

**Trace element and stable isotope  
dispersion halo around a high  
sulfidation epithermal Au-Ag deposit  
emplaced in Quarzitic Sandstone:  
The Lagunas Norte Deposit,  
Northern Peru**

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The Lagunas Norte high sulfidation epithermal Au-Ag deposit is, with 11.2 Moz of total resources, the most important ore deposit discovered recently in Peru. It is largely hosted by folded, Cretaceous quartzitic sandstone of the Chimu Formation, but ~30% of the ore was emplaced in the Miocene Calipuy Group volcanic rocks overlying the quartzites, as well as in two phreatomagmatic diatreme breccia bodies cutting the Cretaceous units. Due to the low reactivity of the quartzites, the alteration halo around the deposit is obscure so that the deposit eluded discovery until 2001. However, stable-oxygen isotope geochemistry combined with multi element data can vector to ore.

The oxygen isotopic composition of quartz reflects hydrothermal alteration beyond the halo visible in the relatively pure (mostly >95% SiO<sub>2</sub>) sandstones. Regional background δ<sup>18</sup>O values of unaltered sandstones are between 13.2‰ and 13.8‰ whereas much higher δ<sup>18</sup>O values between 16.5‰ and 16.8‰ in finegrained yellowish quartz veins in the sandstones (silice parda) and vuggy quartz in the volcanic rocks record the influence of the mineralizing fluid. The quartzitic sandstones affected by hydrothermal fluids near the deposit show δ<sup>18</sup>O values between 14‰ and 15‰ and similar elevated values are observed near faults to the north of the deposit. The highest δ<sup>18</sup>O values in the silica parda correlate with high Ti and Te contents but low Ga and Pb contents relative to those of the unaltered quartzites. Mobile elements like Na and K are commonly below detection limit (ALS Chemex - ICP-MS ME-ICP06 & ME-MS61), even in the unaltered sandstones. We conclude that stable isotope geochemistry is a potentially powerful tool when defining the extent of hydrothermal fluid flow in non-reactive host rocks.

**Rate of spheroidal weathering  
determined by U-Series nuclides  
(Rio Icacos basin, Puerto Rico)**

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Spheroidal weathering is a classical process, which often defines the transition of bedrock to saprolite in many rock types and many climatic settings. Here we propose to evaluate the rates of spheroidal weathering by analyzing U-series nuclides in weathering profiles, including a spheroidal weathering zone, developed on quartz diorite in the Rio Icacos watershed (Puerto Rico), following the approach used in other contexts [1,2]. U-series nuclides, as well as major element and trace element concentrations have been analysed along two profiles collected in the Rio Icacos watershed. Major and trace element data obtained for the two profiles confirm that chemical weathering mainly occurs at the rindlet/saprolite transition. The U-series nuclides variations along the profiles show a complex U-mobility pattern, compared to that of <sup>226</sup>Ra-<sup>230</sup>Th disequilibria variation. Large Ra-Th fractionation is observed at the rindlet/saprolite transition. Modelling of the <sup>226</sup>Ra-<sup>230</sup>Th disequilibrium suggests a downward migration of the bedrock-saprolite front at 8m/100ka. The variations of U-Th disequilibria in the rindlets zones constituting the bedrock/saprolite transition zone is consistent with such a fast weathering rate, and also consistent with the surface denudation rate of 6m/100ka inferred for this region by cosmogenic nuclides [3, 4]. These data therefore suggest that the weathering and erosion processes in this watershed have reached a steady state. The results emphasize the potential of combining U-series nuclides and cosmogenic isotopes to constrain the steady or transient state of alteration systems.

[1] Dequincey *et al.* (2002) *Geochim. Cosmochim. Acta* **66**, 1197-1210. [2] Chabaux *et al.* (2003) *CR Geosciences* **335**, 1219-1231. [3] Brown *et al.* (1998) *Earth Planet. Sci. Lett.* **129**, 723-728. [4] Riebe *et al.* (2003) *Geochim. Cosmochim. Acta* **67**, 4411-4427.