Trace Element Variations in TiO_2 due to Polymorphism and Age: Implications for Rutile as a Pathfinder Mineral in Complex Terranes

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The trace element (W, V, Sn and Sb) composition of rutile (TiO_2 – $P4_2/mnm$) may reach ~2 wt % in some gold deposits (e.g., Hemlo Au deposit in Canada and Golden Mile Au deposit in Kalgoorlie Goldfields, WA) and has the potential to be used as a vectoring tool to discover mineralized ore systems. However, the common occurrence of other TiO_2 polymorphs—anatase ($I4_1/amd$) and brookite (Pbca)—has the potential to complicate the utilization of rutile in recognizing the distal footprints of ore deposits. Here we present a combined electron backscatter diffraction (EBSD) and petrochronology study of TiO_2 from the Capricorn orogen of Western Australia to document the distribution of trace elements within TiO_2 phases in a suite of samples containing different types and ages of TiO_2 polymorphs.

Eight samples from sedimentary (Mesoproterozoic Edmund Basin), metasedimentary, and igneous rocks (Archean to Proterozoic Gascoyne Province, western Capricorn orogen) were selected for analysis. Heavy mineral separates from the selected samples were obtained from the Geological Survey of Western Australia (GSWA). The textual relationships between TiO_2 minerals and the surrounding mineral phases were examined in thin section under optical microscope and SEM/EDS and the textures of separated grains were examined by EDS and EBSD. The different TiO_2 polymorphs were discriminated by differences in the electron backscatter diffraction patterns of the three polymorphs. Results show a complex distribution of TiO_2 polymorphs within individual samples and across the suite of samples. Rutile was the most common TiO_2 polymorph present, but a number of samples also contained anatase/rutile and anatase/brookite associations. The complex textural relationships include growth of anatase rims around rutile, formation of “porous” rutile textures typically associated with the growth of (101) twins, close association of anatase and chlorite alteration, intergrowth of rutile and chloritoid (most likely at the expense of biotite), as well as intergrowth of ilmenite and anatase.

Simultaneous measurement of trace element composition and the U-Pb isotopes within the suite of microstructurally quantified TiO_2 grains was undertaken on ~840 grains (4200 analyses) using the laser ablation split stream (LASS) method at UCSB (Kylander-Clark et al., 2013). Trace element compositions were found to be quite different between the different TiO_2 polymorphs, with Fe, Cr, and Sb showing the greatest variations. Furthermore, W, V, Nb, and Ta trace element concentrations in rutile in one of the samples increased with a decrease in age, thus providing a possible link between the timing and incorporation of certain trace elements in rutile crystal structure. This study shows that the use of trace element compositions in rutile as a pathfinder for ore deposits is compromised by the presence of different polymorphs as well as different ages of TiO_2 within individual samples and sample suites. However, the integration of EBSD and petrochronology provides a systematic methodology for the discrimination of these competing effects and highlights the importance of characterizing the texture, polymorph type, and chemistry in unaltered, altered, and mineralized bedrock prior to their use as potential pathfinder minerals.