Petrographic, Geochemical, and Structural Analysis of Pegmatite-Hosted REE Mineralization in the Forget Lake Area, Northern Saskatchewan

Kaylee Tymo[1], Guoxiang Chi[1], Kathryn Bethune[1], Irvine R. Annesley[2], James Smith[2], Ricardo Franco[2]

[1]University of Regina, [2]Appia Rare Earths & Uranium Corp.

Introduction

Rare earth elements (REE) have become an integral part of the economy as they provide for green technology, which is currently in high demand. In recent years, a number of REE occurrences have been found in the Beaverlodge Domain, northeast of Lake Athabasca (Normand, 2014). Even though exploration has been on the rise in these areas, many deposits remain to be discovered. Geological characterization and genetic studies of the REE mineralization are required to guide further exploration. In particular, the southeastern part of the Forget Lake area, which contains known REE mineralization, has yet to be documented. In the summer of 2023, a three-hole drilling program was conducted in the area to discover its possible REE mineralization hosted by pegmatites. This study will provide documentation of field geological, structural, geochemical, and petrographic analyses of this area. Additionally, it will discuss about the genesis of the REE mineralization and its implications for future exploration in the area.

Geological Setting

The Beaverlodge Domain is located just north of Lake Athabasca. It is a part of the southern Rae Province that is divided into several lithotectonic domains. The Beaverlodge Domain is bounded by the Oldman Bulyea shear zone, the Grease River shear zone, and the Black Bay fault (Fig. 1). It consists of Archean to middle Paleoproterozoic rocks. The rocks in this study area consist mainly of metasedimentary rocks of the Murmac Bay Group (2.33-2.17 Ga), Archean gneisses, and granitoid rocks (Bethune et al., 2013). These rocks record the effects of Archean tectonics and several Paleoproterozoic tectonic events.

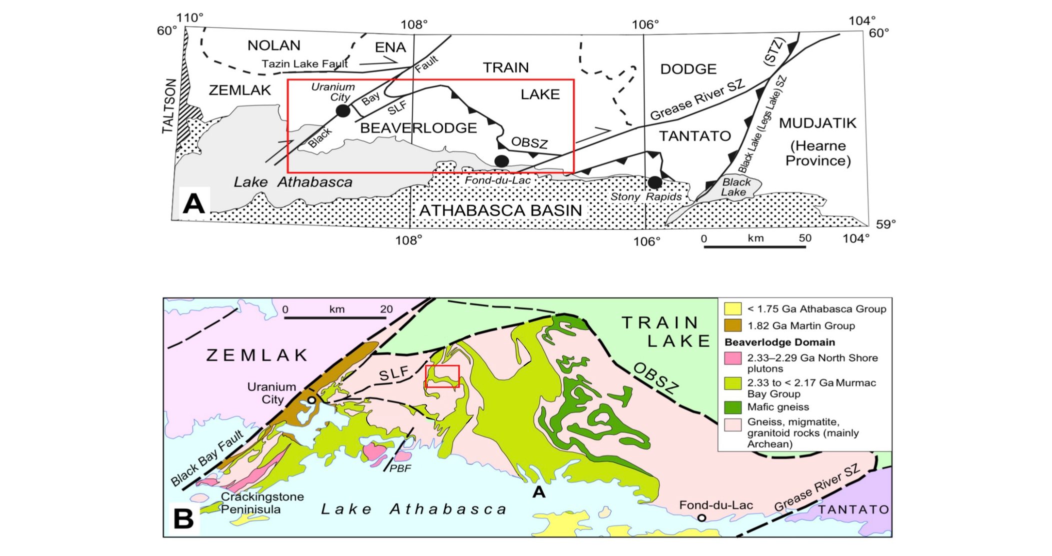

Figure 1: A - Location of the Beaverlodge Domain. B - Simplified geology of the Beaverlodge Domain, including the study area defined by a red box. Modified from Bethune et al. (2013).

Local Geology

The Forget Lake area is a part of a large regional fold. It is known for its high-grade REE mineralization, which is associated with the contacts between Archean rocks and Paleoproterozoic supracrustal packages along the eastern limb of the fold and around the hinge line. One of the most significant REE occurrences in the area is at Alces Lake, which is located 5 km northeast of the study area at Forget Lake. This occurrence is situated on the eastern limb of the regional fold and is characterized with monazite mineralization within a biotite segregation band of granitic gneisses. The mineralization coincides with a 450m-long anomaly discovered by ground and airborne surveys where radioactivity is high due to the rich thorium content in the rocks. A bulk rock analysis returned a value of 29 wt% of total rare earth elements (TREE), which consists of 53% monazite by weight (Normand, 2014).

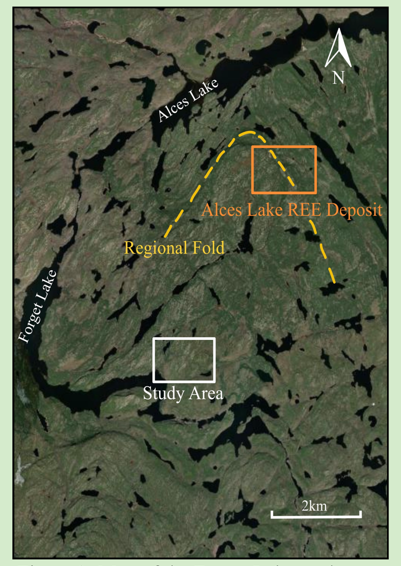

Figure 2: Map of the Forget Lake study area relative to the Alces Lake REE deposit.

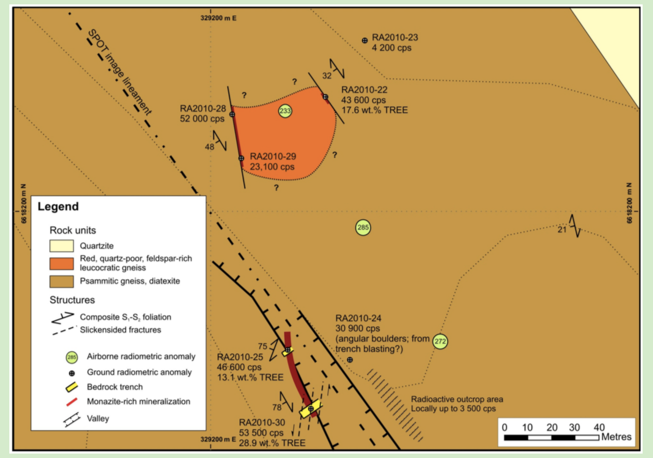

Figure 3: Local geology of the Alces Lake monazite occurrence, approximately 5km northeast from the study area. Modified after Normand (2014).

Field Observations

A detailed outcrop map was created in the area where the Western Anomaly drill program was conducted. The field map consists of five lithologic units with two separate generations of pegmatite. The pegmatites are similar in composition and appearance from a field perspective. Still, one generation cross-cuts the other, indicating two different pegmatite units for in the study area. The other units are amphibolite, mafic paragneiss, and felsic paragneiss with xenoliths of pegmatite within it. The geological contacts between the pegmatite and the other units are sharp. Radioactivity levels are highest near the contact between the second generation of pegmatite and the shear zone, where it is biotite-rich. This radioactivity could indicate monazite mineralization.

Figure 4: The first generation of pegmatite defined by the outcrop map in Figure 7. Photo shows the felsic nature of the unit along with the large plagioclase and quartz grains.

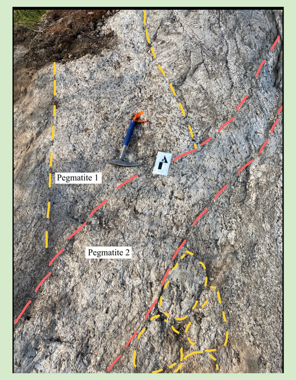

Figure 5: The intersection between the first and second generation of pegmatite. Cross-cutting relationships indicate that pegmatite 1 is relatively older than pegmatite 2.

Figure 6: Amphibolite representative unit defined by its mafic composition.

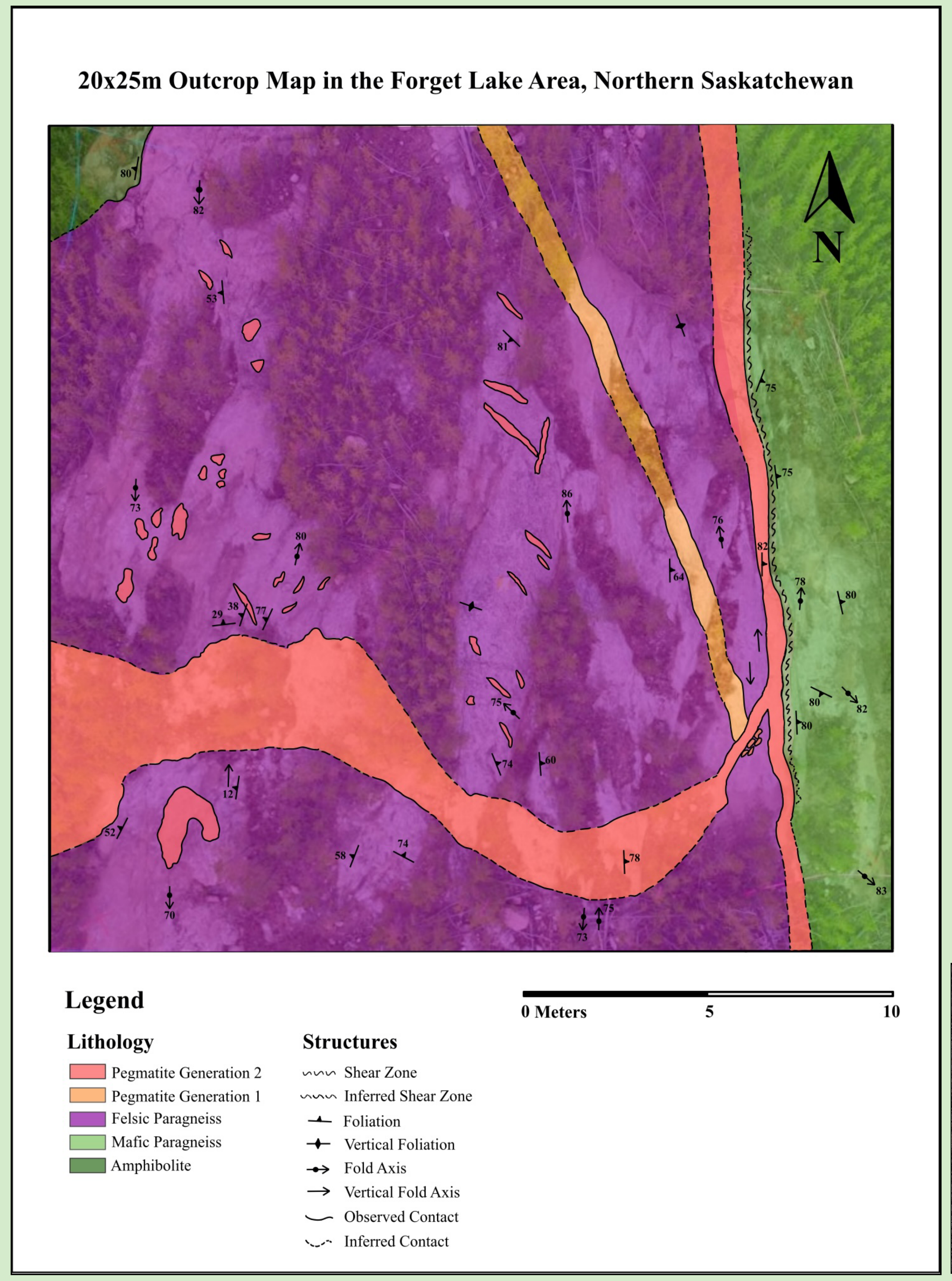

Figure 7: Detailed 20x25m outcrop map near Forget Lake and the 2023 Western Anomaly drilling program.

Figure 8: Mafic paragneiss representative unit near the shear zone. Small fragments of deformed pegmatite is also shown here.

Figure 9: Felsic paragneiss unit that exhibits tight folding along the S_1 foliation plane. The tight folding creates an S_2 fabric denoted in the photo.

Figure 10: A shear zone with dextral shear sense. Felsic paragneiss and pegmatite straddle the shear zone. The S_1 foliation exhibits drag from the shearing.

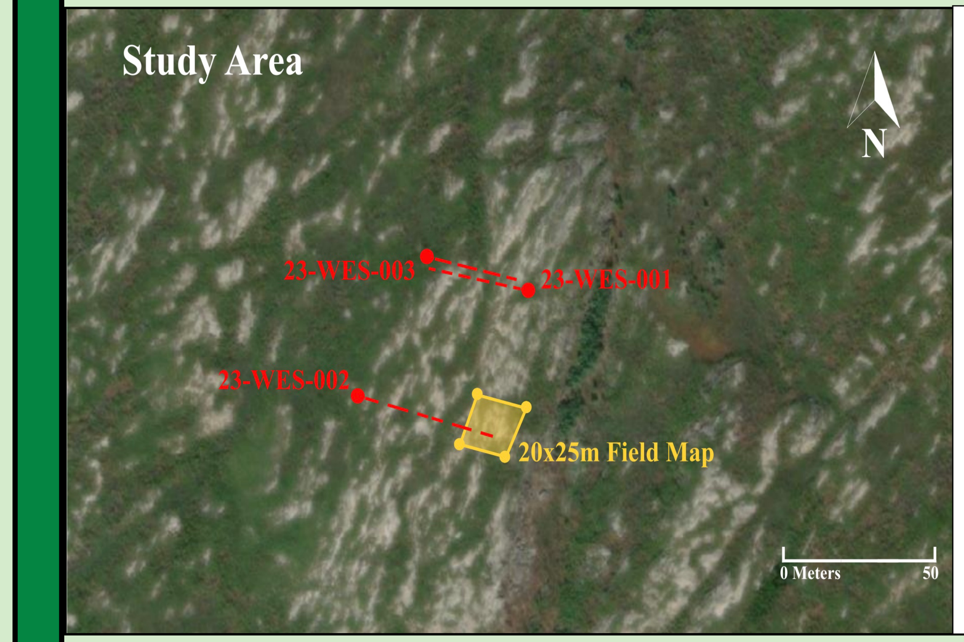

Figure 11: Map of the study area. Defines the location of the outcrop map relative to the three drill-holes in this study.

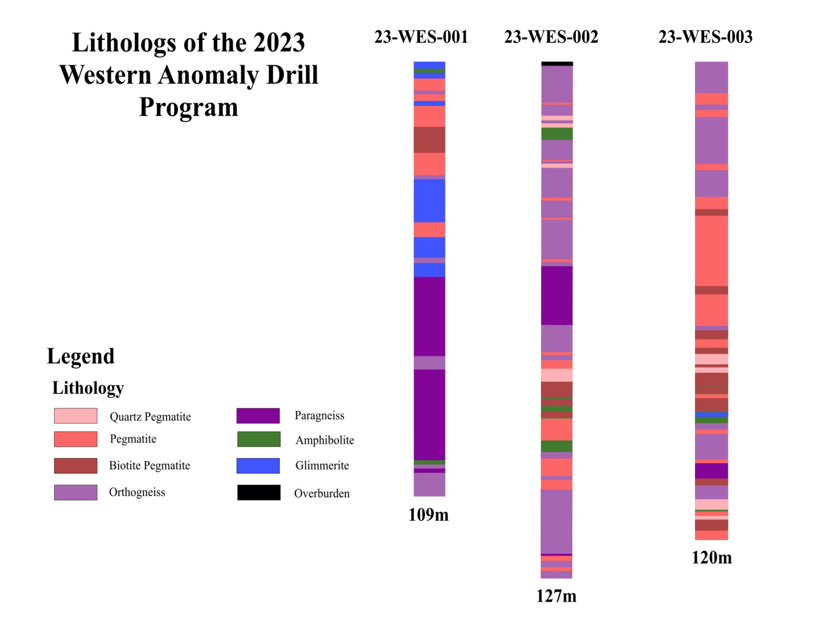

Figure 12: Lithologs of all three drill holes used for this study. Most of the units found in the drill core are also found in the field map shown in Figure 7.

Preliminary Petrography

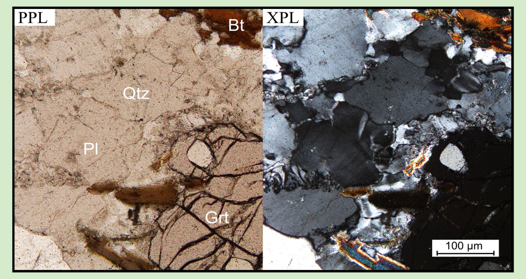

Figure 13: Felsic paragneiss representative. The sample exhibits fine to medium sized grains, and consists of mainly quartz, plagioclase feldspar, biotite, and garnet. There is also an S_1 foliation defined by the alignment of micaceous minerals.

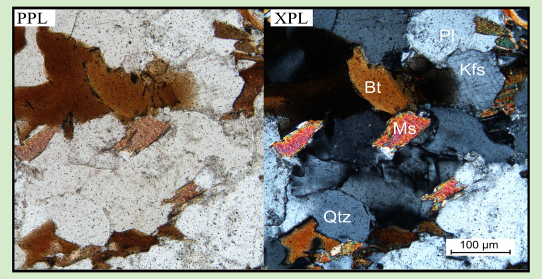

Figure 14: Mafic paragneiss representative. The section has an abundant amount of micas relative to the felsic paragneiss. Mineralogy is typical of a paragneiss, with a weak S_1 foliation defined by the alignment of micaceous minerals.

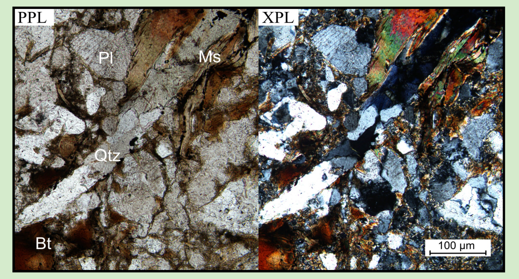

Figure 15: Amphibolite representative. The entire section is fine-grained with mainly quartz, plagioclase, biotite, and muscovite. However, the section lacks hornblende and other mafic minerals.

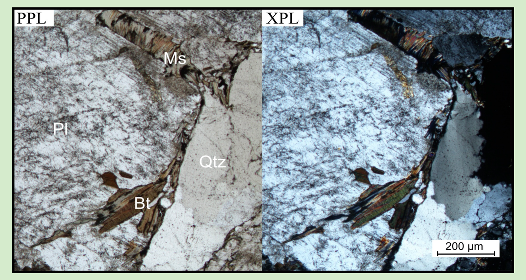

Figure 16: The first generation of pegmatite from the field map. The section is medium to coarse-grained, with abundant plagioclase feldspar and quartz. Small amount of micas are present and appear in-between minerals and fractures.

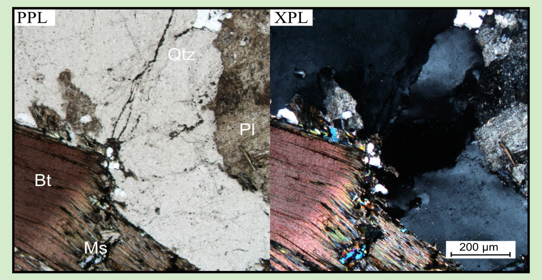

Figure 17: Sample taken from the second generation of pegmatite along the edge of the shear zone. Defined by coarse-grained plagioclase feldspar and quartz with large micaceous bands that appear to be deformed. The feldspars are also heavily deformed, defined by a dusty appearance.

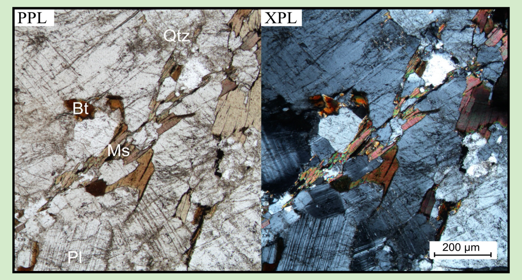

Figure 18: Representative for the second generation of pegmatite. Section is similar to the first generation of pegmatite but has a higher amount of micaceous minerals scattered throughout. Micas are tabular, unlike the banded micas in the sample near the shear zone.

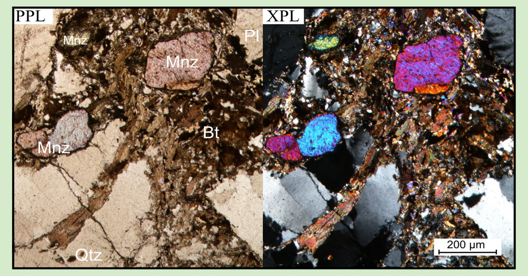

Figure 19: High-relief monazite with high-interference colours in a pegmatite. Monazite grains are often found in biotite-rich areas.

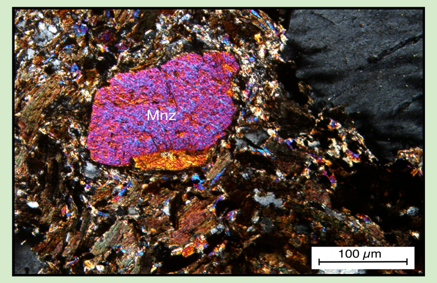

Figure 20: Close-up view of a monazite grain in XPL. Mineral exhibits high-interference colours and also appears in Figure 19.

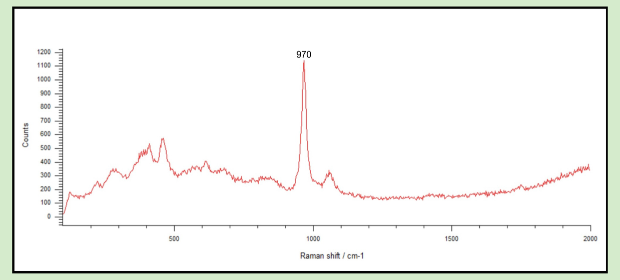

Figure 21: Raman spectroscopy performed on the monazite grain shown in Figure 20. The analysis returned a value of 970 which is characteristic of monazite.

Geochemical Analysis

The chondrite-normalized REE pattern shown in Figure 22 is enriched in light rare earth elements (LREE) as the plot is positively-skewed. The pegmatites in particular exhibit strong LREE enrichment with negative Eu and Tm anomalies. In contrast, the paragneisses and amphibolite show a flat pattern with small Eu anomalies and a Ce anomaly in the mafic paragneiss.

The Harker diagrams plotted a variety of major and trace elements against silica which is the bulk constituent of these rocks. The paragneisses and amphibolite plotted similarly across all diagrams, except for strontium (Sr) and lithium (Li), where their values were high relative to the two generations of pegmatite. Conversely, the pegmatite generations had several anomalies across the diagram plots. Both of the pegmatites exhibit high K_2O and total REE values. The sample from the second generation pegmatite taken along the shear zone has a total REE value that is nearly double the value of the other lithologies.

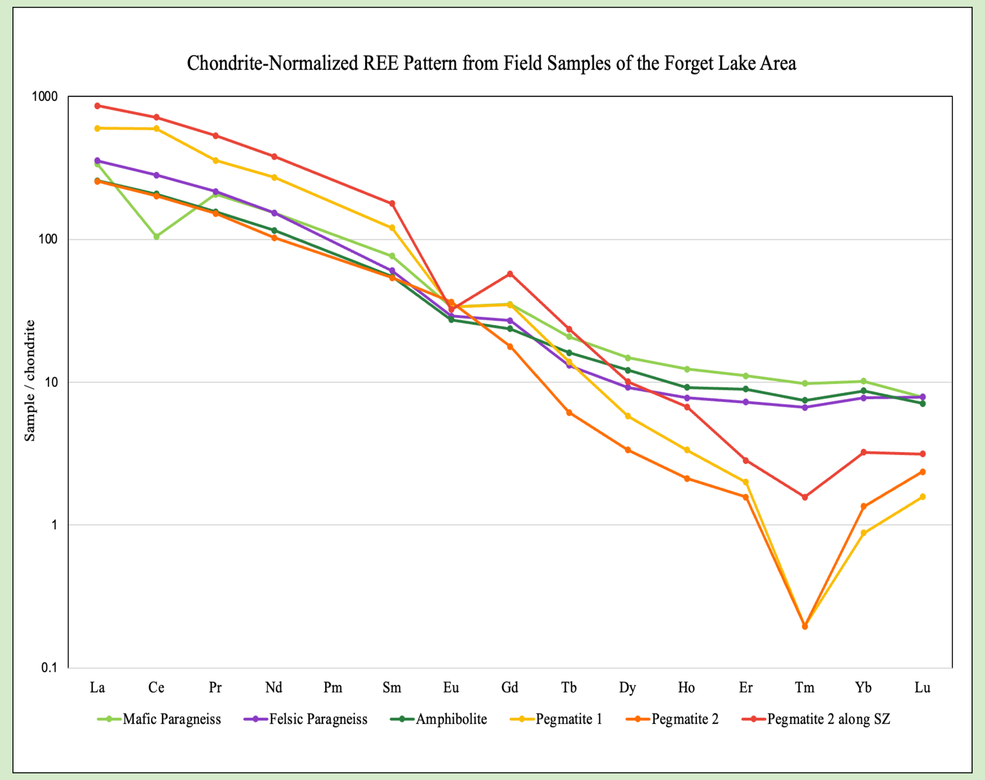

Figure 22: Chondrite-normalized REE pattern plotted from the five lithologies shown in the field map (Fig. 6). An additional sample from the second generation of pegmatite is added to the plot, this sample was taken directly along the shear zone that appears on the east side of the map.

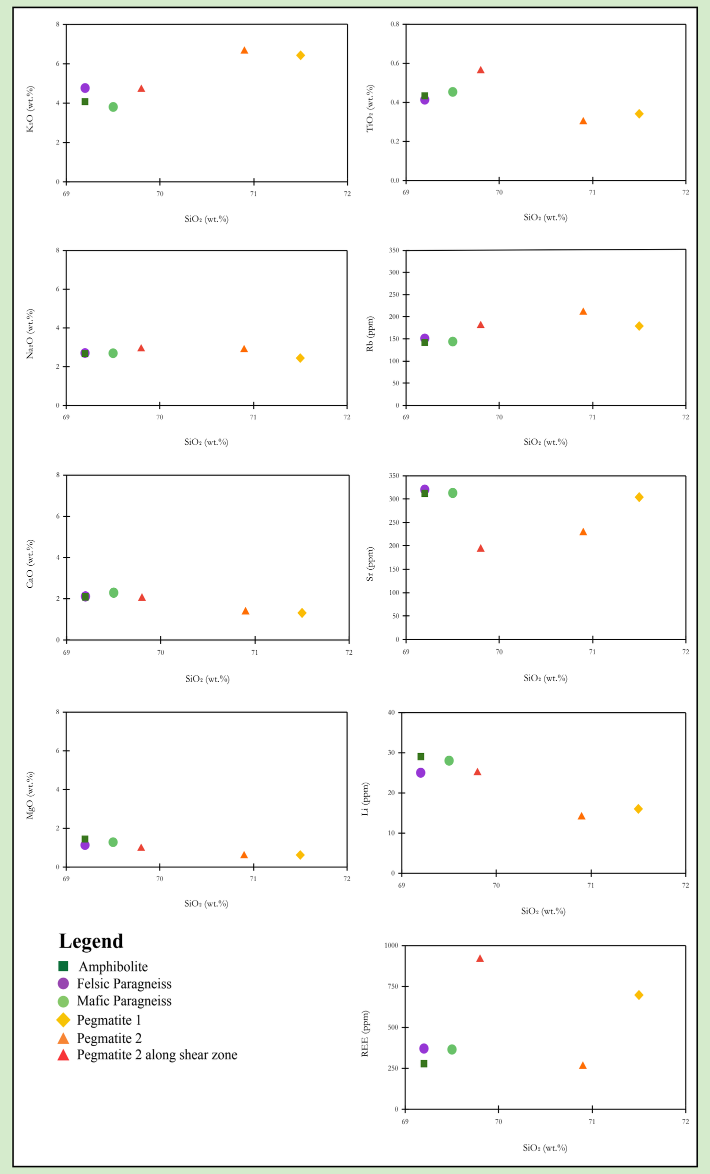

Figure 23: Harker diagrams plotted from the same six samples of the chondrite-normalized REE pattern. Diagrams include a variety of major and trace elements plotted against the silica content in the given sample.

Structural Analysis

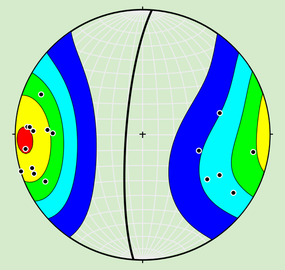

Figure 24: Stereonet plot showing the average foliation orientation of 184/79 from the field map area (Fig. 6). N = 21

A range of both brittle and ductile structures were encountered during field mapping. The host rocks are strongly foliated to gneissic. The average orientation to foliation is 184/79 (Fig. X). The S_1 foliation plane is folded, related hinge lines and axial traces trend nearly north-south. The shear zone on the east side of the map in Figure 6 is localized in the mafic paragneiss unit. The shear zone is sub-vertical and is characterized by abundant biotite that defines a phylonitic and apparent dextral shear sense. The latest structures are sub-vertical fractures, with predominant orientations of NNE and WNW (Fig. 3). These fractures appear to be a part of a joint set.

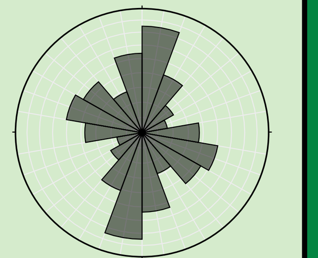

Figure 26: Rose diagram that shows the average fracture orientations trending NNE and WNW.

Figure 25: The S_1 foliation plane defined by the felsic paragneiss unit in the field.

Figure 27: A set of factures that are close to the average orientation of brittle structures in the area.

Preliminary Conclusions

The southeastern part of the Forget Lake area is hosted by a series of both felsic and mafic paragneisses that exhibit strong foliation and multiple events of deformation defined by folding and shearing on the outcrop. The area also contains amphibolite and different generations of pegmatite due to cross-cutting relationships. The drilling program that occurred in the summer of 2023 confirms that the same lithologies are found at depth, with the addition of quartz and biotite-rich pegmatites, glimmerite, and orthogneiss. The pegmatites found at surface contain monazite mineralization and are heavily enriched in LREE. The mineralization is often found in biotite-rich areas of the pegmatites.

Future Work

1) Further petrographic techniques, including electron microprobe analysis (EMPA), scanning electron microscopy (SEM), and potentially additional work using Raman spectroscopy.

2) Advanced 3D plotting of the drill holes to surface data.

3) Geochemical analysis on core samples from all three drill-holes in the area.

4) Conduct a structural analysis using the drill hole data to potentially tie the mineralization to the major deformational events.

Acknowledgements

This project would not be possible without the funding provided by Appia Rare Earths and Uranium Corp., as well as the access to their drill hole database for this study. The research is partially supported by NSERC-DG (to Chi). The team at Alces Lake is also thanked for their hard work and knowledge provided throughout the field season.

References

Annesley, I. R., Poliakovska, K., Sykes, J., & Pandur, K. (2019). The Geology and Mineralogy of High-Grade Rare Earth Element (REE-Th-U) Mineralization at Alces Lake, Saskatchewan (Canada). In Proceedings of the 15th SGA Biennial Meeting (pp. 1732-1735).

Ashton, K. E., Rayner, N. M., Heaman, L. M., & Creaser, R. A. (2014). New Sm-Nd and U-Pb ages from the Zemlak and south-central Beaverlodge domains: a case for amalgamated Taltson basement complex and proto-Rae cratonic blocks within the Rae Province of northwestern Saskatchewan. Summary of Investigations, 2, 2014-4.

Bethune, K. M., Berman, R. G., Rayner, N., & Ashton, K. E. (2013). Structural, petrological and U–Pb SHRIMP geochronological study of the western Beaverlodge domain: Implications for crustal architecture, multi-stage orogenesis and the extent of the Taltson orogen in the SW Rae craton, Canadian Shield. Precambrian Research, 232, 89-118.

Normand, C. (2011). Investigation of the REE mineralization potential in: the Forget Lake and Archie Lake areas, Beaverlodge Domain; the Miller Lake area, Train Domain; and the Bompas Lake–Upper Eva Lake area, Tantato and Mudjatik domains. Summary of Investigations, 2, 2011-4.

Normand, C. (2014). Rare earths in Saskatchewan: Mineralization types, settings, and distributions. Saskatchewan Ministry of the Economy, Saskatchewan Geological Survey, Report, 264, 105.