

A multifaceted investigation of the critical mineral systems of the Canadian Shield of northeastern Alberta

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Summary

The Alberta Geological Survey (AGS) carried out a multidisciplinary study of the critical mineral potential of the Canadian Shield in Alberta in the summer of 2023. This work included satellite-based multispectral analysis of bedrock (Rivard, 2023; Chowdhury and Kelly, 2024a), geochemical analysis of historical bedrock samples (Meek et al., 2023), and 1:20,000 scale geological mapping and sampling (Belosevic et al., 2024) with collection of in-situ spectral measurements (Chowdhury and Kelly, 2024b). Numerous historical mineral occurrences were re-examined to better understand the critical mineral systems present. These studies focused on the Leland Lakes and Andrew Lake regions of northeastern Alberta (Figure 1). The local geology of the study area consists of basement quartzofeldspathic gneisses and subordinate amphibolite bands belonging to the Archean to Paleoproterozoic Taltson basement complex (TBC) and high-grade packages of metasedimentary rocks belonging to the Paleoproterozoic Rutledge River complex (RRC). These basement units were intruded and reworked by various suites of granitoid plutons of the Taltson magmatic zone (TMZ) between ca. 1.99 and 1.92 Ga. The TBC and RRC experienced amphibolite- to granulite facies peak metamorphic conditions and coeval deformation that produced an initial phase of isoclinal folding and generation of a strong regional foliation. This was followed by contemporaneous intrusion of TMZ plutons and deformation associated with the Taltson orogeny that reoriented these structures into a NNE-SSW orientation. Results from field mapping indicate that the basement gneisses of the Leland Lakes area are more widespread than previously understood. Results of geochemical analysis suggest that the TBC has potential to host igneous rare-earth element (REE) mineralization. In the Andrew Lake area, abyssal-style pegmatites sourced from the TBC show strong enrichment in light REEs and occur in similar tectonic settings as those found in the Alces Lake area of northwestern Saskatchewan. Additionally, S-type granitoids belonging to the Slave granitoid batholith display promising geochemical fractionation indicators such as low Mg/Li and Nb/Ta ratios as well as proximity to major regional structures that provide both the source and mechanism for transport of LCT pegmatitic melts. Anomalous uranium concentrations were identified in leucogranites and pegmatites associated with shear zones near Spider and Cherry Lakes, south of Andrew Lake.

Theory / Method / Workflow

Geological fieldwork took place over four weeks and was completed by AGS staff and several geological consultants (Belosevic et al., 2024). Traverses were planned prior to the field season using publicly available aerial imagery, public and privately available digital elevation models (e.g. NASA JPL, 2013), compiled geological maps (Godfrey 1961, 1963, 1966; Godfrey and Langenberg, 1986) geochemical data from historical samples (Meek et al., 2023), historical mineral occurrences (Lopez et al., 2020), and recently acquired high-resolution aeromagnetic data (Alberta Geological Survey, 2023). A total of 394 stations were visited by the AGS where outcrops were described and sampled to assess their geological and geochemical characteristics. Representative hand samples were collected via geological hammers and channel saws. Additional information was collected including magnetic susceptibility measurements, gamma-ray spectra, and hyperspectral absorption features.

Results, Observations, Conclusions

REE-bearing pegmatites identified in the Andrew Lake area were generated under mid- to high-grade metamorphic conditions and occur as pods, boudins and dykes emplaced along structurally controlled zones. These pegmatites have geochemical signatures that place them within the abyssal subclass of mineralized pegmatites after Černý and Ercit (2005), with elevated LREE's, uranium, thorium and titanium. These polyphase pegmatites are characterized by strongly enriched LREE's, fractionated HREE's, and strongly negative europium anomalies. These geochemical signatures are remarkably similar to a suite of granitic gneisses in the area that have an emplacement age of 2.3 Ga (McNicoll et al., 2000). Regional metamorphic events including the Arrowsmith orogeny and Taltson orogeny may have played a crucial role in generating repeated partial melting and remobilization along structural conduits. Bedrock geochemical REE results are available in Figure 2.

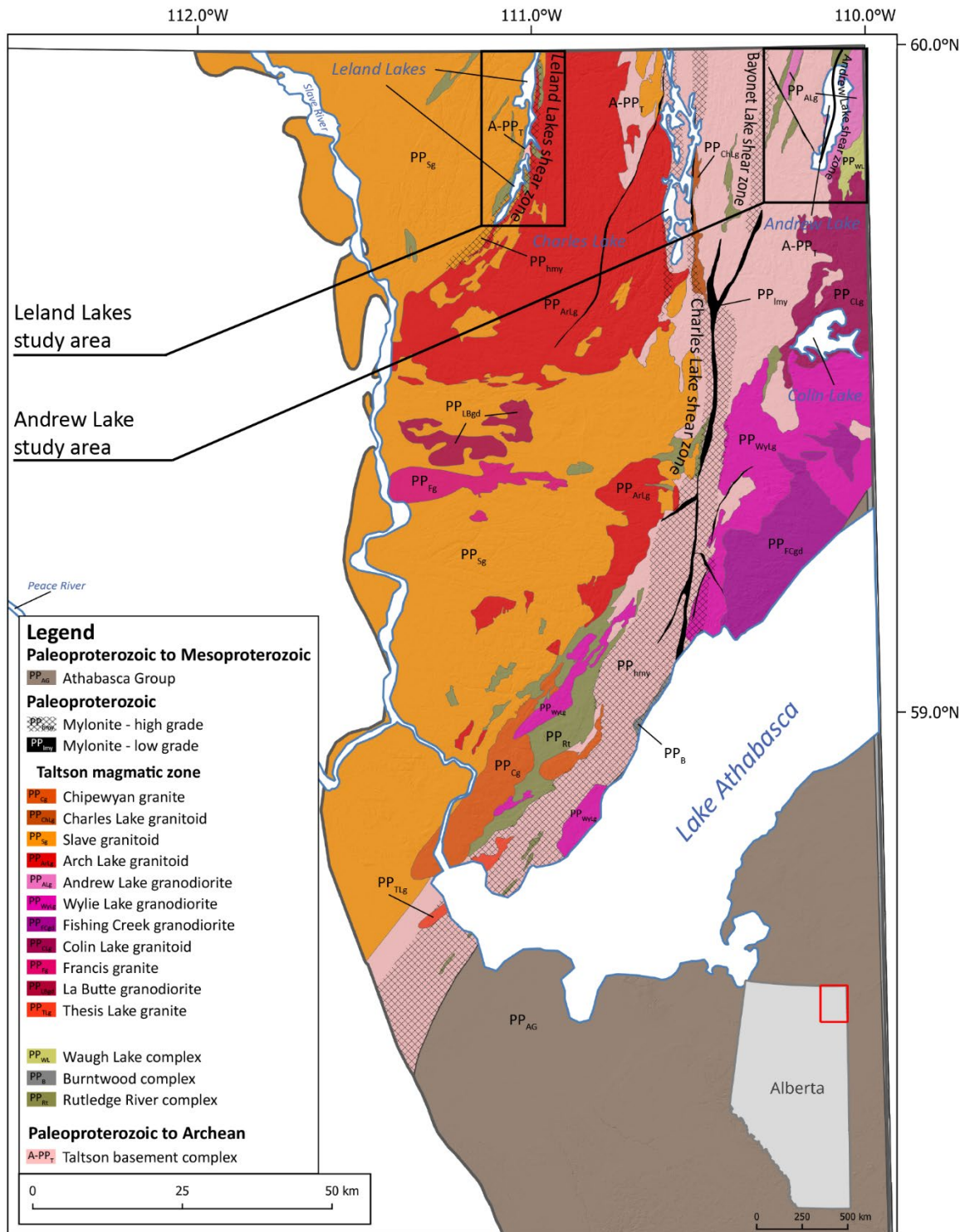


Figure 1. Simplified geological map adapted from Belosevic et al. (2024) with bedrock geology from Godfrey (1986) and Prior et al. (2013).

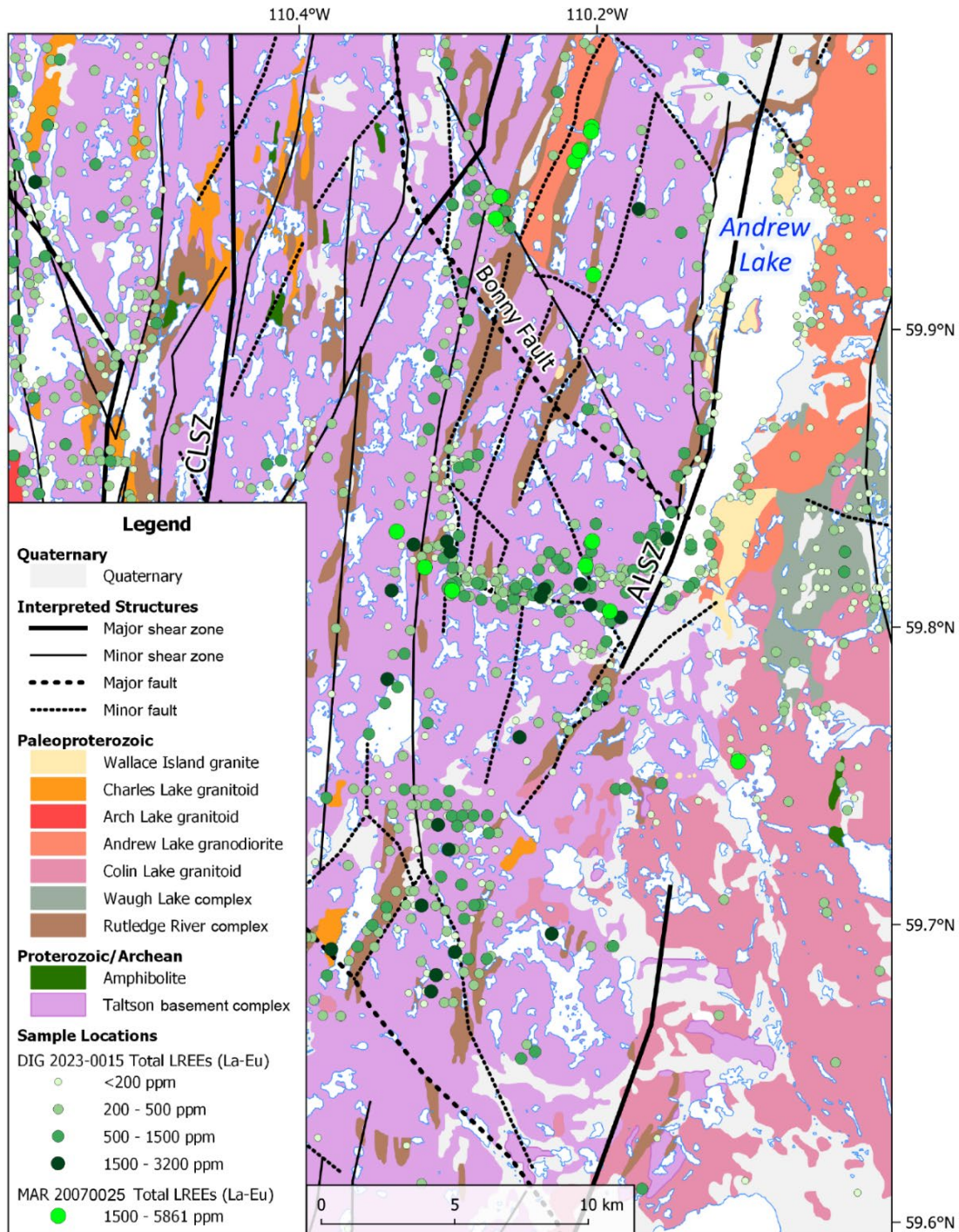


Figure 2. Total LREE (ppm) from samples analyzed in the Andrew Lake area, with bedrock geology from Paná (2010), interpreted structures from Lopez et al. (2024), and geochemistry from Meek et al. (2023) and Smith and Griffith (2007). ALSZ = Andrew Lake Shear Zone; CLSZ = Charles Lake Shear Zone.

The Slave granitoid batholith found west of the Leland Lakes shear zone displays a variety of geochemical indicators that indicate favourable conditions conducive for genesis of the lithium-cesium-tantalum (LCT) subclass of granitic pegmatites. Favourable fractionation indicators include low Mg/Li, Nb/Ta and K/Rb ratios (Černý, 1989; Selway et al., 2005), particularly towards the eastern margin of the Slave granitoid (Figure 3). Additionally, the fertility of the Slave granitoid is emphasized due to its peraluminous character and average whole-rock lithium content of 75 ppm which is well above the average upper continental crust concentration of 20 ppm (McLennan, 2001).

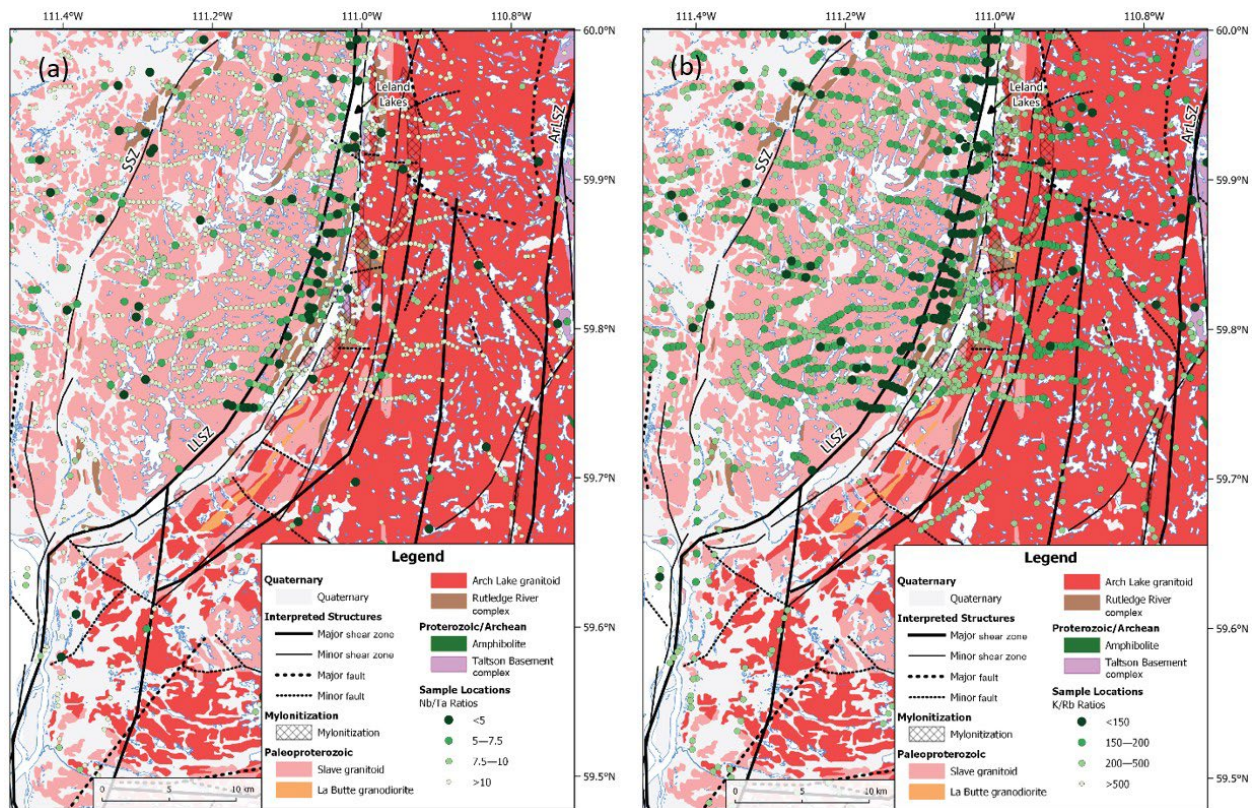


Figure 3 - Granite fertility fractionation indicators in the Slave granitoid with bedrock geology from Paná (2010), interpreted structures from Lopez et al. (2024), and geochemistry from Meek et al. (2023). (A) Nb/Ta ratios, with notably low values localized along the eastern margin of the pluton, along the LLSZ; (B) K/Rb ratios showing a concentration of low values similarly localized along the LLSZ. SSZ = Slave Shear Zone; LLSZ = Leland Lakes Shear Zone; ArLSZ = Arch Lake Shear Zone.

Historical occurrences were revisited in 2023 in order to better understand the controls on uranium enrichment. In the Spider Lake area, uranium mineralization is associated with strongly sheared contacts between migmatitic TBC and mylonitized RRC. These mineralized contacts appear to be splays of the Andrew Lake shear zone that trends NNE-SSW which may have acted as a conduit for mineralizing fluids. At Cherry Lake, gamma-ray spectrometer readings of up to 40,000 counts per second and uranium concentrations of up to 930 ppm were obtained from a large outcrop of sheared Colin Lake granite. The area has been historically examined for its uranium potential with historical results of up to 17,957 ppm obtained from sheared and faulted granitic gneiss (Langenberg et al., 1993).

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