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Mechanisms, Textures and Element Mobilisation During the Hydrothermal Mineral Replacement of Rhabdophane by Monazite

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Understanding the mobilities of U, Th and the rare-earth elements (REEs, La – Lu) in regolith is vital for modelling the formation of critical metal deposits and the supergene transport of radionuclides. Rhabdophane ($\mathit{REE}PO_4 \cdot 0.66H_2O$) and monazite ($\mathit{REE}PO_4$) are important REE ore minerals, geochronological markers and actinide-bearing mineral phases - though their relative hydrothermal stabilities are unconstrained. In this work, experiments were conducted at below 200°C to replace U and Th-bearing rhabdophane by monazite via a coupled dissolution-reprecipitation reaction. During replacement, microscopic rhabdophane textures such as bowtie morphologies (comprised of thousands of individual prisms) and spherulites (comprised of concentric bowties) are pseudomorphically preserved by the proximal re-precipitation of authigenic monazite prisms (*Figure. 1*). Nevertheless, the distinct morphologies of the monoclinic monazite, compared to the hexagonal rhabdophane prisms, infer that replacement is *not* pseudomorphic at the nanoscale. This is supported by X-ray diffraction data, where the rate of replacement increases with aqueous phosphate activity such that monazite precipitation is rate-limiting [1].

Results indicate how: 1) rhabdophane is a viable precursor to hydrothermal monazite below the temperatures required for the direct precipitation of monazite from solution (>200°C) [2] or for rhabdophane annealing (>500°C) [3], and; 2) this replacement can be both microscopically pseudomorphic *and* nanoscopically non-pseudomorphic. Secondary hydrothermal monazite may therefore be texturally identical and indistinguishable from rhabdophane in low temperature geological environments, given the complex nature of fine-grained rhabdophane-monazite intergrowths and the potential for microscopic pseudomorphism. When coupled with the potential of heterogenous REE, U and Th partitioning into the fluid and monazite during rhabdophane replacement [4], low-temperature hydrothermal monazite geochronology should be conducted with caution since the initial rhabdophane U-Th-Pb geochronometer may have undergone fluid-mediated alteration. Inferences of element mobility also indicate that subsequent stages of hydrothermal activity during the formation of critical REE deposits may fractionate the REEs following rhabdophane replacement.

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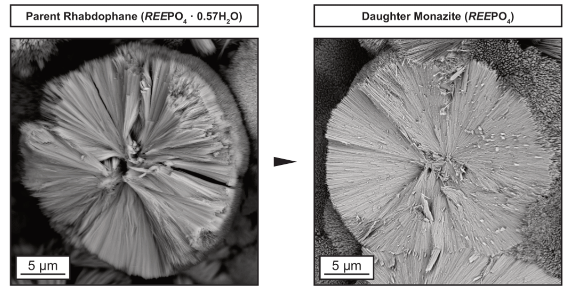

Figure 1: Spherulitic textures of acicular U-Th-bearing rhabdophane, comprised of concentric bowtie agglomerations that persist before (lhs) and after (rhs) hydrothermal replacement by monazite below 200°C. Though the spherulite textures themselves are preserved pseudomorphically during replacement, each of the individual REE-phosphate prisms undergo notable morphological evolution at the nanoscale.