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Clustering and interfacial segregation of radiogenic Pb in a mineral host-inclusion system: Tracing two-stage Pb and trace element mobility in monazite inclusions in rutile

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Abstract

Accessory minerals like zircon, rutile and monazite are routinely studied to inform about the timing and nature of geological processes. These studies are underpinned by our understanding of the transfer processes of trace elements and the assumption that the isotopic systems remain undisturbed. However, the presence of microstructures or Pb-bearing phases in minerals can lead to the alteration of the Pb isotopic composition. To gain insight into the relationship between Pb isotopic alterations from inclusions and microstructures, this study focused on inclusions from an ultra-high-temperature metamorphic rutile. The studied inclusions are submicrometer monazites, a common mineral rich in Pb but normally not present in rutile. The sample is sourced from Mt. Hardy, Napier Complex, East Antarctica, an ultra-high-temperature (UHT) metamorphic terrane. By applying correlative analytical techniques, including electron backscatter diffraction mapping, transmission electron microscopy (TEM), and atom probe tomography, it is shown that monazite inclusions are often in contact with low-angle boundaries and yield no preferred orientation. TEM analysis shows the monazite core has a mottled texture due to the presence of radiation damage and nanoclusters associated with the radiation damage defects that are rich in U, Pb, and Ca. Some monazites exhibit a core-rim structure. The rim yields clusters composed of Ca- and Li-phosphate that enclose Pb nanoclusters that are only present in small amounts compared to the core, with Pb likely diffused into the rutile-monazite interface. These textures are the result of two stages of Pb mobility. Initial Pb segregation was driven by volume diffusion during UHT metamorphism (2500 Ma). The second stage is a stress-induced recrystallization during exhumation, leading to recrystallization of the monazite rim and trace element transport. The isotopic signature of Pb trapped within the rutile-monazite interface constrains the timing of Pb mobility to ca. 550 Ma.

Keywords: Rutile, monazite, Pb mobility, atom probe tomography