

First in situ U-Pb dating of supergene copper mineralization: case study from Atacama Desert, Chile

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Direct dating of copper mineralization remains challenging, yet an important objective for both metallogenic studies and prospecting purposes. Here, we present a first attempt of U-Pb dating of copper-rich minerals from the Mina Sur exotic deposit from the Chuquicamata copper mine (Chile).

The Mina Sur exotic copper deposit is located in northern Chile, within the Chuquicamata mining district, about 6 km south of the world class Chuquicamata porphyry copper deposit. It was discovered in 1957 from drilling in sub-alluvial channels and copper extraction began in 1969 (Mortimer et al., 1977). The copper mineralization consists mainly of chrysocolla, Mn-rich chrysocolla (also known as copper-pitch or black chrysocolla), pseudomalachite bedding and atacamite emplaced mainly as cement in gravels but also filling fractures in the bedrock. Geomorphological, mineralogical and structural studies have shown that the Mina Sur deposit is derived from the lateral migration of copper-rich solutions from the Chuquicamata porphyry deposit. The latter was formed by the 33-31 Ma old hydrothermal alteration (Ar-Ar dating of K-feldspar and sericite) of the 35-33 Ma old porphyry (U-Pb dating on zircon). However, the age of the Mina Sur exotic deposit is unknown.

A suite of Mn-rich chrysocolla clasts surrounded by pseudomalachite layers have been characterized and dated by in-situ U-Th-Pb LA-ICP-MS analyses. The data obtained on pseudomalachite define a concordant date of 19.45 ± 0.21 Ma, which is interpreted as crystallisation age of the pseudomalachite layers. In the Mn-rich chrysocolla clasts, the data yield concordant to sub-concordant dates between 13.6 ± 0.2 Ma to 5.8 ± 0.1 Ma (under ns-LA-Q-ICP-MS) and 24.1 ± 0.3 Ma to 6.0 ± 0.1 Ma (under fs-LA-HR-ICP-MS). These dates are therefore not consistent with the date obtained on the pseudomalachite layers that coat them. These could reflect either Pb loss linked to late fluids that affected specifically these clasts or to an analytical bias due to the fact that there is no chrysocolla standard available for in-situ U-Pb dating. However, the consistency of the results obtained for Mn-rich chrysocolla clasts on ns-LA-Q-ICP-MS and fs-LA-HR-ICP-MS is promising.

This preliminary study demonstrates, for the first time, that supergene copper mineralization can be dated by the U-Th-Pb method. Furthermore, the age obtained on pseudomalachite indicate that Mina Sur deposition took place at ca. 20 Ma, about 10 Ma after the unroofing and hydrothermal alteration at Chuquicamata, a result that is consistent with the supergene ages already known supergene in the mining district.

Keywords: supergene copper mineralization, Atacama Desert, U-Pb *in situ* dating, chrysocolla, pseudomalachite