

Carbon-sulfur-metal-rich Graphitic Pelitic Gneisses from the Fraser Lakes Zone B Deposit Area, Saskatchewan, Canada: Implications for Metal Source(s)

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Abstract. The U-Th-REE mineralization at Fraser Lakes Zone B is hosted by ~1800 Ma granitic pegmatite/leucogranite sheets intruding the tectonic decollement between basal Paleoproterozoic Wollaston Group pelitic (+/-graphitic, +/-sulfides) gneisses and underlying Archean granitoid orthogneisses. These carbon-sulfur-metal-rich pelitic gneisses are inferred to be metamorphosed (in part highly metalliferous) black shales deposited in a continental margin marine environment. Major, trace element, and REE geochemistry of these gneisses is highly variable, but still reflects original sedimentary facies variations of metal content and constrains original paleoredox conditions. Besides their structural role in the location of the mineralization, they are probably also the source of many of the elements present in unconformity-type deposits (e.g. U, Ni, Cu, Mo, and V) and of the possible reductants.

Keywords. Graphitic pelitic gneisses, carbon-sulfur-metal-rich, metal source, U deposits, Fraser Lakes area

1 Introduction

The Athabasca Basin of northern Saskatchewan hosts the world's most prolific high-grade uranium deposits. These unconformity-type (U/C-type) deposits occur mainly at (classical U/C-type), below (basement-hosted), and above (perched) the interface between the basin and its underlying crystalline basement complex (Thomas et al. 2000; [Annesley et al. 2005](#); [Jefferson et al. 2007](#); [Kyser and Cunev 2009](#); among others).

The genetic model(s) for this deposit type is (are) overall well established (Jefferson et al. 2007; [Cuney 2009](#); [Kyser and Cuney 2009](#); and references therein). However, several outstanding questions remain; including what is the source(s) of uranium and associated metals for these polymetallic deposits.

Systematic drilling programs made in the Fraser Lakes area (Fig. 1) by JNR Resources Inc. from 2008 through 2011 discovered new uranium deposits; Fraser Lakes Zone A and Zone B. This drilling also identified numerous Cu, Mo, Ni, Pb, Zn, and V anomalies.

Detailed core logging and sampling, in conjunction with follow-up petrographic and geochemical studies, revealed that carbon-sulfur-metal-rich graphitic pelitic gneisses and associated meta-sediments of the basal Paleoproterozoic Wollaston Group are the source of the metal anomalies.

This short paper summarizes the results of a detailed study of C-S-metal-rich graphitic pelitic gneisses from the Fraser Lakes area.

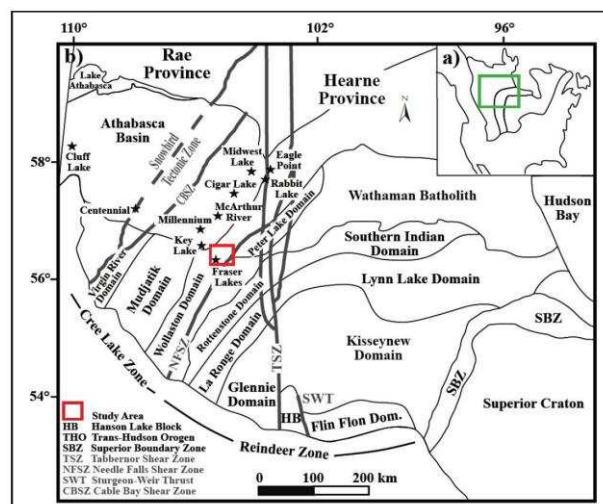


Figure 1. Regional geological setting: **a)** Map of North America, showing the Archean Hearne-Rae and Superior cratons, welded by the Paleoproterozoic Trans-Hudson Orogeny. The location of Figure 1b is denoted by the green box. **b)** Lithotectonic domains within northern Saskatchewan and Manitoba, showing the location of several unconformity-type uranium deposits within the eastern and central Athabasca Basin. The location of Figure 2 is shown by the red box; figure modified after Annesley et al. (2005).

2 Regional Geological Setting

Fraser Lakes Zone B is located ~20-25 km southeast of

the Athabasca Basin within the eastern Wollaston Domain, Hearne Province, Canada (Fig. 1). The Hearne Province, formerly known as the Cree Lake Zone (Lewry and Sibbald 1980), is comprised of the northeast-trending Peter Lake, Wollaston, Mudjatik, and Virgin River domains (Annesley et al. 2005; Jefferson et al. 2007). The basement lithologies include Archean orthogneisses, Paleoproterozoic pelitic to psammitic gneisses/schists, and mafic to felsic intrusions of Hudsonian age, that all were metamorphosed during the ca. 1.9-1.7 Ga Trans-Hudson orogeny on the eastern side of the Athabasca Basin (Chiarenzelli et al., 1998; Annesley et al. 2005). Many of the unconformity-type uranium deposits within the eastern Athabasca Basin are hosted within or in the vicinity of the Wollaston-Mudjatik transition zone (WMTZ) (Annesley et al., 2005).

3 Fraser Lakes U-Th-REE Deposit

The Fraser Lakes area is underlain by Archean and Paleoproterozoic rocks of the eastern Wollaston Domain (Figs. 1 and 2). The Fraser Lakes area offers fair to good outcrop exposures of the various Archean and Paleoproterozoic lithological units, including the mineralized granitic pegmatites and leucogranites. No Athabasca sandstones are present in the immediate study area (~25 km to NW – see Fig. 2). Most of the geological structures are known from outcrops, drilling, airborne geophysics, and/or satellite imagery (Figs. 2, 3, 4, 5; for details refer to Annesley et al. 2009, 2010; McKechnie et al. 2012, 2013).

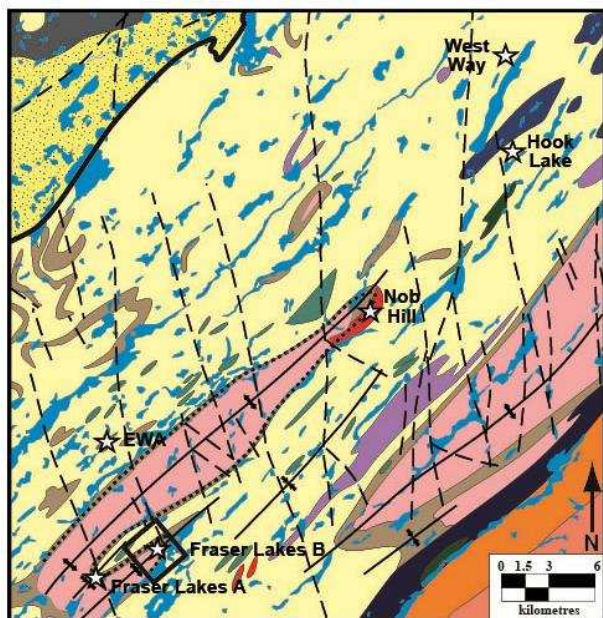


Figure 2. Regional geological map of the Fraser Lakes and surrounding area, after McKechnie et al. (2012, 2013) and modified from Ray (1980).

Fraser Lakes Zone B occurs immediately west of Fraser Lakes, and is located within a highly tectonized contact between Archean granitoids and the overlying basal Wollaston Group metal-rich pelitic metasediments (Fig. 2). This tectonized contact/shear zone is folded around Archean granitic domes, and is thickest within the NE-plunging antiformal noses (Figs. 2 and 3). There are multiple generations of granitic pegmatites: 1) the mineralized pegmatites are usually syntectonic and older, and 2) the non-mineralized pegmatites are typically late-tectonic and younger. U-Pb age dating of magmatic uraninite returned ages ranging from 1850-1780 Ma for mineralized granitic pegmatites (Annesley et al. 2010, McKechnie et al. 2012, Mercadier et al. 2013).

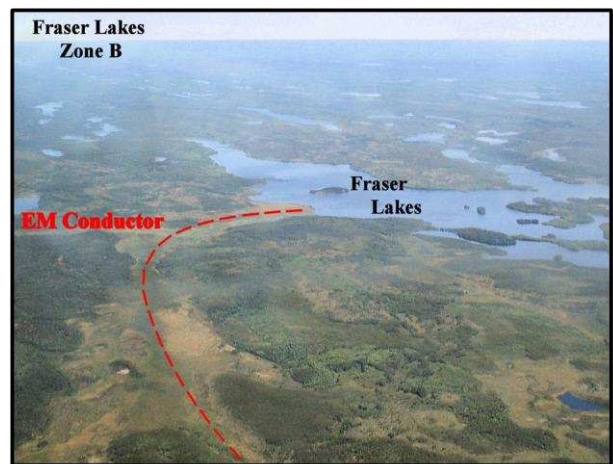


Figure 3. Photo from airplane that shows the immediate Fraser Lakes area, with folded C-S-metal-rich electromagnetic (EM) conductor/mineralized zone; looking northeast.

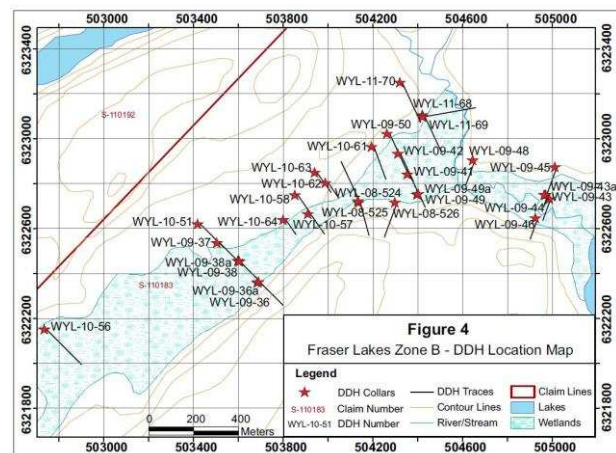


Figure 4. DDH Location Map for Fraser Lakes Zone B, from Armitage and Sexton (2012).

The U-Th-REE mineralized granitic pegmatites at Zone B occur in a NE-plunging antiformal fold nose cut by an E-W dextral ductile-brittle cross-structure and younger NNW-trending and NNE-trending brittle faults. McKechnie et al. (2012, 2013) sub-divided the mineralized pegmatites into two groups on the basis of their U, Th, and REE contents and relative position within the fold nose: U-rich Group A intrusives and Th-REE-rich Group B intrusives.

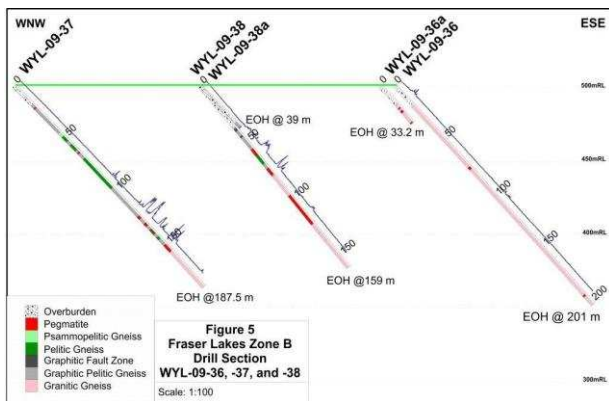


Figure 5. DDH X-section for drill holes WYL-09-36, -36A, -37, and -38, with a 20 to 30 meter-thick metal-rich graphitic package at the Archean/Paleoproterozoic tectonic contact (from Annesley et al 2010). Note the downhole radiometric profiles with elevated values within mainly the U-rich granitic pegmatites. EOH designates end of drill hole.

4 Petrography

In the greater Fraser Lakes area, the Wollaston Group consists of a number of lithological units (Fig. 2). However within the immediate study area, it is composed mainly of pelitic gneisses that can be subdivided into non-graphitic and graphitic sulfide-rich varieties; the latter being the focus of this study.

The graphitic pelitic gneisses are typically porphyroblastic (garnet and/or cordierite and/or sillimanite), and the grain size ranges from very fine to medium grained, locally coarse-grained, with an average size of <2 mm. These gneisses are comprised mostly of quartz, plagioclase, K-feldspar, biotite, and ubiquitous graphite (up to a maximum of 10–15% modally) with/without abundant sulfides. They also contain varied amounts of inclusion-rich cordierite porphyroblasts, sillimanite bundles, garnet porphyroblasts, pyrite, chalcopyrite, sphalerite, galena, ilmenite, and rutile. Accessory minerals include zircon, apatite, monazite, titanite, and uraninite. The graphitic gneisses are overall quite heterogeneous in composition and generally interlayered with the non-graphitic pelitic gneisses,

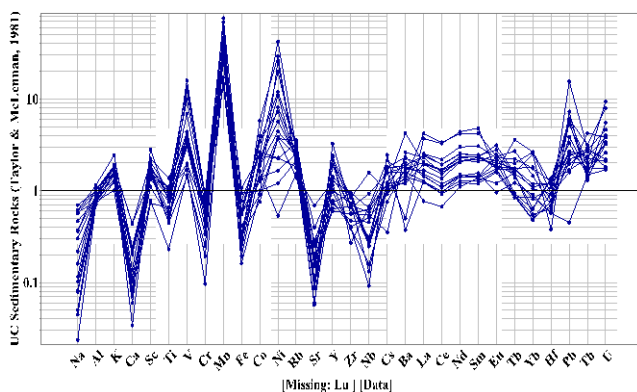


Figure 6. Spiderplot for representative C-S-metal-rich samples from DDHs WYL-09-037, WYL-09-038, and WYL-08-512; normalized to average upper crust for sedimentary rocks of Taylor and McLennan (1981). Enrichments are noted for K, Sc, V, Mn, Co, Ni, Rb, Y, Ba, REES, Pb, Th, and U.

especially near the tectonic contact with the underlying Archean orthogneisses, which is where most of the mineralized pegmatites have been emplaced. Two main alteration assemblages are recognized in the basal rock package: 1) an early, retrograde assemblage of chlorite, muscovite, leucoxene, clay minerals, and epidote, and 2) a late, fracture-related/controlled assemblage of hematite, chlorite, and clay minerals.

5 Whole-rock Geochemistry

The graphitic pelitic gneiss samples from both split core (0.5 meter interval composites) and individual spot samples display extreme variation in chemical composition, with SiO_2 ranging from 35.0 wt. % to 65.0 wt. %, and Al_2O_3 from 10.5 wt. % to 22.0 wt. %. This compositional variation reflects their mineralogical variation. The samples with the lowest SiO_2 content (<40 wt. %) also have the highest Fe_2O_3 tot with high K_2O content; indicating they are biotite-rich. The range in major-element compositions is similar to that presented by Tran et al. (2003) in their study of metasedimentary rocks from other parts of the Wollaston Domain.

The samples of graphite-bearing pelitic gneisses from both split cores and individual spot samples show highly variable C and S contents, ranging from 0.5 to 7.5 and 0.2 to 16.0 wt%, respectively, with varied metal concentrations. However, the highest Ni (2600 ppm), Cu (1500 ppm), Mo (1740 ppm), Zn (943 ppm), and Co (137 ppm) are in the most S-rich (i.e. sulfidic) rocks; whereas the highest Cr (259 ppm) and V (815 ppm) are in the most Fe-rich rocks. Uranium (up to 100 ppm) and Th (up to 557 ppm) are enriched relative to the North American Shale Composite (NASC) with values of 2.66 ppm U and 12.30 ppm Th. The abundances of Co, Cr, La, Ni, Th, U, V, and Zn are comparable to, but much higher than, those of post-Archean shale. When normalized and compared to the average values of upper sedimentary crust and to upper crust, we observe highly anomalous values, respectively, for K, Sc, V, Mn, Co, Ni, Rb, Y, Ba, REES, Pb, Th, and U (Fig. 6), and for Rb, Ba, Th, U, K, and REES (Fig. 7).

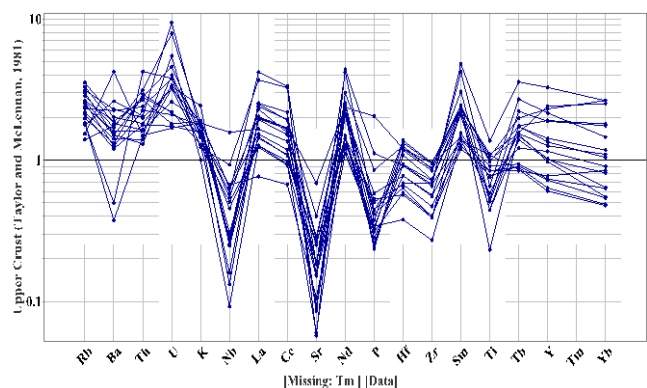


Figure 7. Spiderplot for representative C-S-metal-rich samples from DDHs WYL-09-037, WYL-09-038, and WYL-08-512; normalized to upper crustal values of Taylor and McLennan (1981). Enrichments are noted for Rb, Ba, Th, U, K, and REES.

6 Summary and Conclusions

After assessing element mobility, we conclude the wide range of chemical variation in the fresh graphitic pelitic gneisses reflects original sedimentary facies variations of metal content and constrains original paleoredox conditions. The authors opine that pre-Athabasca basal Wollaston Group graphitic pelitic gneisses have not only a strong structural control on the localization of the uranium deposits (Thomas et al. 2000, Annesley et al. 2005, Jefferson et al. 2007), but also their large metal enrichments represent the most likely metal source for many of the metals found within the U/C-type uranium deposits and they may also represent a source of reductants (carbon and sulfur species, NH₄⁺ liberated from the alteration of the K-micas (Pascal et al. 2015).

These gneisses also contain significant amounts of U, Th, and REE. Low-batch melting of these gneisses can explain quite well the metal endowment of the magmatic U-Th-REE deposit at Fraser Lakes Zone B; making this zone both potential economic ore (i.e. Hudsonian-age mineralization) and potential source rock for the Mesoproterozoic U/C-type uranium deposits of the Athabasca Basin.

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