A paleomagnetic study within the Chuquicamata porphyry copper deposits, Central Andes, Chile

N. Astudillo [1,2], P. Roperch [3], B. Townley [1], & C. Arriagada [1]

[1] Departamento de Geologia Universidad de Chile. Plaza Ercilla 803 Santiago, Chile
[2] IRD - UR154 LMTG, 14 Avenue Edouard Belin, 31400 Toulouse, France
[3] IRD - UR154 LMTG and Géosciences Rennes, 35542 Rennes, France

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INTRODUCTION

The Chuquicamata porphyry copper deposit is longitudinally cut by a major N-S fault, the West Fissure. Several structural studies (Reutter et al.1996; Tomlinson and Blanco, 1997) indicate large sinistral displacement. Sinistral displacements should be characterized by counterclockwise rotations. However, the general pattern of tectonic rotations within the forearc of northern Chile is systematically clockwise (e.g. Arriagada et al., 2003). Preliminary results of Anisotropy of Magnetic Susceptibility (AMS) show foliation planes oriented N100, almost orthogonal to the trend of the West Fissure Fault, in 2 sites within the Fortuna Intrusive complex (Astudillo et al. 2003). In this study, we report the results of a detailed paleomagnetic study carried out within the Chuquicamata mine on both sides of the main fault.

GEOLOGICAL SETTING

To the east of the West Fissure Fault, the dominant host rock is the East porphyry (35-34 Ma), intruded by the West and Banco Porphyries (34-33 Ma). Hydrothermal alteration processes begin with an early selective potassic and propilitic alteration, followed by the main-stage of pervasive phyllic alteration (quartz-molibdenite, quartz-sericite, late enargite-pyrite) associated with disseminated and stockwork sulfide mineralization. The Fortuna intrusive complex (Fiesta and Antenna granodiorite) crops out on the western side of the main fault system. The Fiesta granodiorite is the dominant intrusive within the mine. The Fortuna complex presents selective post-magmatic alteration (potassic, chloritic) and low-grade mineralization.

PALEOMAGNETIC RESULTS

Characteristic magnetizations

A total of 168 paleomagnetic samples were drilled at 21 sites within the mine and adjoining sector, and 136 samples were taken from 11 drill cores, in the different geological units defined at the mine. Characteristic remanent magnetizations were determined after detailed thermal or alternating field demagnetization. All samples from the Fiesta granodiorite have an unusual behavior due to a complex magnetic mineralogy. Cooling of the samples down to liquid nitrogen temperature in zero fields removed up to 80% of the natural remanent magnetization. This behavior indicates the presence of multidomain magnetites. AF demagnetizations at 10-20mT remove the same low coercivity magnetization carried by multidomain magnetite. Above 20mT, there is no further AF demagnetization leaving a characteristic direction carried by high coercivity magnetic minerals. Thermal demagnetization of the characteristic magnetization is mostly obtained in the temperature range 580-

590°C with about 20% of the magnetization remaining at 600°C. This characteristic magnetization with unblocking temperatures just above the Curie point of magnetite suggests that the magnetization is carried by oxidized magnetite. However, titanohematite associated to hydrothermal alteration of ilmenite and titanomagnetite is also observed (Townley et al., this meeting)

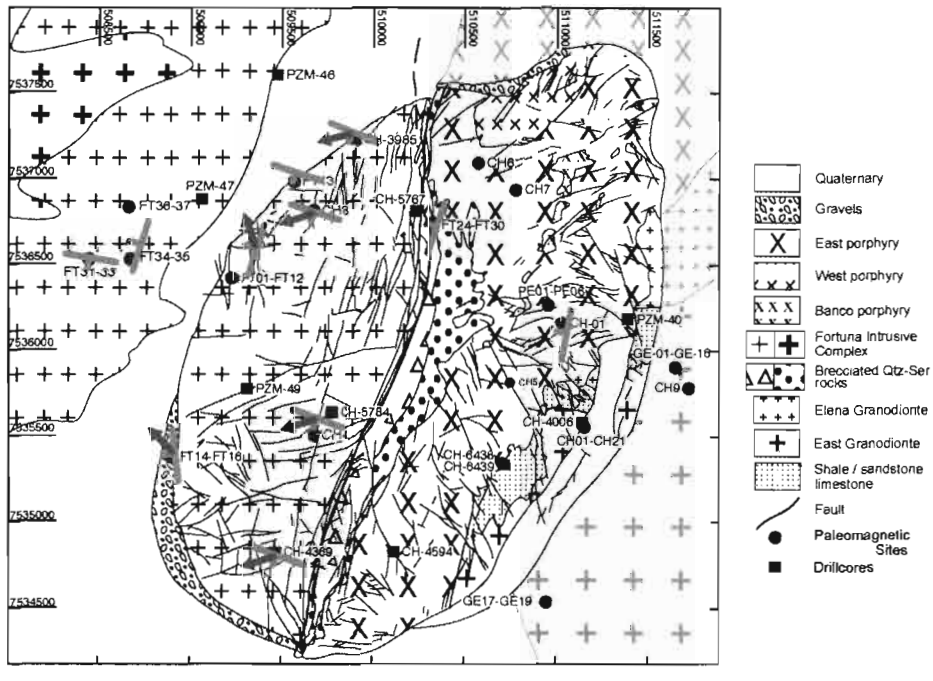

Figure 1. Local geology of Chuquicamata mine. In the diagram the magnetic foliation (light blue) and the characteristic declination (red) of the remanent magnetization are shown.

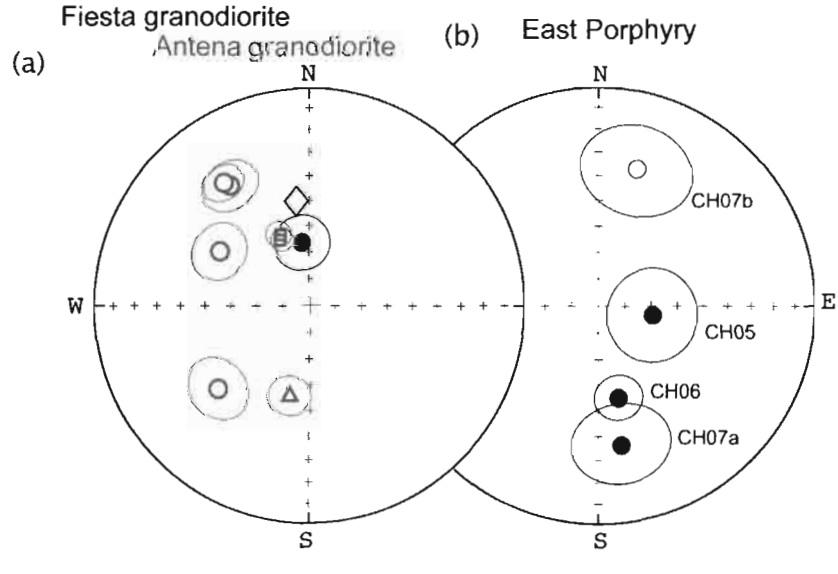

Figure 2: Equal-areaa projection of characteristic directions in the mine (a) Fiesta (pink circles), Antena granodiorite (blue squares) and site CH4 (Pink triangle). (b) East porphyry. Diamond: 40 Ma reference direction.

For the Fiesta granodiorite, all sites except one have negative inclinations (black circle in Fig.2A). The site with steep positive inclination is located within the cataclastic zone of the West Fault. Within the Fortuna

intrusive complex, there are large deviations in the declination of the characteristic magnetization from the Eocene expected direction (figure 2A). This difference is still more anomalous in two sites (site CH4 and CH8).The characteristic direction for the Antenna granodiorite is slightly steeper than the expected one. The characteristic directions in the East porphyry show predominantly positive inclination indicating that the main hydrothermal alteration occurred during a period of reversed polarity.

Magnetic Fabrics

Measurements of Anisotropy of Magnetic Susceptibility (ASM) were made in order to determine the strain field recorded by the intrusive rocks. AMS in the analyzed intrusives (Fiesta and Antenna granodiorite; East porphyry) is in the range 10-30%. The corresponding ellipsoids are mainly oblates with mostly sub vertical foliation planes. Magnetic lineations are mostly sub-horizontal. One of the most striking features of the AMS data is the large variation in azimuth of the magnetic foliation from site to site (Figure 3), with two groups of AMS tensors with almost orthogonal orientation. At several sites the magnetic foliation is roughly N20° with subhorizontal lineations within the foliation plane while at other sites (CH04 and CH08) the magnetic foliation is oriented N100. At site CH04 the lineation is more steeply inclined (40°). Within the Fiesta granodiorite, the magnetic susceptibility is in the same range 0.015 –0.04 SI. Anisotropy of Anhysteretic remanent magnetization confirms that the AMS magnetic carrier is in all cases multidomain magnetite.

One striking feature is the good correspondence between the orientation of the AMS ellipsoids and the characteristic remanent magnetization. Magnitude of AMS in the Antenna granodiorite is lower than the one observed in the Fiesta granodiorite. At both sites the magnetic foliation is subvertical and oriented toward the NE.

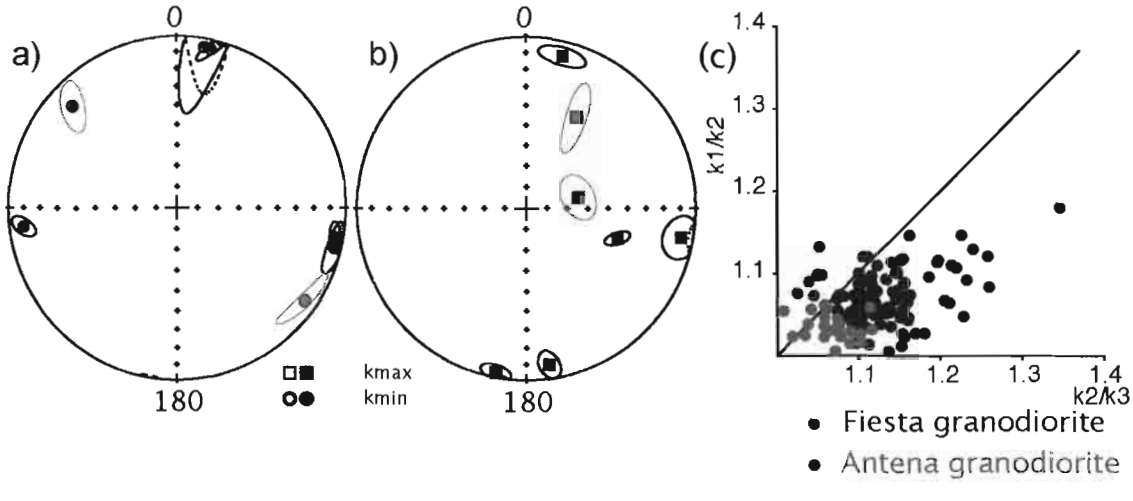

Figure 3: AMS results in Fiesta (red and green) and Antenna Granodiorite (Blue). (a) Pole of foliations; b) AMS lineations, c) magnetic foliation versus lineation.

DISCUSSION

The most puzzling results of the detailed paleomagnetic study are the changes in the orientation of AMS ellipsoids together with the apparent counterclockwise rotation of the characteristic remanent magnetizations

within the Fiesta granodiorite (Figure 4). Anisotropy of ARM in different coercivity windows (0-10mT, 10-20, 20-60mT) is always coherent with AMS. This suggests that the AMS is not polygenic and composed of the sum of two different families of magnetic fabrics carried by two types of magnetite with different coercivities. Fracturing is important in the Fiesta granodiorite with one set of vertical fractures oriented N100 and sub-parallel to one group of magnetic foliation. However, observations of thin section only show a few kinks in biotite without evidence for mild to severe internal deformation. Major changes are never observed within a site where samples were taken over several tens of meters of outcrops but occur between sites separated by a few hundreds of meters. Inversion of anisotropy tensors could occur when single domain grains of magnetite are the AMS carriers. In contrast, remanent magnetizations should behave as passive markers.

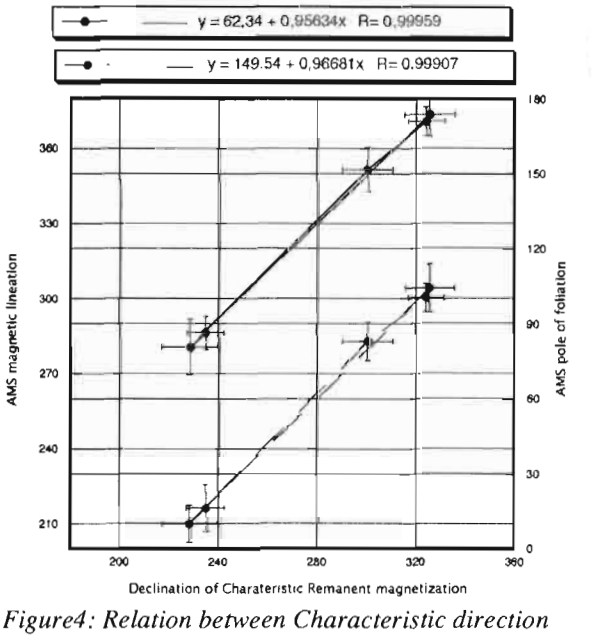

Figure4: Relation between Characteristic direction and AMS lineation and foliation for sites in the Fiesta granodiorite

Thus, our favored interpretation is that the observed deviation in AMS and remanent magnetization are due to vertical-block rotations. If this interpretation is correct, the paleomagnetic data indicate that the Fortuna block was disrupted in several small blocks rotated counterclockwise from 30 up to more than 90°. This interpretation is in agreement with the large sinistral displacement along the West fault system (Tomlinson, A. and Blanco, 1997). Although the paleomagnetic results within the Chuquicamata orebody are not numerous enough to clearly identify small blocks there are also indications for tilted blocks on the eastern side of West fissure.

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