



Nanoscale evidence of partial resetting of the U-Th-Pb systems in monazite due to anisotropic and incomplete replacement

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Evaluations on the possible resetting of geochronological systems during fluid rock interactions are crucial for correct geological reconstructions. Amongst the different minerals used as geochronometers, monazite is quite versatile because it is ubiquitous, data concordance can be controlled by three decay series, and composition/age can be measured concomitantly at a micro- to nanoscopic scale. In this experimental study, natural monazite crystals (Manangotry) were placed under alkali conditions at 400, 500 and 600°C, 200MPa, to clarify alteration mechanisms and their impact on the U-Th-Pb geochronological systems. Monazite experimental products show a replacement rim (altered domain), in which in-situ isotopic and EMP U-Th-Pb dating yields intermediate ages between the monazite standard (555 Ma) and complete experimental resetting (0 Ma). Nanoscale observations reveal that partial resetting is best explained by a nanomixture of primary (Mnz1) and secondary monazite (Mnz2) due to anisotropic replacement. At 400 °C (and 500 °C), altered domain corresponds to Mnz2 nanochannels and pore/inclusion of Si-rich amorphous material propagating through Mnz1. The anisotropic propagation of the reaction front is caused by preferentially oriented dissolution and/or fracturing at the reaction interface. At 600 °C, the Mnz2 component becomes more important in the altered domain, due to progressive textural and chemical equilibration. This leads to an apparently homogeneous rim of altered material with no pore/inclusion at the microscopic scale. However, the reaction front propagates anisotropically, in association with dislocations. As a result, Mnz1 relics can be found in altered domain apparently homogeneous at the microscopic scale. Another important feature is that secondary inclusions can occur in the core rather than in the rim of the monazite products.

Since no structural Pb or Pb nano-inclusions were observed, Pb measured in altered domains is attributed to the Mnz1 contribution. Composition of fluid and solid products indicate a fractionation of Th and U during monazite replacement that accounts for the difference in the Th-Pb and U-Pb ages. While forefront in-situ dating techniques have the spatial resolution to date mineral rims at a micrometer scale, they are unable to resolve a nanoscale mixture of pristine and secondary monazite that could occur particularly in samples altered at low geological temperature conditions.