitic rocks with a coplanar magmatic fabric. To the west the foliation decreases progressively into east-dipping stratified rocks of the La Negra and Canto del Agua Formations. Close to the contact migmatites develop in metamorphic rocks (Godoy and Welkner, 2003). The foliation is defined by strongly oriented biotite flakes and amphibole prisms, disseminated or forming coarse, anastomosing planes subparallel to a planar fabric defined by quartz-feldspathic aggregates. Cross-cutting sheared and unsheared granitic veins throughout indicate that the shear zone is synplutonic with respect to the Infiernillo intrusive. For the most part, the shear zone has down-dip stretching lineations given by alignments of hornblende. An east-side down sense of shear is also given by  $\sigma$ -type plagioclase porphyroclasts and by CS shear band cleavage developed in fine grained ultramytonitic bands.  $^{40}\text{Ar}/^{39}\text{Ar}$  ages of ca. 130 Ma obtained in the Infiernillo Plutonic Complex (Valenzuela, 2002; Gipson *et al.*, 2003) provide an age for the main displacements along this synplutonic shear zone.

## **THE LOS COLORADOS FOLD AND THRUST SYSTEM**

The Los Colorados Fold and Thrust System represents the central branch of the AFS at this latitude. It includes a set of NNE faults in a belt of up to 5 km in width that trends across the Huasco Province for about 80 km to the south from the Colorados Mine (Figure 1). The structures deform volcanics and limestones of the Lower Cretaceous Punta del Cobre Formation (Segerstrom and Ruiz, 1962) and Lower Cretaceous Chañarcillo Group (Segerstrom and Parker, 1959) respectively from east to west. The main structure, from which the system takes its name, was called the Colorado fault by Thiele and Pincheira (1987). This is a vertical fault that for most of its length coincides with the western margin of the Retamilla Plutonic Complex (c. 126 Ma; Fig. 1). It produces the greatest stratigraphic separation and constitutes the master fault of the system. Other faults sole into the Colorado Fault giving a positive flower geometry. Synplutonic mylonitic rocks exposed at the Quebrada Chañaral, contain strong NE-plunging lineations with left-oblique east-down sense of fault displacement. To the west, reverse faults carry thrust sheets of Chañarcillo and Punta del Cobre Formations. Strongly foliated limestones within these sheets and the fault traces display shallowly-plunging lineations with indications of left-lateral sense of shear. This displacement may reflect a component of strike-slip partitioned from a regional scale transpression. Faults of this structural system thrust Chañarcillo limestones over older Punta del Cobre volcanics indicating an “out of sequence” structure. Although west vergent folds are associated with these structures, the young-over-old relationship implies that the system initially accommodated extensional deformation and was then inverted by contraction. Kinematic compatibility between these early extensional displacements and the left-oblique east-down displacements along the Colorado Fault suggest that the structural system as a whole accommodated an early left-transensional stage. An  $^{40}\text{Ar}/^{39}\text{Ar}$  age of 126 Ma obtained for the Guanteme-Retamilla Plutonic Complex (Valenzuela, 2002, Gipson *et al.*, 2003) gives an estimate for the age of this phase. So far there is no upper bracket to constrain the age of the late

contractional displacements. Two alternative ages can be considered: an early Late Cretaceous age, by correlation with the left transpressional stage described at the eastern margin of the Coastal Batholith, at the latitude of the Candelaria mine (Arévalo and Grocott, 1997), or a Late Cretaceous-Early Paleocene age suggested by reverse displacements on synplutonic mylonites adjacent to ca. 67-64 Ma plutons at the western margin of the Main Cordillera at the latitude of Vallenar (Gipson et al., 1993; Truelove et al. 2003).



### THE ALGARROBO SHEAR ZONE

The Algarrobo Shear Zone constitutes the eastern-most branch of the AFS. It is a NNE trending, steeply-dipping, low-grade mylonitic belt located at the western margin of the Lower Cretaceous La Higuera Pluton (ca. 123 Ma) where the intrusive is in contact with volcanic and volcanoclastic rocks of the Punta del Cobre Formation (Figure 1). The textures are ultramylonitic to protomylonitic where strongly oriented biotite, epidote, chlorite and hornblende have formed in

the matrix implying greenschist facies conditions. Aligned biotite crystals on the foliation planes define a shallow stretching lineation and plagioclase  $\sigma$ -type porphyroclast systems indicate a sinistral sense of displacement. The mylonites have not yet been dated. An  $^{40}\text{Ar}/^{39}\text{Ar}$  age of ca. 123 Ma for the La Higuera Pluton (Valenzuela, 2002; Gipson et al., 2003) cannot directly be attributed to the mylonites since these rocks bear a low temperature mineralogy. We suspect that these textures may mask an early high temperature shear zone, as described farther north in the Chañaral and Copiapo regions (Wilson and Grocott, 1999; Arévalo 1999), this age may closely pre date the shear zone.

## CONCLUSIONS

The Coastal Cordillera of the Huasco province represent an exceptional region where stratified rocks register a complete range of emplacement-related and regional structures with different styles and amount of deformation all associated with the AFS. Three NNE trending fault systems: the Infiernillo Shear Zone, the Los Colorados Fold and Thrust System and the Algarrobo Shear Zone can be ascribed to this structural system. The Infiernillo Shear Zone represents a high temperature shear zone with down-dip stretching lineations and east-side-down sense of shear active during the emplacement of the Infiernillo Pluton. The Los Colorados Fold and Thrust System represent a structural zone where pre-existing left transtensional ductile and brittle faults where inverted during a left transpressional stage to define a fold and thrust system with a positive flower type of geometry. The Algarrobo Shear Zone represent a low temperature sinistral shear zone which probably overprinted a synplutonic pluton high temperature shear zone

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