



SULFUR-RICH PLUTONIC ROCKS CONTAINING PRIMARY IGNEOUS ANHYDRITE IN THE EL TENIENTE CU MEGABRECCIA DEPOSIT, CENTRAL CHILE

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El Teniente, central Chile (34°S), is the world's largest Cu deposit (Skewes et al., 2002, 2005). Primary igneous anhydrite occurs in plutonic rocks previously described by mine geologists as the matrix of “microdiorite” and “andesite” igneous breccia. “Microdiorite” igneous breccia forms a 150 m wide stock at level Teniente-5 (Fig. 1). This stock is called “Porphyry A” although this rock is neither a porphyry (Fig 2), nor a diorite (Table 1). These igneous breccias were emplaced along the contact between the Teniente Mafic Complex and the Sewell Tonalite pluton, and occur within the center of a Cu-rich (>1-2%) hydrothermal breccia pipe complex (Fig. 1).

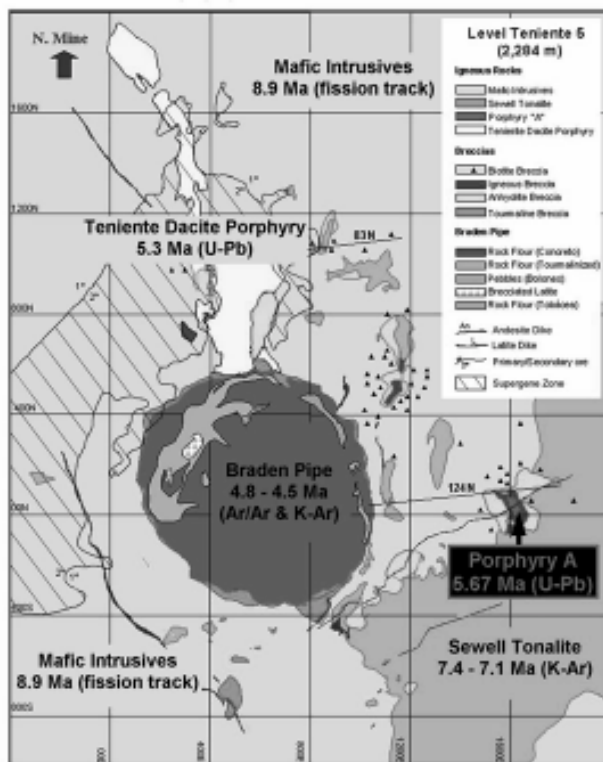


Figure 1. Map of El Teniente deposit at level Teniente 5 (2,284 m), illustrating the major lithologic units in the area of the mine and their ages (Skewes et al., 2002, 2005). Igneous breccias (including “Porphyry A”) containing primary igneous anhydrite occur in the center of the Cu-rich hydrothermal breccia complex east of the Braden Pipe.

The matrices of these igneous textured breccias contain biotite, quartz, Na-plagioclase, K-feldspar, anhydrite, apatite, rutile, zircon, magnetite and sulfides (bornite, chalcopyrite and pyrite), but not amphibole. Plagioclase and biotite are fresh and unaltered to sericite and chlorite (Fig. 2),

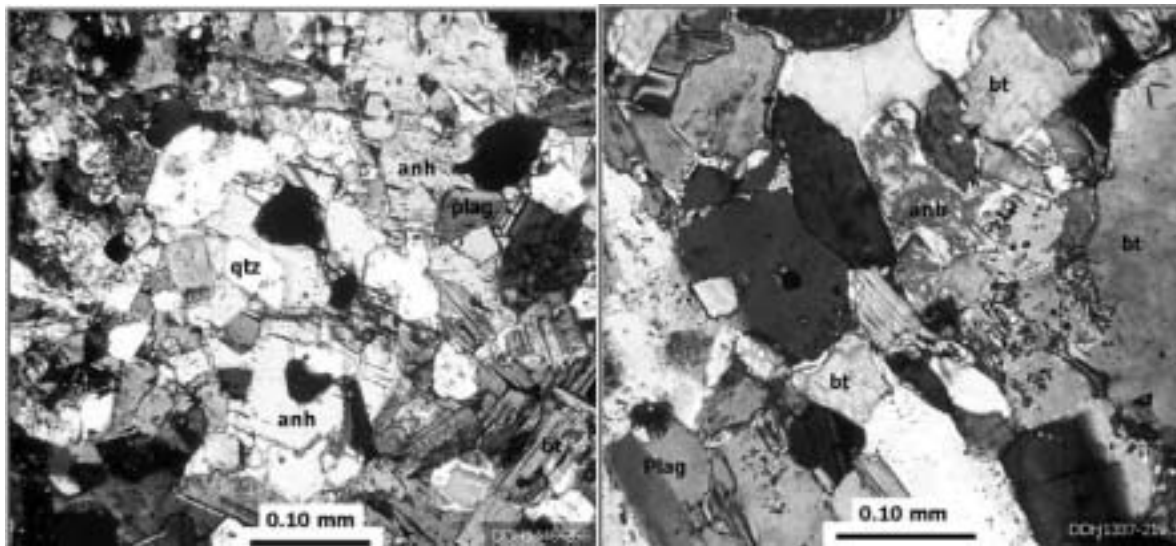


Figure 2. Photomicrographs of Porphyry A “microdiorite” (left) with poikilitic anhydrite (anh) enclosing quartz (qtz), plagioclase (plag) and biotite (bt), and igneous “andesite” breccia (right) with interstitial anhydrite. Note that neither rock is porphyritic, and in neither is biotite or plagioclase altered to chlorite or sericite.

except locally in haloes of hydrothermal veins. Anhydrite in these rocks, as well as biotite and k-feldspar, are interpreted as having crystallized directly from magmas rather than being secondary alteration phases. Modal abundance of biotite ranges from >50% in the more mafic “andesitic” varieties (<52 wt % SiO₂ and >5 wt % each of FeO, MgO and CaO; Fig. 2 and Table 1) to <10% in less mafic “microdioritic” rocks. Plagioclase is always Na-rich, ranging from oligoclase to albite, indicating that anhydrite crystallized contemporaneously with plagioclase, sequestering Ca from the plagioclase and also inhibiting the growth of amphibole. Planar crystal boundaries between anhydrite and other phases, as well as inclusions of silicate minerals within anhydrite, are other lines of evidence for anhydrite being a primary igneous phase in these rocks. Primary igneous anhydrite has textures which vary from interstitial to poikilitic (Fig. 2) as its modal abundance increases from <10% to >30%. These anhydrite-bearing plutonic rocks may contain >3% S (Table 1) and >0.5% Cu, an order of magnitude greater than S and Cu contents of typical Andean basalts and volcanic rocks containing primary igneous anhydrite (Fig. 3).

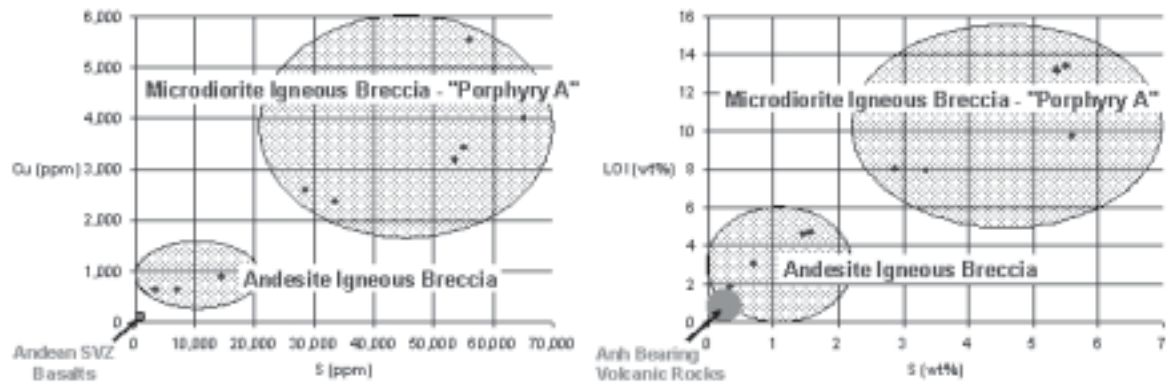


Figure 3. S versus LOI and Cu in the igneous “andesitic” and “microdioritic Porphyry A” breccias compared to previously published values for volcanic rocks with primary igneous anhydrite and typical Andean basalts.

Table 1. Major element, S, Cu and Sr-isotopic composition of representative “andesite” and “microdiorite” igneous breccia matrices containing primary igneous anhydrite.

Breccia Type	Microdiorite	Andesite
<i>core #</i>	<i>DDH1446-266</i>	<i>DDH1473-970</i>
SiO ₂	56.34	48.45
TiO ₂	0.42	1.01
Al ₂ O ₃	13.86	18.62
Fe ₂ O ₃	2.74	7.54
MnO	0.02	0.03
MgO	1.41	4.73
CaO	6.72	5.73
Na ₂ O	3.80	4.33
K ₂ O	5.68	3.63
P ₂ O ₅	0.17	0.22
LOI	7.99	4.66
TOTAL	99.14	98.95
S _(ppm)	33,500	14,400
Cu _(ppm)	2,380	899
Plag*	An 2-7	
⁸⁷ Sr/ ⁸⁶ Sr	0.70410	0.704415

The matrix of "Porphyry A" has been dated by U-Pb in zircons as late Miocene (5.67 Ma; Fig. 1), a time with no evidence of coeval volcanic activity in the area of the deposit (Fig. 4; Skewes et al., 2002, 2005). Lack of volcanic activity at this time

may have prevented devolatilization of magma in the large, long-lived magma chamber underlying the deposit (Stern and Skewes, 2005). This allowed the SO₂ and H₂O contents of magma near the roof of this chamber to increase to the point that it generated hydrothermal anhydrite and igneous breccia pipes, subsequently intruded by the Cu and SO₂-rich magma that crystallized to form the anhydrite-bearing "Porphyry A microdiorite" stock.

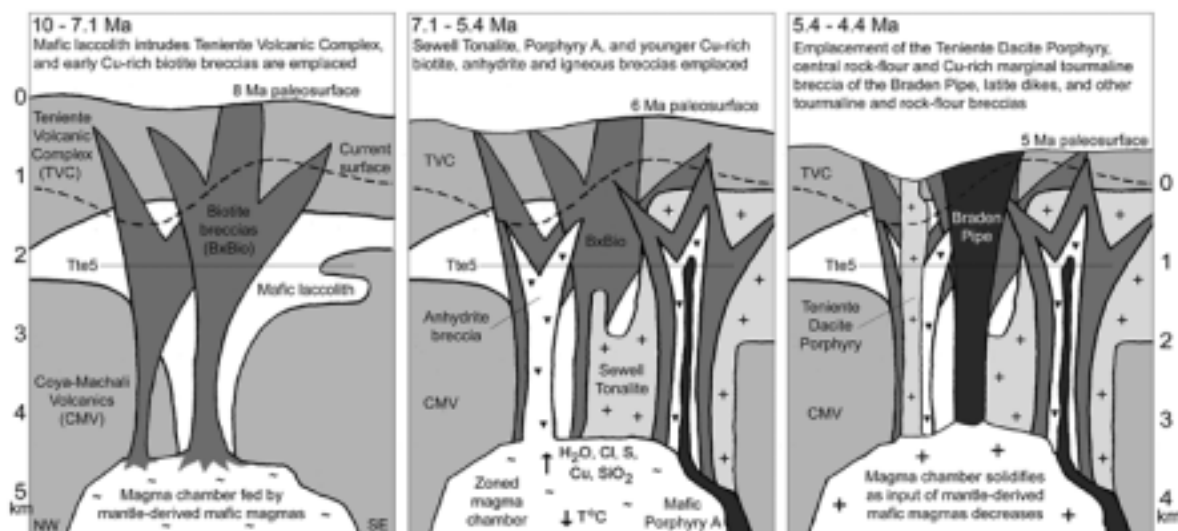


Figure 4. Multistage model for the evolution of the El Teniente Cu megabreccia deposit (Skewes et al., 2002, 2005; Stern and Skewes, 2005). “Porphyry A” formed at 5.7 Ma, prior to the intrusion of the Teniente Dacite Porphyry and Braden Pipe.

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