Characterization and Management of Natural Resources

(U-Th)/He dating of goethite from the gossan of Moroccan supergene deposits

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Numerous secondary (supergene) deposits are hosted in the Moroccan High-Atlas and Anti-Atlas. These deposits form when buried rocks and primary (hypogene) ore bodies are exposed at the Earth's surface and undergo the oxidation of sulfides and native metals, the dissolution of host rocks, and the reconcentration of (mainly metallic) elements. The weathering leads to the formation of four mineralogical zones, from base to top: the hypogene zone (primary sulfides such as chalcopyrite – $CuFeS_2$), the cementation and enrichment zone (secondary sulfides such as chalcocite – Cu_2S), the oxidized zone (oxides, carbonates, sulfates, silicates such as malachite – $Cu_2CO_3(OH)_2$), and the leached zone or gossan (iron (oxyhydr-)oxides).

The interesting potential of supergene ore deposits lies in their relatively high metal and Rare Earth Elements (REE) content, combined to their reasonably easy extraction process related to the softened host rocks and the near-surface situation. In the last decade, a renewed interest in these deposits is associated to the increase of metals and REE demand for new technologies. Supergene deposits are also of environmental interest, as they provide natural analogues for the dissolution (corrosion), transport, and subsequent deposition of metals in natural and man-made environments (e.g. the acid mine drainage processes).

Our knowledge about the formation of supergene deposits is refined through the (U-Th)/He dating of goethite (FeOOH), which is the most common and stable iron oxihydroxide under atmospheric conditions, and which is widely distributed in the gossan zone. The method is based on the radioactive decay of U, Th, and Sm and on the release of ^4He atoms at each chain reaction. The measurement of parent and daughter elements concentration gives access to the time elapsed since the crystallization of goethite. A wide set of goethite samples from various places of the High Atlas and Anti-Atlas have been dated in order to precise the adaptation of the (U-Th)/He method to this kind of material, and to verify the existence of a relation between the weathering and crystallization of supergene goethite, and geodynamic events defined in these mountain belts. For example, we could relate the precipitation of goethite in copper deposits located in the oriental High Atlas with several recent alpine uplifts.