GS-10 Rare metals scoping study of the Brezden Lake intrusive complex, western Manitoba (part of NTS 64C4)

by T. Martins, C.G. Couëslan and C.O. Böhm

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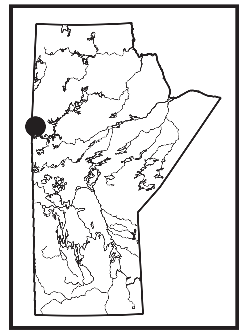

Summary

The Brezden Lake intrusive complex is a heterogeneous multiphase intrusive body, identified as having the potential to host rare metals and rare earth elements. This heterogeneous intrusive complex is located southwest of Lynn Lake where it is hosted by Burntwood Group metasedimentary rocks and peraluminous granitoid intrusions of the Kisseynew Domain. Localized metasomatism led to enrichment in rare earth elements, and carbonate was identified associated with this metasomatism. Petrographic study revealed granoblastic calcite and calcite replacing other mineral phases. Granoblastic calcite suggests equilibrium and could be derived from a carbonate fluid, whereas interstitial and replacing calcite suggests nonequilibrium and possible remobilization of the carbonate. No carbonatite was found associated with the Brezden Lake intrusive complex but many aspects including mineralogy, textures and geochemistry are similar to the syenite that hosts the carbonatite at Eden Lake.

Introduction

This report summarizes the preliminary findings of seven days of reconnaissance mapping of the Brezden Lake intrusive complex in western Manitoba during July 2012. This area was previously studied by the Manitoba Geological Survey in the 1970s during a regional mapping project, and later mapped in detail by McRitchie (1988) as a potential host for zirconium mineralization. The current findings are part of a larger study focused on rare earth elements (REE) and rare metal potential of rocks in various parts of the province. The primary objective of this project is to examine the intrusive body at Brezden Lake for its potential for rare metals and REE mineralization. The Brezden Lake intrusive complex was considered similar to the Eden Lake syenite (McRitchie, 1988), which has been explored as a potential REE deposit (Medallion Resources, 2010).

Geological setting

Brezden Lake is located roughly 96 km southwest of Lynn Lake and is only accessible by air. The Brezden Lake intrusive complex is exposed over a length of about 4 km and a width of about 0.8 km along the eastern side of Brezden Lake (Figure GS-10-1). The Brezden Lake intrusive complex intrudes the metasedimentary units of the Burntwood Group at the northern flank of the Kisseynew Domain (KD), as primarily identified by Lenton (1981), very close to the limit of the subdomain boundary defined by Zwanzig (2008).

The KD is a metasedimentary basin in the internal zone of the Trans-Hudson Orogen. The tectonic setting of the Kisseynew basin continues to be 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 KD 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 rocks from the Burntwood Group at Brezden Lake were exposed to lower temperature metamorphic conditions than Burntwood Group rocks in the central KD. Lenton (1981) identified at least one (possibly two) major prograde metamorphic event with metamorphic conditions in the range from 600 to 630°C at 2.5 kbar.

Geology of the Brezden Lake intrusive complex

The Brezden Lake intrusive complex is a heterogeneous multiphase intrusive body that ranges in composition from granite to syenite. From the limited observations of rarely exposed textural relationships, the syenite appears to be older than the granite. This conclusion is based on the observation of syenite rafts within the granite, which was also reported by McRitchie (1988). Pegmatitic phases have been observed to cut the syenite indicating that they were emplaced at a later date (Figure GS-10-2a). Heterogeneity is not uncommon for

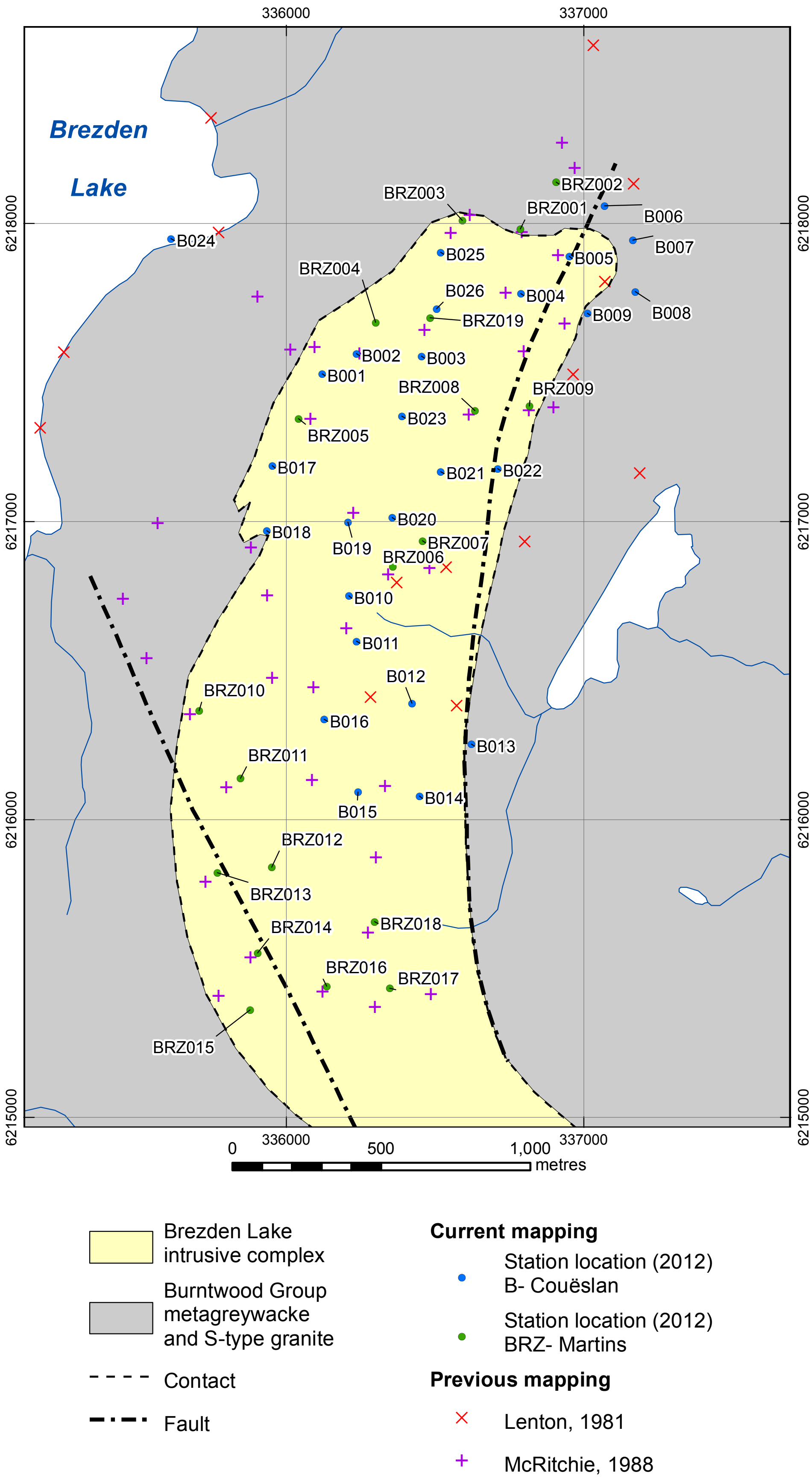

Figure GS-10-1: *Simplified geological map of the Brezden Lake intrusive complex, western Manitoba, after McRitchie (1988).*

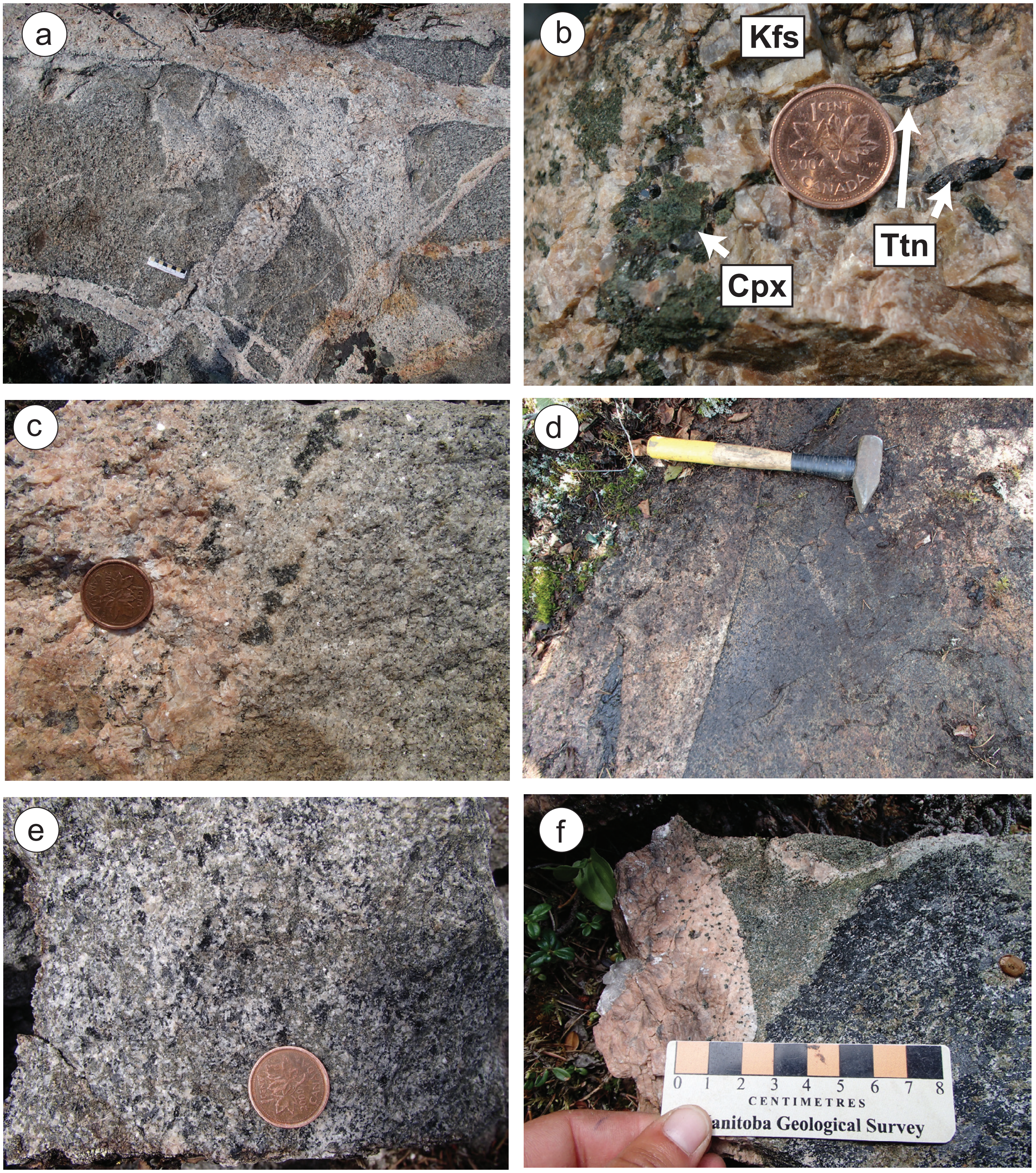

Figure GS-10-2: *Outcrop photographs with examples of the different phases of the Brezden Lake intrusive complex, western Manitoba, evidencing its heterogeneous character:* ***a)*** *late pegmatite cutting the melasyenite;* ***b)*** *coarse-grained syenite evidencing the main mineral phases as visible in the outcrop;* ***c)*** *medium-grained biotite syenite with concentration of mafic minerals in centimetre-sized clots;* ***d)*** *syenite with metre-scale concentration of mafic minerals;* ***e)*** *metasomatic phase of the syenite with carbonate;* ***f)*** *metasomatic phase of the syenite. Abbreviations: Cpx, clinopyroxene; Kfs, K-feldspar; Ttn, titanite.*

these types of intrusions and was also observed at Eden Lake (Couëslan 2005; Chakhmouradian et al., 2008) and Burntwood Lake (McRitchie 1987; Martins et al., 2011). Outcrop observations, however, were very limited due to mature and extensive lichen cover, making geological interpretations difficult.

A hand-held spectrometer (Radiation Solutions Inc., RS-125 Gamma-Ray Spectrometer/Scintillometer) was used to help identify potential REE-bearing zones. Although it is common for REE-bearing minerals to contain Th and U, this is not the case for the Brezden Lake intrusive complex. In contrast, the use of a 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 outcrops of the Burntwood Lake syenite (Martins et al., 2011). At Brezden Lake the spectrometer background readings varied from 150–250 counts per second (cps), and locally reached only about 500 cps in many outcrops, not revealing a direct correlation between high concentrations of Th, or U and REE-bearing minerals.

The striking characteristic of the Brezden Lake intrusive complex is its heterogeneity (Figure GS-10-2). In a single outcrop it was common to find a range of rock types, some of which were interpreted to be of possible metasomatic origin. This division has been supported by geochemistry results. The nonmetasomatized rocks include clinopyroxene-bearing granite with quartz, plagioclase, K-feldspar, clinopyroxene and minor apatite, magnetite, titanite and zircon; amphibole-quartz syenite, crudely banded with quartz, plagioclase, K-feldspar, amphibole, biotite and zircon; syenite with K-feldspar, clinopyroxene, plagioclase, titanite, amphibole, allanite, oxides and sulphides, zircon and apatite; and melasyenite, recrystallized with K-feldspar, biotite, clinopyroxene, amphibole, titanite, zircon, apatite, allanite, and oxides and sulphides.

In summary, the minerals found in these rocks are very similar but their modal proportions are quite variable. The metasomatized rocks (Figure GS-10-2e, f) also have similar mineralogy to what was described above. However, these rocks have higher amounts of allanite, titanite and apatite, are the only ones where carbonate is present, and show complex textural relationships and complex replacement textures (see petrography for detailed description).

Overall, the intrusive complex is weakly to moderately foliated, with a general trend of 300° present mostly in the margins, whereas the core of the intrusion appears to be undeformed. McRitchie (1988) described an eastward-dipping (30–50°) foliation and slightly less foliated, more massive syenitic core.

Petrography

Thin sections of representative samples from the Brezden Lake intrusive complex were carefully studied under transmitted and reflected light to describe their mineralogy, characterize their textures and, when possible, infer their genetic relationships.

The different intrusive phases of the Brezden Lake complex commonly contain microcline, albite, clinopyroxene, amphibole, apatite, quartz, plagioclase, biotite, titanite, allanite (and other epidote-group minerals), zircon, magnetite and sulphide minerals, with local calcite. Although the mineralogy is similar in all rock types, the modal proportions of each mineral, and complexity in terms of textural relationships and replacement, is highly variable.

Microcline is locally perthitic and commonly surrounded by secondary albite. Clinopyroxene is a major phase and is locally replaced by amphibole (and rarely calcite). Subhedral to anhedral apatite is inclusion-rich and occurs in variable amounts. Higher percentages of apatite are found in the samples of the metasomatized phases. Titanite is frequently zoned, and complex zoning is locally observed (Figure GS-10-3a). Small titanite grains are associated with clinopyroxene, whereas larger discrete grains of titanite form in the groundmass. Allanite (up to 2 mm) is present in variable amounts and composes up to 3% of the rock. Allanite is typically fresh with minimal alteration (rarely metamict) and locally overgrown by epidote (Figure GS-10-3b). Subhedral to euhedral zircon is a common accessory mineral. Calcite was only found in the metasomatized phases of the syenite. Its paragenesis is not clear. The granoblastic habit of most of the carbonate in these rocks suggests that it attained equilibrium with the surrounding minerals (Figure GS-10-3c). The preferred interpretation is that the carbonate was derived from a CO_2-rich metasomatizing fluid; however, derivation from a carbonated syenitic magma cannot be ruled out. Further work is required to clarify the origin of the carbonate and/or the source of the metasomatic fluid. Minor interstitial carbonate, and carbonate replacement of clinopyroxene (Figure GS-10-3d), is likely the result of later remobilization by low temperature fluids.

Geochemistry

Representative whole-rock geochemistry results from the Brezden Lake intrusive complex can be found in Table GS-10-1. The complete dataset is available online (Data Repository Item DRI2012006[1]). The samples from the Brezden Lake intrusive complex fall into the metaluminous field of the aluminum saturation index (ASI)

[1] MGS Data Repository Item DRI2012006, containing the data or other information sources used to compile this report, is available online to download free of charge at http://www2.gov.mb.ca/itm-cat/web/freedownloads.html, or on request from minesinfo@gov.mb.ca or Mineral Resources Library, Manitoba Innovation, Energy and Mines, 360–1395 Ellice Avenue, Winnipeg, Manitoba R3G 3P2, Canada.

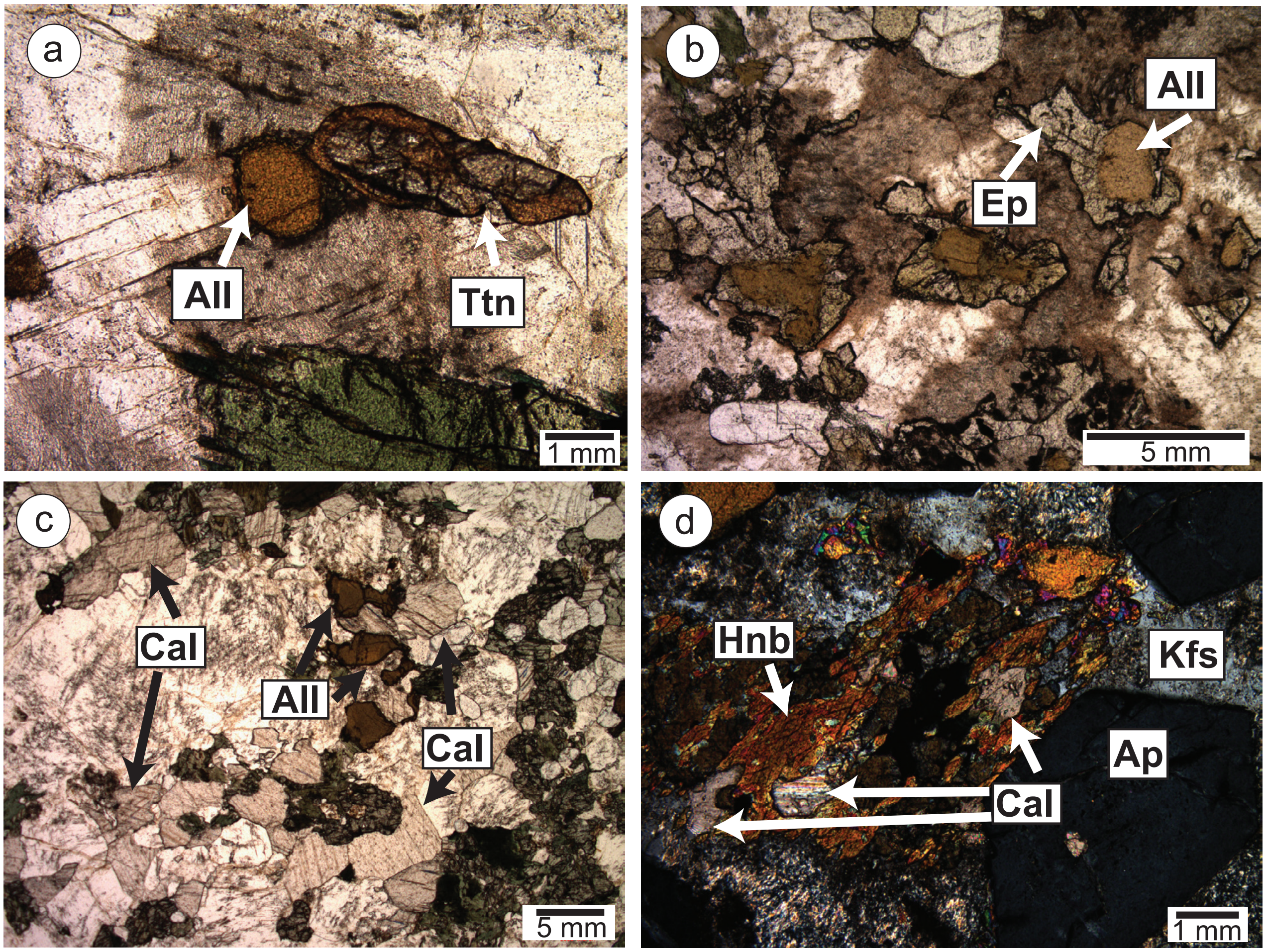

***Figure GS-10-3:** Photomicrographs representing common mineralogical characteristics of the Brezden Lake intrusive complex, western Manitoba: **a)** complex zoning of titanite; **b)** epidote overgrowing allanite; **c)** granoblastic calcite in apparent equilibrium with the other mineral phases; **d)** clinopyroxene being replaced by hornblende, and calcite surrounded by apatite and sericitized K-feldspar. Abbreviations: All, allanite; Ap, apatite; Cal, calcite; Ep, epidote; Hnb, hornblende; Kfs, K-feldspar; Ttn, titanite.*

diagram with the exception of the clinopyroxene granite, which is slightly peraluminous.

Overall there is an extreme enrichment in Ba and Sr with maximum values of 11 870 ppm of Ba and 4970 ppm of Sr. Similar enrichment is found at Eden Lake and Burntwood Lake (McRitchie, 1988). The metasomatized samples are the most enriched in REEs (ranging from 1123 to 1778 ppm, total REE+Y), particularly the ones where carbonate was observed (ranging from 1626 to 2504 ppm, total REE+Y). The melasyenites are the second group of rocks with high values of REEs, with total REE+Y ranging from 643 to 1040 ppm. The lowest content of REEs is found in the hornblende and biotite granites with less than 88 ppm of REE+Y.

Chondrite-normalized REE patterns for nonmetasomatized phases of the Brezden Lake intrusive complex have negative slopes, which indicate an enrichment in light rare earth elements relative to heavy rare earth elements (Figure GS-10-4a).

The primitive-mantle–normalized multi-element diagram shows relative enrichment in large-ion lithophile elements (Rb, Ba, REE) and relative depletions in high-field-strength elements (Nb, Ta, Zr, Hf, Ti). These patterns are similar to the least altered homogeneous samples from the Eden Lake and Burntwood Lake intrusive complexes (Figure GS-10-4a, b).

Chondrite-normalized REE patterns and the primitive-mantle–normalized multi-element diagrams for the metasomatized phases of the Brezden Lake intrusive complex show a noticeable enrichment in Rb, Ba, Sr, Zr and Nb. The REE and multi-element patterns for these samples are also similar to the patterns from the Eden Lake and Burntwood Lake syenite complexes (Figure GS-10-4c, d).

Economic considerations

Rare metals, including REEs, continue to be in high demand by a number of industries from automobile

Table GS-10-1: Bulk rock geochemistry of representative samples from the Brezden Lake intrusive complex, western Manitoba

	BRZ002	BRZ003	BRZ014	BRZ017	BRZ019	B005	B022	B025	B026B
	Grano-diorite	Metasom. syenite	Metasom. syenite	Cpx granite	Metasom. syenite	Metasom. syenite	Metasom. syenite	Metasom. syenite	Metasom. syenite
					Oxide (wt.%)				
SiO_2	73.97	46.83	47.87	72.24	41.43	48.72	45.84	53.81	39.8
Al_2O_3	14.32	11.58	10.62	13.81	8.05	10.65	9.63	10.22	10.87
Fe_2O_3	0.99	9.2	11.17	1.44	12.08	7.54	6.48	7.9	11.91
MnO	0.012	0.25	0.234	0.025	0.223	0.137	0.105	0.234	0.202
MgO	0.28	3.25	5.77	0.4	6.46	7.59	8.83	2.83	7.22
CaO	2.17	15.49	13.9	1.59	19.74	14.85	13.08	14.73	16.12
Na_2O	3.91	1.48	2.74	3.52	1.62	2.21	0.95	2.13	0.55
K_2O	3.07	5.25	2.08	5.65	1.69	2.84	5.77	3.33	4.47
TiO_2	0.091	0.35	0.583	0.121	0.845	0.718	1.198	0.254	0.64
P_2O_5	0.01	3.13	2.95	0.18	5.67	2.94	5.29	2.79	4.76
LOI	0.3	4.11	0.78	0.19	1.01	0.76	0.85	1.62	1.81
Total	99.123	100.92	98.697	99.166	98.818	98.955	98.023	99.848	98.352
					Element (ppm)				
Sc	1	10	22	3	27	27	30	8	31
Be	3	5	10	2	5	5	3	4	7
V	11	112	162	20	147	121	106	94	144
Ba	1462	7939	3623	2594	1768	2290	11870	4197	4086
Sr	1137	6858	2812	1699	3465	3711	3670	4970	3207
Y	2	118	80	9	93	45	66	81	77
Zr	73	46	56	54	183	168	87	41	202
Cr	bdl	bdl	60	bdl	bdl	20	140	bdl	bdl
Co	bdl	11	23	1	28	24	25	9	29
Ni	bdl	bdl	bdl	bdl	bdl	20	120	bdl	bdl
Cu	10	bdl	40	bdl	30	bdl	10	bdl	20
Zn	bdl	140	200	bdl	200	110	130	160	130
Ga	14	18	20	14	24	22	16	17	19
Ge	1	3	3	1	3	2	2	4	2
As	bdl	6	6	bdl	7	bdl	bdl	bdl	6
Rb	48	87	37	90	44	73	194	53	100
Nb	1	12	17	4	12	27	7	15	22
La	5.2	424	297	23.4	379	214	193	442	253
Ce	8.9	1040	726	49.1	990	526	432	1050	633
Pr	0.96	134	97.7	6.52	132	71.3	56.1	131	88.1
Nd	3.3	562	414	26.7	569	293	250	547	396
Sm	0.5	95.6	71.1	5.1	98.6	47.8	49.5	88.8	76
Eu	1.47	22.3	15.8	1.37	22.3	10.8	12.2	19.9	18.2
Gd	0.3	56.3	40.2	3.2	57.9	26.9	35	50.1	48.4
Tb	bdl	6.1	4.3	0.4	6	2.8	3.9	5.1	4.7
Dy	0.3	25	17.3	1.8	22.7	10.3	15.5	19.5	18.4

Abbreviations: bdl, below detection limit; Cpx, clinopyroxene; LOI, loss-on-ignition; Metasom., metasomatized; ∑ REE, total rare earth elements

Table GS-10-1: Bulk rock geochemistry of representative samples from the Brezden Lake intrusive complex, western Manitoba *(continued)*

	BRZ002	BRZ003	BRZ014	BRZ017	BRZ019	B005	B022	B025	B026B
	Grano-diorite	Metasom. syenite	Metasom. syenite	Cpx granite	Metasom. syenite	Metasom. syenite	Metasom. syenite	Metasom. syenite	Metasom. syenite
					Element (ppm) *(continued)*				
Ho	0	3.8	2.6	0.3	3.3	1.5	2.2	2.8	2.6
Er	0.2	8.5	6.2	0.7	6.9	3.4	4.7	5.8	5.6
Tm	0	1.05	0.73	0.1	0.7	0.41	0.48	0.68	0.63
Yb	0.3	6.2	4.4	0.5	4	2.3	2.4	4.1	3.5
Lu	0.07	0.91	0.65	0.09	0.54	0.33	0.34	0.67	0.5
Hf	1.8	3.4	10.6	1.3	5.5	7.2	3	1.4	15.2
Ta	0.2	0.4	0.5	0.5	0.2	0.9	0.5	0.8	1.9
Tl	0.3	0.6	0.3	0.7	0.4	0.5	1.5	0.3	1
Pb	23	23	27	20	16	36	10	13	29
Th	0.8	31.2	28.4	1.4	26	25.4	6.7	36.5	25.6
U	1.8	7.3	9.5	0.8	8.1	15.9	2.2	8	11.8
∑ REE	21.5	2385.76	1697.98	119.28	2292.94	1210.84	1057.32	2367.45	1548.63

Abbreviations: bdl, below detection limit; Cpx, clinopyroxene; LOI, loss-on-ignition; Metasom., metasomatized; ∑ REE, total rare earth elements

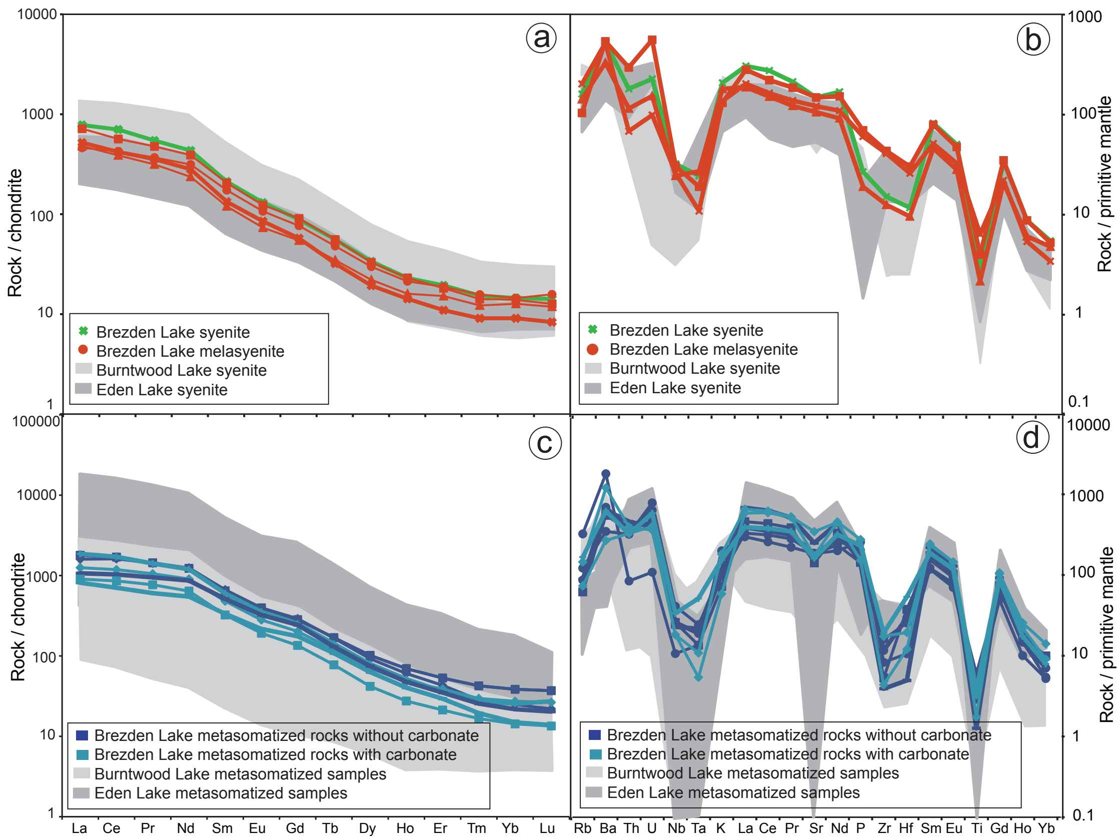

Figure GS-10-4: *Normalized trace-element compositions of samples from the Brezden Lake intrusive complex, western Manitoba (primitive mantle of McDonough and Sun 1995) compared to Eden Lake and Burntwood Lake rocks:* ***a)*** *chondrite-normalized REE patterns for nonmetasomatized rocks of Brezden Lake;* ***b)*** *primitive-mantle–normalized multi-element diagram for nonmetasomatized rocks of Brezden Lake.* ***c)*** *chondrite-normalized REE patterns for metasomatized rocks of the Brezden Lake intrusive complex;* ***d)*** *primitive-mantle–normalized multi-element diagram for metasomatized rocks of Brezden Lake. Data for the Eden Lake rocks are from Couëslan (2005) and Chakhmouradian et al. (2008); data for the Burntwood Lake rocks are from Martins et al. (2011).*

and electronics manufactures to medical applications (see Alonso et al., 2012 for detailed information on the demand for REEs for clean technologies). Over 500 rare metal and REE occurrences have been identified throughout Canada, as compiled by Simandl et al. (2012).

In Manitoba, over 40 rare metals and REE occurrences are presently known. This number is steadily growing as new discoveries continue to be made and known occurrences, such as the Brezden Lake intrusive complex, are further assessed. Geochemical analysis of the Brezden Lake intrusive complex revealed up to 3055 ppm of total REEs, which is comparable to the highest total REE concentrations of 3585 ppm for the clinopyroxene-feldspar fenite at Eden Lake, Manitoba (Couëslan, 2005). Moreover, the mineralogical (clinopyroxene, titanite, allanite, apatite and carbonate) and textural similarities (e.g., textural and modal heterogeneities) as well as trace element geochemistry make it a potential target for REE exploration. Even though outcrop observations of the Brezden Lake intrusive complex were very limited, geochemical results and petrographic study suggest that some of the heterogeneity and mineralogy of the Brezden Lake intrusive complex could be due to pervasive alkali and carbonate metasomatism, similar to metasomatism that is observed in the mineralized rocks at Eden Lake.

Geochemical results, particularly the high total of REEs, together with compositional, textural and alteration characteristics similar to the Eden Lake syenite, warrant further investigation of the Brezden Lake intrusive complex as a potentially interesting target for REE exploration.

Acknowledgments

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