A STRUCTURAL MODEL FOR THE DEVELOPMENT OF FE-CU MINERALISATION WITHIN THE ATACAMA FAULT SYSTEM, (25°00' S - 27°15' S), NORTHERN CHILE.

Christopher G. BONSON, John GROCOTT & Andrew H. RANKIN

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

KEY WORDS: fault systems, Fe-Cu mineralisation, northern Chile

INTRODUCTION

The Coastal Cordillera of the Central Andes, northern Chile hosts extensive hydrothermal base- and precious-metal mineralisation of late Mesozoic - early Cenozoic age. Detailed field, petrologic and structural investigation of selected mineral deposits within the Atacama fault system has enabled a structural model for the mineralisation to be constructed and has allowed two styles of hydrothermal Fe mineralisation to be assigned to different phases of tectonism within the Andean margin.

ATACAMA FAULT ZONE

The Atacama fault zone, a 1000 km long, trench-linked, predominantly left-lateral, strike-slip fault zone (Brown *et al.*, 1993) is the dominant structural feature of the Coastal Cu-Fe belt. The fault zone is comprised of NNE-SSW trending fractures formed during late Jurassic to early Cretaceous times, as a response to south-easterly directed, oblique subduction of the Aluk plate. Initial ductile shearing, associated with the emplacement of the main lower Cretaceous batholith, *circa* 130-125 Ma (Dallmeyer *et al.*, 1996), was followed by arc abandonment and cooling. This lead to the development of a brittle fault system which acted as a conduit for circulating hydrothermal fluids.

MAGNETITE-DOMINATED MINERALISATION

The NNE oriented fractures, which comprise the Atacama fault zone, host numerous occurrences of magnetite-dominated mineralisation, collectively referred to as the Cretaceous (Atacama-Coquimbo) Iron Belt. Magnetite-dominated deposits, pertaining to two styles of magnetite mineralisation, were studied in the Coastal Cordillera of the Lower Cretaceous batholith.

Kiruna-type, *magnetite-apatite* mineralisation was studied at Mina Fresia and Mina Carmen (Fig. 1). These mineral deposits comprise lenticular bodies with a principal mineralogy of magnetite (>60%), and variable amounts of haematite, apatite, actinolite and scapolite. Quench textures, fine vein networks and large volumes of propylitised wall-rocks, suggest that the magnetite fluid had a low viscosity which is attributed to an abundance of volatiles. It is thought that these mineral deposits formed during the pegmatitic stage of crystallisation.

Two examples of magnetite-actinolite-chalcopyrite mineralisation were studied at Mina Las Adrianitas and Mina Cerro Negro Norte, to the south of the field area (Fig. 1). These deposits comprise andesitic composition volcanics (Bandurrias Formation) replaced by magnetite, and are irregular in form. The replacement magnetite is cut by quartz veins and fracture controlled actinolite, and is sometimes found in microbreccias. In addition, disseminated pyrite and chalcopyrite occurs throughout the mineral

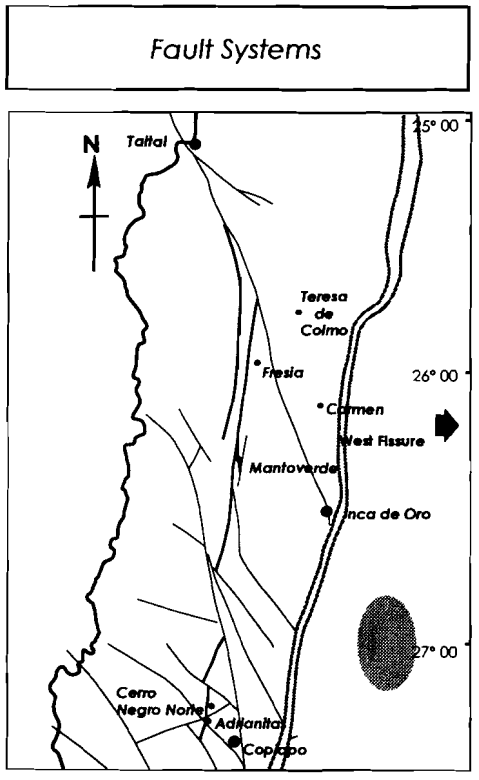

Fig. 1 Simplified map illustrating the different generations of fractures that comprise the Atacama fault system.

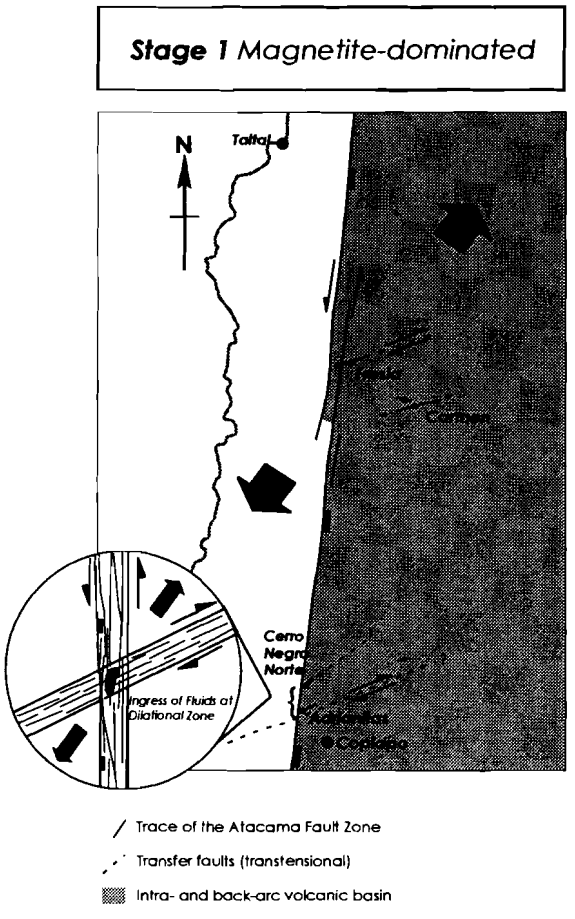

Fig. 2 Tectonic setting of magnetite-dominated mineralisation in the Lower Cretaceous. AFZ fault comprises the western margin to the back- or intra-arc basins, with the ENE trending fracture zones representing transfer zones in the faulted margin.

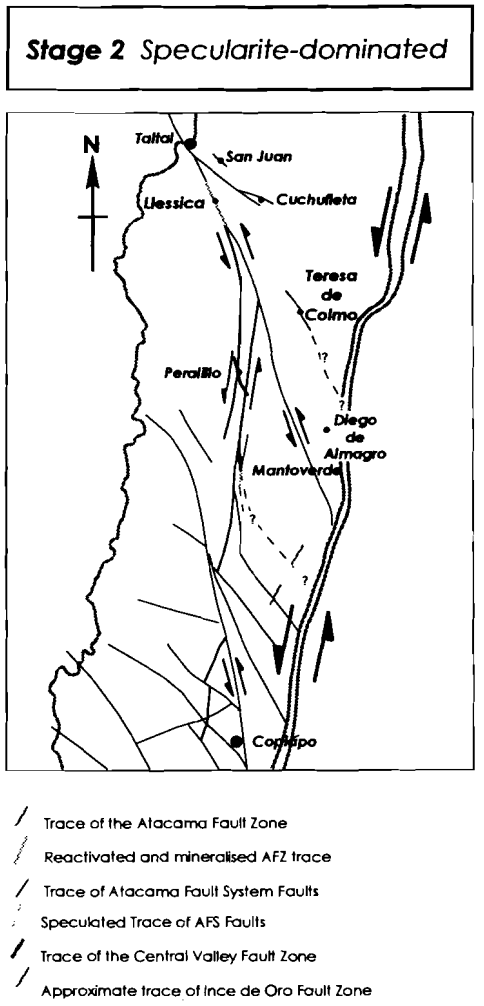

Fig. 3 Tectonic setting of specularite-dominated mineralisation in the Mid-Upper(?) Cretaceous. Mineralisation occurs in dilational fault structure (jogs or bends) along NW AFS faults or along reactivated segments of the AFZ.

deposits, as well as minor apatite. By analogy with the Punta del Cobre Cu(Fe) deposit (Marschik & Fontboté, 1995), these deposits probably represent examples of hydrothermal mineralisation associated with deep seated plutons, with temperatures of formation around 400°-500° C.

The Atacama fault zone may have acted as the western bounding fault of the Neocomian intra- and back-arc basins (Thiele & Pincheira, 1987). The stress regime in the back-arc was probably similar to the transtensional environment in which many lower Cretaceous arc-plutons are emplaced (Grocott *et al.*, 1994). The mineralisation at magnetite-dominated mines generally has a N-S (010-020°) orientation, related to the Atacama fault zone, and/or a ENE-WSW orientation related to a set of transfer faults in the Atacama fault zone which seem to have been important ENE-WSW lineaments during the arc/ back-arc development. (Fig. 2). The location of magnetite-dominated deposits at the intersection of the two fault sets suggests that these zones were important in the focusing of crustal fluids. The shear sense of the transfer structures would be right-lateral under a sinistral transtensional regime (Fig. 2), explaining the common observation of ENE-NE oriented faults offsetting the Atacama fault zone along its length. Mina Fresia lies very close to one such right-lateral zone. It is inferred that magnetite-rich fluids (and their source magmas ?) utilised the N-S Atacama fault zone fractures and the ENE oriented fracture zones (displacement transfer structures ?) as conduits, and that transtensional displacements created dilational zones within the areas of fracture intersection, where the mineralising fluids were focused (Fig. 2).

Published ages of the magnetite-dominated mineral deposits, close to the Atacama fault zone, range in age from 128 Ma at Boqueron Chañar (Oyarzún, 1990), south of the field area, to *c.* 102 Ma at Cerro Imán, Copiapó (Zentilli, 1974).

ATACAMA FAULT SYSTEM

The Andean margin has been affected by extensional tectonics until *c.* 80 Ma (see Mpodozis & Allmendinger, 1993; Arévalo & Grocott, this conference), after which it is thought that the margin became dominated by transpression. Post *c.* 80 Ma, magmatic and structural activity stepped towards the east, with the formation of the recently recognised Central Valley Fault Zone (Taylor *et al., in review*), thought to be a terrane boundary between the Coastal Cordillera and Precordillera (Fig. 1). As a result of displacements along the Central Valley fault zone, large NW-trending sinistral shears propagated through the forearc, cutting and displacing the Atacama fault zone (Fig. 1) and the lower Cretaceous batholith. These faults are referred to collectively as the Atacama fault system. Sinistral displacements along the NW Atacama fault system shears caused clockwise block rotations with *circa* 35° of rotation (Randall *et al., in press*).

SPECULARITE-DOMINATED MINERALISATION

Numerous small-medium sized specularite-dominated mineral deposits occur throughout the Coastal Cordillera. The mineralisation typically takes the form of hydrothermal breccias, cemented with a matrix of specularite, or as fault-hosted specularite veins. Specularite is the principal mineral within the breccia matrixes and veins. In addition, Cu sulphides (and supergene Cu minerals) are found distributed throughout, as well as minor magnetite.

Specularite-chalcopyrite mineralisation frequently occurs in hydrothermal implosion breccias at dilational jogs along NW trending, sinistral strike-slip faults, inboard (towards the E) of the Atacama fault zone, e.g. Teresa de Colmo (Fig. 3). The NW trending host faults belong to the Atacama fault system and are probably associated with the accommodation of crustal scale fault block rotation, and therefore fault block shape change. However, this style of mineralisation is also found along the N-S trending Atacama fault zone. It is inferred that mineralising hydrothermal fluids (and their sub-volcanic sources ?) utilised re-activated segments of the Atacama fault zone as transport pathways and were focused into fault-hosted dilational structures. For example, the Mantoverde deposit comprises a hydrothermal breccia located along a dilational bend of a Mantoverde fault, which transfers displacement between two reactivated segments of the Atacama fault zone (Fig. 3). The extent of Atacama fault zone reactivation is unclear, but was geometrically necessary to accommodate the shape change during crustal scale block rotation.

Dates for the age of mineralisation are, at present, constrained by structural arguments alone. An upper age for the specularite mineralisation during the AFS development is *tentatively* thought to be 80

Ma. This argument is based on the premise that displacements on low-angle extensional fault systems in the Sierra de Fraga (Mpodozis & Allmendinger, 1993)(Fig. 1) are incompatible with sub-vertical sinistral strike slip displacements in the Atacama fault system. Therefore, the AFS is thought to post-date the phase of mid-Cretaceous extensional tectonics.

CONCLUSIONS

1. Magnetite dominated mineralisation appears to be strongly linked to the Atacama fault zone and an ENE trending fault set, which are likely to have been important in the development of the volcanic intra- and back-arc basins, during the lower Cretaceous.

2. Specularite-chalcopyrite mineralisation took place during the development of the Atacama fault system during the Upper Cretaceous. Mineralising fluids were focused into dilational fault structures associated with NW trending shears of the Atacama fault system and along reactivated segments of the Atacama fault zone.

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