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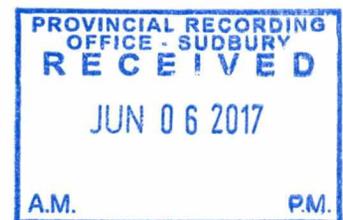
**EXPLORATION UPDATE ON THE LACKNER LAKE ALKALIC COMPLEX, CHAPLEAU  
AREA**

Lackner and McNaught townships, Sudbury Mining District

Report for International Explorers and Prospectors Limited

Frederick W. Breaks, Ph.D., P.Geo.

May 10, 2017



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## INTRODUCTION

This report briefly summarizes recent work undertaken on the Lackner Lake alkalic complex from late 2016 to the present time. The work has focused upon mineralogical and bulk rock geochemical evaluation in order to develop potential exploration targets. The commodities of exploration significance include the rare earth elements, Y, Nb, Ta, Zr, Ti, U and Sc. No academic research has been undertaken on the complex since the early 1960's (Hodder 1961).

## LITHOCHEMISTRY

Lithochemical data on 47 samples from drill hole 66-11-01 on claim 4214383 were received from ALS Global Labs on January 20, 2017. Currently these data are undergoing a detailed examination and will be incorporated into a collective data base that comprises all lithochemical data acquired by the company from 2007 to the present.

## ROAD IMPROVEMENT PROGRAM

A road improvement program will commence shortly to upgrade the current road system involving two road systems. The Camp Lake Road loop, which provides access to the McVittie magnetite deposit, and the Zone 6 and Zone 8 niobium deposits (Breaks 2016), will be widened along bushed-in sections. Secondly, the Lackner Lake Road, which connects with the old MNR fire tower road, will similarly also be improved as this road network gives access to the Zone 3-4 niobium-apatite-magnetite deposit and also to the centre and north-central parts of the complex in vicinity of the Pole Lake REE-Th-Ba-Nb occurrence (Figure 1).



Figure 1. Location of access roads to various mineral deposits in the Lackner Lake alkalic complex that will be focus of road improvement.

## ELECTRON MICROPROBE INVESTIGATION

Mineralogical work involved an examination of 26 thin sections with a Nikon Labophot-Pol polarizing microscope that comprised many different lithologic units of the complex. The thin sections were produced by Janwill Petrographics at Laurentian University. Eight polished thin sections were sent to Dr. A.G. Tindle at The Open University on February 2, 2017 for electron microprobe (EMP) verification of minerals in various rock types and the final data-set was received on February 27.

## RESULTS

The electron microprobe work produced 423 analyses on 22 different minerals and the results of the study can be found in a March 13 report (Breaks 2017). Compositions of the various essential and accessory minerals include pyrochlore, diopside, hedenbergite, hastingsite, ilmenite, magnetite, ilmenomagnetite, biotite, phlogopite, muscovite-paragonite, calcite, fluorapatite, fluorite, clinohumite, pyrite, pyrrhotite, chalcopyrite, Ba-rich K-feldspar, albite, nepheline, zircon and ancylite.

The above minerals confirmed by the electron microprobe work occur in the following lithologic units with sample numbers in table below:

Rock Type	Location	Sample #
Ijolite breccia	Zone 6 Fe-Ti-P-Nb-Th-U-Ta deposit	14-554
Apatite-calcite-clinohumite-magnetite rock	NE Camp Lake Fe-Ti-Nb-Th-Sc occurrence	14-508
Mesocratic coarse-grained nepheline syenite mineralized with pyrochlore	Drill Core from DH66-11-01	19151
Leucocratic syenite segregation of hastingsite-magnetite-diopside-Ba-rich K-feldspar	Drill Core from DH66-11-01	26362
Mesocratic coarse-grained hastingsite-biotite-diopside syenite segregation	Drill Core from DH66-11-01	26374
Silicocarbonatite zone - nepheline-biotite-calcite-diopside-apatite rock	Drill Core from DH66-11-01	19152
Silicocarbonatite zone - carbonatite and adjacent carbonate alteration	Drill Core from DH66-11-01	26380
Nepheline syenite	Drill Core from DH66-11-01	26392

### Pyrochlore $(\text{Na,Ca,U,Th,REE,Sr,Ba,Pb,K,Mn})_{2-x}(\text{Nb,Ti,Ta,Zr,Fe,Si})_2\text{O}_6(\text{F,OH})_{1-y}\cdot n\text{H}_2\text{O}$

Pyrochlore is a potential ore mineral for Nb and Ta in the Lackner Lake alkalic complex and focus was upon this mineral with 173 analyses amassed in six samples. The mineral has a considerable range in composition with variable amounts of other metals such as Ba, Sr, U, Th and Zr. Niobium has an overall mean in pyrochlore of 49.61 wt.%  $\text{Nb}_2\text{O}_5$  within a range of 43.3 to 57.86 wt.% whereas tantalum averages 2.24 wt.%  $\text{Ta}_2\text{O}_5$  in a range of 0.87 to 3.83 wt.%. Notable are two distinct data clusters for tantalum in pyrochlore centred at 2.5 wt.% and 3.7 wt.%  $\text{Ta}_2\text{O}_5$ .

Numerous species names for pyrochlore are applicable to electron microprobe derived data: *pyrochlore (sensu stricto)*, *barian pyrochlore*, *bariopyrochlore*, *uranian pyrochlore*, *barian-uranian pyrochlore* and *uranian-barian pyrochlore*.

## Phoscorite

Clinohumite [ $Mg_3(SiO_4)_4F_2$ ] was tentatively identified in a calcite-magnetite rock (sample 14-508) at the NE Camp Lake zone as fine-grained, strongly birefringent grains intergrown with magnetite. It has a similar composition to olivine but differs in lower EMP totals in the 92 to 98 wt.% range perhaps due to unanalyzed  $H_2O$  from alteration (1.52 to 2.64 wt.%  $H_2O+$ ; Handbook of Mineralogy). As this mineral is, in essence, a hydrated equivalent of olivine, the EMP analyses suggest a classification of the clinohumite-calcite-magnetite rock as phoscorite.

Phoscorite may be associated with large polymetallic deposits as exemplified by the giant Kovdor mine in Russia (Krasnova et al. 2004) and the Foskor mine in the Phalaborwa alkalic complex of the Republic of South Africa (Fontana 2006). The Lackner Lake phoscorite occurrence is the first identified in Ontario to the author's knowledge. Only 24 phoscorite occurrences are currently known world-wide (Krasnova et al. 2004).

## Late stage REE-rich Mineralization

Mineralization related to late-stage possible carbothermal activity was identified in sample 19151 from drill hole 66-11-01. It occurs as late fracture fillings of ancyllite-Ce [ $CeSr(CO_3)_2(OH) \cdot H_2O$ ], zircon and fluorapatite. Ancyllite is a potential rare earth element ore mineral as it contains high amounts of  $La_2O_3 + Ce_2O_3 + Pr_2O_3 + Nd_2O_3$  (42.8 wt.% in Lackner Lake complex) and low levels of uranium and thorium. Ancyllite represents the most important potential ore mineral at the Bear Lodge deposit in Wyoming where Rare Element Resources Ltd. defined a measured and indicated resource of 6.8 million tonnes grading 3.75 wt% TREO.

The scale and distribution of this style of mineralization is currently unknown in the Lackner Lake complex and thus further field and mineralogical investigation is required. Elsewhere in Ontario, ancyllite is known only at 4 other localities: Carb Lake carbonatite, Sturgeon Narrows alkalic complex, and Monmouth Township: <https://www.mindat.org/min-216.html>

Recently ancyllite was verified in ferrocyanatite at the Prairie Lake carbonatite near Thunder Bay, Ontario associated with burbankite and strontianite <http://www.marketwired.com/press-release/nuinsco-resources-limited-high-ree-content-minerals-discovered-at-prairie-lake-tsx-nwi-1806295.htm>

## RECOMMENDATIONS

Two previous recommendations in Breaks (2016) have been undertaken (electron microprobe mineral verification) or have been initiated (road improvement program). A number of recommendations remain that will enhance progress of exploration in the Lackner Lake alkalic complex:

1. Compilation of all lithochemical data acquired by the company from 2007 to present. This will include recent data from drill hole 66-11-01 received on January 21, 2017.

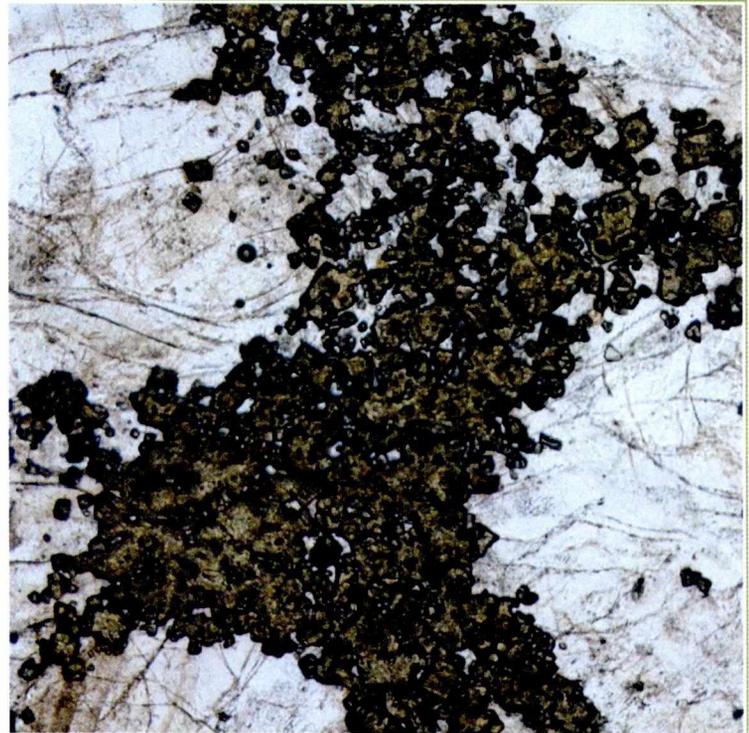
2. NE Camp Fe-Th-Nb-Sc occurrence - labour needed to clean out old blast pits found in the 2014 field work so that a thorough surface sampling program can be undertaken to assess the scandium and niobium mineral potential. These pits have been heavily overgrown by vegetation, perhaps dating from the 1950's.
3. Ground magnetic survey over the NE Camp Lake Fe-Th-Nb-Sc occurrence. Elevated scandium (mean 85 ppm, range 53 to 114 ppm) was documented by Breaks (2016) in old blast pits of this zone. A ground magnetic survey would accurately define extent of the magnetite-rich rocks that have been provisionally been identified as clinohumite-bearing phoscorite.
4. Drill program: vertical holes within airborne magnetic low near Lackner Lake in order to test for possible carbonatite core zone in area of no rock exposure.
5. Drill testing of carbonatite zones originally defined by Multi-Minerals at Zone 8 and Zones 3-4. . To the author's knowledge, no drill core from the historic work in the 1950's and 1960's has survived from any of the mineralized zones. Zone 8 has a historic resource of 80 million tonnes of 0.25% Nb<sub>2</sub>O<sub>5</sub> (Sage 1988) but there are no data for other metals of possible economic interest (eg. Sc, Y, Zr, Ta, U and REE). A few drill holes across each zone could provide important data especially for Zones 3-4 and 8 that are not well exposed on surface.

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# Mineralogical Investigation of SW Part of Lackner Lake Alkalic Complex, Chapleau area, Ontario



Report for International Explorers  
and Prospectors Limited  
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3/14/2017

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## EXECUTIVE SUMMARY

This study was advanced owing to a paucity of modern mineralogical analysis for various lithologies associated with mineralization in the Lackner Lake alkalic complex. No university-based research has been undertaken on the complex since the early 1960's (Hodder 1961). Such mineralogical data is needed to generate new exploration models. Previous lithochemical and gamma ray spectrometer survey results were presented in Breaks (2016).

The Lackner Lake complex hosts significant historical resources:

- Zone 2: 80 Mt averaging 0.18 wt.% Nb<sub>2</sub>O<sub>5</sub> over 420 m strike and depth of 240 m
- Zone 3-4: 37 Mt of 13.7 % magnetite, 21.3 % apatite, 0.17 % Nb<sub>2</sub>O<sub>5</sub> to the 150 m depth
- Zone 6 Fe-P-Ti-Th-Nb-U-Ta deposit: 5 Mt to 150 m depth averaging 70 wt.% Fe, 21.9 % apatite and 0.17 % Nb<sub>2</sub>O<sub>5</sub>; 2.72 wt.% ΣREO in 90% apatite concentrate
- Pole Lake REE-Ba-Th-Nb occurrence: ΣREO+Y<sub>2</sub>O<sub>3</sub> up to 9.6 wt.%
- NE Camp Lake Fe-Ti-Nb-Th-Sc occurrence (mean : 0.15 wt.% Nb<sub>2</sub>O<sub>5</sub> ; 85 ppm scandium) .
- Apatite concentrates: mean 2.80 wt.% ΣREO in range of 1.96 to 3.25 wt.%; mean Y<sub>2</sub>O<sub>3</sub> 1168 ppm in range of 800 to 1360 ppm

A total of 423 analyses on 22 different minerals were produced with a Cameca SX-100 electron microprobe at The Open University in the UK. Compositions of the various essential and accessory minerals identified in the current investigation include pyrochlore, diopside, hedenbergite, hastingsite, ilmenite, magnetite, ilmenomagnetite, biotite, phlogopite, muscovite-paragonite, calcite, fluorapatite, fluorite, clinohumite, pyrite, pyrrhotite, chalcopyrite, Ba-bearing K-feldspar, albite, nepheline, zircon and ancyllite.

Pyrochlore is a potential ore mineral for Nb, Ta and possibly the rare earth elements in the Lackner Lake alkalic complex and focus was upon this mineral with 173 analyses. Numerous species names for pyrochlore are applicable to electron microprobe derived data: *pyrochlore (sensu stricto)*, *barian pyrochlore*, *bariopyrochlore*, *uranian pyrochlore*, *barian-uranian pyrochlore* and *uranian-barian pyrochlore*.

Niobium has an overall mean in pyrochlore of 49.61 wt.% Nb<sub>2</sub>O<sub>5</sub> within a range of 43.3 to 57.86 wt.% whereas tantalum averages 2.24 wt.% Ta<sub>2</sub>O<sub>5</sub> in a range of 0.87 to 3.83 wt.%. Notable are two distinct data clusters for tantalum in pyrochlore centred at 2.5 wt.% and 3.7 wt.% Ta<sub>2</sub>O<sub>5</sub>.

The mesocratic biotite-K-feldspar-diopside nepheline syenite of sample 19151 is unique with the highest mean Ta<sub>2</sub>O<sub>5</sub> values (3.66 wt.%) and Nb<sub>2</sub>O<sub>5</sub> (54.41 wt.%) in pyrochlore. These types of magmatic segregations are common in the core of drill hole 66-11-01 and future exploration should focus upon their distribution in the host ijolite and scale range in the Lackner Lake complex as a whole.

Considerable overall chemical variation was observed in pyrochlore, summarized for means and ranges in table below for the entire database:

Metal Oxide	Mean (wt.%)	Range (wt.%)
Nb2O5	49.61	43.3 to 57.86
Ta2O5	2.24	0.87 to 3.83
BaO	4.06	0.00 to 12.91
SrO	1.1	0.43 to 2.26
UO2	4.84	1.48 to 8.08
ThO2	2.38	0.39 to 6.81
TREO	1.1	0.03 to 3.78
ZrO	1.5	0.55 to 2.34

In most cases UO<sub>2</sub> exceeds ThO<sub>2</sub> in pyrochlore except for the Zone 6 Fe-Ti-P-Nb-Th-U-Ta deposit where a reversal is notable with ThO<sub>2</sub> (mean 6.04 wt.%) significantly higher than UO<sub>2</sub> (mean 2.42 wt.%).

BaO and UO<sub>2</sub> exhibit a tendency in replacement zones along pyrochlore grain margins and within internal fractures that may attest to influence of late carbothermal fluid activity.

The presence of clinohumite [Mg<sub>9</sub>(SiO<sub>4</sub>)<sub>4</sub>F<sub>2</sub>], which is essentially a hydrated olivine, is regarded by the author as logical evidence to classify the magnetite-carbonatite rocks at this occurrence as phoscorite. Phoscorite is a rare rock with only 21 localities known globally (Krasnova et al. 2004) and the Lackner Lake occurrence appears to be the first in Canada. Large mineral deposits can be associated with phoscorites as at Phalaborwa, RSA, Kovdor, Russia and Araxa, Brazil (Krasnova et al. 2004, Fontana 2006; Chachmouradian and Wall 2012).

Late stage REE-rich mineralization, marked by ancylite [CeSr(CO<sub>3</sub>)<sub>2</sub>(OH) · H<sub>2</sub>O] and fluorapatite was discovered in fractures contained in highly altered nepheline from a mesocratic biotite-K-feldspar-diopside nepheline syenite (19151) hosted in foliated ijolite. Distribution and scale range of this stage of REE mineralization in the Lackner Lake complex is currently unknown.

## INTRODUCTION

There is a paucity of modern mineralogical work undertaken on the Lackner Lake alkalic complex that is restricted to electron microprobe (EMP) work on two samples from the Pole Lake REE-Th-Ba-Nb occurrence (Breaks 2016). Previous studies on mineralogy were mainly done in 1950's and early 1960's (e.g., Hodder 1961). Newer mineralogical verification work is thus needed to generate exploration models.

Eight samples were submitted for EMP analysis to A.G. Tindle, at The Open University, Milton Keynes, UK and analyzed from February 16 to 20, 2017. Dr. Tindle is a well known electron microprobe geoscientist in the UK and author of numerous peer reviewed publications (e.g., Tindle and Breaks 1998) that include a major reference book on Minerals of Britain and Ireland (Tindle 2006).

The mineral deposit and occurrences represented by these samples were recommended for mineralogical investigation in a recent report submitted Feb 20, 2017 to Mines and Minerals Division of the Ministry of Northern Development and Mines for assessment work filing.

The targeted samples include:

- Nb-Ta-REE-Ba-Sr-U mineralization associated with carbonatite zones and mesocratic to leucocratic syenite segregations in ijolite from drill core (DDH 66-11-01),
- nepheline syenite that directly underlies the carbonatite mineralized ijolite in drill core (DDH 66-11-01),
- Zone 6 deposit (Fe-Ti-P-Nb-Th-U-Ta), and,
- NE Camp Lake Fe-Ti-Nb-Th-Sc occurrence (magnetite-rich rock).

A total of 423 compositions of 22 different minerals were verified with the EMP and all data are presented in Appendix 1.

## ANALYTICAL PROCEDURES

Mineral composition data were determined on eight polished thin-section by Dr. A.G. Tindle with a Cameca SX-100 electron microprobe at the Dept. of Earth Sciences, The Open University, Milton Keynes, UK. Analytical conditions and standards used in the electron microprobe analysis (EMPA), are given below and all electron microprobe data are found in Appendix 1.

Mineral analyses from the Department of Earth Sciences at the Open University were collected using a Cameca SX-100 microprobe operating in wavelength-dispersive mode and equipped with four wavelength dispersive spectrometers. An operating voltage of 20kV and probe current of 20nA (measured on a Faraday cage) were used. Count times varied from 20 to 80 seconds per element depending on the count rate per second per nanoamp. This ensured that those elements with a high relative count rate were measured to a similar precision to other elements with low relative count rates. For most minerals a beam diameter of 10 microns was used, but for beam sensitive minerals such as potassium feldspar a 20 micron beam was used instead. Data were corrected using a 'PAP' correction procedure (Pouchou & Pichoir 1985).

## Calibration standards and X-ray lines measured

synthetic LiF (F K $\alpha$ )	synthetic ScPO <sub>4</sub> (Sc K $\beta$ )	synthetic SrTiO <sub>3</sub> (Sr L $\alpha$ )	pollucite (Cs L $\alpha$ )
jadeite (Na K $\alpha$ )	rutile (Ti K $\alpha$ )	synthetic YPO <sub>4</sub> (Y L $\alpha$ )	barite (Ba L $\alpha$ )
forsterite (Mg K $\alpha$ )	hematite (Fe K $\alpha$ )	cassiterite (Sn L $\alpha$ )	Ta metal (Ta M $\alpha$ )
feldspar (Al, Si and K K $\alpha$ )	willemite (Zn K $\alpha$ )	stibnite (Sb L $\alpha$ )	synthetic WO <sub>3</sub> (W M $\alpha$ )
synthetic KCl (Cl K $\alpha$ )	synthetic GaP (Ga K $\alpha$ )	synthetic zirconia (Zr L $\alpha$ )	crocoite (Pb M $\alpha$ )
bustamite (Ca and Mn K $\alpha$ )	synthetic RbBr (Rb L $\alpha$ )	Nb metal (Nb L $\alpha$ )	

It should be noted that amongst the rare earth elements the electron microprobe can only precisely analyze for La<sub>2</sub>O<sub>3</sub>, Ce<sub>2</sub>O<sub>3</sub>, Pr<sub>2</sub>O<sub>3</sub>, Nd<sub>2</sub>O<sub>3</sub> and Y<sub>2</sub>O<sub>3</sub>. This is due to strong interference patterns especially within the heavy rare earths (A.G. Tindle, personal communication, 2009). Thus low totals between 73 and 94 wt.% could in part reflect presence of the rare earth elements from Sm to Lu but in some minerals or could represent unanalyzed H<sub>2</sub>O. The short comings of electron microprobe analysis for rare earths beyond Nd in the periodic table can be averted by utilizing LA-ICP-MS (laser-ablation inductively coupled mass spectrometry) analysis that is also available at The Open University.

Scandium cannot be accurately analyzed with the EMP due to strong interference between barium L-alpha and scandium K-beta spectral lines (A.G. Tindle. personal communication 2017). Analysis of scandium in polished thin sections is best undertaken via laser ablation inductively coupled mass spectrometry (LA-ICP-MS). This is recommended for those samples with anomalous scandium such as from the NE Camp Lake Fe-Ti-Nb-Th-Sc occurrence (Breaks 2016).

## **LITHOLOGIES ANALYZED BY ELECTRON MICROPROBE**

Representative compositions of the various essential and accessory minerals identified in the current investigation include pyrochlore, diopside, hedenbergite, hastingsite, ilmenite, magnetite, ilmenomagnetite, biotite, phlogopite, muscovite-paragonite, calcite, fluorapatite, fluorite, clinohumite, pyrite, pyrrhotite, chalcopyrite, Ba-bearing K-feldspar, albite, nepheline, zircon and ancylite.

Pyrochlore, the most important economic mineral, was the central focus of the investigation and a summary of its compositional variation. Previous EMP work by A.G. Tindle confirmed britholite-(La), britholite-like mineral, monazite-(Ce), a secondary REE mineral, and Y+LREE-bearing fluorapatite at the Pole Lake REE-Ba-Th-Nb occurrence. Coexisting phases identified there include phlogopite, nepheline, aegirine-augite, calcite, barite and K-Na feldspar (Breaks 2016).

The ensuing images document the range of sample material from the Lackner Lake alkalic complex analyzed by the Cameca SX-100 electron microprobe.

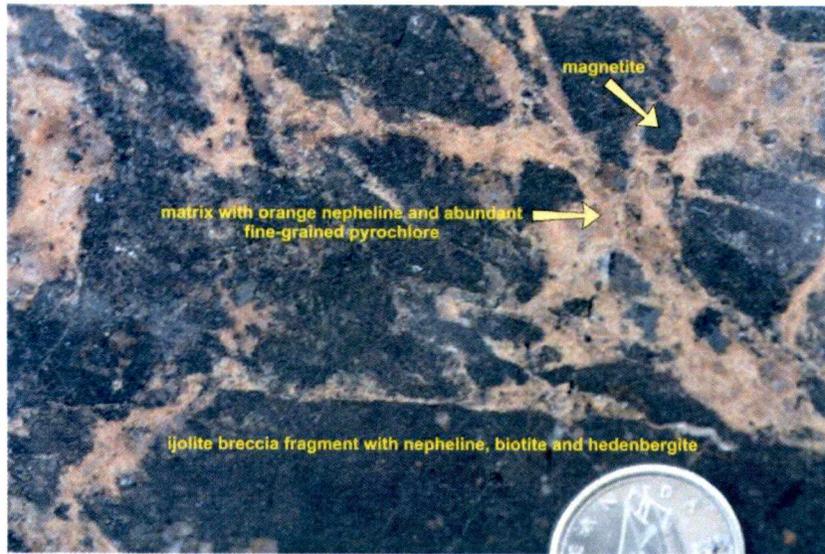


Photo 1. Zone 6 Fe-Ti-P-Nb-Th-U-Ta deposit: 14-554



Photo 2. NE Camp Lake Fe-Ti-Nb-Th-Sc phoscorite occurrence: 14-508

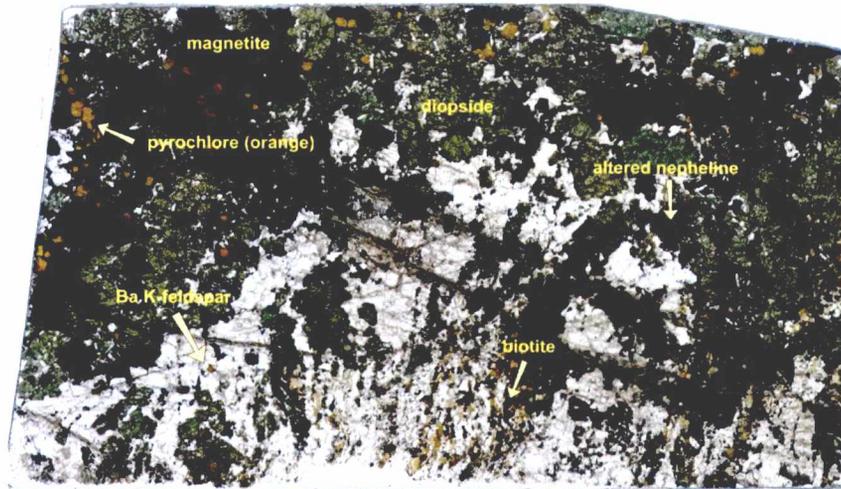


Photo 3. Mesocratic coarse-grained nepheline syenite mineralized with pyrochlore: 19151



Photo 4. Leucocratic syenite segregation of hastingsite-magnetite-diopside-Ba-rich K-feldspar (yellow stain): 26362

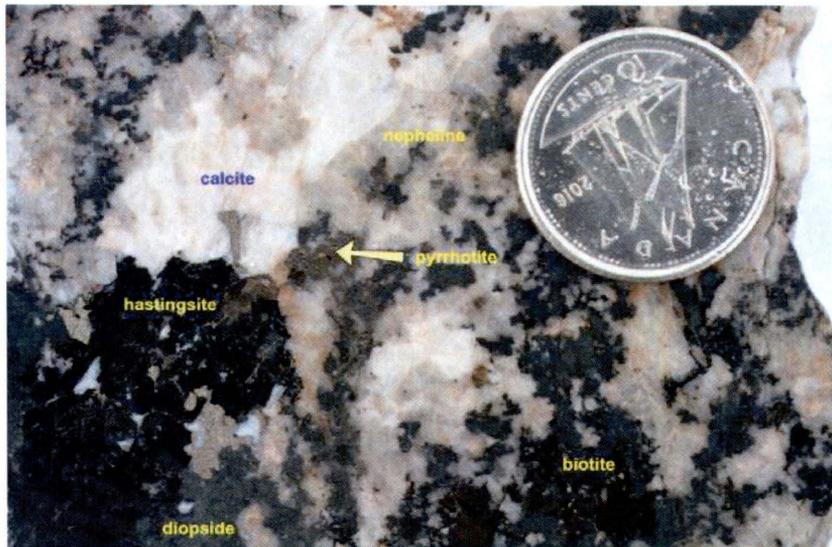


Photo 5. Mesocratic coarse-grained hastingsite-biotite-diopside syenite segregation - 26374

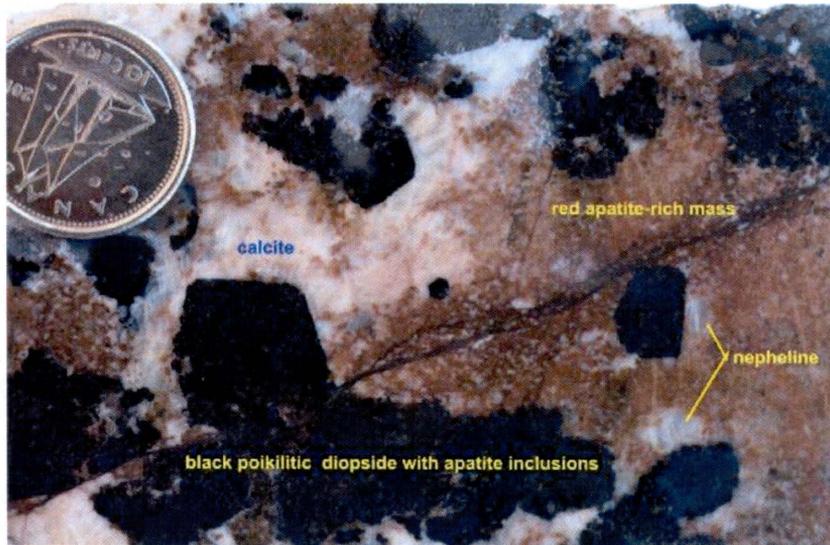


Photo 6. Silicocarbonatite zone - nepheline-biotite-calcite-diopside-apatite rock: 19152



Photo 7. Silicocarbonatite zone - carbonatite and adjacent carbonate alteration in sample 26380.

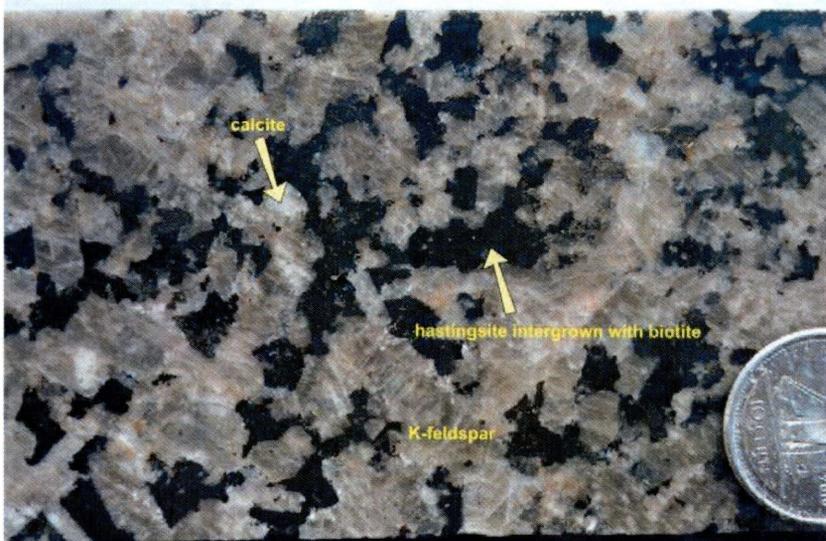


Photo 8. Biotite-hastingsite-nepheline syenite: 26392

## RESULTS

All data produced by the EMP are given in Appendix 1 and individual mineral composition summaries are presented in various tables of this section.

### Pyrochlore Group

Practical formal species names for the Pyrochlore Group do not appear to exist. A provisional mineral naming scheme for pyrochlore was devised by A.G. Tindle based on cation variation at site A and

referenced from the Handbook of Mineralogy (see links in REFERENCES for pyrochlore, uranpyrochlore, and bariopyrochlore ).

This nomenclature, summarized in Table 1, is applicable to electron microprobe derived data, as produced for this report, and based upon practical long-standing usage of mineral names such as bariopyrochlore and uranpyrochlore in the literature.

Table 1. Pyrochlore group species nomenclature used for the Lackner Lake alkalic complex.

Pyrochlore Species Name	%Uranium / $\Sigma$ A-Site cations	%Barium/ $\Sigma$ A-Site cations
Pyrochlore ( <i>sensu stricto</i> )	<10	<10
Barian pyrochlore	<10	10 to 20
Bariopyrochlore	<10	>20
Uranian pyrochlore	>10	<10
Barian-uranian pyrochlore	>10	10 to 20
Uranian-bariopyrochlore	>10	>20
Uranpyrochlore	>20	<10

The Ba vs U+Th diagram provides a species classification on the basis of the respective percentages of total A-site cations shown in Table 1 and based upon atoms per formula unit (apfu) data in Appendix 1. Percentage of uranium in total A-site cations varies from 4.40 % to 15.84 % and therefore is insufficient to classify as uranpyrochlore that requires values that exceed 20 % (Handbook of Mineralogy).

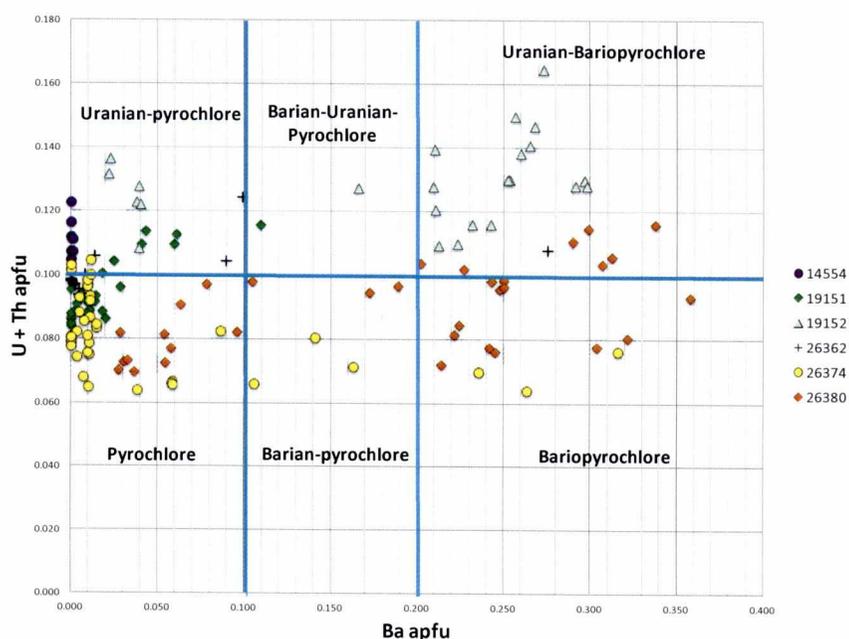


Figure 1. Ba vs U+Th apfu diagram for Lackner Lake species nomenclature division of pyrochlore from the Lackner Lake alkalic complex.

### Pyrochlore Compositional Variation in the Lackner Lake Alkalic Complex

This mineral group has considerable chemical variation particularly in alkaline intrusive rocks and carbonatites. The general formula as modified for the pyrochlore supergroup is  $A_2Nb_2(O,OH)_6Z$  where A is Na, Ca,  $Sn^{2+}$ , Sr,  $Pb^{2+}$ ,  $Sb^{3+}$ , Y, REE,  $Th^{4+}$ ,  $U^{4+}$ ,  $H_2O$  or  $\square$  and Z is OH, F, O,  $H_2O$  or  $\square$

<<https://www.mindat.org/min-3316.html>>

The detailed mineral formula and structural diagram for pyrochlore from alkaline rocks and associated carbonatite is given at the Anton Chackmouradian website:

<[http://www.umanitoba.ca/science/geological\\_sciences/faculty/arc/pyrochlore.html](http://www.umanitoba.ca/science/geological_sciences/faculty/arc/pyrochlore.html)>

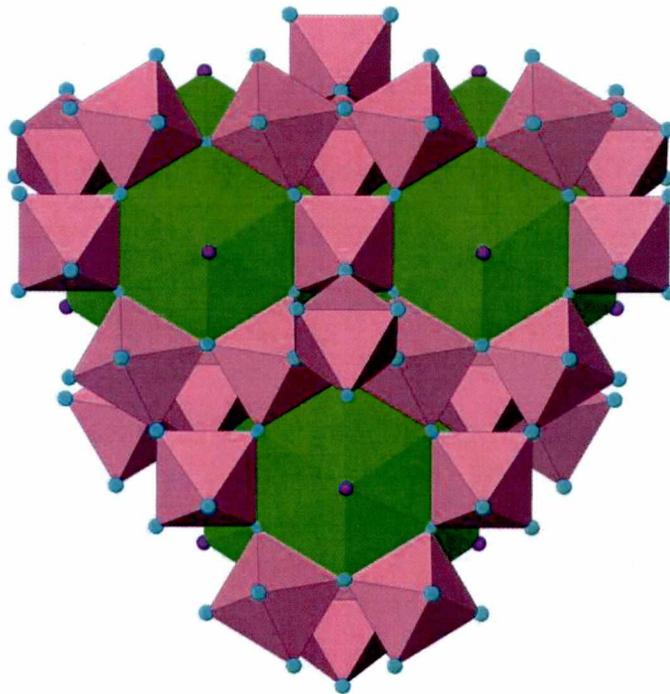


Figure 2. Crystal structure of pyrochlore . Pink = 3-D network of  $(Nb,Ti,Ta,Zr)O_6$  octahedra connected by oxygen atoms (blue spheres), green = A-site large cations in 8-fold coordination with  $O^{2-}$ , OH and F (purple spheres). Source: [http://www.umanitoba.ca/science/geological\\_sciences/faculty/arc/pyrochlore.html](http://www.umanitoba.ca/science/geological_sciences/faculty/arc/pyrochlore.html)

Pyrochlore is the main potential ore mineral for Nb and Ta in the Lackner Lake alkalic complex and the present investigation focused upon this mineral with a total of 173 mineral analyses (Appendix 1). It occurs in six samples (Table 2) with very impressive development in ijolite breccia at the Zone 6 Fe-Ti-P-Nb-Ta-Th-U deposit (Photos 1, 9 and 10). A grab rock sample analysis (1634554 in Breaks 2016) revealed 1.73 wt.% Nb , 647 ppm Ta, 2516 ppm Th, and 755 ppm U from this deposit. Probe sample 14-554 was taken from a representative hand specimen of this bulk rock analysis.

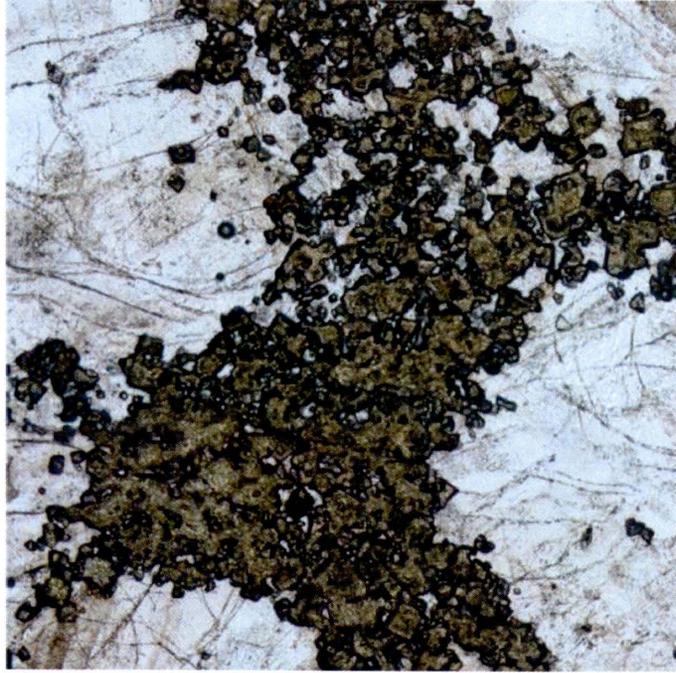


Photo 9. Massive segregation of pyrochlore mineralization enclosed in nepheline from matrix of ijolite breccia at the Zone 6 Fe-Ti-P-Nb-Th-U-Ta deposit. Sample 14-508 that represents a loose specimen from a large rock pile of blasted rock excavated from test pit on Beaverdam Lake.

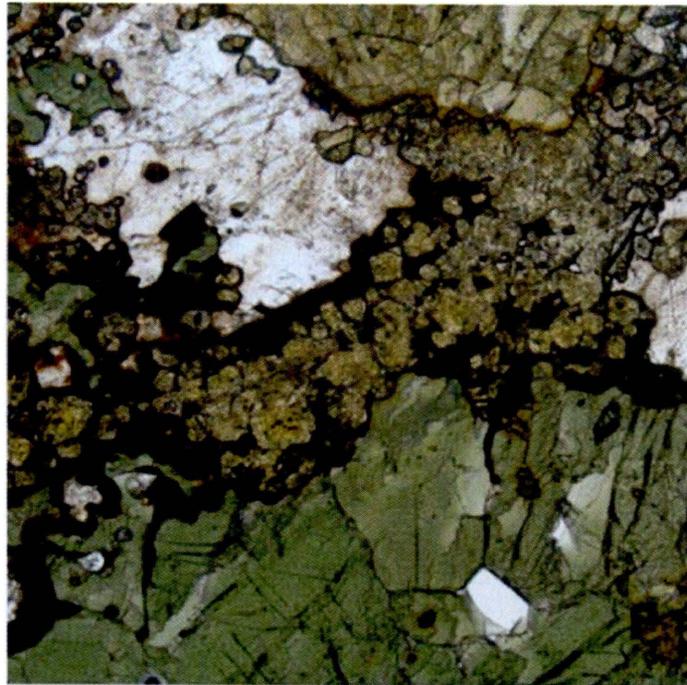


Photo 10. Pyrochlore partly enclosed by magnetite and adjacent to green diopside and white nepheline. Sample 14-554 from the Zone 6 Fe-Ti-P-Nb-Th-U-Ta deposit.

The oxide totals are sometimes low (87 to 95 wt.%) and due to the missing H<sub>2</sub>O content in the analyses. Analyses from the literature indicate a variation of H<sub>2</sub>O+ between 4.11 and 8.17 wt.% in bariopyrochlore and 4.49 wt.% in uranpyrochlore (Handbook of Mineralogy). Other low total issues are due to sample decomposition during analysis with the EMP as there can exist excessive H<sub>2</sub>O in some grains that caused damage of the carbon coating on the polished thin sections.

Mean values for various oxides in pyrochlore in six samples are presented in Table 2. The overall respective means and ranges for Nb<sub>2</sub>O<sub>5</sub>, Ta<sub>2</sub>O<sub>5</sub>, total Light REO, BaO, SrO, UO<sub>2</sub>, ZrO and ThO<sub>2</sub> in wt. oxides, in the entire database are summarized in Table 3, and reveal the considerable compositional variation. Mean compositions of the various species of pyrochlore are given in Table 4.

Table 2. Mean compositions (wt.% oxide) for various samples with pyrochlore from the Lackner Lake alkalic complex.  
N = number of analyses.

	14-554	19151	19152	26362	26374	26380
Na <sub>2</sub> O	3.81	3.66	1.39	3.93	3.68	1.28
CaO	15.34	12.14	4.02	12.73	12.95	4.66
MnO	0.1	0.21	0.41	0.38	0.04	0.3
BaO	0.02	0.79	7.29	1.66	1.92	7.05
SrO	0.68	0.97	0.84	1.51	1.35	1.02
FeO	0.43	1.03	0.79	0.79	0.31	0.67
UO <sub>2</sub>	2.42	7.01	6.1	5.43	4.15	3.94
ThO <sub>2</sub>	6.04	0.49	2.73	2.49	2.31	2.22
PbO	0.86	1.34	1.01	1.03	0.97	0.89
La <sub>2</sub> O <sub>3</sub>	0.14	0.03	0.13	0.14	0.26	0.06
Ce <sub>2</sub> O <sub>3</sub>	0.24	0.01	1.37	0.3	1	0.82
Pr <sub>2</sub> O <sub>3</sub>	0.13	0.04	0.05	0.09	0.11	0.03
Nd <sub>2</sub> O <sub>3</sub>	0.46	0.08	0.07	0.28	0.33	0.07
TLREO	0.97	0.15	1.63	0.8	1.69	0.98
Y <sub>2</sub> O <sub>3</sub>	0.05	0.02	0.05	0.03	0.07	0.02
SiO <sub>2</sub>	0.06	0.12	1.08	0.04	0.32	0.54
Al <sub>2</sub> O <sub>3</sub>	0.06	0.07	0.09	0.08	0.13	0.05
MgO	0.0	0.01	0.0	0.0	0.0	0.0
P <sub>2</sub> O <sub>5</sub>	0.02	0.02	0.03	0.02	0.02	0.02
Nb <sub>2</sub> O <sub>5</sub>	49.64	54.71	46.06	49.37	48.25	50.67
Ta <sub>2</sub> O <sub>5</sub>	1.62	3.66	2.16	3.45	1.85	1.87
SnO <sub>2</sub>	0.0		0.0		0.01	
TiO <sub>2</sub>	7.56	6.37	10.57	9.08	8.93	8.97
ZrO <sub>2</sub>	1.16	0.72	1.53	0.74	1.8	1.98
F	2.77	2.78	1.07	2.42	3.54	1.37
Cl	0.03	0.02	0.04	0.03	0.09	0.02
<b>Total</b>	94.58	96.43	90.5	96.8	96.07	89.5
N	12	27	36	12	53	33

The percentage of uranium of the total A-site cations varies from 5.24 to 15.77 % that is not sufficient to classify any of the pyrochlore analyses as uranpyrochlore. This species is defined on the basis of uranium in excess of 20 % of the total A-site cations (Handbook of Mineralogy). Uranium has a mean of 4.99 wt.% within a range of 1.48 to 8.05 wt.% for the entire database. As significant amounts of thorium can be present (mean 2.66 wt.%, range 0.42 to 6.73 wt.%), the apfu values of these two radionuclides were combined in the species classification of Figure 1.

Table 3. Means and ranges for various oxides in pyrochlore from entire database for the Lackner Lake alkalic complex. Number of analyses = 173.

Metal Oxide	Mean (wt.%)	Range (wt.%)
Nb <sub>2</sub> O <sub>5</sub>	49.61	43.3 to 57.86
Ta <sub>2</sub> O <sub>5</sub>	2.24	0.87 to 3.83
BaO	4.06	0.00 to 12.91
SrO	1.1	0.43 to 2.26
UO <sub>2</sub>	4.84	1.48 to 8.08
ThO <sub>2</sub>	2.38	0.39 to 6.81
TREO	1.1	0.03 to 3.78
ZrO	1.5	0.55 to 2.34

Table 4. Mean compositions for pyrochlore and various species in the Lackner Lake alkalic complex.

	pyrochlore	pyrochlore	uranian pyrochlore	barian- uranian pyrochlore	pyrochlore	uranian pyrochlore	barian- uranian pyrochlore	uranian- bario pyrochlore	pyrochlore	uranian pyrochlore	pyrochlore	bariopyrochlore	barian- pyrochlore	bariopyrochlore	barian-uranian pyrochlore	uranian pyrochlore	uranian bariopyrochlore
	14554	19151	19151	19151	19152	19152	19152	19152	26263	26263	26372	26372	26372	26380	26380	26380	26380
Na2O	3.81	4.46	0.20	0.00	3.89	1.66	1.28	0.86	4.01	2.97	4.08	0.62	1.81	0.40	1.17	0.90	0.56
CaO	15.34	13.34	7.15	5.57	9.90	6.83	3.38	2.26	13.43	5.12	13.83	5.89	9.43	3.17	5.76	5.73	2.67
MnO	0.10	0.18	0.35	0.41	0.13	0.24	0.36	0.51	0.33	0.95	0.04	0.03	0.05	0.39	0.29	0.23	0.36
BaO	0.02	0.41	2.05	4.17	1.49	2.64	8.25	9.48	1.45	4.01	0.81	10.67	6.42	10.22	4.22	3.92	9.55
SrO	0.68	0.77	1.83	1.81	0.92	0.74	0.70	0.85	1.41	2.64	1.30	1.72	1.61	1.39	0.76	0.71	0.97
FeO	0.43	1.07	0.87	0.61	0.90	0.73	0.84	0.78	0.81	0.51	0.31	0.32	0.35	0.75	0.90	0.78	0.71
UO2	2.42	6.94	7.33	7.26	7.10	6.57	5.36	5.84	5.38	5.99	4.36	2.60	3.22	2.95	4.62	3.61	4.15
ThO2	6.04	0.48	0.55	0.52	2.29	2.68	2.90	2.81	2.45	2.86	2.31	2.20	2.37	2.16	2.31	2.28	2.17
PbO	0.86	1.31	1.45	1.41	1.20	1.00	1.03	0.98	1.02	1.18	1.01	0.72	0.75	0.65	0.50	0.85	0.99
La2O3	0.14	0.02	0.05	0.02	0.06	0.06	0.16	0.15	0.14	0.14	0.24	0.38	0.40	0.08	0.07	0.01	0.04
Ce2O3	0.24	0.00	0.02	0.12	0.06	0.47	1.54	1.83	0.26	0.76	0.71	3.20	2.23	1.48	0.13	0.26	1.16
Pr2O3	0.13	0.04	0.04	0.00	0.12	0.11	0.00	0.03	0.10	0.00	0.11	0.09	0.11	0.02	0.00	0.00	0.01
Nd2O3	0.46	0.09	0.02	0.00	0.27	0.17	0.16	0.01	0.29	0.09	0.37	0.00	0.23	0.00	0.14	0.10	0.00
TlREO	0.97	0.16	0.13	0.14	0.51	0.81	1.86	2.03	0.79	0.99	1.43	3.67	2.97	1.57	0.34	0.37	1.21
Y2O3	0.05	0.02	0.03	0.00	0.02	0.03	0.06	0.03	0.00	0.07	0.11	0.12	0.12	0.01	0.04	0.00	0.03
SiO2	0.06	0.08	0.34	0.01	0.59	0.89	2.17	1.15	0.04	0.00	0.24	1.11	0.47	0.47	0.68	0.37	0.49
Al2O3	0.06	0.06	0.09	0.07	0.06	0.05	1.11	0.05	0.08	0.10	0.11	0.42	0.13	0.04	0.07	0.05	0.05
MgO	0.00	0.01	0.01	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
P2O5	0.02	0.02	0.02	0.02	0.04	0.03	0.10	0.03	0.02	0.02	0.02	0.01	0.01	0.02	0.00	0.04	0.02
Nb2O5	49.64	54.34	56.59	55.28	45.76	45.42	45.68	46.31	49.16	51.62	48.58	45.48	46.99	51.54	50.49	53.34	49.87
Ta2O5	1.62	3.61	3.83	4.09	2.99	2.34	1.30	2.01	3.48	3.22	1.90	1.51	1.55	1.62	1.85	2.00	1.89
SnO2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00
TiO2	7.56	6.27	6.93	6.36	10.80	11.00	10.03	10.45	8.98	10.16	8.97	8.63	8.71	8.26	9.01	9.37	9.10
ZrO2	1.16	0.72	0.72	0.79	1.46	1.34	1.32	1.61	0.74	0.74	1.81	1.77	1.83	1.88	1.95	1.96	1.95
F	2.77	3.33	0.39	0.14	3.26	2.42	0.65	0.35	2.60	0.39	3.77	1.67	2.75	0.85	1.84	1.52	0.53
Cl	0.03	0.02	0.02	0.01	0.04	0.08	0.06	0.03	0.03	0.03	0.08	0.10	0.11	0.03	0.08	0.00	0.02
Total	94.58	97.77	90.99	88.85	93.87	88.27	90.30	90.45	97.01	94.49	96.46	92.94	94.55	89.90	87.22	88.41	88.50
N	8	22	4	1	3	4	1	16	11	1	32	3	2	2	2	1	18

N = number of analyses

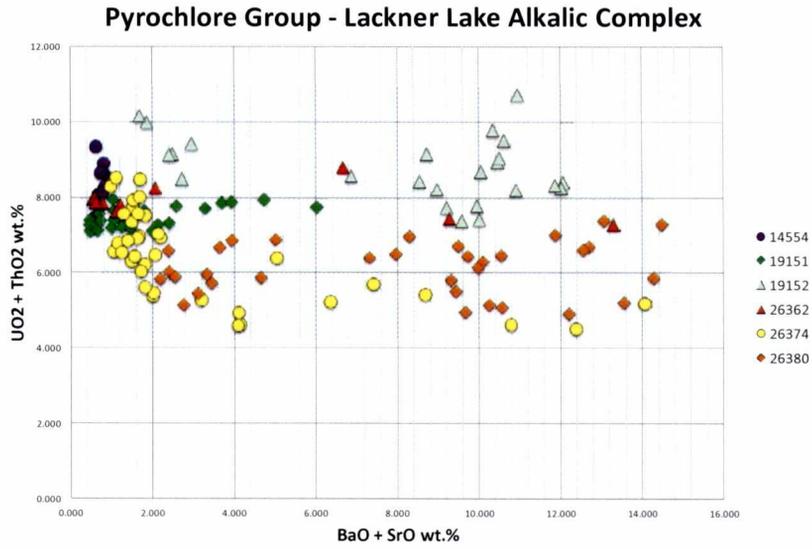


Figure 1. Variation of BaO+SrO vs UO<sub>2</sub>+ThO<sub>2</sub> in wt.% oxides for pyrochlore from the Lackner Lake alkalic complex.

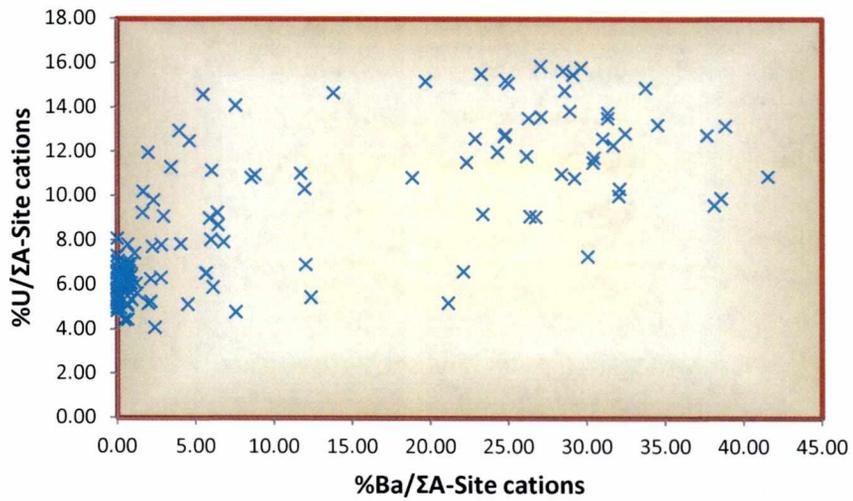


Figure 2. Uranium vs barium as % atoms per formula unit at site-A of the pyrochlore structure.

The following diagrams reveal the considerable compositional variation in the current data base of 173 analyses.

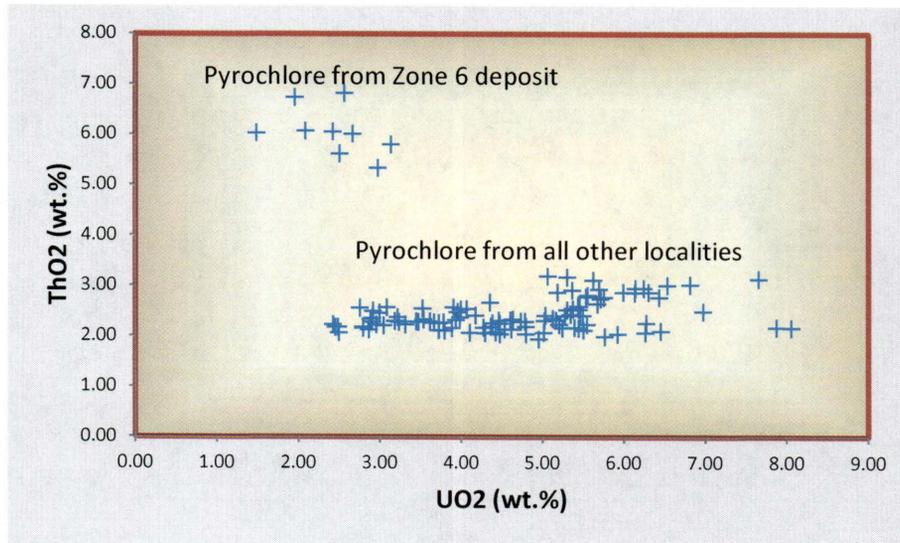


Figure 3. Thorium vs uranium in wt.% oxides from all pyrochlore analyses from the Lackner Lake complex.



Photo 11. Pyrochlore grain from silicocarbonatite zone in sample 26380 that shows patchy zonation and late crosscutting veins with a bright white mineral that could not be identified but possibly a REE phase. Lighter areas contain elevated BaO and SrO vs darker patchy remnants.

Pyrochlore associated with silicocarbonatite zones (26380 and 19152; Photo 11) reveals the widest barium contents with numerous analyses that exceed 8 wt.% BaO and a maximum content of 12.98 wt.%. There is a strong positive association ( $R^2 = 0.83$ ) between BaO and total LREO in pyrochlore for this type of mineralization (Figure 7). Here, elevated BaO and UO<sub>2</sub> tends to occur along crystal margins of pyrochlore or in veins that crosscut the mineral where secondary alteration or recrystallization has occurred (Photo 12).



Photo 12. Pyrochlore from sample 26374 showing late alteration in small masses and veins with elevated BaO and UO<sub>2</sub> in the white areas near grain margins.

Elevated barium contents were also found in mesocratic syenite segregation of sample 26374 (Figure 6) marked by a wide range of values (range: 0.00 to 12.37 wt.% ) in which increase in BaO occurs along crystal margins possibly owing to reaction with late stage carbothermal fluids.

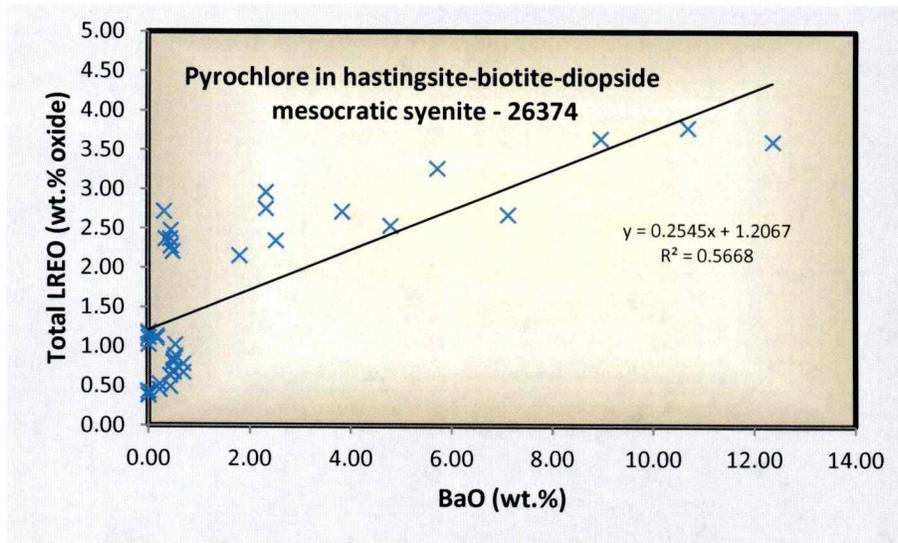


Figure 4. BaO vs total La+Ce+Pr+Nd (wt.% oxides) in pyrochlore from hastingsite-biotite-diopside syenite of sample 26474.

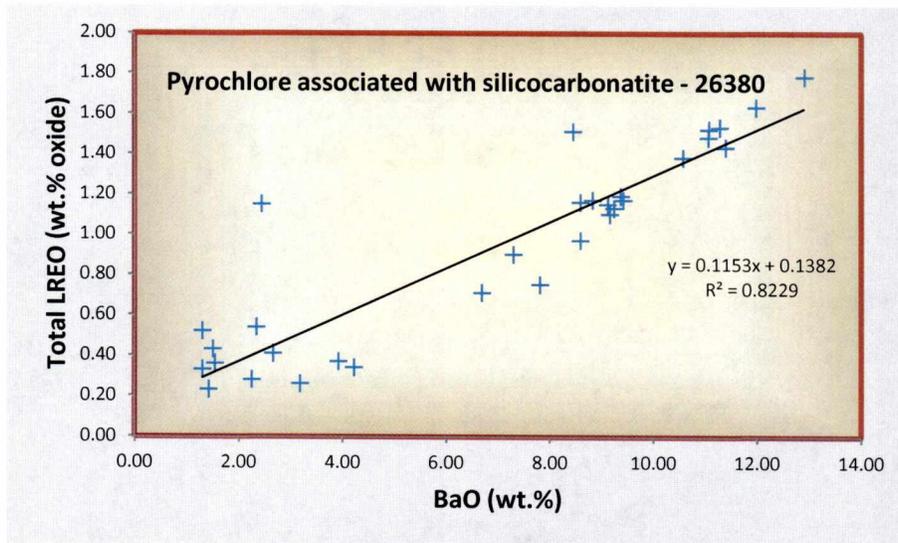


Figure 5. BaO vs total La+Ce+Pr+Nd (wt.% oxides) in pyrochlore from silicocarbonatite of sample 26480.

### Tantalum and Niobium Variation

In the overall database tantalum in pyrochlore has a mean of 2.38 wt% Ta<sub>2</sub>O<sub>5</sub> within a range of 0.97 to 2.94 wt.%. Two data clusters seen in Figure 8 centred at 2% and 3.7%.

Mean values of tantalum and niobium in pyrochlore for individual samples are given in Table 2 where the highest Ta<sub>2</sub>O<sub>5</sub> contents occur in mesocratic and leucocratic syenite segregations hosted in ijolite (samples 19151 and 26362: 3.45 wt.% and 3.66 wt.% Ta<sub>2</sub>O<sub>5</sub>). The mesocratic biotite-K-feldspar-diopside nepheline syenite of sample 19151 is unique with the highest Ta<sub>2</sub>O<sub>5</sub> (3.66 wt.%) and Nb<sub>2</sub>O<sub>5</sub> values (54.71 wt.%).

The Zone 6 Fe-Ti-P-Nb-Th-U-Ta deposit has pyrochlore with a lower mean Ta<sub>2</sub>O<sub>5</sub> content of 1.62 wt.% but with a fairly uniform composition. Pyrochlore from zones associated with silicocarbonatite mineralization (Table 2: 19152 and 26380) have similar lower Ta<sub>2</sub>O<sub>5</sub> values (1.87 and 2.16 wt.). Sample 26374, the third of a syenite segregation in ijolite, has a similar Ta<sub>2</sub>O<sub>5</sub> content at 1.85 wt.%.

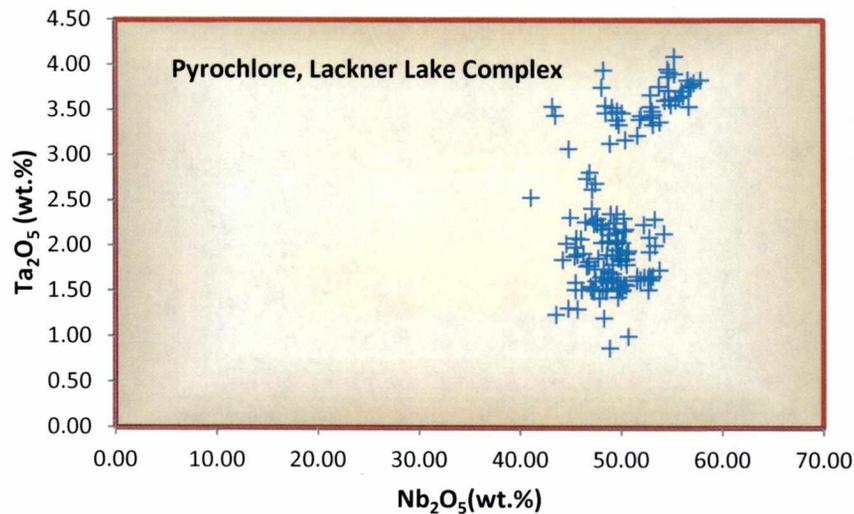


Figure 6. Tantalum vs niobium in wt.% oxide for pyrochlore from the Lackner Lake alkalic complex

## Fluorapatite

Fluorapatite was identified in six samples (Photo 13) and is a potentially important mineral for the critical rare earth elements Dy, Tb, Eu and Nd for high technology applications and phosphorus for the fertilizer industry. The overall database has a mean of 2.86% La<sub>2</sub>O<sub>3</sub>+Ce<sub>2</sub>O<sub>3</sub>+Pr<sub>2</sub>O<sub>3</sub>+Nd<sub>2</sub>O<sub>3</sub> in fluorapatite within a range of 1.34 to 6.09 wt.%. Previous work by Breaks (2016) with four high purity chemically analyzed separates documented a mean of 2.80 wt.% ΣREO in range of 1.96 to 3.25 wt.%. The mean Y<sub>2</sub>O<sub>3</sub> was 1168 ppm in range of 800 to 1360 ppm. Partial analyses of total La<sub>2</sub>O<sub>3</sub>+Ce<sub>2</sub>O<sub>3</sub>+Pr<sub>2</sub>O<sub>3</sub>+Nd<sub>2</sub>O<sub>3</sub> (wt.%) By EMPA gave an overlapping range of mean values for the six samples (Table 5 : 2.33 to 3.30 wt.%).

Elevated strontium also characterizes apatite with a range of mean SrO values of 0.87 to 3.27 wt.% in six sample of Table 5 that is comparable to those determined in four apatite separates: mean 2.80 wt.% ΣREO in range of 1.96 to 3.25 wt.%; mean Y<sub>2</sub>O<sub>3</sub> 1168 ppm in range of 800 to 1360 ppm.

Table 5. Mean compositions of fluorapatite from the Lackner Lake alkalic complex. N = numbers of analyses.

	<b>14-508</b>	<b>19151</b>	<b>19152</b>	<b>26374</b>	<b>26380</b>	<b>26392</b>
<b>P2O5</b>	40.46	40.39	38.99	39.65	37.27	39.33
<b>SiO2</b>	0.94	0.91	1.45	1.28	1.18	1.31
<b>TiO2</b>	0.01	0.00	0.01	0.01	0.02	0.01
<b>Al2O3</b>	0.00	0.00	0.00	0.00	0.01	0.01
<b>FeO</b>	0.03	0.05	0.06	0.03	0.04	0.05
<b>MnO</b>	0.02	0.04	0.04	0.04	0.02	0.05
<b>MgO</b>	0.05	0.04	0.04	0.04	0.03	0.03
<b>CaO</b>	52.84	52.54	50.55	51.01	50.67	50.54
<b>Na2O</b>	0.03	0.03	0.02	0.00	0.00	0.05
<b>SrO</b>	0.87	2.02	3.27	3.20	3.04	2.34
<b>BaO</b>	0.00	0.00			0.00	
<b>Y2O3</b>	0.17	0.11	0.15	0.09	0.09	0.12
<b>ThO2</b>	0.05	0.06	0.17	0.10	0.10	0.13
<b>UO2</b>	0.00	0.01	0.02	0.02	0.01	0.00
<b>F</b>	6.04	6.43	6.26	6.93	6.32	6.47
<b>Cl</b>	0.02	0.01	0.01	0.02	0.01	0.01
<b>F corr.</b>	2.92	3.10	3.02	3.35	3.05	3.12
<b>H2O*</b>	0.35	0.27	0.27	0.13	0.20	0.22
<b>Subtotal</b>	98.74	99.56	98.08	98.96	95.76	97.33
<b>O=F,Cl</b>	1.23	1.31	1.27	1.41	1.29	1.32
<b>Total</b>	97.51	98.25	96.81	97.54	94.47	96.02
<b>Sum LREO</b>	2.40	2.33	3.30	2.87	2.72	3.30
<b>U+Th oxides</b>	0.05	0.07	0.20	0.12	0.12	0.13
LREO sum of La+Ce+Pr+Nd as wt.% oxides						
<b>N</b>	2	4	10	5	13	7

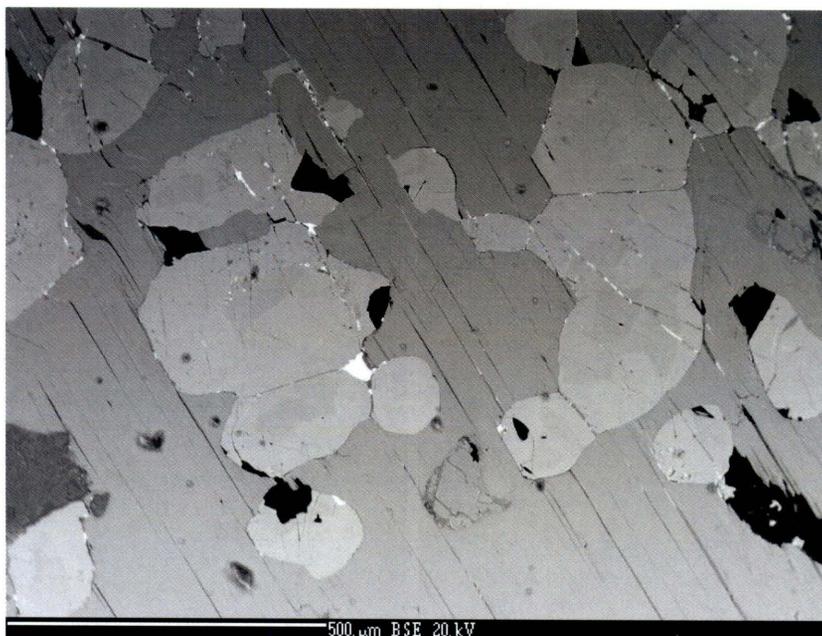


Photo 13. Fluorapatite inclusions in biotite from silicocarbonatite of sample 26380. Mean TREO and SrO respectively at 2.72 and 3.04 wt.%.

### Rare Earth Element Minerals

Rare earth elements are mainly concentrated in fluorapatite but one occurrence of a rare earth element-rich mineral ancylite-(Ce) was documented by the current work.

#### Ancylite-(Ce): $CeSr(CO_3)_2(OH) \cdot H_2O$

This mineral, with a total LREO value of 42.8 wt%, was tentatively identified in a late stage vein cutting across intensively altered nepheline in silicocarbonatite of sample 19151. Ancylite coexists with fluorapatite and zircon as shown in Photo 14. This type of REE-rich mineralization may reflect the carbothermal stage of evolution in a carbonatite system (Mitchell 2006; Wall et al. 2007). Further work is needed to document distribution and scale range of this mineralization stage.

The single analysis is given below:

La2O3	Ce2O3	Pr2O3	Nd2O3	TLREO	MgO	CaO	FeO	SrO	F	Na2O
12.17	24.72	1.61	4.28	42.78	0.66	3.21	0.83	10.53	3.24	0.71

P2O5	SiO2	TiO2	ThO2	UO2	Al2O3	Cl	Total	O=F, Cl	Total
0.04	1.60	0.07	0.54	0.04	0.19	0.00	91.81	1.36	90.45



Photo 14. Late vein enriched in ancyllite and fluorapatite with local zircon and hosted in diopside from sample 19151.

### Biotite-Phlogopite Series

Minerals of this series are widespread in the Lackner Lake complex and typically consist of biotite with a range in Mg/Mg+Fe apfu from 0.48 to 0.74. Phlogopite, with a Mg/Mg+Fe value of 0.04, was only documented at the NE Camp Lake Fe-Ti-Nb-Th-Sc occurrence that is characterized by the second highest bulk rock MgO value (16.2 wt.%) found to date in the complex.

Table 6. Mean compositions of biotite-phlogopite series minerals from the Lackner Lake complex. N = number of analyses.

	14-508	19151	26362	26374	26392
SiO <sub>2</sub>	34.55	32.48	33.43	33.92	34.74
TiO <sub>2</sub>	0.20	3.04	2.67	4.19	3.08
Al <sub>2</sub> O <sub>3</sub>	13.38	11.91	12.41	13.58	12.00
FeO	2.12	19.92	20.42	20.56	28.39
MnO	0.10	0.64	0.79	0.76	0.93
MgO	25.98	11.98	11.71	10.16	6.22
CaO	0.03	0.01	0.03	0.00	0.04
Na <sub>2</sub> O	0.25	0.18	0.22	0.28	0.37
K <sub>2</sub> O	8.39	9.46	9.39	8.29	8.86
SrO	0.04	0.01	0.04	0.13	0.01
BaO	5.51	0.59	0.38	2.80	0.29
ZnO	0.05	0.07	0.07	0.07	0.09
F	4.50	2.56	2.76	1.92	1.15
Cl	0.03	0.02	0.06	0.01	0.05
H <sub>2</sub> O*	1.72	2.39	2.34	2.85	3.13
Subtotal	96.85	95.22	96.70	99.51	99.34
O=F,Cl	1.90	1.08	1.17	0.81	0.49
Total	94.94	94.14	95.53	98.70	98.85
N	1	2	2	3	4

This mineral series may contain elevated BaO particularly for phlogopite in phoscorite of sample 14-508 that has a mean value of 5.52 wt.% (Table 6).

## Amphibole Supergroup

A dark brown amphibole, which occasionally occurs in conspicuous coarse, irregular masses up to 2 by 4 cm, was noted in three samples. The amphibole consists exclusively of various species of hastingsite  $\text{NaCa}_2(\text{Fe}_4^{2+}\text{Fe}^{3+})(\text{Si}_6\text{Al}_2)\text{O}_{22}(\text{OH})_2$  and mean compositions for various samples are given in Table 7.

Table 7. Mean compositions of hastingsite from the Lackner Lake complex. N = number of analyses.-

	26374	26380	26392
SiO2	34.88	37.28	38.25
TiO2	2.47	2.09	2.32
Al2O3	10.70	11.14	10.04
Cr2O3	0.00	0.00	0.00
Fe2O3	2.25	3.50	2.08
FeO	18.03	17.14	22.68
MnO	1.00	1.02	1.02
MgO	7.25	7.58	4.57
NiO	0.00	0.00	0.00
ZnO	0.04	0.06	0.07
CaO	11.31	11.01	10.13
Na2O	1.80	1.78	2.58
K2O	2.65	2.84	2.16
BaO	0.28	0.30	0.06
SrO	0.51	0.41	0.26
PbO	0.00	0.00	0.00
F	1.28	1.13	0.69
Cl	0.02	0.01	0.01
H2O*	1.18	1.34	1.52
Subtotal	95.61	98.60	98.44
O=F,Cl	0.54	0.48	0.29
Total	95.07	98.12	98.14
N	4	4	26

## Pyroxene Supergroup

### Diopside-Hedenbergite Series

Dark green to black pyroxenes are present in six samples. The black colouration is unusual and apparently restricted to silicocarbonatite Nb-REE-Ba-Sr mineralization in sample 19152 (Photo 6). Pyroxene compositions are typically diopside with an absence of sodic pyroxenes such as aegirine and aegirine-augite. Hedenbergite was documented in two samples at the Zone 6 Fe-Ti-P-Nb-Th-U-Ta deposit (Table 7: 14-554) and in nepheline syenite (Table 8: 26392) that lies below the ijolite-hosted Nb-

REE-Ba-Sr mineralized zone in drill hole 66-11-01 (sample 26392). Mean compositions of Ca-Mg-Fe pyroxenes are given in Table 8 below.

Table 8. Mean composition of diopside and hedenbergite from the Lackner Lake complex. N = number of analyses.

	14-554	26392	19151	19152	26362	26374
SiO <sub>2</sub>	49.85	49.83	43.83	47.76	44.70	48.75
TiO <sub>2</sub>	0.28	0.33	0.32	0.68	0.37	0.71
Al <sub>2</sub> O <sub>3</sub>	0.78	1.65	2.27	3.19	2.19	3.00
Cr <sub>2</sub> O <sub>3</sub>	0.00	0.00	0.00	0.00	0.00	0.00
Fe <sub>2</sub> O <sub>3</sub>	2.77	2.70	10.33	4.52	8.82	3.39
FeO	15.26	17.54	8.65	11.10	9.09	11.89
MnO	1.08	0.93	1.00	1.06	1.10	1.00
MgO	6.32	4.81	6.20	7.67	6.65	7.90
CaO	19.57	17.43	21.22	22.04	21.66	21.83
Na <sub>2</sub> O	0.01	0.04	0.00	0.01	0.01	0.02
K <sub>2</sub> O	2.33	3.38	1.57	1.17	1.29	1.27
<b>Total</b>	<b>98.27</b>	<b>98.64</b>	<b>95.40</b>	<b>99.21</b>	<b>95.86</b>	<b>99.76</b>
N	10	6	9	6	7	2

## Clinohumite

Clinohumite [Mg<sub>9</sub>(SiO<sub>4</sub>)<sub>4</sub>F<sub>2</sub>] was tentatively identified in calcite-magnetite rock (sample 14-508) of the NE Camp Lake zone as a fine-grained, strongly birefringent grains intergrown with magnetite. It has a similar composition to olivine but differs in lower EMPA totals in the 92 to 98% range perhaps due to unanalyzed H<sub>2</sub>O from alteration (1.52 to 2.64 wt.% H<sub>2</sub>O+: Handbook of Mineralogy). The mean composition of five EMP analyses is given below. As this mineral in essence a hydrated equivalent of olivine, this EMP analysis suggests the classification of the calcite-magnetite rock as phoscorite.

SiO <sub>2</sub>	TiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	MgO	CaO	MnO	FeO	ZnO	SrO	BaO
36.76	0.02	0.46	45.41	0.18	1.44	11.32	0.05	0.03	0.08
Na <sub>2</sub> O	K <sub>2</sub> O	F	Cl	Total	O=F, Cl	Total			
0.03	0.16	0.24	0.01	96.20	0.10	96.09			

## Nepheline and K-feldspar

Analyses of these two minerals are summarized as mean values in Table 9. Muscovite-paragonite series minerals occur as secondary phases due to commonly intense alteration of nepheline and typically imparts a pink colouration to the replaced nepheline pseudomorphs.

Table 9. Mean compositions of K-feldspar and nepheline from the Lackner Lake complex. N = number of analyses.

	K-feldspar				Nepheline	
	26374	19151	26362	26392	14-554	26393
SiO <sub>2</sub>	55.44	56.77	62.65	45.22	28.43	0.04
TiO <sub>2</sub>	0.03	0.03	0.03	0.01	8.36	12.05
Al <sub>2</sub> O <sub>3</sub>	19.11	18.78	19.25	31.37	22.06	1.62
MgO	0.24	0.00	0.00	0.00	0.05	3.08
CaO	0.23	0.06	0.03	0.05	0.05	0.02
MnO	0.03	0.00	0.00	0.00	1.68	2.47
FeO	1.42	0.12	0.08	0.74	21.65	74.10
ZnO	0.01	0.00	0.01	0.00	0.12	0.36
SrO	0.92	1.27	0.94	0.05	0.06	0.06
BaO	1.85	2.84	1.16	0.02	0.08	0.12
Na <sub>2</sub> O	2.29	1.83	4.51	15.27	10.10	0.02
K <sub>2</sub> O	11.45	12.05	9.13	5.57	4.34	0.00
F	0.01	0.04	0.04	0.02	0.06	0.00
Cl	0.01	0.01	0.01	0.00	0.02	0.01
Subtotal	93.04	93.80	97.83	98.32	97.05	93.95
O=F, Cl	0.01	0.02	0.02	0.01	0.03	0.00
Total	93.04	93.78	97.81	98.31	97.02	93.95
N	14	9	12	12	15	4

Barium generally replaces potassium in K-feldspar and mica minerals (Taylor 1965). The highest barium contents were found in K-feldspar from the leucocratic and mesocratic syenite segregations in ijolite host of samples 26362 and 26374 with a respective means of 3.54 wt.% and 5.47 wt.% (Table 9). In rocks where there is pyrochlore it is likely barium is preferentially accommodated in that mineral *vis-a-vis* coexisting K-feldspar as in sample 19151 with its lower mean BaO ( 0.74 wt %) in the K-feldspar.

### Magnetite, Ilmenite and Ilmenomagnetite

Fe-Ti oxides are widespread accessory and essential minerals in various lithologies of the complex. Notable modal concentrations occur at the Zone 6 Fe-P-Ti-Th-Nb-U-Ta deposit and NE Camp Lake Fe-Ti-Nb-Th-Sc occurrence and probe analyses gave an overall range in TiO<sub>2</sub> contents from 0.00 to 3.06 wt.% for both localities. Ilmenomagnetite, with a range in TiO<sub>2</sub> of 11.58 to 12.58 wt.%, was also documented at both of these localities. The occurrence of ilmenite is restricted to silicocarbonatite of sample 19152.

### Sulphides

Pyrrhotite is most widespread sulphide and was found in five samples. Pyrite occurs in four samples and chalcopyrite in two samples (19152 and 26374). Highest bulk rock copper value of 470 ppm in the database occurs in sample 26374 with 2% sulphur. Elevated nickel (4.07 wt.%) was determined in one pyrite analysis from silicocarbonatite (19152) that suggests the presence of the bravoite variety of pyrite.

## Calcite

Calcite was briefly evaluated as a potential host for the rare earth element in two samples: phoscorite (14-508) and silicocarbonatite (26380). The rare earth elements were not detected, however, elevated amounts of SrO were found with respective mean values of 1.55 and 5.71 wt.% with highest value associated with silicocarbonatite mineralization (26380).

## SUMMARY

The current electron microprobe investigation verified 22 different minerals in a total of 423 analyses. This work focused upon a wide range of lithologies collectively in the core of drill hole 66-11-01 in the south-central part of the complex and at two magnetite-rich deposits in the Camp Lake area (Zone 6 Fe-Ti-P-Nb-Th-U deposit and NE Camp Lake Fe-Ti-Nb-Th-Sc occurrence in the southwestern part).

Pyrochlore is the main economic mineral for Nb, Ta and possibly REE and reveals a wide range for primary compositions and overprinting alteration in the following lithologies:

- silicocarbonatite (19152 and 26380)
- mesocratic and leucocratic syenite segregations hosted in ijolite (19151, 26362 and 26374)
- Zone 6 Fe-Ti-P-Nb-Th-U deposit with high bulk rock values of Nb (1.72 wt%) and Ta (464 ppm).

Barium, strontium, thorium and uranium are important substituents in the pyrochlore structure that give rise to following species nomenclature based upon the BaO vs U+Th apfu diagram:

*pyrochlore (sensu stricto), barian pyrochlore, bariopyrochlore, uranian pyrochlore, barian-uranian pyrochlore and uranian-barian pyrochlore*

Niobium in pyrochlore has an overall mean of 54.61 wt.% within a range of 43.49 to 57.86 wt.% Nb<sub>2</sub>O<sub>5</sub>. Tantalum in pyrochlore is also of economic interest with an overall mean of 2.24 wt.% within a range of 0.87 to 4.09 wt.% Ta<sub>2</sub>O<sub>5</sub>. Two main data clusters are notable in Figure 8 and centred at 2% and 3.7% wt.% Ta<sub>2</sub>O<sub>5</sub>.

The mesocratic biotite-K-feldspar-diopside nepheline syenite of sample 19151 is unique with the highest mean values in pyrochlore for Ta<sub>2</sub>O<sub>5</sub> (3.66 wt.%) and Nb<sub>2</sub>O<sub>5</sub> ( 54.41 wt.%) found in this study. These types of magmatic segregations are common in the core of drill hole 66-11-01 and future exploration should focus upon their distribution in the host ijolite and range in scale in the Lackner Lake complex as a whole.

Late stage enrichment of rare earth elements, due to the mineral ancylite and associated fluorapatite, occur along veins within intensely altered nepheline from a mesocratic syenite (19151) segregation hosted in foliated medium-grained ijolite. The distribution and scale of the late stage of REE enrichment is unknown at present on the property and attention should be given to obtaining further data on this mineralization type in the future exploration.

The presence of clinohumite [ $Mg_3(SiO_4)_4F_2$ ], which is essentially a hydrated olivine, is regarded by the author as logical evidence to classify the magnetite-carbonatite rocks at this occurrence as phoscorite.

Phoscorite is a rare rock with only 21 localities known globally (Krasnova et. al 2004) and the Lackner Lake occurrence appears to be the first locality in Canada. Large mineral deposits can be associated with phoscorites as at Phalaborwa, RSA, Kovdor, Russia and Araxa, Brazil (Krasnova et. al 2004, Fontana 2006, Chackmouradian and Wall 2012).

The EMP work verified the elevated levels of  $La_2O_3+Ce_2O_3+Pr_2O_3+Nd_2O_3$  in fluorapatite (mean = 2.88 range: 1.44 to 6.06 wt.%) that overlap with contents in four high purity apatite separates analyzed by a commercial laboratory (Breaks 2016: mean 2.56 wt.%, range 1.76 to 3.00 wt.%).

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Clinohumite

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Pyrochlore

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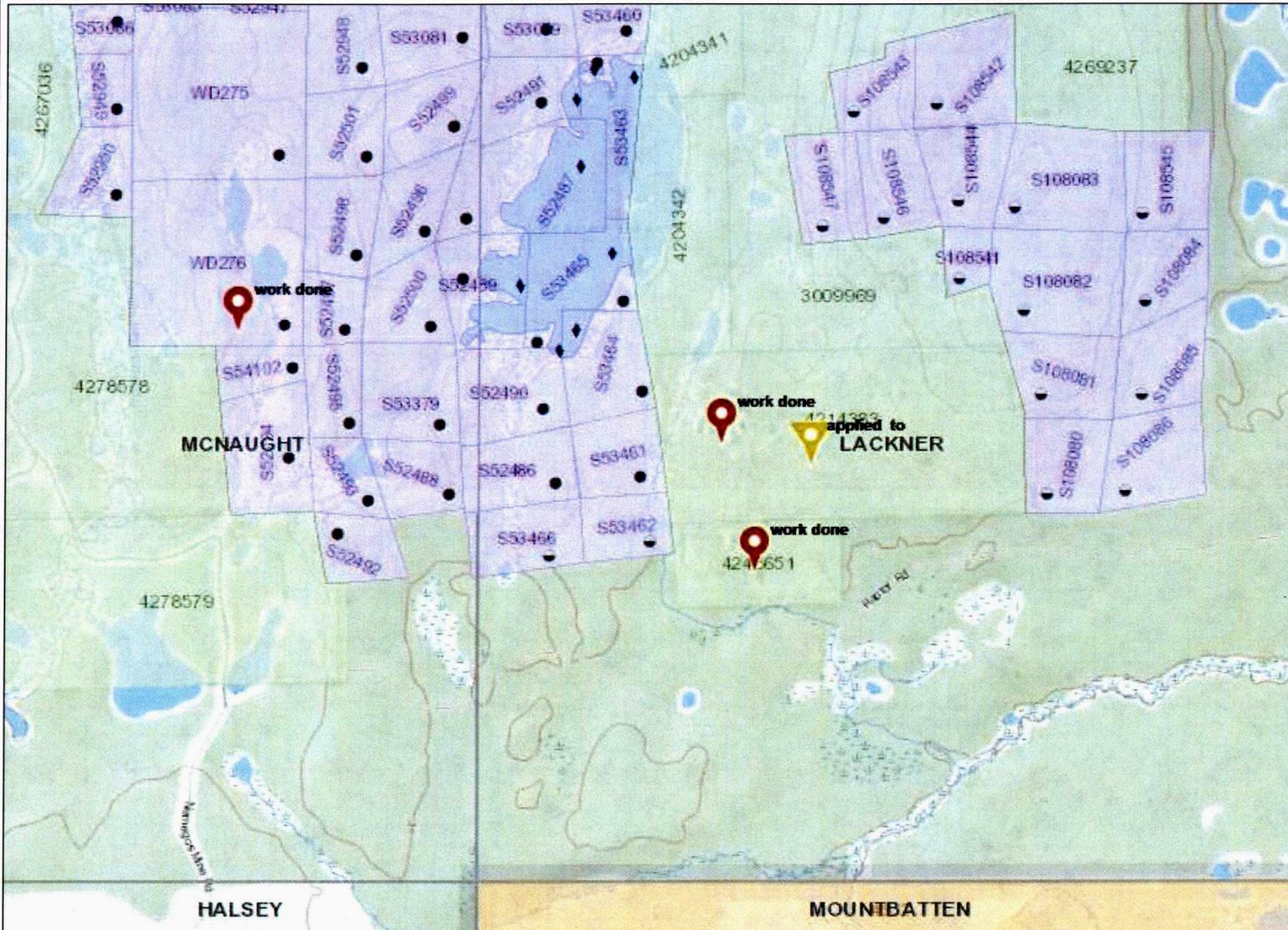
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**APPENDIX 1. Electron microprobe analyses of various minerals from the Lackner Lake alkalic complex, Ontario. See attached Excel file.**



Legend

- Administration Boundaries**
  - Mining Divisions
  - Resident Geologist District
  - Townships and Areas
  - UTM Grid
  - Geographic Lot Fabric
  - Other Federal Land
- Mineral Tenure Grid**
  - OMTG Tenure Grid
- Alienations**
  - Withdrawal
  - Notice
- Unpatented Claim**
  - Active
  - Reconciled
  - Pending
- Disposition**
  - Disposition
- Disposition Symbols**
  - Camp
  - Disposition Unknown/Pending
  - Freehold Patent Mining Rights Only
  - Freehold Patent Surface Rights Only
  - Freehold Patent Surface and Mining Rights
  - Land Use Permit
  - Leasehold Patent Mining Rights Only
  - Leasehold Patent Surface Rights Only
  - Leasehold Patent Surface and Mining Rights
  - License of Occupation Mining Use Only
  - License of Occupation Surface Use Only
  - License of Occupation Surface and Mining Rights
  - License of Occupation Uses Not Specified
  - Order in Council
  - Tower
  - WPLA
- Geology Layers**
  - AMIS Sites
  - AMIS Features
  - Drill Holes
  - Mineral Occurrences



Projection: Web Mercator



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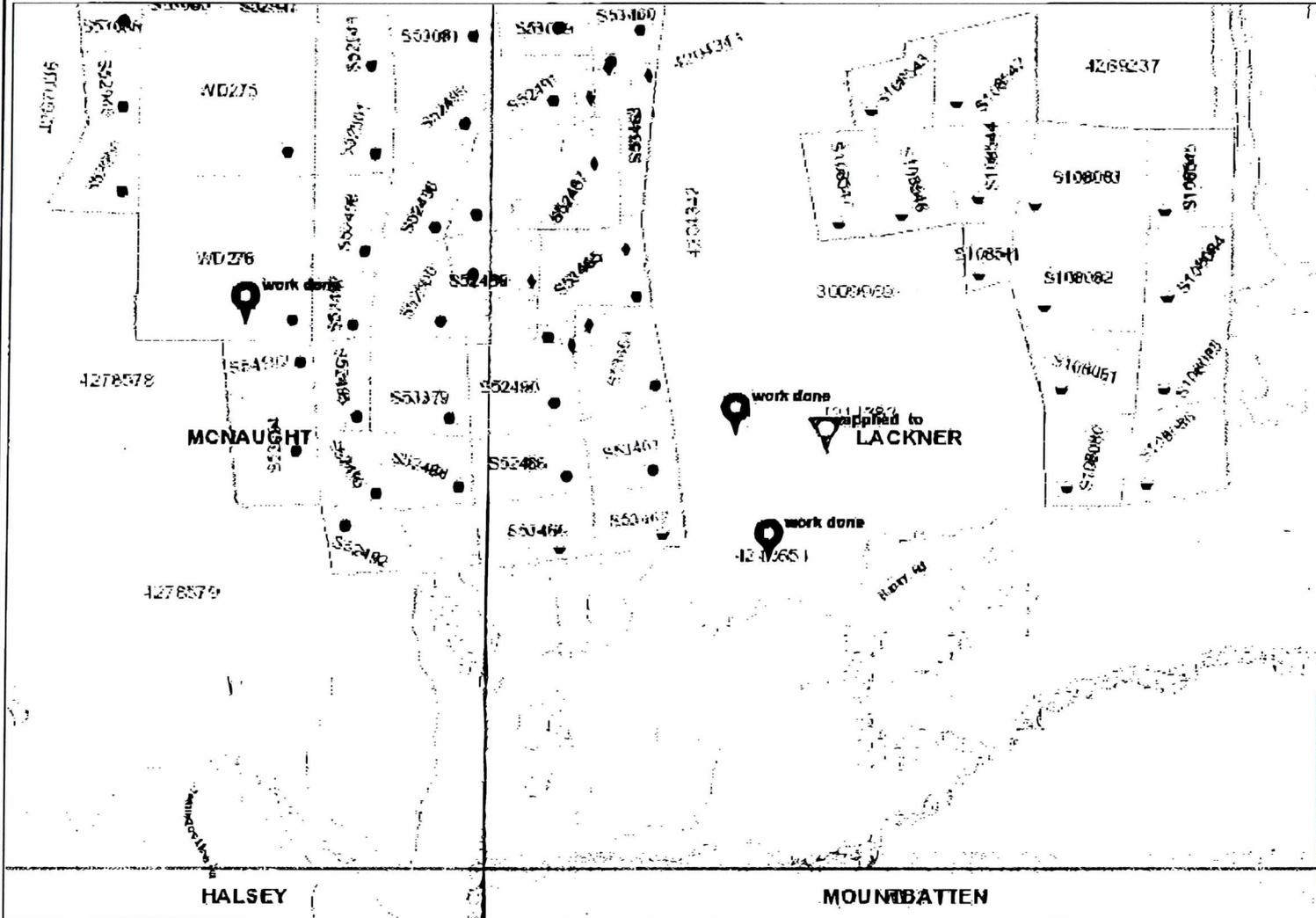


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Notes:  
declaration

No. 1120 P. 10



Legend

- Administration Boundaries
  - Mining Divisions
  - Resident Geogical District
  - Territorial Boundaries
  - UTM Grid
  - Geographic Lat/Long
  - Other Federal Land
- Mineral Tenure Grid
  - CLTO Tenure Grid
- Alienations
  - Withdrawn
  - Notice
  - Unpatented Claim
  - Active
  - Proposed
  - Pending
- Disposition
  - Declaration
- Disposition Symbols
  - Camp
  - Declaration Unknown/Pending
  - Freehold Patent Mining Rights Only
  - Freehold Patent Surface Rights Only
  - Freehold Patent Surface and Mining Rights
  - Leasehold Patent
  - Leasehold Patent Mining Rights Only
  - Leasehold Patent Surface Rights Only
  - Leasehold Patent Surface and Mining Rights
  - License of Occupation/Min Use Only
  - License of Occupation Surface Use Only
  - License of Occupation Surface and Mining Rights
  - License of Occupation Uses Not Specified
  - Other in Court
  - Town
  - WPA
- Geology Layers
  - AMS Area
  - AMS Features
  - Drift Hole
  - Mineral Occurrences

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Projection: Web Mercator



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