Hydrothermal alteration and mineralization in Santo Domingo Sur Iron Oxide (-Cu-Au) (IOCG) deposit, Atacama Region, Chile

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Abstract. The Santo Domingo Sur (SDS) deposit, near Diego de Almagro, is a recent IOCG discovery in the Chilean Iron Belt (CIB) containing 486 Mt at 0.32% Cu, 0.043 ppm Au and 27.2% Fe. Recent field work and petrographic studies have refined the main geological features and provided insight into the time-space evolution of the hydrothermal system. SDS is hosted by volcanic and volcaniclastic rocks correlated with the Early Cretaceous Punta del Cobre Formation and the Bandurrias Group, and a limestone-bearing volcanic section that may belong to the Chañarcillo Group. These rocks are intruded by variably altered sills and small stocks. Mineralization occurs as chalcopyrite-bearing semi- to massive specularite and magnetite mantos with minor veins and breccias. The mantos zone forms an outer rim of specular-hematite over a magnetite-rich core. Hydrothermal zoning goes from distal, low-moderate-T Na(Ca) associations, recognized in the upper levels of the orebody, towards proximal and moderate-T Na(Ca) minerals in the deeper parts of the deposit. Nearby garnet-magnetite-rich skarns surround oligoclase-actinolite(-scapolite-titanite) altered quartz diorites. SDS has similarities with the Candelaria / Punta del Cobre and Mantoverde districts.

Keywords. IOCG, Santo Domingo, alteration, mineralization

1 Introduction

Iron-oxide (-Cu-Au) (IOCG) systems are numerous and widely distributed globally and throughout geologic time space (Williams et al. 2005). A well-known province is the Mesozoic belt along the subduction margin of southern Peru and northern Chile. The major deposits located in this belt (Candelaria and Mantoverde, Chile and Raul-Condestable, Peru) has been well described during the last decade, however several uncertainties still remain in relation to the understanding of their formation. The source of metals, sulfur and salinity are not well constrained and the proposed genetic models, fundamental for an effective exploration, are still subject of debate (Barton and Johnson 2000; Pollard et al. 2000; Williams et al. 2005).

Ongoing geological studies at Santo Domingo area focus on documenting the main features of the deposit, enabling comparison with other deposits in the region in support of both project development and continued exploration. This paper summarizes the geology of the Santo Domingo Sur area and provides new documentation of the hydrothermal alteration and mineralization features, their timing and spatial relations with respect to the main ore body, and a brief comparison with other IOCG systems in the Chilean Iron Belt (CIB).

2 Geologic and mineralization framework

During Jurassic through Early Cretaceous, the Coastal Cordillera of northern Chile and southern Peru developed a volcanic-plutonic arc and back-arc basin tectonic setting, producing hundreds to thousand of meters of volcanic and volcaniclastic rocks, represented by La Negra and Punta del Cobre formations, and the Bandurrias Group. In addition, a contemporaneous marine sediment deposition took place at the back-arc basin characterized by the Chañarcillo Group. These supracrustal rocks were roughly coeval with emplacement of plutonic complexes; collectively they provide evidence for preservation of high structural levels and they form favourable host rocks for iron oxide (-Cu-Au) mineralization (Marschik and Fontbote 2001). Broadly contemporaneous with arc development, the Atacama Fault System (AFS) initiated during Early Cretaceous as a major left-lateral strike-slip, N-S arc-parallel fault system, accommodated the emplacement of Early Cretaceous (~132 to 106 Ma) plutonic complexes (Grocott and Taylor 2002). This geologic framework provided the setting for the development of magnetite-apatite-actinolite dominated and hematite-magnetite (-Cu-Au) rich systems along the CIB. The main examples within 50 km of Santo Domingo include the hematite- to magnetite-rich Mantoverde and the Cu-barren magnetite dominated Carmen deposit (Fig. 1; Benavides et al. 2007; Rieger et al. 2010).

3 Santo Domingo district geology

The rocks in Santo Domingo area (8 x 5 km) are represented by a sequence of andesitic volcanic flows and volcaniclastic units that have been correlated with Punta del Cobre Formation and possibly Bandurrias Group. Drilling and surface exposures show that these rocks interfinger with limestones, clastic rocks and tuffs of the Chañarcillo Group. The andesitic flows are well exposed in the Santo Domingo area and commonly are massive to
brecciated, containing abundant amygdules filled by mixtures of quartz, calcite, epidote, chlorite, limonites and copper oxides (Rennie 2010). The flows are aphanitic to porphyritic and exhibit 10-30% (1-7 mm) euhedral white tabular plagioclase commonly with minor hornblende phenocrysts. The volcaniclastic rocks, consist of tuffaceous clastic rocks, and lithic and crystal tuffs (andesitic), intensely altered and mineralized. These are massive to poorly bedded and fine- to medium-grained (0.02-0.3 mm), and they comprise most of the sedimentary package in the area (Rennie 2010). In the SDS deposit, this sequence hosts the bulk of mineralization, and passes laterally into limestone and carbonate sediments, commonly massive to thickly bedded and fine-grained (Fig. 2). Several intrusive phases are recognized in the Santo Domingo area. The first one is a medium-grained equigranular diorite, which best crops out in the southern part of the district. In addition, diorite-andesitic porphyritic sills with fine groundmass and 30-35% of subhedral plagioclase phenocrystal are intruding in the SDS sequence. Finally, a set of feldspar – hornblende porphyry dykes is cutting all other rocks types.

Figure 1. Geological map of Santo Domingo area. Geology modified after Lara and Godoy (1998). Kch = Chañarcillo Group; Kpdc = Punta del Cobre Formation; Kdi = Cretaceous diorite. Red = limit of the Fe-Cu orebody. SDS = Santo Domingo Sur; IR = Iris; IN = Iris Norte; ES = Estrellita.

Faults in the Santo Domingo area are the N-S Iris Fault, which intersects a N-W fault in the southern edge of SDS orebody, an E-W fault that is controlling the mineralized occurrences around Estrellita (ES) deposit, and a major NNE-SSW fault located in the northern part of the district (Fig. 1).

3.2 Hydrothermal alteration and mineralization

Several iron-oxide (-Cu-Au) mineralization styles occur in the Santo Domingo area. Specular-hematite ± copper oxides veins and hydrothermal breccias are the typical near-surface mineralization. The main modes of occurrence are iron oxide replacement mantos within volcaniclastic rocks, structurally controlled mineralization characterized by north-west trending moderate to steeply north-east dipping veins and hydrothermal breccias (Fig. 1), and massive magnetite-apatite replacement (Carmen). Iris and Iris Norte deposits represent the northern extension of SDS, and both deposits exhibited similar hydrothermal features. On the other hand, the Estrellita (ES) deposit is characterized by structurally and stratigraphically controlled specularite-rich breccias and minor mantos with copper oxides (Fig. 1). At district scale hydrothermal alteration in the Santo Domingo area is represented by albite ± epidote replacing the feldspars and actinolite + chlorite affecting the mafic minerals. In addition, quartz ± carbonate and later carbonate veins are common and widely distributed in the area. In the southern part of the district (Fig. 1), garnet + magnetite ± pyrite skarns are developed in the vicinity of several quartz-diorite dykes and plugs, and are characterized by oligoclase + actinolite ± scapolite ± titanite assemblages.

Fieldwork, core logging, and new petrographic studies in the Santo Domingo Sur deposit provide evidence for hydrothermal zoning from proximal to distal mineral associations, which are spatially distributed in the upper and lower levels of the main orebody. At SDS, chalcopyrite-bearing semi-massive to massive specularite and magnetite mantos partially replace several volcaniclastic units. The mantos are 4 to 20 m thick and extend laterally up to 700 m. A lateral zoning exists inside the mantos from an outer specular-hematite domain toward a more magnetite rich core in the center of the deposit (Fig. 2). The Cu-Fe sulfides are more abundant in the specular-hematite domain, with chalcopyrite ± pyrite ± bornite. In addition, several steep veins, mainly composed of specular-hematite ± muskavite and chalcopyrite cut the volcaniclastic rocks, the mantos, and the lower and upper andesitic
flows.

In detail, hydrothermal features in the orebody are complex with multiple overprinting components including some with late carbonate ± quartz-bearing assemblages. The distal zones are characterized by specular-hematite ± mushketoivite with chalcopyrite ± bornite ± chalocite (Fig. 3). Iron oxides in this zone show complex cycling between hematite and magnetite. Early elongate specularite crystals have been transformed into mushketoivite following a zoned pattern, from an inner specularite crystal towards an outer zone with magnetite. The main Cu-sulfide is chalcopyrite that replaces early magnetite + pyrite associations, and is found interstitial to specularite ± mushketoivite and replacing fractures in early pyrite. Distal hydrothermal associations consists of early actinolite ± albite ± epidote ± titanite and later chlorite + actinolite + carbonate ± quartz consistent with low to moderate-T Ca(Na) alteration (Fig. 3). Actinolite crystals are fine grained and show radial patterns, and their shape is preserved after carbonate replacement. Potassium silicate alteration is sparse, and is found as K-feldspar associated with later actinolite crystals, which is chlorite (Fig. 3). Early associations exhibited a timing relationship with later actinolite crystals, which is consistent with low to moderate-T Ca(Na) alteration (Fig. 3). Actinolite + carbonate ± quartz consistent with low to moderate-T Ca(Na) alteration (Fig. 3). This situation appears to be similar for the Candelaria, Punta del Cobre and Mantoverde districts. SDS also resembles Candelaria, Punta del Cobre and Mantoverde in that copper is closely related to the hematitic facies and that hypogene magnetite is poor in copper (or removed copper). The stratabound character and clear lithologic control are akin to the manto deposits (Candelaria, some in Punta del Cobre district) in contrast to the strongly discordant ores of Mantoverde, parts of Punta del Cobre and Ojancos Viejo districts (Marschik and Fonbóte 2001; Benavides et al. 2007; Rieger et al. 2010; Kreiner and Barton this volume).

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**References**


