GS-8

The Burntwood Lake alkali-feldspar syenite revisited, west-central Manitoba (part of NTS 63N8)

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Summary

A five day geological investigation of the Burntwood Lake syenite was conducted in August of 2011 to evaluate the potential for rare earth element mineralization. The syenite is located in the northwestern arm of Burntwood Lake and is hosted by Burntwood Group metasedimentary rocks of the Kisseynew Domain and peraluminous granite. The syenite forms a heterogeneous intrusion that is modally and texturally diverse. The heterogeneity appears to be the result of a combination of crystal fractionation, metasomatism and possibly contamination. A hand-held spectrometer was utilized in the field to search for zones of elevated radioactivity that could potentially correlate with elevated rare earth element concentrations. A recessively weathered thorium-enriched vein was located along with discontinuous bands of massive apatite, which are enriched in both rare earth elements and thorium. The rocks of the Burntwood Lake syenite are typically metaluminous to weakly peralkaline and are enriched in light rare-earth elements and large-ion lithophile elements, and depleted in high-field-strength elements. The Burntwood Lake syenite bears many mineralogical, textural and geochemical similarities to the carbonatite-hosting syenite complex at Eden Lake, a target of rare earth element exploration.

Introduction

This report outlines the preliminary results of five days of geological investigations in the Burntwood Lake area of west-central Manitoba in August 2011. The area was previously studied by the Manitoba Geological Survey in the early 1970s during a regional mapping project, and later mapped in detail by McRitchie (1987) as a potential host for zirconium mineralization. The current study is part of collaborative work between the Manitoba Geological Survey and the University of Manitoba that is focused on rare earth element (REE) and rare metal potential in alkaline rocks throughout the province. The primary objective of this project is to examine the syenite body at northwestern Burntwood Lake for its potential for REE mineralization. The Burntwood Lake syenite is reported to have many similarities to the Eden Lake syenite, which has been explored as a potential REE deposit (McRitchie, 1988; Medallion Resources, 2010).

Geological background

Burntwood Lake is located about 70 km northwest of the town of Snow Lake and is accessible only by air. The lake is located in the central Kisseynew Domain (KD), a metasedimentary basin in the internal zone of the Trans-Hudson Orogen. The tectonic setting of the Kisseynew basin remains a matter of debate. It has been interpreted as back-arc, intra-arc or fore-arc (Ansdell et al., 1995; Zwanzig, 1997; Zwanzig and Bailes, 2010). The area is largely underlain by turbidite-derived metagreywacke of the Burntwood Group (Zwanzig, 1990), which was deposited between ca. 1860 and 1840 Ma (Machado et al., 1999). Early folding and thrusting (D_1) occurred during 1842–1835 Ma sedimentation and predated metamorphism in the KD. The D_1 deformation phase was accompanied by the intrusion of calcalkaline plutons from ca. 1840 to 1820 Ma. The youngest calcalkaline intrusions in the KD are represented by the enderbitic Touchbourne suite, which was intruded between ca. 1830 and 1820 Ma (Gordon et al., 1990; Machado et al., 1999), prior to the main tectonometamorphic event. Two generations of nappe-like folding (F_2–F_3, 1820–1800 Ma) were accompanied by the intrusion of peraluminous granitoids (1820–1810 Ma; Kraus and Menard, 1997; White, 2005). The majority of the KD experienced low-pressure granulite-facies metamorphic conditions of 750 ±50°C and 5.5 ±1.0 kbar (Gordon, 1989) following D_2 (White, 2005). Peak metamorphic conditions continued through D_3. Folding and faulting continued during D_4 and D_5 until after ca. 1790 Ma (Zwanzig, 1999).

The geology of the Burntwood Lake syenite

The Burntwood Lake syenite is a compositionally and texturally heterogeneous body that intruded Burntwood Group metasedimentary rocks and peraluminous granitoid rocks (Figure GS-8-1). The syenite body is subdivided into two main units based on field observations, a pink-beige syenite and a brick-red syenite. At present, the only significant mineralogical difference between the two syenite units is the colour of the feldspar; however, petrographic studies are pending. The syenite intrusion shows wide variations in texture and modal compositions at outcrop scale. The syenite is locally cut by quartz-bearing (up to 20%) pegmatites with sharp contacts. A rare

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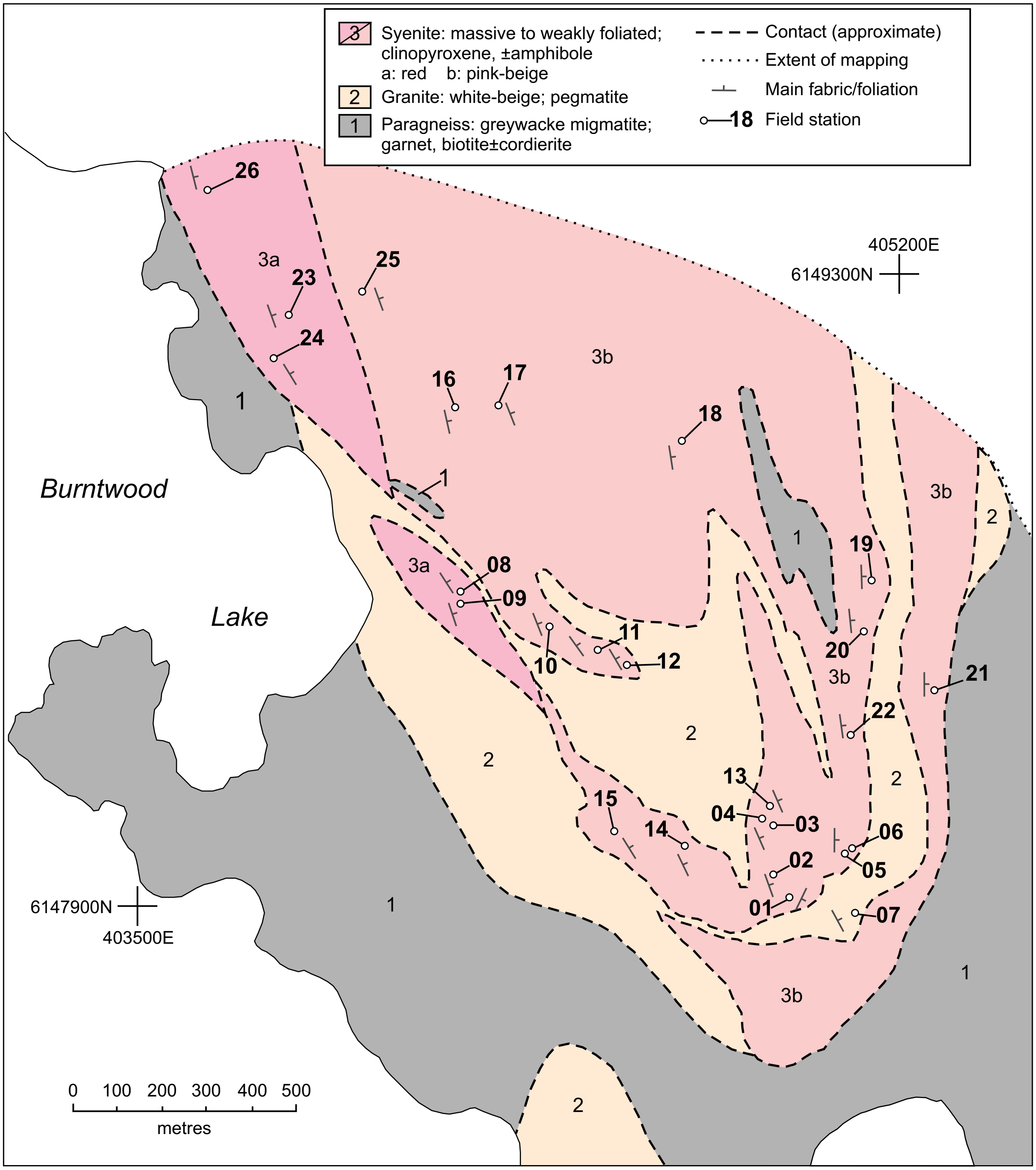

Figure GS-8-1: Schematic geological map of the Burntwood Lake syenite, after McRitchie (1987).

fluorite-bearing quartz syenite phase was also identified. Outcrop observations, however, were strongly compromised by mature and extensive lichen and moss cover, which resulted in limited and poor outcrop exposures and made establishing field relations between potentially different syenite units unfeasible.

The pink-beige and reddish-pink Burntwood Lake syenite phases are variably fine- to coarse-grained and massive to weakly foliated throughout the study area. The syenite typically contains titanite (1–3%), apatite (2–5%), clinopyroxene (10–30%, locally uralitized) and feldspar. The feldspar is generally coloured, either pink-beige (Figure GS-8-2a) or pink-red (Figure GS-8-2b); however, localized zones appear bleached white. Biotite and quartz (up to 3%), and trace amounts of sulphide are common. Outcrops are both texturally and modally heterogeneous (Figure GS-8-2c). Within a single outcrop, the rock varies from fine- to coarse-grained, and mafic minerals may

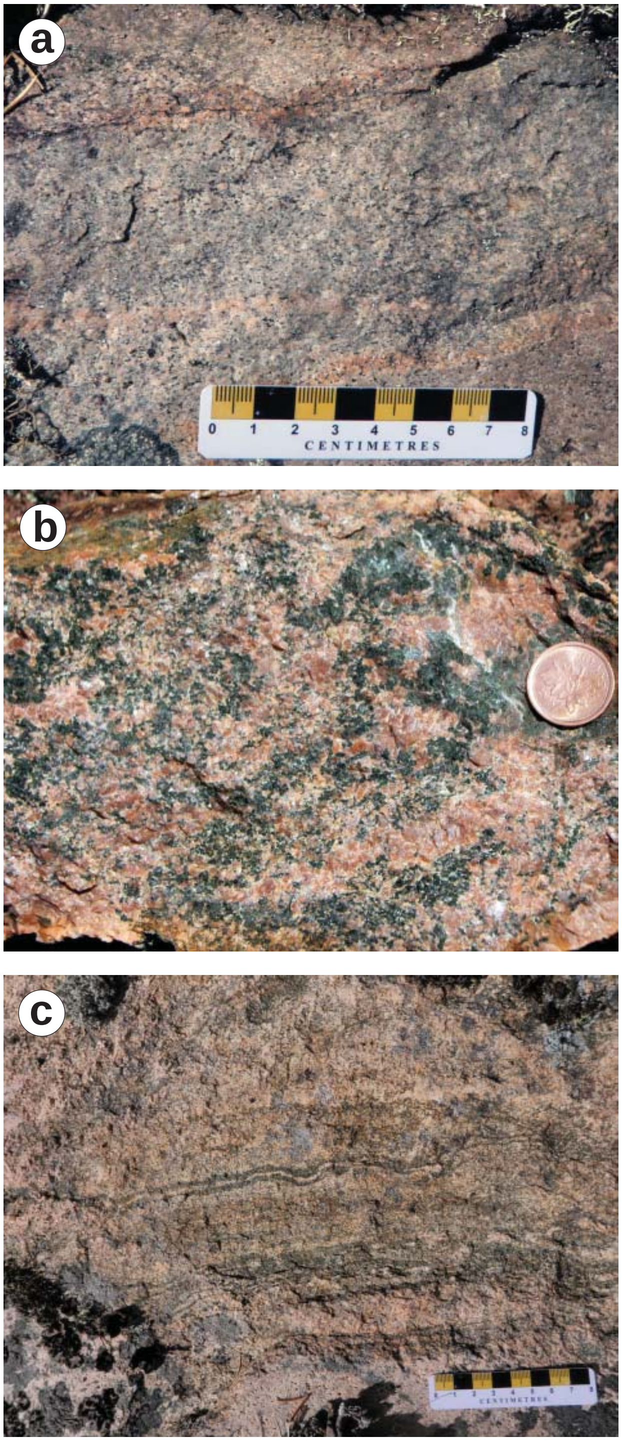

Figure GS-8-2: *Photographs of* ***a)*** *the pink to beige syenite,* ***b)*** *the red syenite, and* ***c)*** *an example of the heterogeneous nature of the Burntwood syenite. Scale card is in cm.*

locally compose up to 80% of the rock. Although clinopyroxene is the most common ferromagnesian mineral, biotite and hornblende also occur. The mafic-rich zones form relatively equant clots, irregular patches (Figure GS-8-3a), discontinuous layers, and veins (Figure GS-8-3b, c), and the contacts of these features range from diffuse to sharp. Apatite is typically enriched in these zones composing up to 10% of the rock, and trace amounts of carbonate are locally present. The various mafic-rich features likely represent a combination of magmatic (cumulate and/or fractionated) phases, metasomatic phases and possibly entrained xenolithic material.

In addition to mafic-rich horizons, several other mineralogically distinct syenite phases were observed. Local diffuse zones and veins within the syenite contain up to 7% titanite. These titanite-enriched zones often have a bleached white or light green colour, and may represent zones of metasomatism (Figure GS-8-3d). Fine-grained, massive apatite rock was observed at two localities (stations 04 and 13) in narrow (<15 cm) discontinuous bands. It is unclear if these bands represent metasomatic veins or cumulate horizons. A Th-enriched, recessively weathered vein at station 13 is discussed below.

Fluorite-bearing quartz syenite was observed in outcrops at stations 021 and 022 (Figure GS-8-1). It is fine-grained, massive and appears relatively homogeneous. It contains fluorite (2–3%), clinopyroxene (10–20%), quartz (15–20%) and pinkish-beige feldspar. Although field relationships with the host syenite are obscured, the fluorite-bearing quartz syenite may represent a more highly fractionated phase of the intrusive complex. Fluorite-bearing feldspathic veins are locally present within the main syenite phase.

The subcircular surface shape of the exposed, southern part of the Burntwood Lake syenite (Figure GS-8-1) is interpreted as a primary igneous feature of the intrusive complex rather than a tectonic overprint. In the study area, metasedimentary gneiss is strongly deformed and migmatitic, and leucogranitic rocks along the margins of the syenite body are strongly foliated, folded and layered. The Burntwood Lake syenite, however, appears invariably undeformed to only weakly foliated, even along its margins. Internal heterogeneities and compositional layering are interpreted as magmatic and/or metasomatic rather than tectonic features, although the syenite is commonly granoblastic and primary textures are largely recrystallized. Our observations are thus in contrast to McRitchie (1987) who described intense internal foliation, gneissosity and folding within the syenite complex.

Hand-held spectrometer results

Because REE-bearing minerals commonly contain Th and U, a hand-held spectrometer (Radiation Solutions Inc. RS-125 Gamma-Ray Spectrometer/Scintillometer) was used on all outcrops. The spectrometer was instrumental in identifying exposures with anomalously high concentrations of REEs (e.g., massive apatite) and Th (Th-rich vein) that otherwise were not readily visible in outcrop. Background readings varied from 150 counts per second (cps) to 350 cps in beige syenite. At station 13, highly elevated counts were traced over several metres along a recessively weathered Th-rich vein and/or fracture

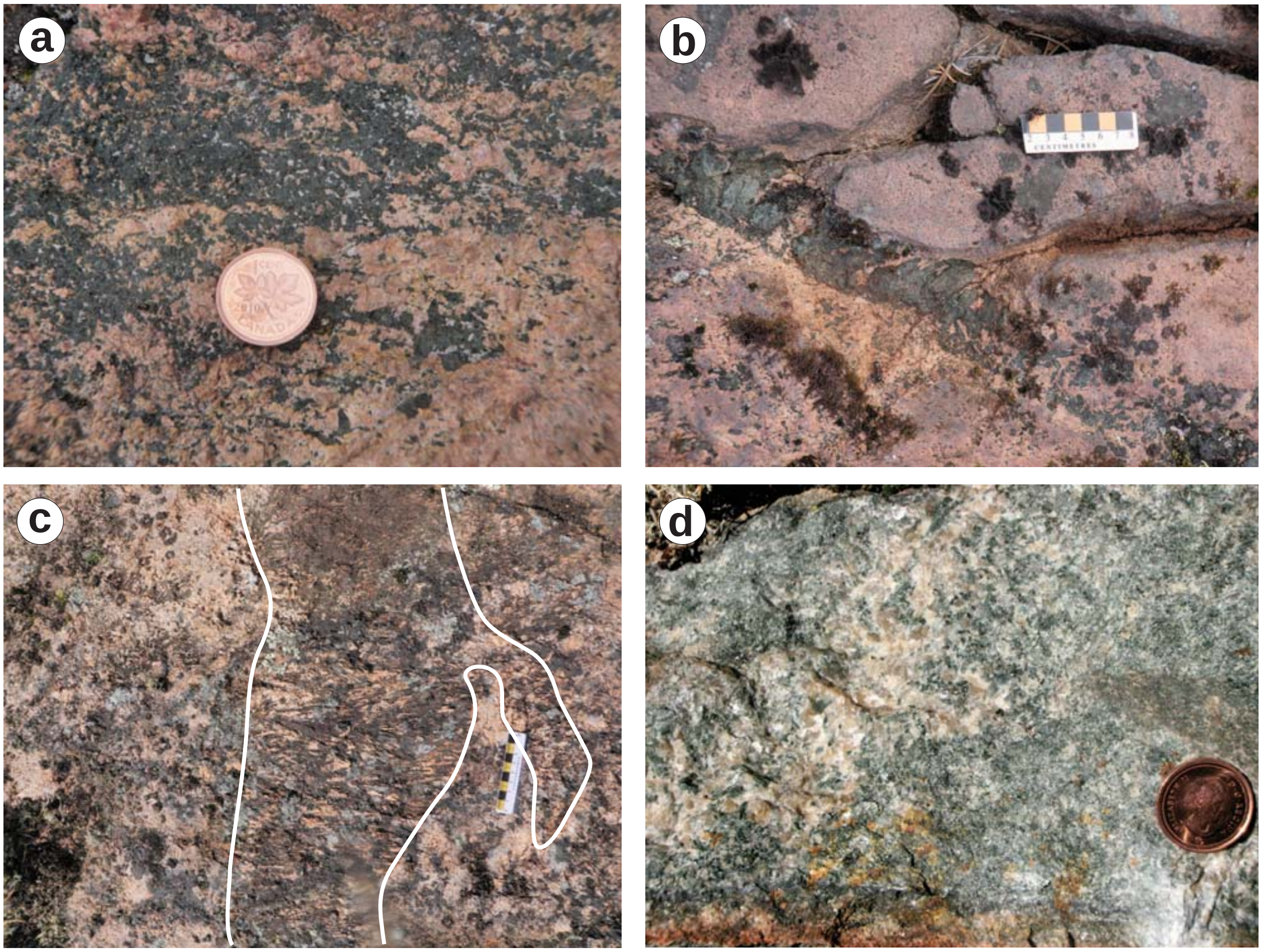

Figure GS-8-3: *Photographs of heterogeneous phases of the Burntwood syenite:* **a)** *apatite- and clinopyroxene-rich red syenite, the apatite appears chalky white;* ***b)*** *and* ***c)*** *metasomatic, mafic-rich veins;* ***d)*** *light green, titanite-rich, metasomatized syenite. Scale card is in cm.*

in beige syenite; the highest spectrometer reading was 28 000 cps with a spectral assay yielding 557 ppm U and 8048 ppm Th. Due to the recessive weathering of the vein, Th-enriched material was difficult to sample, and the source of the Th signal remains uncertain. A discontinuous band of massive apatite, located approximately 10 m away, yielded elevated spectrometer readings of approximately 1000 cps. A sample of the massive apatite rock was collected and yielded elevated Th (84.4 ppm) and REE (3810 ppm total REE+Y) concentrations (Table GS-8-1).

Geochemistry

Bulk rock geochemical analyses of representative samples from the Burntwood Lake syenite are listed in Table GS-8-1. Samples from the Burntwood Lake syenite complex are typically metaluminous to borderline peralkaline. This is in contrast to the surrounding white-beige granite, which is mineralogically peraluminous, containing garnet and locally cordierite. Chondrite-normalized REE patterns for relatively homogeneous samples of Burntwood Lake syenite are light rare-earth element (LREE)-enriched with steep negative slopes (Figure GS-8-4a). Primitive mantle-normalized multi-element diagrams display strong relative enrichments in large-ion lithophile elements (Rb, Ba, LREE) and relative depletions in high-field-strength elements (Nb, Ta, Zr, Hf, Ti) (Figure GS-8-4b). Such multi-element patterns are typically associated with rocks derived from an arc setting. Both REE and multi-element patterns are strikingly similar to syenite from the Eden Lake complex (Couëslan, 2005; Figure GS-8-4b).

Chondrite-normalized REE, and primitive mantle-normalized multi-element diagrams were also generated for more mafic, heterogeneous and possibly metasomatic rocks collected at the intrusive complex (Figure GS-8-4c, d). The patterns are similar overall to those of the more homogeneous syenite phases (Figure GS-8-4a, b). Metasomatic rocks and carbonatite from the Eden Lake complex are included for comparison.

Table GS-8-1: Bulk geochemical analyses of representative samples from the Burntwood Lake syenite.

Sample	108-BL-11-011	108-BL-11-015	108-BL-11-026	108-BL-11-021	108-BL-11-013b	108-BL-11-002A	108-BL-11-014	108-BL-11-006A
	Beige syen	Beige syen	Red syen	Fl Qtz syen	Ap vein	Metasom, Ttn-rich	Mafic-rich	Metasom
Oxide (wt%)								
SiO_2	61.98	61.81	59.77	65.39	34.67	59.13	59.4	58.31
Al_2O_3	15.46	14.68	12.78	15.57	5.43	13.65	14.07	12.59
Fe_2O_3	3.96	3.39	5.93	2.57	4.58	3.57	5.43	5.63
MnO	0.113	0.091	0.133	0.052	0.111	0.069	0.124	0.102
MgO	1.69	2.27	2.33	0.80	4.15	3.32	1.84	3.95
CaO	5.20	5.81	6.31	3.50	29.87	8.06	7.25	10.47
Na_2O	3.94	3.90	4.05	4.70	1.08	4.14	3.21	2.73
K_2O	6.67	6.91	6.18	6.02	2.69	4.67	6.76	5.10
TiO_2	0.051	0.035	0.128	0.368	0.451	1.172	0.364	0.39
P_2O_5	1.00	1.05	0.94	0.60	16.92	0.51	1.27	0.97
LOI	0.67	0.44	0.30	0.78	0.71	0.95	0.48	0.47
Total	100.70	100.40	98.85	100.30	100.70	99.24	100.20	100.70
Element (ppm)								
Sc	4	5	3	4	4	6	5	14
Be	4	4	2	3	5	4	5	4
V	49	45	59	19	61	33	49	59
Ba	2421	1186	1674	1590	2015	3222	3576	6451
Sr	1528	757	792	1448	4638	3069	2541	2928
Y	19	17	11	20	113	30	34	22
Zr	302	7	46	40	62	469	45	299
Co	3	4	4	2	5	8	4	13
Zn	170	110	160	150	160	110	180	150
Ga	25	21	21	28	30	23	24	21
Ge	2	2	1	2	5	2	2	2
Rb	134	172	163	186	83	109	180	125
Nb	bdl	bdl	2	15	23	66	31	14
Sn	2	4	4	3	4	11	10	2
Cs	bdl	bdl	bdl	bdl	0.8	bdl	bdl	bdl
La	136	56	67.6	173	693	126	225	134
Ce	312	131	169	358	1620	299	482	306
Pr	39.6	17.2	23.4	41.8	208	40.4	58.3	38.8
Nd	161	73.5	101	159	877	173	234	159
Sm	23.3	12.2	15.5	22.1	135	29.4	34.4	24.5
Eu	4.31	2.37	3.43	4	29.2	6.42	7.22	5.46
Gd	12.9	7.5	8.4	11.9	78.4	16.9	19.5	14.3
Tb	1.2	0.9	0.8	1.2	7.7	1.9	2	1.4
Dy	5	4.1	3.1	5	30.5	7.9	8.5	5.9
Ho	0.7	0.6	0.4	0.7	4.1	1.1	1.2	0.8
Er	1.7	1.3	1	1.5	8.1	2.6	2.9	1.9
Tm	0.2	0.16	0.13	0.18	0.88	0.27	0.34	0.2
Yb	1.2	1	0.8	1	4.5	1.5	2	1.1
Lu	0.18	0.15	0.13	0.14	0.53	0.2	0.27	0.16
Hf	5	0.3	1.2	1.2	4	8.6	1.5	6.1
Ta	bdl	bdl	0.2	0.8	0.6	1.8	3	0.6
Tl	0.9	1.1	1	1.2	0.5	0.7	1.1	0.7
Pb	22	15	11	23	59	31	28	41
Th	6.7	1.2	2	20.2	84.4	14.4	24.7	20.8
U	2.4	0.3	0.1	3.6	22.5	8.3	7.5	6.5

Abbreviations: Ap, apatite; bdl, below detection limit; Fl, fluorite; LOI, loss-on-ignition; Metasom, metasomatized syenite; syen, syenite; Ttn, titanite

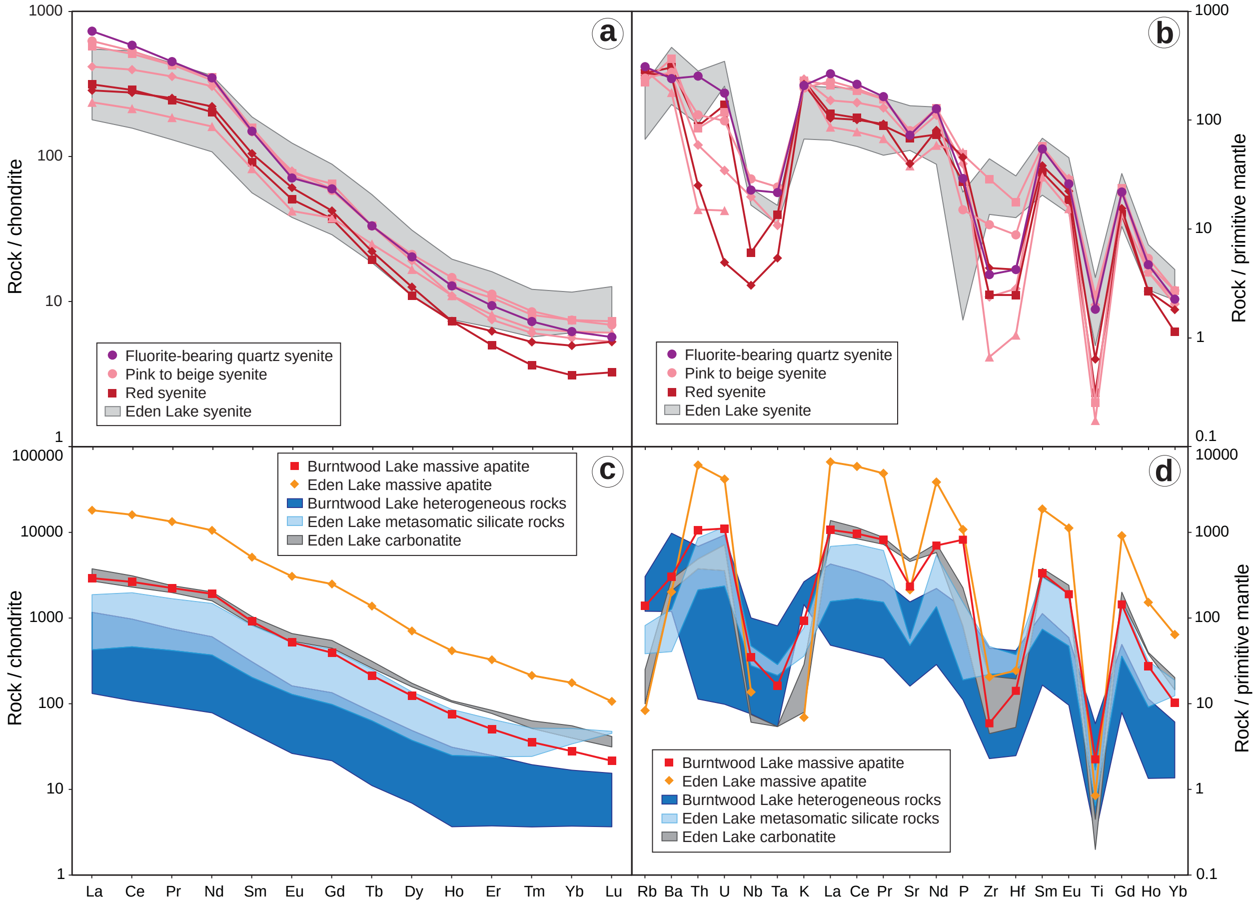

Figure GS-8-4: *Normalized trace-element compositions of the Burntwood Lake syenite (primitive mantle of McDonough & Sun 1995) compared to Eden Lake complex.* ***a)*** *Chondrite-normalized REE diagram for syenites from Burntwood Lake, and* ***b)*** *primitive mantle-normalized multi-element diagram for syenites from Burntwood Lake.* ***c)*** *Chondrite-normalized REE diagram for heterogeneous rocks collected from the Burntwood Lake syenite, which likely represent a combination of magmatic and metasomatic rocks.* ***d)*** *Primitive mantle-normalized multi-element diagram for heterogeneous rocks collected from the Burntwood Lake syenite. The grey field outlines representative analyses of metasomatic rocks from the Eden Lake complex; analyses of carbonatite and a massive apatite vein from Eden Lake are also given for comparison. Data for the Eden Lake rocks are from Couëslan (2005) and Chakhmouradian et al. (2008).*

Economic considerations

At present, the REE market is controlled by China, which has recently imposed a number of restrictions on its REE exports. The globally growing interest in REEs and the importance of finding them outside of China (for political and economic reasons) makes the Burntwood Lake syenite an interesting target for REE exploration. Rare earth elements have a wide variety of uses and are essential for hybrid vehicles, wind turbines and powerful magnets, just to mention a few applications. A growing demand for REEs in recent years and reduced exports from China have led to an increase in worldwide exploration for REE. New sources for these elements are currently being explored, developed and brought online in both Canada and the United States (e.g., Mountain Pass property in California, Molycorp Minerals, 2011; Nechalacho rare earth element deposit in the Northwest Territories, Avalon Rare Metals, 2011; and Strange Lake deposit in Québec, Quest Rare Minerals, 2011).

The Burntwood Lake syenite bears many similarities to the Eden Lake Complex, which has been an exploration target for REE mineralization (Medallion Resources, 2010). Both syenite complexes are characterized by textural and modal heterogeneity; are dominantly metaluminous; are characterized by similar trace element geochemistry; and contain abundant clinopyroxene, titanite, apatite, and locally carbonate and fluorite. As with the Eden Lake syenite, at least some of the heterogeneity of the Burntwood Lake syenite appears to be the result of alkali metasomatism.

Encouraging evidence for both Th and REE enrichment was found in the form of Th-enriched vein (spectral assay of 8048 ppm Th and 557 ppm U) and massive apatite rock. Thorium- and REE-enriched veins at Eden Lake typically contain 1400–7400 ppm Th (Couëslan, 2005). The massive apatite vein with total REE+Y content of 3810 ppm is strikingly similar to the total REE+Y contents of carbonatite at Eden Lake (3439–4330 ppm, Couëslan, 2005; Chakhmouradian et al., 2008).

Geochemical and mineralogical similarities between the Burntwood Lake syenite and Eden Lake syenite suggest that the two complexes could be derived from a geochemically similar (mantle?) source. The location of both complexes within the internal zone of the Trans-Hudson Orogen of Manitoba implies that there could be potential for other similar intrusive complexes within the region. Syenites have also been reported at Brezden and McVeigh lakes (McRitchie, 1988) and may warrant investigation.

Acknowledgments

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