VOLCANIC STRATIGRAPHY AND GEOLOGICAL SETTING OF THE EL DOMO VMS DEPOSIT, ECUADOR

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ABSTRACT
The El Domo deposit is a Cu-Au-Zn-Ag-Pb volcanogenic massive sulfide (VMS) formed in an intra-magmatic arc basin of Eocene age (Macuchi Unit). It is the largest known Au-rich VMS deposit in the Western Cordillera of Ecuador, with a total indicated and inferred resources of 10Mt at 1.6% Cu, 2 g/t Au, 2% Zn, 0.1% Pb and 42 g/t Ag (Matias et al, 2014).Most of the metallic mineralization at the El Domo occurs in a large stratabound massive sulfide lens at the contact between a rhyodacite dome and overlying volcaniclastic mass flows. The main ore minerals are pyrite, sphalerite and chalcopyrite and less abundant galena, bornite, tennantite, stromeyerite and proustite. The El Domo deposit has a similar setting to other Andean VMS deposits like La Plata and Macuchi (Chiaradia et al., 2008). Broadly global equivalents are the bimodal-felsic deposits of the Hokuroko basin (Japan) and the VMS deposits of Tasmania (Halley and Roberts, 1997).

INTRODUCTION
The El Domo VMS deposit is located in the Western Cordillera of Ecuador (Figure 1) within mafic volcanic rocks of the autochthonous Macuchi arc (Eocene), constructed upon the Pallatanga oceanic plateau, which is in its turn accreted to the continent at the end of the Cretaceous (Chiaradia, 2009; Vallejo et al., 2009).

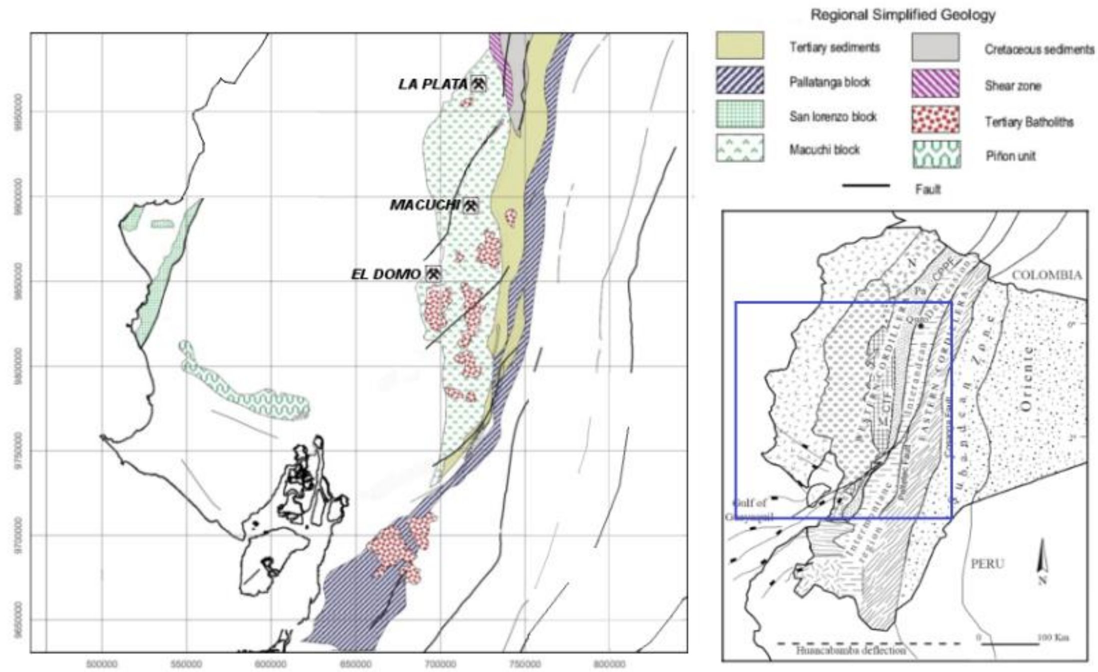

Figure 1.*Geologic map of the Western Cordillera of Ecuador between 0° and 2° S, (after Kerr et al., 2002)*

VOLCANIC STRATIGRAPHY
El Domo area shows a well-defined volcanic stratigraphy (Figure 2). It includes a basal rhyodacite dome complex overlain by two interdigitated volcaniclastic mafic to intermediate sequences and two coherent younger dome complexes, one andesitic and another rhyolitic, that have intruded the sequence in the northern and the southern parts of the property. The massive sulfides mainly occur in

the contact between the basal rhyodacite and the volcaniclastic sequence, and also, locally underlying the main andesite dome ("El Domo") (Figure 3).

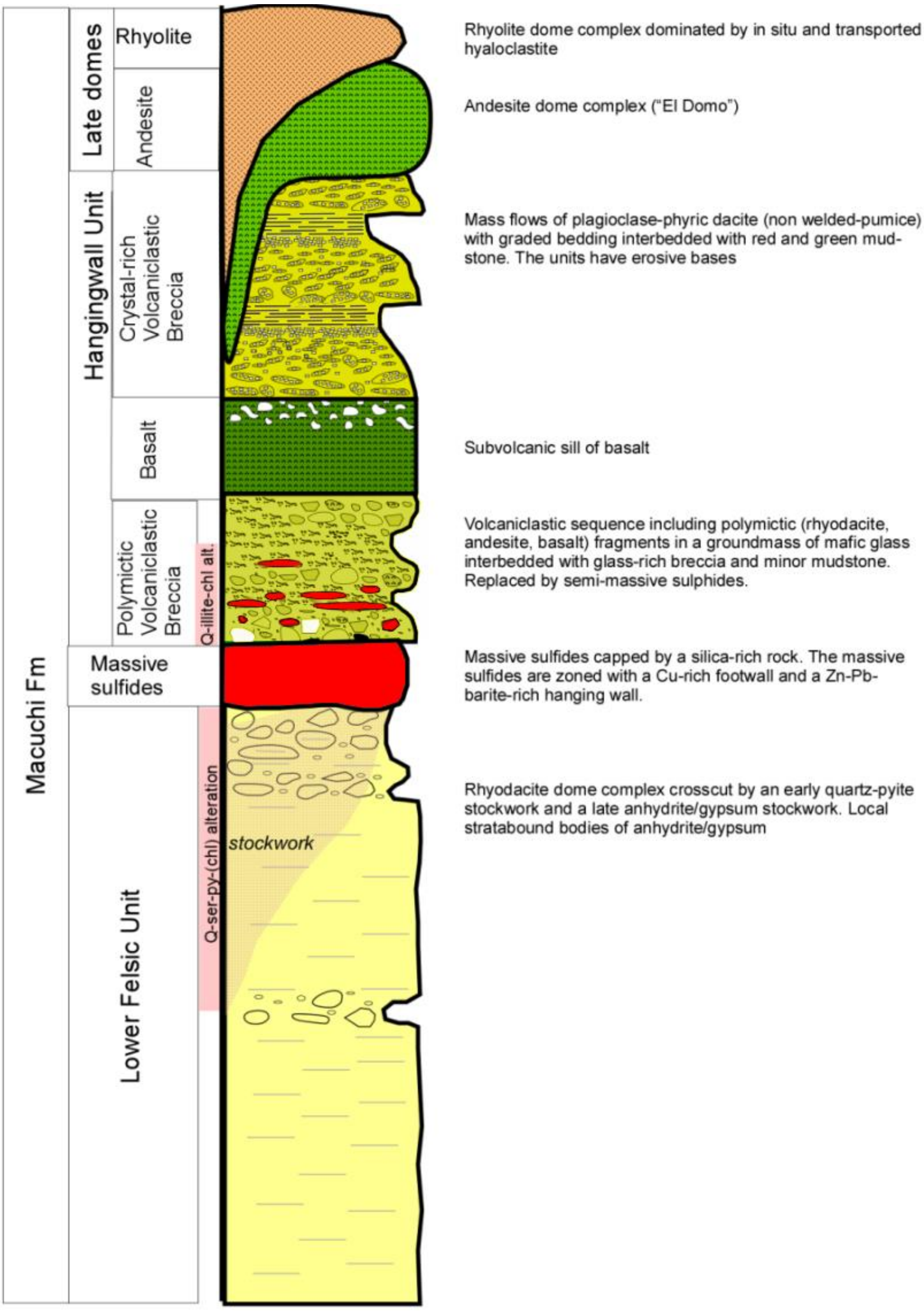

Figure 2. *Synthetic column showing the main lithofacies of the El Domo VMS deposit*

HYDROTHERMAL ALTERATION

The massive sulfides are related to a major zone of hydrothermal alteration, which includes extensive sericitization-silicification in the rhyodacitic footwall, and widespread silicification-chloritization-argillitization (±magnetite ±barite) in the overlying mafic volcaniclastic rocks, this last alteration consist of the replacement of glass by phyllosilicates, mainly nontronite, smectite, illite, and carbonate, chlorite, with variable amounts of quartz and pyrite. The rhyodacite shows a well-developed sulfide-bearing quartz-rich stringer zone that is superimposed by a later large stockwork zone of gypsum replacing earlier anhydrite.

SETTING OF THE EL DOMO VMS DEPOSIT

The structural framework at El Domo consists of a northeast-trending graben bounded by steep faults (Mayor, 2010). In the mineralized area, the volcaniclastic beds are almost flat-lying above the rhyodacite dome complex, but form a gentle asymmetric anticline with a steeper limb adjacent to the late andesite dome (Figure 3).

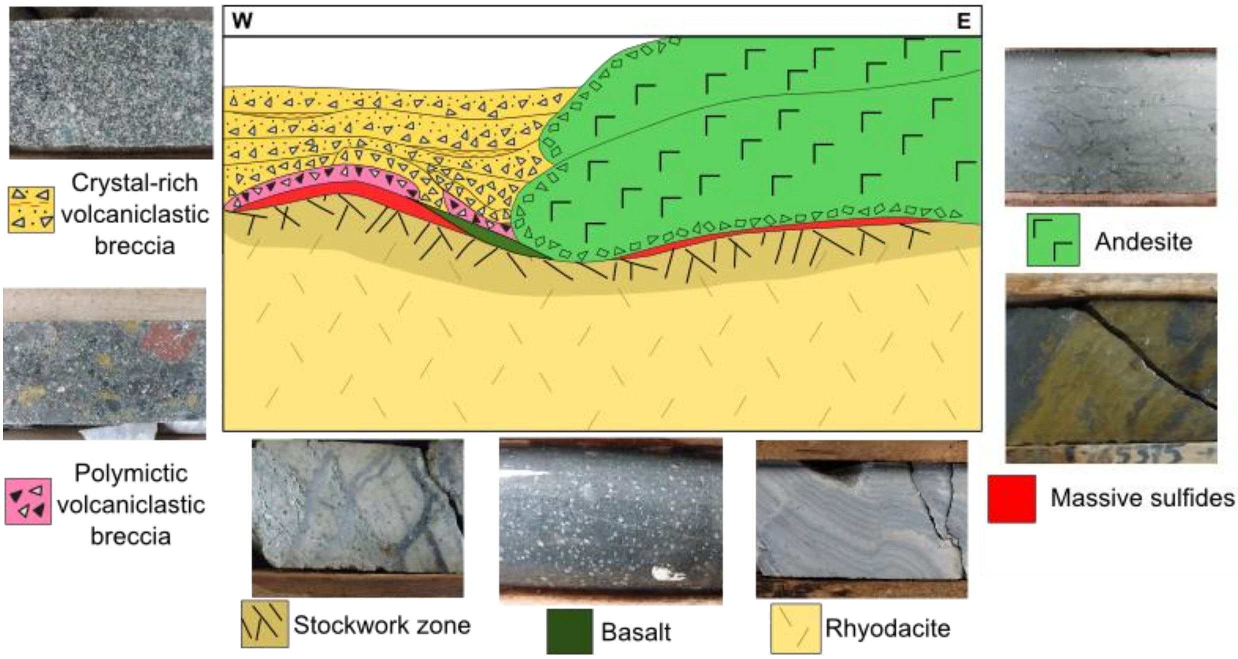

Figure 3. *Volcanic lithofacies reconstruction of the El Domo VMS deposit based on drillholes*

PRINCIPAL STYLES OF MINERALIZATION

Several styles of mineralization have been identified in the El Domo project, including:

1. Stockwork zone: hosted by the lower felsic unit and beneath the massive sulfides, with veins and disseminations of pyrite, chalcopyrite and sphalerite.

2. Stratabound massive sulfides: located at the contact between the lower felsic unit and the polymictic volcaniclastic breccia (Main Ore Zone). This ore zone is a lens that hosts more than 90% of the identified resources. The ore lens shows a marked vertical zonation with a lower Cu-rich zone and an upper Zn-Pb-(Ba) one. A polymetallic ore, including most of the silver and gold, is located at the contact between these two zones. Finally, the massive sulfides are overlain by a barite layer and a chert cap.

3. Semi-massive to disseminated ore: located as irregular stratabound lenses within the polymictic volcaniclastic breccia, with the sulfides disseminated within the groundmass of the breccia or replacing the clasts. The ore assemblage is similar to that of the massive sulfides. Despite its relative high-grade this type of mineralization includes only a small part (<4%) of the total tonnage.

4. Possible fossil fault scarp collapse breccias with transported massive sulfide blocks and clasts, likely located near the hanging wall of the volcaniclastic polymictic breccia.

DISCUSSION

VMS deposits occur in specific geological environments where they can accumulate and be preserved. Recent studies have shown that the largest VMS deposits formed as replacements of volcanic or volcaniclastic rocks below the seafloor, the exhalative ones being less common in the geologic record due to their lesser capability of accumulation and preservation (Tornos et al. in press). The massive sulfides at the El Domo have been interpreted by Franklin (2009) as, at least partially, formed in submarine mounds, similar to those found nowadays in the oceanic floor, including a massive mound and a breccia apron. Main arguments for the exhalative genesis include the location on seafloor depressions, the presence of a possible exhalite zone, the occurrence of breccia zones related with the dissolution of anhydrite, and the presence within the massive sulfides of cm-sized tubes that are interpreted as relicts of tubeworms (Pratt 2008).

Our results suggest, in agreement with other studies (Pratt 2008; Vallejo 2013), that there is little evidence of formation of chimneys, sedimentary mound breccias and sulfide-rich sediments in the El Domo deposit. We suggest that most, if not all, of the massive sulfides at the El Domo district formed by shallow submarine replacement of the glassy rocks, several evidences indicate that the replacement took place in the early diagenesis, before compaction and synchronously with the devitrification of the glass. They include the selective replacement of perlite and the mimic replacement of the glass fragments by sulfides. However, the massive sulfides show only subtle structures, mostly remnants of breccias and a banding that we interpret as inherited from the protolith; no sedimentary banding or brecciation has been found, something probably related with the hydrothermal refining. The replacement is located both in the uppermost carapace of the dome complex, and the highly permeable and reactive lower polymictic volcaniclastic breccia.

There are few, if any, similar VMS deposits to those of the Macuchi Unit. Despite the location above felsic domes is a rather common feature in most of the major districts such as the Hokuroko province, the Iberian Pyrite Belt, the Bergslagen district or the Noranda camp, in none of these places the mineralization replaced mafic glass-rich sequences. The mineralization in these districts is hosted either by shale, pumice-rich rocks capping the domes or as stratabound bodies between individual flows or volcaniclastic rocks. In this aspect, the El Domo deposit is rather unique.

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