Geophysical Research Abstracts
Vol. 12, EGU2010-13675, 2010
EGU General Assembly 2010

Coupled dissolution-precipitation in natural monazite: effect of irradiation damage or fluid mediation?

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The LREE orthophosphate monazite is a common accessory mineral, important as a U-Th-Pb geochronometer in both metamorphic and magmatic rocks. In order to correctly interpret measured ages, it is essential to properly understand mechanisms that control them. Few studies have shown that coupled dissolution-crystallisation in the presence of a fluid phase is a mechanism incomparably more efficient that solid state diffusion to reset isotopic signature within monazite grains. It is known that dissolution-precipitation is efficiency enhanced by the presence of defects within crystals. Because of its high actinide contents (U and Th), monazite receives intense self-irradiation doses. In contrast to zircon (a silicate), monazite (a phosphate) is less sensitive to irradiation. Natural amorphous monazite has never been reported and the only proof that monazite lattice was destroyed by irradiation is shown by the presence of lattice distortion (strained lattice); this is because defect healing is more efficient than amorphization.

The present study focuses on large (cm) single monazite crystals from five distinct localities in Norway, Madagascar, Srilanka, Zwaziland and Morefield. They have different chemical compositions, especially with regard to U, Th and Pb contents, and have ages ranging from ca. 500 to 1000 Ma. Nevertheless, all of them share the same petrographic features. Optical microscope and SEM images reveal variably intense fracturation. BSE imaging in the SEM indicates that monazite is composed of multiple phases: an unaltered monazite (Mnz1) + an altered monazite (Mnz2) associated with Th-rich phase (Thorium silicate or Thorium oxide) +/- Xenotime, depending on the initial composition of Mnz1. Analogous textures were already described by Seydoux-Guillaume et al. (2007) and Hetherington and Harlov (2008;). The alteration textures are always associated with radial cracks emanating from the high radioactive phase (Th-rich phase). The question addressed in the discussion is the role and the chronology of each process, i.e. irradiation vs coupled dissolution-precipitation. U-Th-Pb ages obtained by chemical dating on electron microprobe from altered and unaltered monazites show no significant differences. Therefore U-Pb dating using SIMS and LA-ICP-MS are in progress to determine precise isotopic age that would refine the alteration chronology. Finally, these results will be compared with experimental work, which are currently investigating the role of structural defects on coupled dissolution-precipitation in monazite.

Hetherington and Harlov (2008). Am. Mineral., 93, 806-820.
Seydoux-Guillaume et al. (2007). Eur. J. Mineral., 19, 7-14.