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The origin of Ti-oxide minerals below and within the eastern Athabasca Basin, Canada

Erin E. Adlakha[1,2,*], Keiko Hattori[2], Mitchell J. Kerr[1], and Brandon M. Boucher[3]

[1]Department of Geology, Saint Mary's University, 923 Robie Street, Halifax, Nova Scotia B3H 3C3, Canada
[2]Department of Earth and Environmental Sciences, University of Ottawa, 25 Templeton Street, Ottawa, Ontario K1N 6N5, Canada
[3]Department of Earth Sciences, University of New Brunswick, 2 Bailey Drive, Fredericton, New Brunswick E3B 5A3, Canada

Abstract

Titanium oxide minerals along the P2 fault in the eastern Athabasca Basin are characterized to constrain their origin and the geological history of the area. Two types of rutile are recognized in the basement rocks. Early rutile is disseminated in graphitic metapelite and quartzite, and it formed during regional metamorphism and post-metamorphic hydrothermal activity. Late rutile occurs as a needle-like alteration product of mica and likely formed during retrogression of the basement. In graphitic metapelite, early rutile commonly occurs with an assemblage of oxy-dravite, quartz, graphite, zircon, pyrite, biotite, and muscovite. In quartzite, rutile occurs with quartz, sillimanite, muscovite, and zircon. Metamorphic rutile is characterized by high Nb/Ta ratios (up to 47) with high concentrations of U (up to 126 ppm) and V^{4+} (up to 1.44 wt%; V valance calculated from EPMA data). Hydrothermal rutile contains distinctly low Nb/Ta (as low as 4.80) with high Ta (≤3050 ppm), and relatively low V (as V^{3+}; as low as 0.02 wt%) and U (as low as 9.06 ppm), reflecting fluids in reduced oxidation conditions. Anatase forms small anhedral (rarely coarse and euhedral) grains in the basal sandstones and altered basement rocks. In sandstones, anatase occurs with the late diagenetic mineral assemblage, whereas in basement rocks it commonly occurs with the clay-sized minerals related to uranium mineralization. In both rocks, anatase likely formed through the dissolution of rutile and/or other Ti-bearing minerals. Anatase is characterized by variably high Fe (up to 0.99 wt%; possibly contributed by hematite micro- or nanoinclusions) and U (up to 180 ppm). The mineral assemblages and composition of anatase suggest its protracted crystallization from relatively low temperature, oxidizing, acidic, uraniferous fluids of the sandstones during late diagenesis and hydrothermal activity. Therefore, the occurrence of anatase records the incursion of basin fluids into the basement, and the interaction of basement rocks with fluids responsible for the formation of the McArthur River uranium deposit. The results of this study confirm that Ti-oxides are useful in unraveling the geological history of an area that underwent prolonged hydrothermal activity.

Keywords: Rutile, anatase, P2 fault, McArthur River, unconformity-type uranium deposits, alteration