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Hafnium isotopes in zircon: Evidence for multiple episodes of iron oxide-apatite mineralization and fluid alteration

Peter M. Valley, Christopher M. Fisher, and John M. Hanchar
Memorial University, St. John's, Canada (pvalley@mun.ca)

The combination of hafnium (Hf) isotopes, trace element contents, and U/Pb ages in the same zircon domains, provides new information on the creation, evolution, and fluid alteration of Kiruna-type iron oxide-apatite deposits in the Lyon Mountain granite, Adirondack Mountains, New York. The Lyon Mountain granite is host to numerous zircon-bearing iron oxide-apatite deposits. Hafnium isotopic compositions and rare earth element contents in individual zircon crystals were measured in situ in both host granites and ore bodies by laser ablation-multicollector-inductively coupled plasma-mass spectrometry. Ore bodies that contain apatite with low contents of Lu have zircon with initial epsilon Hf (t) (e.g., less than +7) indistinguishable from those of the their host granite and are typical of relatively juvenile Proterozoic crust. Ore bodies that contain apatite with high Lu contents have zircon that are extremely radiogenic with respect to Hf and have initial epsilon Hf (t) values as high as + 40. The same zircon crystals analyzed for the Hf isotopic composition in this study were previously analyzed in situ for U-Th-Pb ages by ion-microprobe. These U-Th-Pb ages demonstrate that zircon from the ore bodies are 20 to 60 Ma younger than their respective granite hosts. Additionally, ore zircon are enriched in heavy rare earth elements compared to their granite hosts. Together, with field and petrographic evidence, these data suggest that early-formed ore bodies containing magnetite, low and high Lu apatite, and clinopyroxene were remobilized by secondary fluid alteration, which released Hf and Zr and rare earth elements. The breakdown of Lu rich apatite provides a mechanism to account for the highly radiogenic Hf isotopic compositions of some zircon. Zircon ages in the ore are contemporaneous with the emplacement of dikes that crosscut the regional fabric of the Adirondack Highlands leading to the possibility that fluids circulating during orogenic collapse of the Adirondack Highlands are responsible for secondary mineralization and remobilization of iron oxide-apatite deposits and the production of hydrothermal zircon.