

# Andacollo copper–gold district, La Serena, Chile: preliminary data from the porphyry copper and possible relationships between Cu and Au mineralization

J. Guzmán, S. Collao and R. Oyarzun

The Andacollo mining district is located in the Coquimbo region of Chile at 30°14' south, 71°06' west, some 55 km southeast of La Serena, at a mean elevation of 1030 m within a semi-arid hilly landscape (Fig. 1). Current mining activity in the district is concentrated on copper and gold. These metals are mined, respectively, from a porphyry copper deposit and epithermal, manto and vein gold deposits of adularia–sericite type.<sup>11,13</sup> Other types of mineralization include mercury veins hosted by carbonate rocks. The gold veins are controlled by a northwest-trending set of normal faults, whereas the manto-type mineralization is strata-bound and largely confined to andesite breccias, dacites and sites of strong fracturing. The lateral and vertical continuity of the mantos is strongly controlled by rock type, faulting and intensity of fracturing. The gold deposits have been the focus of a recent study,<sup>11</sup> but comparable information on the Andacollo porphyry has not become available. A brief, updated geological perception of the porphyry is now presented and possible relationships between the copper and gold deposits are analysed.

## Geology of district

The Andacollo district is mostly confined to a fault-bounded, north–south depression partially filled with Tertiary gravels, some of which contain Au placer-type deposits (Fig. 1). The geology of the district consists largely of the volcanic–volcaniclastic Quebrada Marquesa Formation, of Barremian–Albian age.<sup>1,14</sup> The stratigraphy of this formation at Andacollo is shown in Table 1.

Table 1 Units and ore deposits of Quebrada Marquesa Formation at Andacollo,<sup>9,11,13</sup>

Unit	Thickness, m	Lithology	Ore deposits
Carbónica (top)	240	Limestones, andesites, conglomerates	Mercury veins
Veintiuna Vuelta	350	Ignimbrites	
Pichilingo	200	Andesites	Copper–gold veins
Andacollo	800	Andesites, dacites, trachytes, volcanic breccias	Manto and vein gold deposits; porphyry copper
Cerro Negro	300	Andesites	Gold veins
Cerro Toro (base)	680	Andesites, volcanic breccias, dacites, trachytes	Manto and vein gold deposits

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The Cerro Toro unit rests on top of the volcaniclastic facies of the Arqueros Formation (Auterivian–Barremian).<sup>1,12</sup> The Quebrada Marquesa rocks were extensively block-faulted and tilted by at least two sets of normal faults—northwest (early) and north–south (late). These two sets correspond to regional directions, and Middle Cretaceous and Tertiary ages, respectively, can be assigned to them.<sup>11,12</sup> At the regional scale the Quebrada Marquesa Formation is intruded by a Lower to Middle Cretaceous batholith that varies in composition from diorite to granite.<sup>12</sup> Shallow intrusions related to the batholith include dykes, sills and stocks, the latter well exemplified by the presence of the Andacollo porphyry.

## Andacollo porphyry

The Andacollo porphyry belongs to the so-called Pacific belt<sup>7</sup> (22–34° south), which runs north–south, parallel to the main Cenozoic porphyry belt in a westward position. Although the Pacific belt porphyries are of less economic importance than their huge Cenozoic counterparts (e.g., Chuquicamata and La Escondida), they are of major interest. The Andacollo porphyry is being mined by Minera Carmen de Andacollo (CDA), which outlined 33 400 000 t of recoverable ore at 0.76% Cu within a roughly north–south elongated body of 1800 m × 1200 m. The mining and metallurgical procedures are typical of modern operations in Chile, comprising an open-pit mine and integrated bacterial leaching–solvent extraction–electrowinning, which outputs high-grade copper cathodes (99.99% Cu).

The porphyry is hosted by andesites and trachytes belonging to the Andacollo unit of the Quebrada Marquesa Formation (Figs. 1 and 2(a)). The intrusive rocks occur as small stocks of irregular shape and NNW-elongated bodies. These rocks vary in composition from granodiorite–tonalite to quartz monzonite (including dioritic facies)<sup>5</sup> and have been dated at 98 ± 2 m.y. and 104 ± 3 m.y. (K/Ar; only available dates).<sup>13</sup> The rocks are affected by NNW-orientated, syn- and post-mineralization faults and a later major episode (at district and regional scale) of north–south normal faulting, which contributed much to the present arrangement of structural blocks in the area<sup>11</sup> (Fig. 1).

Hydrothermal alteration affects both the volcanic and the intrusive rocks and displays a general zonal pattern that includes a core of potassic alteration and an outer halo of phyllic alteration.<sup>7</sup> At the local scale, however, the arrangement of alteration facies is more complex—as exemplified by La Hermosa sector (Fig. 2(a) and (b)).<sup>5</sup> In this area different, irregularly shaped mineral zones are recognized (Fig. 2(b)), comprising (1) potassic alteration, albite–quartz ± K feldspar ± sericite (trachytes) and biotite–albite ± quartz ± K feldspar (andesites), and (2) phyllic alteration, quartz–sericite (dioritic intrusive bodies). Quartz–sericite clearly overlaps the potassic assemblage, which appears to be a quite typical feature of porphyry-type deposits.<sup>6</sup> The mineralization occurs as disseminations and veinlets (stockwork). The mineral paragenesis includes as primary minerals major pyrite, chalcocopyrite, hematite and magnetite and minor bornite, pyrrotite, arsenopyrite and molybdenite.

Preliminary fluid inclusion studies were carried out on quartz phenocrysts and on quartz and calcite from the gangue of sulphide veinlets. The results indicate ranges of 330–420°C and 9–46 equiv. wt% NaCl for the late magmatic and early hydrothermal stage and of 222–350°C and 1.5–52 equiv. wt% NaCl for the late (phyllic alteration) stage<sup>5</sup> (Fig. 2(c)). The wide dispersion of salinity values in the early stage suggests participation of two fluids. Equivalent data for the late stage (phyllic alteration) may be explained in terms of the interplay between meteoric waters and a late fluid of high