Introduction

At Collahuasi mining district in the north Chilean Andes (180 km SE of the Iquique port) a cluster of late Eocene – early Oligocene, giant porphyry Cu-Mo deposits form a distinct E-W alignment, which contrasts with the overall longitudinal orientation of the Chilean porphyry copper belts. This district includes the Quebrada Blanca, Rosario - La Grande, and Ujina deposits, located at altitudes from 4,100 to 4,800 m a.s.l. The resources and production of this porphyry cluster aggregates >45 Mt of contained copper; and it constitutes the third-largest copper concentration in northern Chile associated with the regional, long-lived, north-south, strike-slip Domeyko Fault System [1]; [2]. Currently the Quebrada Blanca, Rosario, and Ujina deposits are exploited by open pit mining, and a number of other prospects have been identified and explored in the region.

We have used a combination of geochronological methods ($^{40}$Ar/$^{39}$Ar, Re-Os, SHRIMP U-Pb) intending to resolve the temporal evolution of the porphyry-related magmatism, to improve the chronology of hydrothermal alteration, and mineralization processes of this cluster of giant porphyry Cu-Mo deposits, and to establish whether the mineralization resulted from a single stage or from multiple superposed hydrothermal events.
Geological background

The porphyry Cu-Mo deposits are located within an uplifted block of Late Paleozoic to early Triassic crystalline basement composed mostly by felsic volcanic rocks and related porphyry and equigranular intrusions of the Collahuasi Group [3]. Thus, the country rocks of these Cenozoic porphyry Cu-Mo deposits are mostly Late Paleozoic igneous rocks. This basement block is about 20 km wide and is bounded by two vertical, N-S-trending regional faults, the West Fault and the Rio Loa Fault, which are part of the Domeyko Fault System. The Quebrada Blanca and Ujina deposits are spatially related to these longitudinal bounding faults, whereas the Rosario deposit is located on a NW-trending subsidiary fault system dipping SW in the middle of the uplifted basement block; the uplift of the basement block and exhumation of the porphyries is inferred to be related initially to the late Eocene Incaic orogeny [4], which is consistent with apatite fission track ages of 41 to 34 Ma for the basement rocks of the Collahuasi area [5] [6], but also additional and more recent uplift (younger than 10 Ma) was significant according to geomorphologic studies [7].

Geochronology

Previous data, mainly K-Ar and some $^{40}$Ar/$^{39}$Ar ages showed the late Eocene – early Oligocene age of the porphyry Cu-Mo deposits of Collahuasi district. The geochronological data showed a range from, 39 to 34 Ma for Quebrada Blanca, and from 35 to 33 Ma for Rosario and Ujina [2]; [4]; [8]; [9]; [10]; [11].

Our new SHRIMP U-Pb zircon data reveal similar crystallization ages from 35 to 36 Ma for the felsic porphyries of Rosario –La Grande and Ujina deposits. The Quebrada Blanca deposit magmatic activity started a bit earlier at 37 Ma, but the U-Pb zircon ages for late felsic porphyries of Quebrada Blanca are coeval to those of the Rosario and Ujina deposits. Thus, at least two events of porphyry intrusion are identified for these deposits. A high sulfidation hydrothermal overprint is apparent at Rosario and La Grande, which according to $^{40}$Ar/$^{39}$Ar data took place at 33 Ma, but no intrusive rocks of this age are exposed within these deposits.

Seven distinct vein types were identified by a detailed study of the stockworks of Rosario and Ujina deposits [12]; three of these are molybdenite-bearing veins. According to crosscutting relationships the molybdenite-bearing veins ordered from oldest to youngest are: molybdenite only, quartz-molybdenite, and quartz-molybdenite ± chalcopyrite–bornite veins. Molybdenite Re-Os dating showed that the molybdenite only veins were formed from 36.8 to 36.2 Ma, the quartz-molybdenite veins were formed from 36.3 to 35.7 Ma, and quartz-molybdenite ± chalcopyrite–bornite veins from Rosario formed from 33.4 to 32.9 Ma. Thus, molybdenite Re-Os ages overall correspond to the ages of
intrusive crystallization in each deposit, but also to the late high sulfidation overprint at Rosario – La Grande.

Conclusions

Our data are consistent with superposed phases of porphyry intrusion and hydrothermal mineralization that took place episodically within a time span of 2 to 3 My in each deposit. The main mineralizing period extended from 37 to 35 Ma when the major porphyry Cu-Mo deposits were formed (Quebrada Blanca, Rosario, and Ujina), and a late high sulfidation hydrothermal event at 33 Ma was superposed only at Rosario – La Grande.

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References


