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Fluid evolution recorded by alteration minerals along the P2 reverse fault and associated with the McArthur River U-deposit

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The basement rocks along the P2 fault are extensively altered, particularly where they host the McArthur River Zone 2 uranium ore body. Two generations of tourmaline occur along the P2: i) early, euhedral-subhedral, coarse-grain (>0.5 mm), dravite (Mg-tourmaline) forms wide (1-2 cm) veins and isolated grains, and ii) later fine-grain (<0.2 mm), radial magnesiofoitite (alkali-deficient dravite) forms veinlets (< 2 mm), overgrowths on earlier dravite, and is disseminated within fine-grain illite. Fe-clinochlore, coarse-grain illite, rutile and hematite are ubiquitous along the P2, and occur as pervasive replacement minerals or confined in veins, and post-date dravite.

Elemental peaks were carefully monitored during trace element analysis (LA-ICPMS) to ensure minerals were free of inclusions. Dravite $[(\square_{0.4}Na_{0.6})(\square_{0.2}Mg_{1.9}Fe_{0.5}Ca_{0.2}Ti_{0.2})(Al_{5.9}Fe_{0.1})(Si_{5.7}Al_{0.3}O_{18})(BO_3)_3(OH_{3.8}F_{0.2})]$ contains 1.24 (± 0.09, 1σ) wt% TiO_2, 89 – 280 ppm Zn, 51 - 630 ppm Cr, 190 - 1500 ppm V, and ranges 98 – 11000 atomic F/Cl. Magnesiofoitite $[(\square_{0.7}K_{0.1}Na_{0.2})(\square_{0.4}Fe_{0.1}Mg_{2.0}Al_{0.5})Al_6(Al_{0.1}Si_{5.9}O_{18})(BO_3)_3(F_{0.02}OH_{3.98})]$ contains 65 – 260 ppm V, 2.9 - 110 ppm Cr, 0.2 – 3.7 ppm U, and 0.2 – 34 ppm Th, and ranges 3.2 - 80 atomic F/Cl. Dravite and magnesiofoitite contain low Li (< 12 ppm) and high Ni (1 – 28 ppm; 13 – 250 ppm); however, they also have contrasting trace element behaviours: dravite is enriched in LREE relative to HREE, $([Ce]_N/[Ce]^*_N) > 1$, and has a positive Eu anomaly, whereas, magnesiotite is enriched in HREE relative to LREE, $([Ce]_N/[Ce]^*_N) < 1$, and has a negative Eu anamoly. Chlorite $[(Fe_{1.9}Mg_{2.6}Al_{1.4})(Si_{2.7}Al_{1.3}O_{10})(OH)_8]$ contains significant Li (40 - 669 ppm), and Mn (803 – 4083 ppm); illite $[(K_{0.9})(Al_{1.8}Mg_{0.1}Fe_{0.1})(Si_{3.2}Al_{0.8}O_{10})(OH)_2]$ contains significant B (17 – 250 ppm), Li (<4.9 – 144 ppm), Ti (36 – 14500 ppm), Rb (343 - 692 ppm), U (<0.01 – 0.6 ppm), Sn (1.2 – 148 ppm), and Ba (78 – 1670 ppm); and both minerals show atomic F/Cl ratios > 10. High F/Cl, U, Th and B, and a negative Eu anomaly in late alteration phases suggests a contribution of pegmatite to the fluid.