

# Composition and U-Th-Pb Chemical Ages of Uranium and Thorium Mineralization at Fraser Lakes, northern Saskatchewan, Canada

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## Summary

The Fraser Lakes uranium and thorium showings are located immediately southeast of the Athabasca Basin, Saskatchewan. The mineralized granitic pegmatites/leucogranites occur within the contact zone between Wollaston Group metasediments and underlying Archean orthogneisses, and are interpreted to outcrop ~200m below the eroded, uplifted paleo-unconformity with overlying Athabasca Group sandstones. They are composed mainly of quartz, feldspars, and biotite, with subordinate amounts of apatite, monazite, allanite, U-rich zircon, uraninite-uranothorite-thorite, and ilmenite. Some uraninite grains are zoned. Uraninite alteration is greatest along grain boundaries and fractures with significant U loss and Pb gain/loss. U-Th-Pb chemical age dating of the uraninite grains yielded a crystallization age of  $1770 \pm 90$  Ma (i.e. the pegmatite age) and some younger age clusters. These younger ages correlate to U-mineralization events documented for unconformity-type uranium deposits in the Athabasca Basin. Post-Athabasca alteration of these granitic pegmatites may have provided some additional U for unconformity-type uranium mineralization.

## Introduction

The Fraser Lakes Zones A and B are located in northern Saskatchewan on the Way Lake Property, owned by JNR Resources Inc., and located approximately 55 km east of the Key Lake uranium mine (Fig. 1). Zone B contains significant U and Th mineralization accompanied by rare earth element (REE) and pathfinder element enrichment. The purpose of this research study is to determine the composition and U-Th-Pb chemical ages of uranium and thorium mineralization of the Fraser Lakes Zone B granitic pegmatites and leucogranites in order to further the understanding of this type of mineralization and its relationship to the high-grade unconformity-type uranium deposits of the Athabasca Basin.

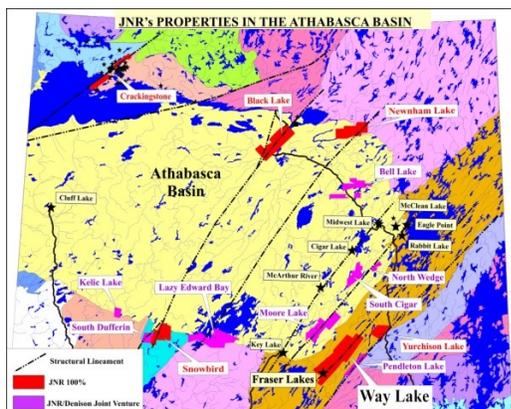


Fig. 1. Geological subdivisions of northern Saskatchewan, with the location of important uranium deposits, and JNR Resources Inc. properties, including Way Lake (JNR Resources Inc., 2009)

## Local Geology

The Fraser Lakes area is underlain by strongly deformed Paleoproterozoic Wollaston Group metasedimentary rocks and Archean orthogneisses of the eastern Wollaston Domain (Annesley et al., 2005, 2009). Zones A and B, the two mineralized zones, are located in regional fold noses adjacent to a 5 km long section of a refolded 65 km long electromagnetic (EM) conductor (i.e. graphitic pelitic gneisses). The granitic pegmatites and leucogranites intruded into and were transported in part as crustal melts within the folded, protomylonitic to mylonitic contact zone between the Wollaston Group metasediments and the underlying orthogneisses.

Zone B sits within a NE-plunging antiformal fold nose, and is cross-cut by a number of NE- and NW- trending brittle faults, which probably provided dilation zones for fluid flow at the now eroded Athabasca/basement unconformity (~200 - 250m above the present-day outcrop surfaces; Annesley et al., 2009).

Regional metamorphism of upper amphibolite to lower granulite facies accompanying deformation in the area was related to the Trans-Hudson Orogen (~1.8 Ga). The low to high-P, high-T metamorphic conditions led to partial melting of the Wollaston Group metasediments and migmatite formation in the middle to lower crust, and the generation of the granitic pegmatites and leucogranites of strongly peraluminous to metaluminous composition. Field contact relationships indicate that granitic pegmatite intrusions were syn-tectonic (mineralized and concordant to gneissosity) to post-tectonic (non-mineralized, discordant) with respect to the fabrics developed during the Trans-Hudson Orogen (Austman et al., 2009).

## Petrography

The granitic pegmatites and leucogranites are fine- to very coarse-grained, massive to foliated to sheared, and essentially unaltered to moderately altered. They are composed mainly of quartz, grey to pink feldspar, and biotite, with subordinate amounts of apatite, monazite, allanite, zircon, uraninite- uranothorite-thorite, and ilmenite with trace pyrite, molybdenite, sphalerite, and rare chalcopyrite. Petrographic and SEM observations revealed that uraninite- uranothorite-thorite, allanite, monazite, and U-rich zircon are the dominant uranium-bearing accessory minerals in the granitic pegmatites and leucogranites. Some uraninite grains are zoned.

## Uraninite Composition and U-Th-Pb Chemical Ages

Uraninite crystals from a representative uranium- and thorium-rich granitic pegmatite in drill hole WYL-09-50 were analyzed for U, Th, and Pb using a Cameca SX-100 microprobe at the Saskatchewan Research Council. Additional microprobe analysis, including more precise ion microprobe work, will be carried out on this and other mineralized co-magmatic samples.

All grains show varying degrees of inhomogeneity related to fracturing, alteration, and in particular core-rim compositional zoning (see Finch and Ewing, 1982, for characteristics of uraninite corrosion). The inner pristine parts of the uraninite grains have  $\text{UO}_2$ ,  $\text{ThO}_2$ , and  $\text{PbO}$  concentrations of 56.29-64.29 wt%, 6.46-8.65 wt% and 14.85-18.40 wt%, respectively. The high  $\text{ThO}_2$  values are characteristic of magmatic uraninites, reported elsewhere in strongly peraluminous to metaluminous granites from Germany (Forster, 1998, 1999) and France (Cuney and Freidrich, 1987; Freidrich et al., 1987), and within leucogranites and granitic pegmatites beneath the Athabasca Basin (Annesley and Madore, 1999; Hecht and Cuney, 2000; Madore et al., 2000; Mercadier et al., 2008; among others). The rare earth elements, represented by analyzes of  $\text{Ce}_2\text{O}_3$  and  $\text{Dy}_2\text{O}_3$ , are present at the 1000s of ppm level. Yttrium (as  $\text{Y}_2\text{O}_3$ ), is present at the 2.00-4.00 wt% level. Calcium concentrations are highly variable at the tenths of a wt% level. Titanium, P, and V contents vary from <0.01 to 0.55 wt%. The altered parts of the uraninite grains show loss of U and either Pb gain or loss, accompanying silica-calcium enrichment.

Single-point chemical ages were calculated using the methodology of Bowles (1990); a rigorous iterative method that produces a best fit between measured Pb and calculated Pb concentrations. Uraninites with greater than 50 wt%  $\text{UO}_2$  yielded ages of 1840 to 1485 Ma. The older group of ages, 1840 to 1759 ( $\pm 90$  Ma) Ma from the least altered uraninite, is interpreted as an approximate age of crystallization, and probably the age of granitic pegmatite emplacement. Younger age clusters down to 1485 Ma indicate times when that the uraninite grains started experiencing disturbances of their U-Th-Pb chemical/isotopic system.

## Discussion and Conclusions

Unconformity-related uranium deposition in the Athabasca basin was focused at the interface between a thick, Paleo to Meso-Proterozoic sandstone cover and an Archean to Paleoproterozoic crystalline basement, where graphite-rich faults were reactivated. The debate is still open between whether uranium was extracted solely from the basin (e.g. Fayek et al. 2002) or the U-rich metamorphic/plutonic basement complex was the dominant source (e.g. Annesley and Madore, 1999; Hecht and Cuney 2000; Madore et al. 2000).

Our study adds to the research of Annesley and Madore (1999), Hecht and Cuney (2000), and Annesley et al. (2000) by demonstrating weak to locally moderate mobilization of uranium from weakly altered, variably fractured granitic pegmatites and leucogranites. SEM and microprobe results show that uraninite alteration is greatest along grain boundaries and fractures, with significant U loss and Pb gain/loss. The preliminary fluid inclusion work of Hecht and Cuney (2000) and the recent extensive research of Mercadier et al. (2008, 2009) confirms the circulation of brines in these hydrothermally altered basement rocks, even to depths >250 meters beneath the unconformity. The mobilization and redistribution are marked by the replacement of monazite by a Th-silicate phase with concurrent liberation of approximately 75% of the U, P, and LREE. This monazite ( $\pm$ uraninite) alteration by brines provides an attractive mechanism for releasing uranium. The U-Th-Pb chemical age dates from the freshest (i.e. old) uraninite grains indicate a primary magmatic crystallization age of ca. 1770  $\pm$ 90 Ma. The younger chemical ages along grain boundaries and fractures imply that uraninite started experiencing disturbances of their U-Th-Pb chemical/isotopic system. These younger ages correlate with isotopic disturbance to the Stage 1 and Stage 2 U-mineralization events of Fayek and Kyser (1997). We conclude that relatively fresh uraninite-bearing granitic pegmatites from the Fraser Lakes area record both 1) the age of pegmatite emplacement and 2) the younger ages of Stage 1 and Stage 2 U-mineralization events in the nearby basin. We also suggest that post-Athabasca alteration of these pegmatites may have provided some additional U for unconformity-type uranium mineralization in the Fraser Lakes area. Drill hole observations and geophysical logging from nearby, highly altered granitic pegmatites and leucogranites indicate that significant mobilization/redistribution of uranium may have occurred.

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