

Effects of high-temperature annealing and low-temperature metamictization on Archean zircon: Constraints from U-Pb isotopes, trace elements, and Raman dating

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ABSTRACT

Zircon is a common accessory mineral that can survive extreme temperature conditions in the crust, although U-Th series radioactive decay is responsible for its self-destruction over long timescales. Upon exhumation at lower temperatures, metamict zircon grains are then more susceptible to isotopic and trace element disturbance. In this work, we investigated the isotopic and trace element behavior of zircon through LA-ICP-MS, coupled with Raman spectroscopy, from two Archean mylonitic samples within the São José do Campestre Massif, northeastern Brazil. U-Pb in zircon dating indicates Paleoarchean (3.3 Ga) sedimentation followed by Mesoarchean (3.0–2.9 Ga) high temperature metamorphism in the mylonitic paragneiss sample, while the mylonitic amphibolite was emplaced during the late Neoarchean (2521 ± 22 Ma) and reached high-temperature conditions during shear zone development and deformation during the Paleoproterozoic (2.0 Ga). Inherited zircon grains in the amphibolite are consistent in morphology and ages with zircon grains from the host paragneiss. However, high-temperature annealing and structure recovery upon entrainment of inherited zircon grains in the hot mafic magma led to the homogenization of trace elements and preservation of internal textures. On the other hand, zircon grains from the host paragneiss accumulated radiation damage over a longer period, leading to the self-destruction of the crystalline structure. Upon later low-temperature fluid influx, non-formula elements were incorporated in metamict grains, as evidenced by the positive correlation between trace elements and radiation damage. Raman zircon dating indicates Cambrian to Late Paleozoic exhumation for these rocks, which agrees with U-Pb in zircon lower intercept ages. Although often avoided in geochronological studies, metamict zircon can provide important constraints on low-temperature events. Collectively, these observations reveal a complex trans-crustal history of zircon recycling and exhumation from the Paleoarchean to the Paleozoic, as well as the rock-dependent behavior of zircon in response to fluid flow and deformation. The results have implications for the interpretation of trace elements in naturally annealed zircon grains, especially those inherited in mafic rocks.

Keywords: U-Pb in zircon, Raman spectroscopy, Archean, Borborema Province