

Deformed monazite yields high-temperature tectonic ages

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Erickson et al. (2015) base their study on microstructures indicating lattice deformation of monazite and link the microstructures with U-Th-Pb in-situ ages of the deformed monazite domains. This study integrating geochronology and microfabrics is crucial for dating high-temperature (HT) deformation events in metamorphic rocks. However, the article appears to be unclear about the role of dissolution and precipitation of monazite and its response to deformation. This may guide those who intend to apply monazite geochronology for dating synmetamorphic HT deformation into making some wrong conclusions.

Erickson et al. suggest that (1) their methodological approach would show for the first time that geochronological analyses of monazite can be used for dating HT-deformation “directly”; (2) earlier studies using U-Th-Pb ages of monazite for dating deformation, which are based on relating the textures of monazite to tectonic fabrics, would have given no more than “indirect” time constraints on HT deformation; and (3) dissolution precipitation would merely be a mechanism of resetting or disturbing the U-Th-Pb systematics at lower temperatures. We wish to make the following comments.

Erickson et al. consider crystal plastic processes of monazite as the only deformation mechanisms that completely reset U-Th-Pb ages, ideally providing precise time constraints of HT deformation. However, dissolution precipitation creep (DPC) is the prevalent deformation mechanism at high- and low-T involving monazite in the presence of a reactive fluid (e.g., Krohe and Wawrzenitz, 2000; Wintsch and Yi, 2002). Syndeformative monazite crystallized during DPC has already been successfully used for direct dating of HT rock deformation since the past decade: intergrain reactions of major phases that participate in DPC link the chemical composition of monazite formed through dissolution-precipitation reactions to deformation. Hence, combining geochronology with microfabrics and the reaction history of monazite allows for directly correlating monazite to a deformation episode in a metamorphic rock (e.g., Getty and Gromet, 1992; Williams et al., 2007; see review in Wawrzenitz et al., 2012, 2015). Though the so-formed monazite is internally strain-free (lacking dislocations, subgrains, or deformation twins), it is still a manifestation of mass transfer in the rock. It forms in strain shadows and strain caps. So its growth age directly dates the timing of rock deformation. Syn-DPC monazite precipitating along the finite extension direction can directly be correlated with the macroscopic lineation, and hence the map-scale deformation structures.

Erickson et al.’s monazite consists of pre-deformative grains recording lattice strain (intragranular misorientations, subgrain walls, and low-angle subgrain boundaries) as well as new grains showing high-angle grain boundaries with respect to the host grain (“isolated grain domains”; Erickson et al., 2015, their figure 2). The chemical compositions of host and new grains appear similar. The authors take this as evidence that “a strain energy” controls nucleation of the new grains and subsequent grain boundary migration being associated with Pb-loss. They argue that fluid-assisted dissolution-precipitation is unlikely attributed to Pb loss because “the rock has undergone granulite-facies metamorphism and, therefore, would have been fluid absent during mechanical reworking”. Though the investigated sample remained relatively dry, Buick et al. (2010) have

shown that, at the time of monazite recrystallization, the surrounding rocks experienced pervasive rehydration. Only a very small amount of water is sufficient to trigger dissolution precipitation reactions (Milke et al., 2013). Partially rehydrated (“dry”) high-grade rocks typically show only localized dissolution of preexisting, and re-precipitation of new, monazite as well as limited compositional alteration of new monazite formed at the expense of preexisting ones. The length scale of fluid transport/fluid-mineral interaction will be small (Wawrzenitz et al., 2015). Lattice deformation will increase the solubility of the old monazite.

Discriminating stress-controlled grain boundary migration recrystallization from grain growth through dissolution precipitation processes is not that easy. Either case will result in microfabrics described for the “isolated grain domain.” The lack of systematically increasing misorientations of crystal lattices from subgrain domains in the host into the “isolated grain domains” would rather favor the second interpretation.

Microstructures diagnostic for crystal plastic creep of monazite are rare and restricted to fluid-deficient rocks, as are the granulites presented by Erickson et al. The rate of dissolution precipitation processes is much faster than that of diffusion processes (Wintsch and Yi, 2002). Therefore, from the presented and preexisting data (Buick et al., 2010), an alternative scenario could as well be possible: monazite deforms in its transitional field from cataclastic to crystal plastic deformation. Localized failure is associated with lattice strain and recovery along fractures. Subsequently, along the fractures that served as fluid conduits, new monazite precipitates. Note that in this case, intracrystalline deformation of old, and precipitation of new, monazite might be temporally separated.

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