Preservation of He within bubbles in 915 Ma euxenite crystals from S Norway pegmatites

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In most rocks, uranium and thorium are concentrated in favorable crystallographic sites in few accessory minerals such as zircon. These minerals are submitted to intense self-irradiation that can lead to amorphization. Irradiation also modifies their host minerals. Here, we focus on euxenite [$(Ca,Fe,Y,REE,Th,U)\ (Ti,Nb)_2\ O_6$] crystals associated with zircon, monazite, and xenotime in rare-metal-rich pegmatites from southern Norway (Iveland-Evje) [1]. Swelling of euxenite crystals in response to radiation damage resulted in the development of a network of cracks in the rock. Euxenite crystals [10 wt% UO_2; 3 wt% ThO_2] are amorphous and partially altered into a silica-bearing [1 wt% SiO_2] euxenite and into pyrochlore, that attest to alteration at low temperature in the presence of a fluid phase. FIB preparation for TEM study performed within unaltered and altered euxenite domains, show distinct amorphous structures. The unaltered domains are densely and homogeneously speckled with both spherical nano-voids, a few nm to 50 nm in diameter, and U-rich nano-domains, 1-50 nm in range. STEM-EELS and EFTEM analyses prove for the first time that these voids are filled with Helium. Radiogenic He was formed by desintegration of U and Th and accumulated within euxenite crystals during 915 Ma ($3.44x10^{20}\alpha$/g, i.e. 2.3 mg/g He in euxenite). In the altered domains nano-voids are absent; in contrast, the presence of nano-pores acts for alteration by fluids. During alteration, He is mobilized by fluids and transferred into the rocks through cracks and grain boundaries. The coalescence and preservation of radiogenic He in bubbles demonstrates that He diffusion is non-uniform in such metamict structure. Diffusion depends on the structural state of the mineral; it may be enhanced by radiation damage but also slown down by the presence of bubbles that can act as trap for He atoms. Chemical alteration, on the contrary redistributes He, which may be incorporated in other minerals and completely disturb U-Th/He dating.

[1] Seydoux-Guillaume *et al*. (2015) *EPSL, **409***, 43-48.