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Iron-Carbonate Precipitates as Footprint for Hidden Miocene Mineralized Bodies in Jaraña, Puno, Peru

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Hot spring deposits are surface manifestations that precipitate around the active vents of continental hot springs within geothermal systems. Sinter (opaline silica) is surface evidence of epithermal systems at depth, and travertine (calcite or aragonite) represents a distal outflow facies of some geothermal system. Globally, the trace element concentrations of precious metals (Au, Ag) and base metals (e.g., Cu, Pb, Zn) in sinter and travertine are related to ore-mineralizing processes at depth.

Peru is characterized by ore deposit minerals exhumed along the Central Andes at high altitudes (>4,000 m.a.s.l), in the same hydrothermal systems as active hot springs. The Jaraña hot springs group is located in the Puno region, southern Peru, located 90 km to the east of the active volcanic arc in the Sillapaca Cordillera. The Jaraña hot springs are structurally influenced by local faults and are hosted within silicified Miocene andesites. The andesitic rocks contain copper sulfide and sulfosalt minerals and may suggest porphyry copper mineralization at depth.

The Jaraña hot springs generate thermal pools and outflow channels of variable depths (~5 cm to 2 m). The thermal waters have a nearly neutral pH (6-6.7) and temperatures ranging from 55° to 74°C. Thermal waters have an alkali-chloride and acid sulfate composition. Moreover, the active hot springs deposits contain minerals such as calcite, halite, and gypsum and chemical enrichments in Ag, Cu, Pb, As, Sn, and Fe. This study focusses on hot spring precipitates below the spring water surface (subaqueous).

The Jaraña subaqueous hot spring deposits are laminated and show markedly different colors (black, orange, white) and luster (metallic, vitreous), clearly suggestive of mineralogical and compositional diversity. X-ray diffraction patterns indicate they comprise a mixture of predominantly calcite and Fe oxides. Petrographic analysis indicates a combination of calcite crystals, polymictic rock fragments, microbial filaments, and diatoms. Cathodoluminescence was used to identify different stages of carbonate deposition, horizons of crystallization, and carbonate fragments. Four-acid digestion results show an inverse relationship between Fe and Ca concentration, consistent with varying proportions of Fe oxide and carbonate material. Furthermore, in situ chemical analysis of individual horizons by laser-ablation ICPMS contributed to identifying variations in silica in vitreous horizons, abundances of Fe, Zn, Pb, and Mo, and the distribution of these elements in the carbonate layers. In addition, the banded horizons contained high levels of As ranging from 174 ppm to 7.12 wt % and correlated to Fe. Samples have variable concentrations of Cu (0.2-268 ppm) and show a positive correlation with base metals such as Zn. However, in samples with high Fe concentrations, Cu is uncorrelated to Fe.

This research documents compositional variability and the concentration of Fe-bearing phases, in distinct laminated horizons of the Peruvian iron carbonate subaqueous precipitates. Trace element and metal enrichments in the iron carbonates may indicate interaction with deeper Cu orebodies, suggesting iron carbonate deposits could be used as a footprint for hidden Miocene or older mineralized bodies at depth.

