GEOLOGY, GEOCHRONOLOGY AND TECTONIC EVOLUTION OF THE EL FALDEO Au-Zn DISTRICT IN THE CHILEAN PATAGONIA

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KEY WORDS: Patagonian Andes, tectonic, geochronology, Au-Zn mineralization.

INTRODUCTION

The El Faldeo Au-Zn district is the southernmost Andean prospect, and is located in a Recent back-arc position, about 100 km east of the axis of the Patagonian Andes at 47°27'S - 72°20'W. Two segments of the Patagonian Andes have been recognized on the basis of structure and magmatic configuration (Ramos and Kay, 1992). The El Faldeo district is located in the southern segment, which differs from the northern one by the presence of extensive exposures of deep-seated Paleozoic metamorphic basement, a foreland fold and thrust belt, a gap in the Recent volcanic arc, Tertiary molasse deposits and Upper Cenozoic plateau basalts. The origin of the segmentation is attributed to the Miocene to Recent collision of the Chile ridge with the trench at about 46°30'S.

The discovery of the El Faldeo mineralization was recently made (Lahsen et al., 1994) as a result of a base and precious metal exploration project in the Chilean Patagonia. The mineralization is mainly hosted in dacitic and rhyolitic tuffs and subvolcanic porphyries (Palacios et al., 1996), and consists of early epithermal (140° - 170°C) gold mineralization and late Zn mineralization deposited at higher temperatures (250° - 330°C) and greater depth (op. cit.). This paper provides a case study of a metallic district in the modern Patagonian back-arc, where the integration of field, radiometric and geochemical data, led to the recognition of its tectono-magmatic evolution on a regional scale and its metallogenic implications.

GEOLOGY OF THE DISTRICT

Stratigraphy

The oldest rocks in the district are polymetamorphic and poyideformed schist, phyllites, quartzites, shales and marbles of the Paleozoic basement (Fig. 1). These rocks are unconformably overlain by an Upper Jurassic homoclinal sequence (N80°E - N80°W/20 - 30N) of sedimentary and volcanic beds, which represents the lowest 200 m of the Ibáñez formation. This sequence occupies two discrete depositional centers and consists from bottom to top of a 50 m thick basal sedimentary breccia and 150 m thick seccession of dacitic and rhyolitic tuffs, felsic lavas, hydrothermal eruption breccia and their sedimentary reworked equivalents. Two intrusive units are recognized in the district: Quebrada Colorada Granodiorite (QCG) and Cordón Esmeralda Tonalite (CET). The former unit is the more extensive and consists of epizonal granodioritic bodies intruding the Ibáñez formation as plutons, sills and dikes. Strong to moderate hydraulic brecciation is a striking feature of most of the QCG exposures. The CET is composed of hornblende-bearing tonalites and diorites, which form two plutons and some related sills and dikes. The CET plutons intrude the Paleozoic metamorphic basement, the Ibáñez formation and the QCG. Their shapes and orientations are clearly controlled by N-S and NW-SE faults.

Petrography of the Ibáñez formation and associated intrusive units

The basal sedimentary breccias of the Ibáñez formation are polymictic, formed by abundant (> 80 vol.%) fragments of schist, quartzite and phyllite of the Paleozoic basement, in a clay matrix. The fragments are both poorly sorted, and rounded, and have sizes variable between 2 and 10cm. The upper sedimentary beds are composed of breccias formed mainly of reworked tuffs, hydrothermal breccias and silicified igneous rocks similar to those outcroping in the district. The fragments are moderately sorted, have centimetric to decimetric sizes and are included in a fine-grained to medium-grained clastic matrix (5-20%), which in places is cemented by barite. The igneous rocks of the district are, in most cases, pervasively silicified and locally argillized, and therefore, primary minerals and textures can be observed in only few remnants. The dacitic and rhyolitic tuffs exhibit variations in grain size from lapilli to ash. Clasts consist of felsic pumice, volcanic rocks and crystal fragments of quartz and feldspar. Rocks of the QCG contain plagioclase, quartz, uralitic amphiboles, biotite, sphene and apatite. The hydraulic fracturing and brecciation that affected the plutons and sills of this unit, gave rise to stockworks or breccias with abundant (> 90%) angular, randomly rotated, granodioritic fragments with a scarce matrix of powdered rock. The CET rocks show an equigranular intergrowth grading to a porphyric texture. The primary mineralogy is partially propylitized and consists of plagioclase, quartz, amphibole, biotite, K-feldspar, magnetite, apatite and zircon.

Mineralization and hydrothermal alteration

The mineralization and hydrothermal alteration of the El Faldeo district developed in four stages (Palacios, et al., 1996), and affected about 12 km2 of Upper Jurassic rocks. Propylitic replacement of primary paragenesis and disseminated mineralization of pyrite characterize the first stage. The second stage gave rise to silicic alteration and to dissemination and veinlets of pyrite, arsenopyrite and gold. Brecciation, stockwork and dissemination were associated with a quartz - sericite - calcite alteration and with pyrite, sphalerite, galena and gold mineralization. The last stage is an open-space filling event, in which quartz, calcite, barite, pyrite and chalcopyrite were deposited. The above mentioned structures of the mineralization and alteration associated with the first three stages, suggest a progressive rupture of the host rocks.

U-Pb, ^{40}Ar-^{39}Ar, K-Ar AND FISSION TRACK AGES

Four zircon fractions from a sample of the CET were prepared for conventional multigrain U-Pb geochronologic analysis. They have discordant U-Pb ages that lie in an array parallel to concordia (Fig. 2). Regressing the U-Pb data results in a chord which intersects concordia at 147 ± 10 Ma, and is interpreted to indicate a late Jurassic crystallization age for the sample. ^{40}Ar-^{39}Ar biotite dating of two samples of the two CET plutons exhibit well-defined weighted mean plateau ages (Fig. 3) of 157.7 ± 1.5 and 158.9 ± 1.5 Ma. K-Ar whole rock dating of two pervasively sericitized samples gave ages of 140 ± 4 and 142 ± 5 Ma. These similar ages are indicative of rapid cooling of the magmatism - alteration - mineralization system at a shallow crustal level. Two apatite mineral separates from CET have been analyzed using the fission track dating technique. Fission tracks ages of the samples are 7 ± 4 and 14 ± 4 Ma.

STRUCTURAL AND TECTONIC SETTING

The most important structures in the district are steeply dipping faults, which in general strike NW-SE, N-S and ENE-WSW (Fig. 1). The NW-SE faults are continuously traceable for about forty kilometers. Shear-sense indicators such as horizontal slickensides and grooves are locally observed, suggesting dextral strike movements. The N-S and the ENE-WSW faults are normal, and most of the dikes and veins were emplaced along them.

The presence of separate depositional centers in the Ibáñez formation, and its thickening and inclination towards the ENE boundary faults, indicate that these faults were active during sedimentation giving rise to a half graben array (Fig. 1). The fault-controlled distribution of the Ibáñez sequence, plutons, dikes and veins, suggests a coeval formation of tectonic basins and spaces for magma emplacement and mineralization. The post-basement units are bounded by linear NW-SE transform segments and N-S and ENE-WSW normal faults, as is expected to occur in a pull-apart basin model in which simultaneous strike-slip movements and extension subparallel to the strike of the transform takes place (Ben-Avraham and Zoback, 1992).

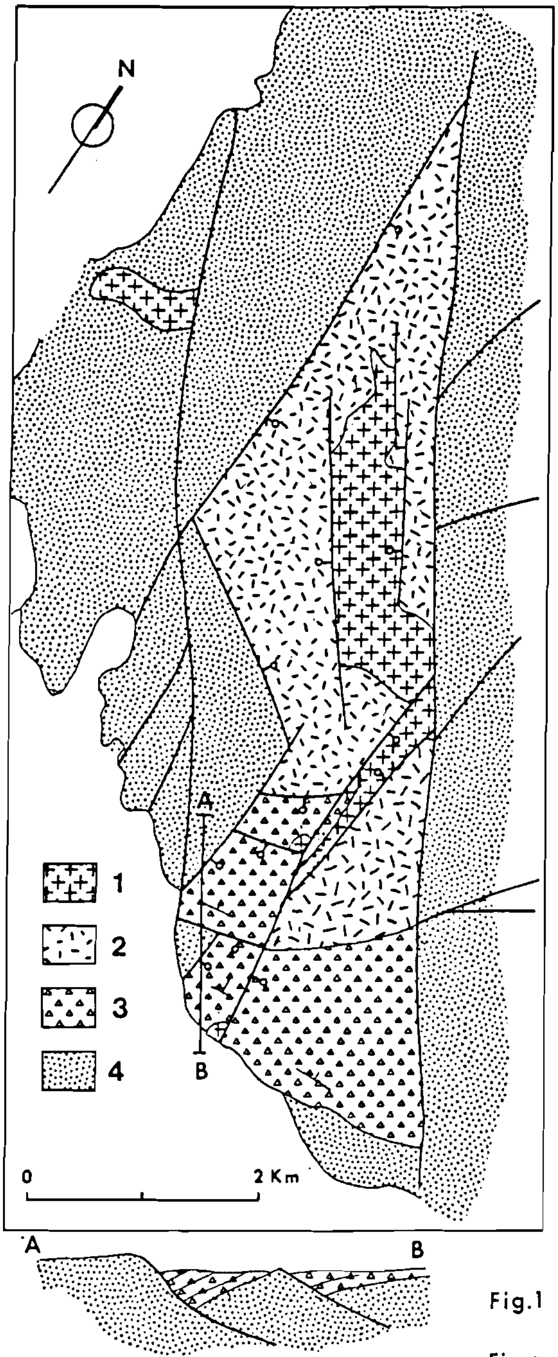


Fig.1

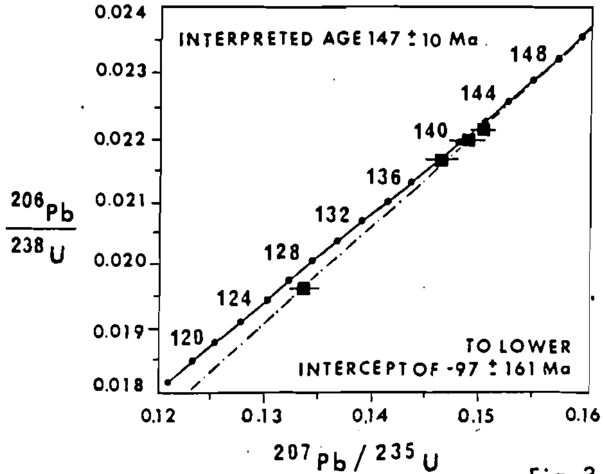


Fig. 3

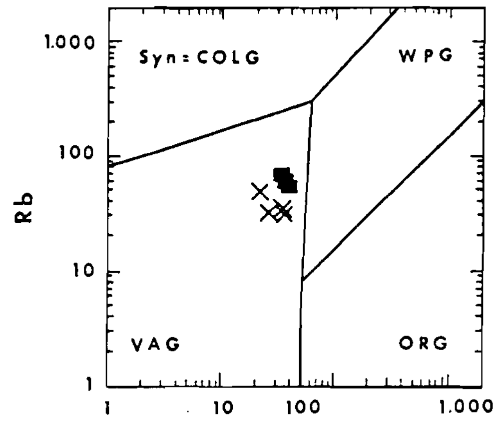
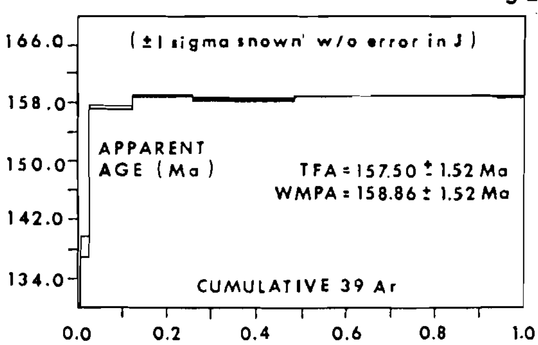


Fig.4

Fig.2



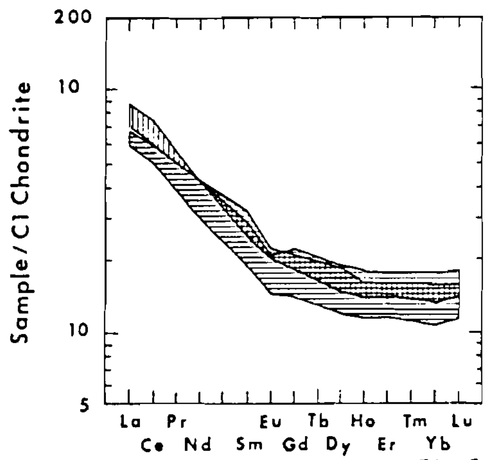


Fig.5

The greater exposure of igneous rocks than sedimentary rocks in the El Faldeo district, indicates that magma supply exceeded sedimentation rate. An effect of the subsidence - filling of the basins is the common presence of sills intruded by vertical dikes forming part of the same magmatic event. Such an intrusive relationship is an indication that sufficiently thick magmatic and sedimentary overburden was present to produce a change of the least principal stress from vertical to horizontal. It is worth noting that the magmatic pressure must exceed the least principal horizontal stress and the tensile strength of the rock cover in order to form discordant intrusions.

A few samples of the CET were geochemically and isotopically analyzed. They exhibit volcanic arc signatures (Fig. 4) and REE patterns similar to typical subduction-related Upper Cenozoic tonalites of the North Patagonian Batholith (Fig. 5). They have Sr^{87}/Sr^{86} ratios of 0.706951 and 0.708203 and εNd of -2.9 and -3.7 suggesting an important crustal contribution in the formation of the CET.

METALLOGENIC IMPLICATIONS

The integration of field, radiometric, geochemical and isotopic data, constrains the alteration - mineralization of the El Faldeo district to an Upper Jurassic extensional arc regime associated with dextral strike-slip and related subsiding pull-apart basin. The results highlight the close links between tectonism, magmatism and mineralization, in which the continental crust made a significant contribution to the origin of both the magmas and the mineralization. Subsidence - filling and coeval mineralization may explain the higher temperature and depth of the late mineralization stage as compared to the earlier one. Release of progressively higher volatile pressure would have been necessary to produce the increase in the degree of rupture of the rocks hosting the mineralization, from veinlets in the first stage, to hydraulic brecciation in the third stage.

The El Faldeo district was preserved at depth for an interval of about 140 m.y. after which the uplift and erosion caused by the Chile ridge - trench collision, brought it to the present position in Late Miocene time.

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LEGEND OF FIGURES

Fig. 1. Geological sketch of the El Faldeo district. 1: Cerro Esmeralda Tonalites (CET). 2: Quebrada Colorada Granodiorites (QCG). 3: Ibáñez formation. 4: Paleozoic metamorphic basement.

Fig. 2. A portion of the concordia diagram showing the U-Pb isotopic data for a CET sample.

Fig. 3. Age spectrum measured on biotite from the same sample as figure 2.

Fig. 4. Rb vs. Y + Nb discriminant diagram for CET samples (crosses). Upper Cenozoic granitoids of the Northern Patagonian Batholith (squares) are also shown for comparison.

Fig. 5. Ranges of chondrite-normalized REE patterns of CET samples (horizontal hatch) and Upper Cenozoic granitoids of the Northern Patagonian Batholith (vertical hatch).