THE "WEST FISSURE" AND THE PRECORDILLERAN FAULT SYSTEM OF NORTHERN CHILE

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RESUMEN

La Falla Oeste, o West Fissure, de la mina de cobre de Chuquicamata muestra en sus rocas de falla estructuras de desplazamiento transcurrente sinistral N-S. Lo cual es opuesto a los desplazamientos dextrales comprobados en otras fallas N-S de la Precordillera del Norte Chileno. De esta forma existen evidencias de una inversión de los movimientos transcurrentes en el Oligoceno.

KEY WORDS: Magmatic arc, strike-slip faults, porphyry copper deposits, tectonic inversion

INTRODUCTION

The Chilean Precordillera, situated between the Longitudinal Valley and the Western Cordillera of northern Chile, was the site of the Andean magmatic arc from the late Cretaceous to the early Oligocene. During the Late Eocene Incaic Phase, the basement with its sedimentary and volcanic cover was folded to elongate, mostly N-S-trending anticlines, and dextral strike-slip faults developed parallel or at low angles to the fold structures (Reutter et al. 1991: Precordilleran Fault System). Orogen-normal shortening and dextral orogen-parallel strike-slip movements are considered as magmatic arc tectonics under the influence of oblique subduction (Scheuber and Reutter 1992). The Precordilleran Fault System is related to the development of the great porphyry copper deposits of that region. The West Fissure which is an essential branch of the Precordilleran Fault System runs, in N-S direction, through the Chuquicamata open pit (68°54' W; 22°16' S). A detailed study of this main fault and other accompanying faults in Chuqicamata and its surroundings (Fig. 1) shows that the kinematics along the West Fissure differ from those of most parts of the Precordilleran Fault System.

GEOLOGICAL SETTING

The exposures of the open pit of Chuquicamata (1.8 km E-W, >4 km N-S) exhibit an abundance of vertical faults belonging to different directional groups. More than 90% of the striae developed on the fault surfaces are horizontal, thus showing that wrench tectonics determined the kinematics. The West Fissure is the most important fault of the Chuquicamata mine, as it separates a western non mineralized granodiorite of ~36 Ma from the mineralized eastern block consisting of Paleozoic granite intruded by porphyries of 32-30 Ma and their alteration products (Maksaev et al. 1988, Maksaev 1990). It can be traced as a continuous structure >100 km to the N and about 20 km to the S. A black argillitic fault gouge up to 2,5 m thick demonstrates that this fault absorbed the maximum of the tectonic energy. Evidently, the throw along the West Fissure is younger than the mineralization and, therefore, it is discussed whether the original westward extension of the mineralization was displaced to the N by dextral slip or to the S by sinistral slip.

As structures indicating dextral slip are frequent in the Precordillera (Reutter et al. 1991), the same sense of displacement was assumed for the West Fissure. The fault pattern of Chuquicamata (Fig. 1) shows several faults entering the the West Fissure from the left at angles of ~15° (e.g. Falla San Lorenzo, F. Chucos, F. Zaragoza) and ~75° (e.g. F. El Negro, F. Balmaceda, F. Estanques Blancos). This asymmetric distribution could be interpreted as a set of Riedel shears accompanying the the West Fissure as the master fault of the system, although the evident dextral displacements along the supposed R' had to be explained by secondary effects. Nevertheless, dextral shear is also suggested by fold structures with a wavelength of ~5 km and NW-SE trending axes which are cut by the West Fissure about 15 km to the N of Chuquicamata.

Because of the arid climatic conditions, the argillitic fault gouge of the West Fissure is well preserved in the pit and shows internal meso- and microstructures which are quite similar to those of coherent cataclastic rocks and mylonites. Especially S-C-fabrics, ecc-fabrics, δ-clasts and σ-clasts could be recognized and their asymmetry, as well as that of folded s-planes, could be used for determining the sense of shear. It turned out that all these structures uniformly indicated sinistral strike-slip, i.e. a displacement contrary to what had been expected. The detection of similar structures in other ~N-S-striking faults of the Chuquimatamata mine, such as F. Americana, F. C-2, F. Chucos, and F. Mesabi, coroborated these results.

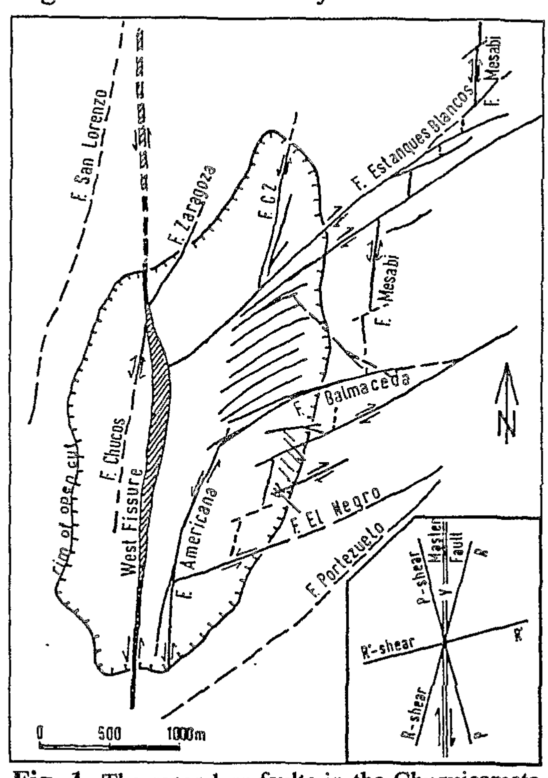

Fig. 1. The secondary faults in the Chuquicamata copper mine apparently form a set of Riedel shears related to a dextral master fault (Reutter et al. 1991, with modifications). However, the shear directions established, as indicated by arrows (dextral, sinistral, and dextral overprinted by sinistral), reveal that such a simple model is not applicable.

These last two faults, however, display not only structures due to sinistral horizontal shear, but also others formed by dextral shear. This is especially true for the Mesabi Fault to the N of the Chuqucamarta mine. There, it follows a band of sediments (Jurassic?) which were rotated in a vertical position during Late Eocene folding of the Precordillera. Dextral shear movement parallel to the strike of these sediments is indicated by vertical folds and mesoscopic S-C- and ecc-fabrics. Evidence of dextral N-S-directed shear also comes from the 36-Ma-old Granodiorita Fortuna at the western side of the Chuquicamata mine. In severals places it is pervaded by N-S-striking and vertically dipping mylonitic bands (Fig. 1), whose age, determined by Maksaev (1990), is slightly younger than that of the intrusion. Dynamic recrystallisation of feldspars in the mylonites indicates temperatures of up to ~500°C during deformation.

CONCLUSIONS

These examples of orogen-parallel dextral shear in the surroundings of the West Fissure of Chuquicamata agree with the observations made in many places of the North Chilean Precordillera between 21° and 25° S (e.g. Sierra de Moreno, Cordillera de Domeyko, and western scarp of the Salar de Atacama). Asymmetric fault arrays and Z-shaped vertical folds in upfolded sediments revealed a uniform dextral sense of shear along parallel faults of the Precordilleran Fault System, while stratigraphic discontinuities across major faults suggested lateral throw possibly in the order of tens of km (Reutter et al. 1991). So, probably, also the West Fissure was generated as a dextral strike-slip fault.

The sinistral shear movement along the the West Fissure and parallel faults in the Chuquicamata mine must be explained by an inversion of the sense of shear when the dextral transpression tectonics had come to an end. Evidence for this chronological sequence comes from the following observations:

- The West Fissure fault rocks, which display the structures of sinistral strike slip, formed at very low temperatures close to the surface. The ductile dextral shear deformation of the mylonites, however, was produced at a depth of >2 km. Thus, an event of uplift and erosion separated the two developments.
- Sinistral movements along the West Fissure are younger than the mineralization of the Chuquicamata deposit and the porphyric intrusions, dated to 32 Ma (Maksaev 1990).

This rises the question if mineralization occurred still during dextral shear or contemporaneously with sinistral shear. In the El Abra copper ore deposit, situated at the eastern side of the West Fissure about 40 km to the N of Chuquicamata, mineralization took place in a complex of granodioritic intrusives 39-32 Ma old (Maksaev 1990), and, as evidendenced by the orientation of joints, faults and veins, under a regime of NE-SW extension which is compatible with sinistral shear in the nearby West Fissure. The maximum of mineralized quartz veins in the Chuquicamata mine also corresponds to NE-SW extension, but other veins which indicate NW-SE and E-W-extensions suggest that mineralization in Chuquicamata took place more or less at the time of the inversion of the shear movement, probably under reduced E-W compression, as testified by a few normal faults (Fig.2).

From a general point of view it can be concluded that the structures connected with the Precordilleran Fault System and the West Fissure reflect, first, strong dextral transpression related to the Incaic Phase, which may have lasted from 38 Ma to <36 Ma. Intrusive activity was at a maximum at this time but continued until 32 Ma. Then, a sinstral transtensive stress regime was established, perhaps as a consequence of reduced convergence rates during the

Oligocene (Pardo-Casas and Molnar 1987) which may have allowed relaxation. The sinistral shear stress at this time is not in accordance with the convergence obliqueness deduced by these authors. It may have been generated by a clockwise rotation of the southern Central Andes, as proposed by Armijo and Thiele (1990) for sinstral shear along the Atacama Fault of the Coastal Cordillera during the Quaternary.

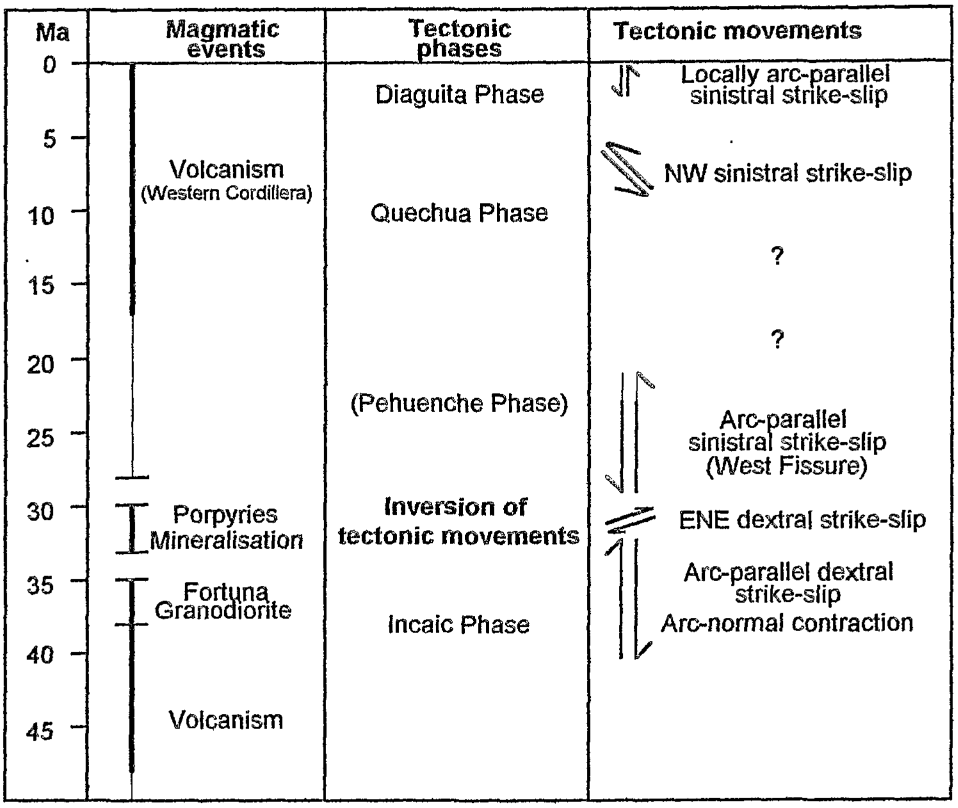

Fig. 2: Sketch of the tectonic development of the Chilean Precordillera near Chuquicamata.

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