Precambrian Rocks of Yellowstone National Park (YNP) and Surrounding Areas: Petrogenesis of Leucogranites

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Introduction

The northern section of Yellowstone National Park (YNP) contains a suite of leucogranitic bodies ranging in scale from cm-scale cross-cutting veins and dikes to 10's of meters-scale outcrops. The units are mainly found within a larger complex of igneous, meta-igneous and metasedimentary rocks in the Slough Creek area, as well as near Hellroaring Trail and Buffalo Plateau. Significant research has been focused on the occurrence and petrogenesis of several calc-alkaline felsic plutons found in this region (i.e. Philbrick et al., 2011, Berndt et al., 2012). The suite of leucogranite rocks represents a unique style of magmatism in the area.

Leucogranites can provide valuable insight into tectonic processes that an area has undergone (e.g., decompression melting, shearing). An earlier, related study (Lexvold et al., 2011) in the area found a single, garnet-bearing leucogranitic pluton that is a peraluminous, S-type granite and represents a dry, high-temperature crustal melt. The current research documents an extended range of leucogranitic rocks across the Slough Creek area of YNP, further constrains the petrogenesis of these rocks, and compares them to the proximal igneous rocks in the region. This is accomplished through the use of field relations, petrography and geochemical analyses.

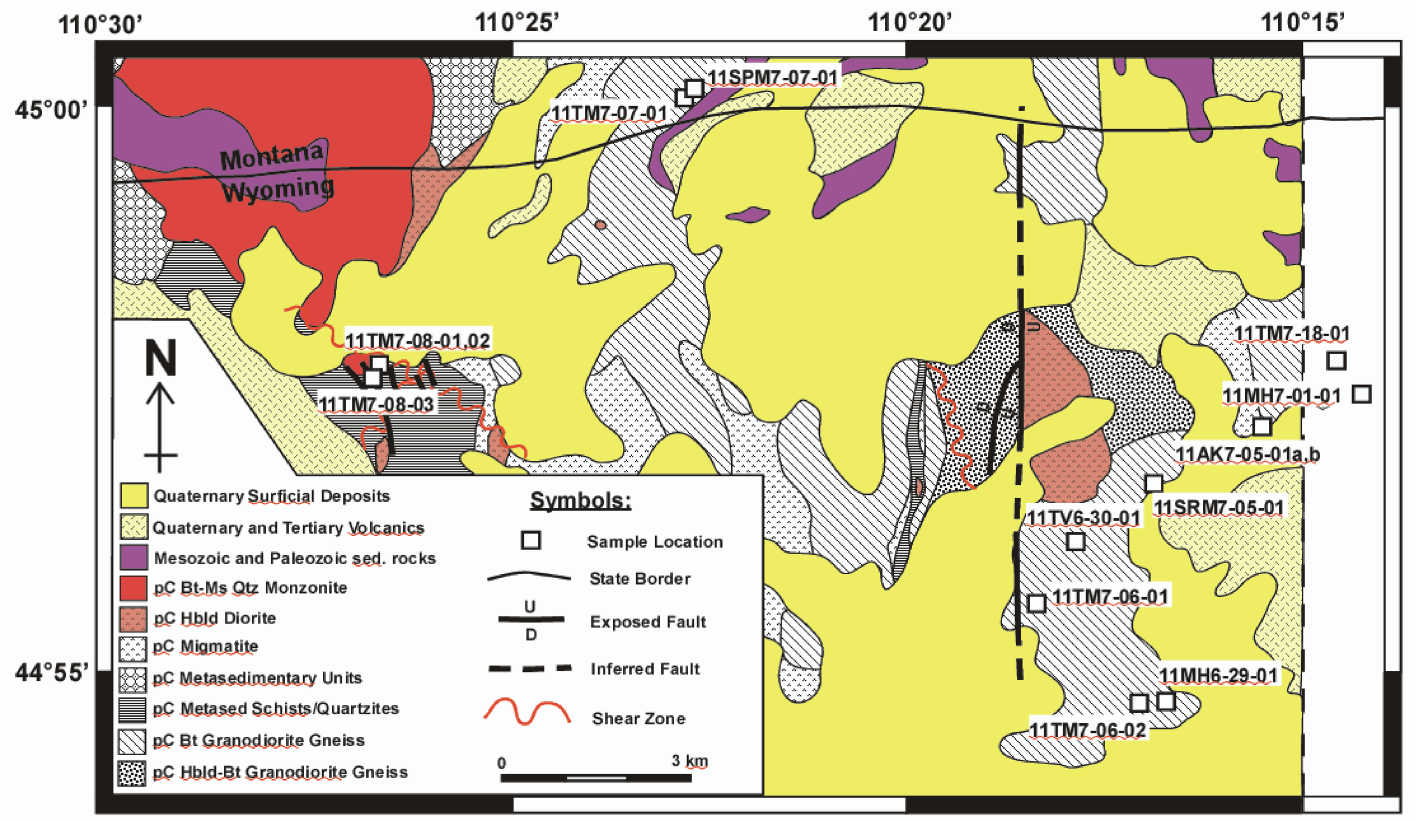


Figure 1. Geologic Map of Northern Yellowstone National Park (modified from Casella et al., 1982). Shown here are the complex relationships present between Precambrian igneous and metamorphic units beneath layers of more recent volcanic and fluvial deposits. Several faults and shear zones are believed to exist in the area. The leucogranite samples are marked and are found mainly within the larger Precambrian biotite granodioritic gneiss unit.

Previous Work

Petrography
- Medium- to coarse-grained, granitic to granodioritic in composition
- Presence of amphibole, garnet, ilmenite and epidote in addition to basic mineralogy seen in the set of samples from current study*

Geochemistry
- Peraluminous signature and a geochemical affinity with syn-collisional or volcanic arc granites

Geothermobarometry
- Peak crystallization conditions of **821-863 ºC** and **7.0-7.3 kbar** obtained using EPMA at The University of Minnesota suggest that the leucogranites crystallized from a dry melt

Field Relations

- Leucogranite bodies range from cross-cutting veins and dikes (cm's) to outcrops (m's)
- Sharp contacts with surrounding igneous and meta-igneous units
- In general, leucogranite bodies appear to cross-cut older igneous and metamorphic units

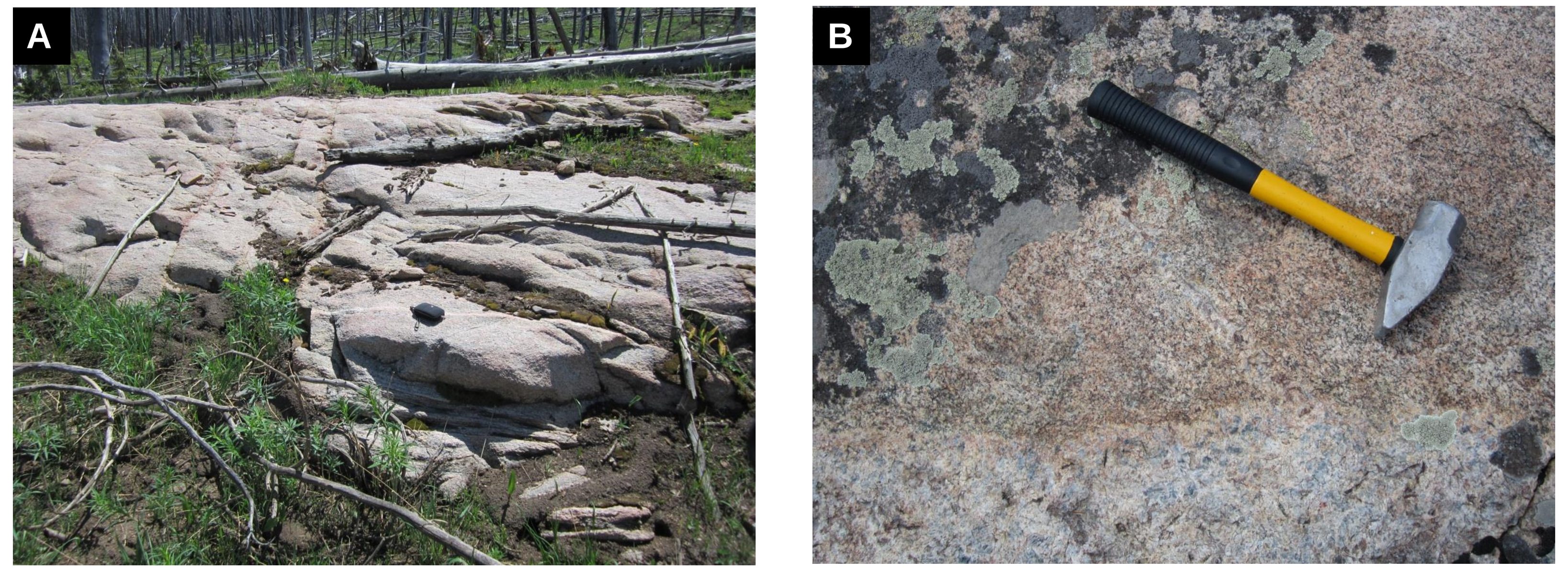
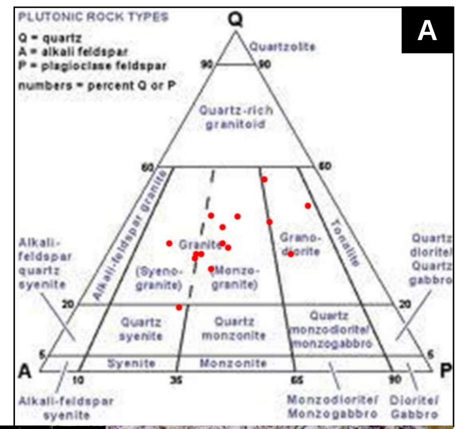


Figure 2. Field photographs of leucogranites **(A)** Largest outcrop of leucogranite encountered in field, located at Buffalo Plateau **(B)** Example of a sharp contact between a large leucogranitic vein and the surrounding igneous unit, a biotite granodioritic geniss

Petrography

Primary
-Primary mineralogy: Qtz+Kfs+Ab+Or±Bt±Ms±Ap±Zr±Op(±Am±Grt±Ilm±Ep)*
- Medium- to coarse-grained with little internal fabric
- Granitic to granodioritic in composition

Secondary
- Secondary minerals include chlorite alteration from biotite and secondary muscovite present in plagioclase along planes of weakness (twinning planes)
- Various levels of quartz recrystallization and deformation twinning in feldspars
- Exsolution textures (perthite/antiperthite) and myrmekite



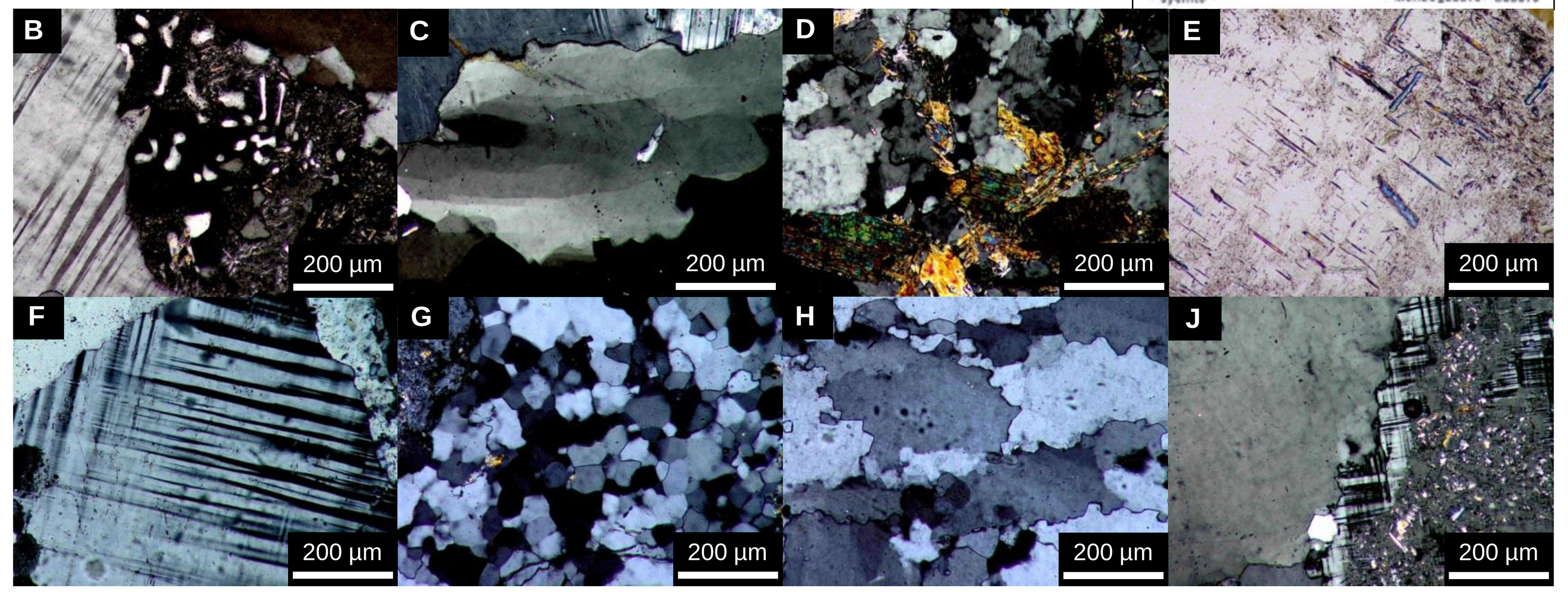


Figure 3. Photomicrographs of leucogranites taken in XPL at 10X. **(A)** IUGS classification **(B)** 11AK7-05-01b myrmekite texture **(C)** 11TM7-07-01 undulatory extinction in recrystallized qtz **(D)** 11TM7-08-01 cluster of micas in recrystallized qtz **(E)** 11AK7-05-01b muscovite laths along planes of weakness in plg **(F)** 11RF7-05-01 deformation twinning in kfs **(G+H)** 11TM7-08-03 various stages of recrystallized qtz **(J)** 11TM7-07-01 intergrowth of kfs and plg

Geochemistry

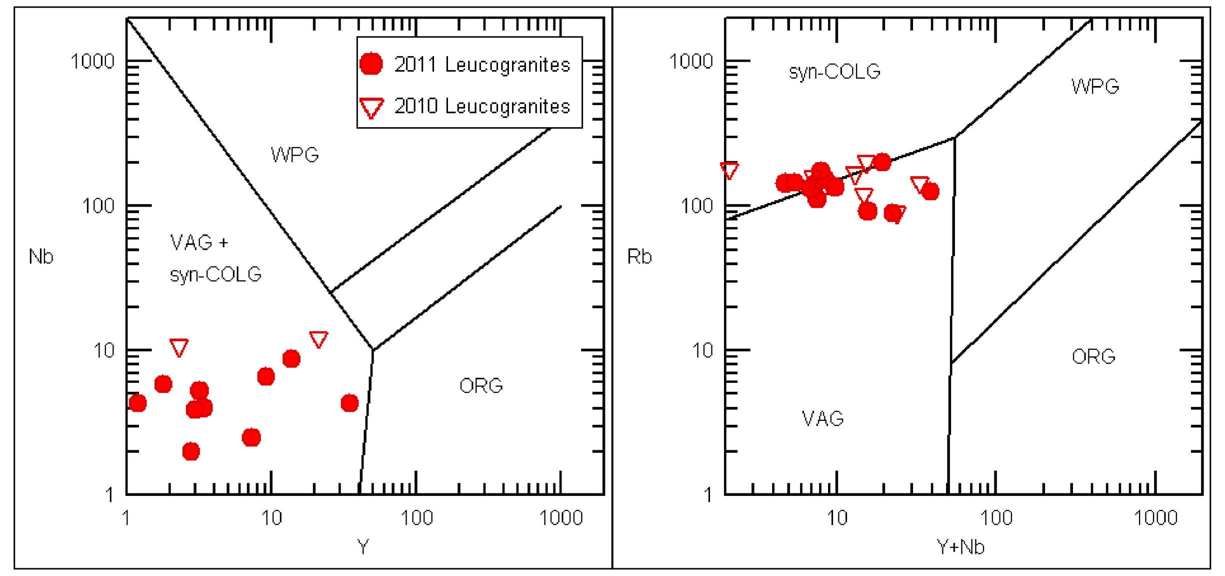


Figure 4. Geochemical variation (ppm) diagrams showing geochemical affinity with syn-collisional granites or volcanic arc granites (Pearce et al., 1984)

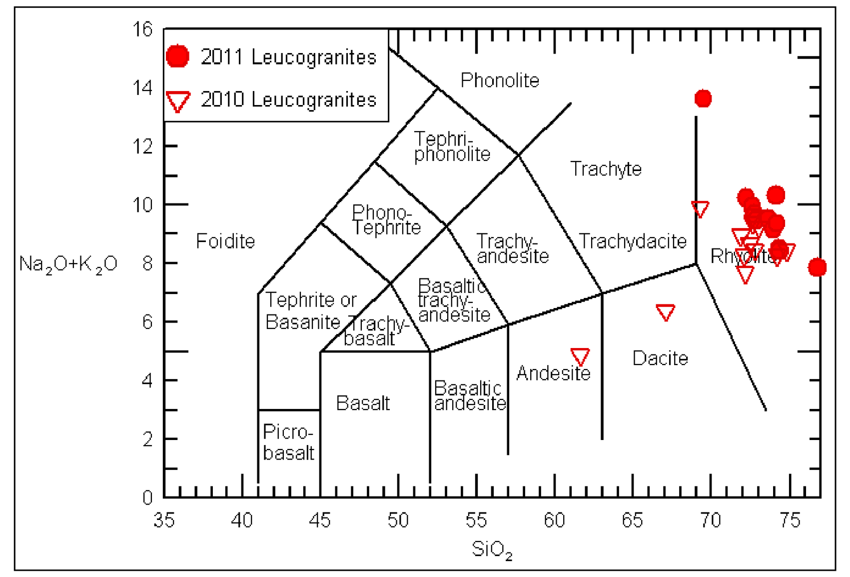


Figure 5. Geochemical variation diagram showing rhyolitic composition of leucogranites (LeBas et al., 1986)

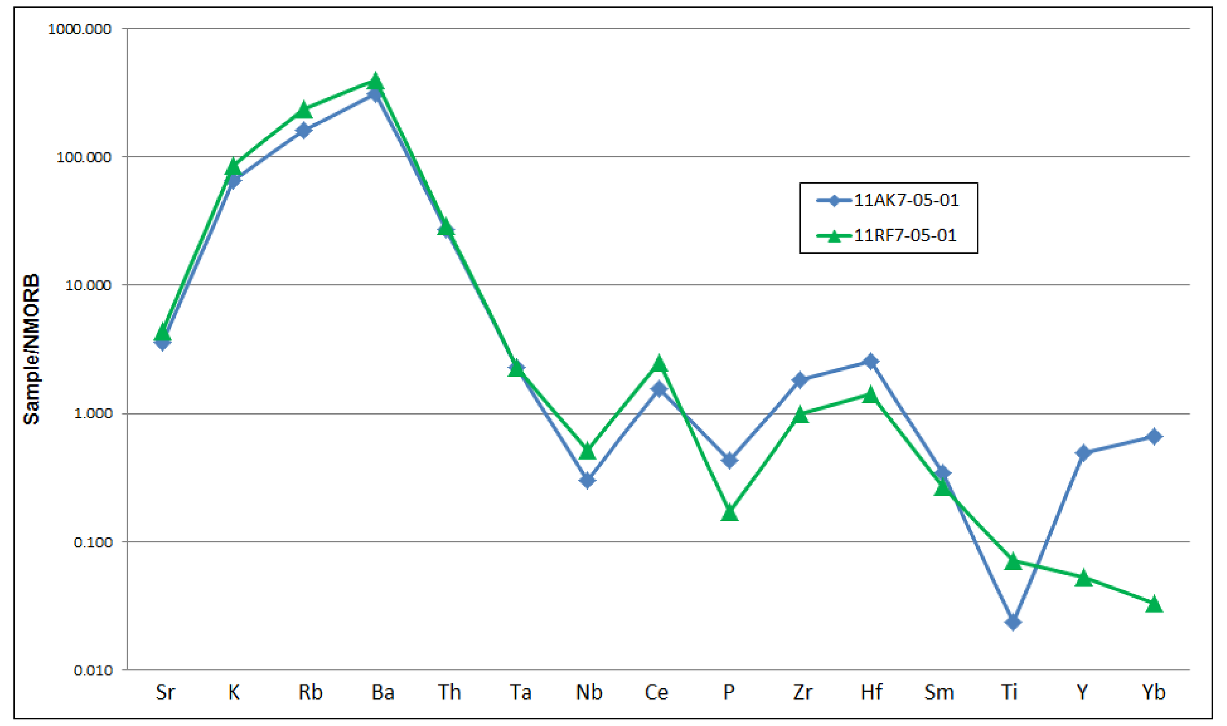


Figure 6. NMORB normalized spider diagram showing positive anomalies for Ce, Zr, Hf in both samples and Y and Yb in 11AK7-05-01

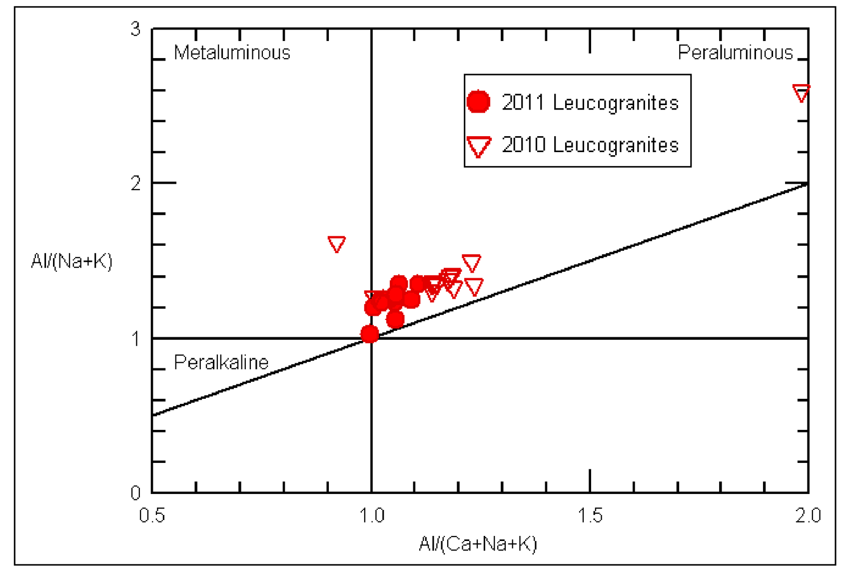


Figure 8. Aluminum to alkali content in leucogranites showing a peraluminous composition (Maniar & Piccoli, 1989)

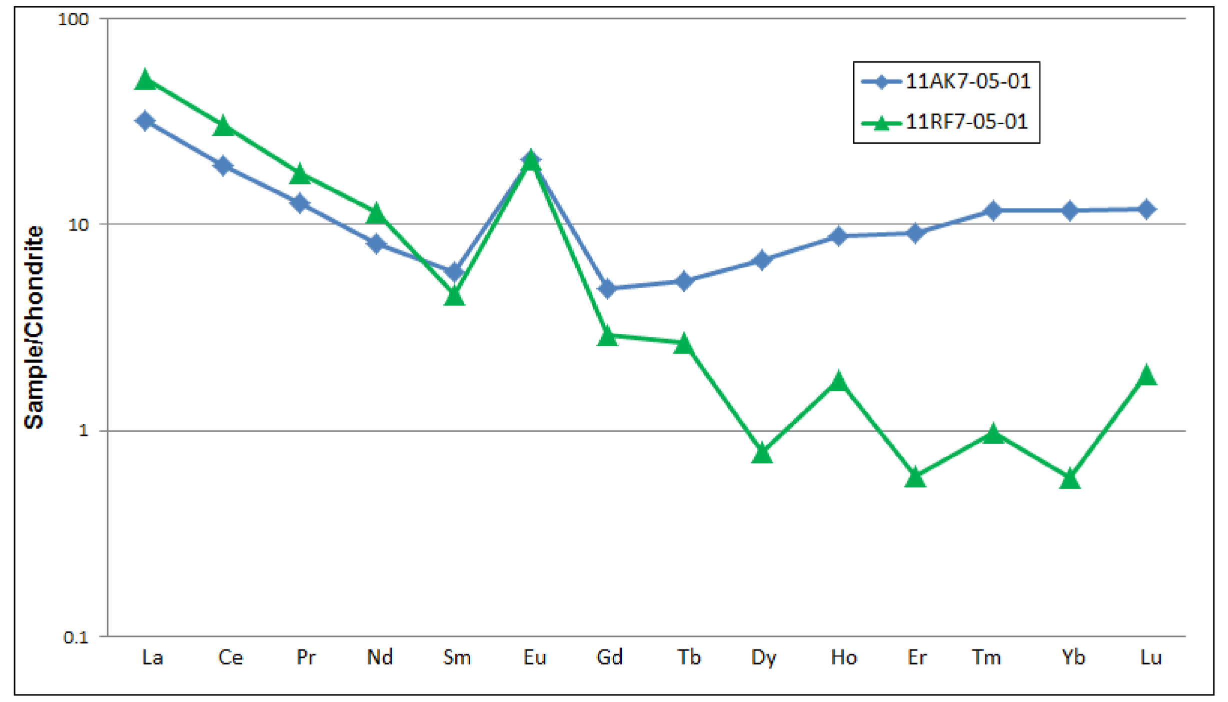


Figure 7. Chondrite normalized spider diagram showing a positive europium anomaly for both samples and enrichment in heavy rare earth elements (HREE) in 11AK7-05-01

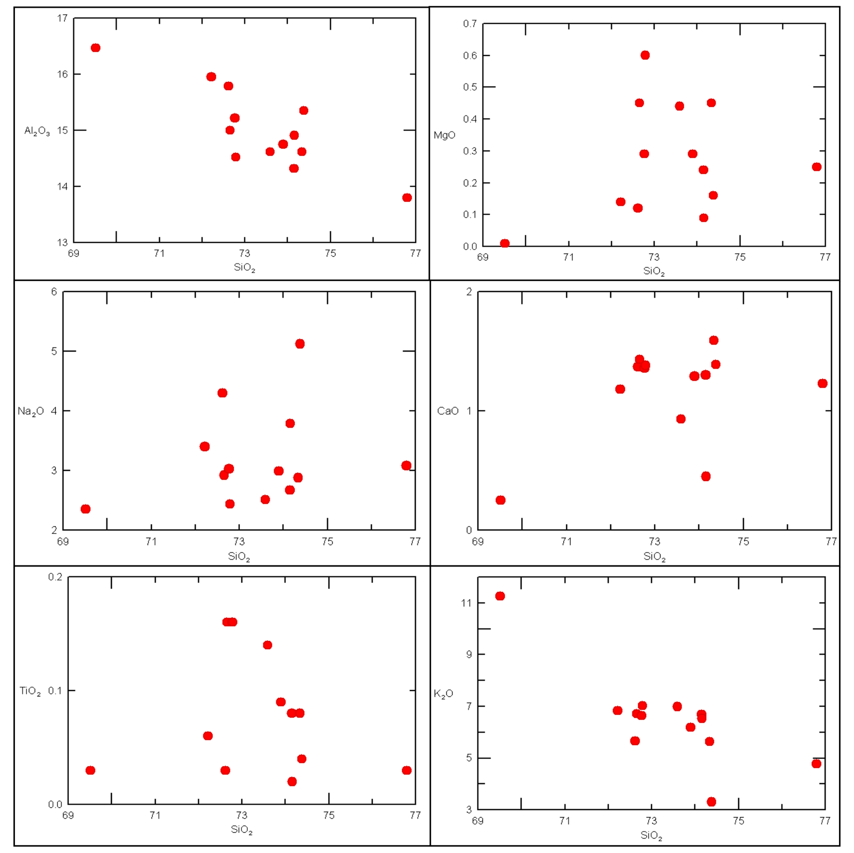


Figure 9. Harker diagrams showing trends of various oxide wt% vs SiO_2 wt% for 2011 leucogranites

Conclusions

- The leucogranite veins, dikes and small outcrops appear to cross-cut the various Precambrian felsic plutons found in the Slough Creek area, implying that they were injected at a later stage.

- The wide range of deformation textures and secondary alteration present suggests that the leucogranites were injected pre- or syn-kinematically with respect to deformation and experienced post-crystallization fluid alteration.

-The leucogranites from this study show similar geochemical trends to those from Lexvold et al. and to leucogranites seen in the Himalayas, possessing a rhyolitic composition and indicating a syn-collisional or volcanic arc granite tectonic setting.

-The leucogranites are significant because they are peraluminous, S-type granites and represent a dry, high-temperature crustal melt, possibly due to post-collisional adiabatic decompression melting.

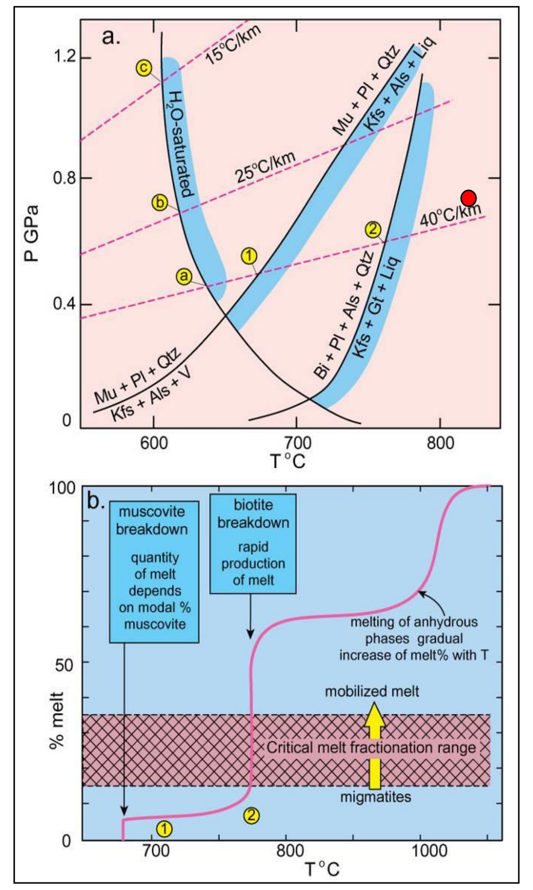


Figure 10. (a) Peak crystallization conditions indicate that the leucogranites were a dry crustal melt. (b) Once the biotite melt curve is breached, garnet and >15% melt is generated, and the liquid is capable of mobilization (Winter, 2001). The red dot represents the leucogranites.

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