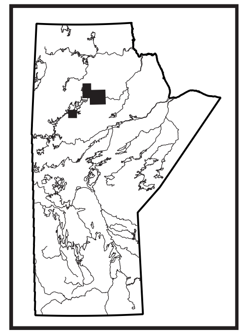
GS-10 Rare-metals scoping study of the Trans-Hudson orogen, Manitoba (parts of NTS 64G3–6, 8, 9, 64B11)

by T. Martins and P.D. Kremer



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Summary

In the scope of studying rare-metal occurrences in Manitoba (initiated by the Manitoba Geological Survey in 2011), fieldwork in the summer of 2013 included an examination of pegmatites at Southern Indian Lake, Partridge Breast Lake and South Bay. This study also included an examination of the Thorsteinson Lake fluorite-bearing granite. Previously reported values of Au, Ag, Bi, Zn and Be in pegmatites at Southern Indian Lake suggest exploration potential. The pegmatites at South Bay are described in further detail, taking into account their mineralogy, internal structure and relationship with the country rock. Results obtained from grab samples in previous work reveal enrichment in Be, Nb, Ta and Cs. This could indicate a possible pegmatite field with Li, Cs and Ta (LCT) affinity. Reported here are mainly field descriptions of these occurrences. Preliminary petrographic studies were carried out in a few samples from Thorsteinson Lake granite but all other petrographic and mineral studies, and geochemical and geochronological results are pending.

Introduction

Different areas with rare-metal potential within the Trans-Hudson orogen[1] (THO) in Manitoba were investigated during the summer of 2013. Bedrock exposures of pegmatites were visited, described in detail and sampled at Southern Indian Lake, Partridge Breast Lake and South Bay, and a fluorite-bearing granite was described and sampled at Thorsteinson Lake.

In the Southern Indian and Partridge Breast lakes area, a variety of pegmatite types have been identified during previous regional mapping programs (Corrigan et al., 2001; Corrigan and Rayner, 2002; Kremer, 2008; Kremer et al., 2009). The main objective of this study is to better characterize these pegmatites in terms of their whole-rock geochemistry (where possible), mineralogy, mode of emplacement and any possible connection with any of the granitic bodies found in the area. A geochronological study is also planned for these pegmatites, provided they contain suitable minerals for dating. At Thorsteinson Lake, representative samples of the fluorite-bearing granite were collected for whole-rock geochemistry, petrography and geochronological studies.

Fieldwork in the South Bay area consisted of describing and sampling the known pegmatite occurrences. The main exposures are located approximately 60 to 70 km northeast of Leaf Rapids, along Provincial Road 493, and close to the turn-off to the old South Bay ferry road. Fairly large exposures of pegmatite and pegmatitic granite are also found along the shoreline of South Bay.

Regional geology

The studied pegmatites intrude supracrustal and plutonic rocks of the Southern Indian and the Lynn Lake–Leaf Rapids domains. Together with the Kisseynew domain, these represent the three main tectonic subdivisions of the northern flank of the THO in Manitoba (Figure GS-10-1).

The Lynn Lake–Leaf Rapids domain includes volcanic and associated epiclastic and sedimentary rocks dated at 1.90–1.88 Ga (Baldwin et al., 1987) and has been broadly correlated with the La Ronge domain in Saskatchewan (Maxeiner et al., 2001). In Manitoba, this domain has been further subdivided into two metavolcanic belts with unique stratigraphic successions, chemistry and structure (Baldwin et al., 1987): the Lynn Lake and Rusty Lake belts. Field relationships suggest that the various volcanosedimentary assemblages were aggregated into a tectonic collage before the emplacement of calcalkaline plutons, which include ca. 1876 Ma gabbro stocks and tonalite. The area is affected by greenschist- to upper-amphibolite–facies metamorphism (Baldwin et al., 1987).

The Southern Indian domain flanks the Lynn Lake and the Rusty Lake belts to the north and, for the most part, correlates with the Rottenstone domain in Saskatchewan (Corrigan et al., 2001). The Southern Indian domain is dominated by variably migmatitic metasedimentary rocks, with lesser areas composed predominantly of metavolcanic and volcaniclastic rocks and rare inliers of latest Archean granitic gneisses (Corrigan et al., 2007; Kremer, 2008; Kremer et al., 2009a). It is intruded to the north by the voluminous ca.1.86–1.85 Ga Chipewyan/Wathaman batholith, a magmatic arc emplaced into the southern margin of the Hearne craton (Corrigan et al., 2000). Metasedimentary and metavolcanic rocks in the Southern Indian domain have been subdivided into several

[1] For the sake of consistency, the Manitoba Geological Survey has opted to make a universal change from capitalized to noncapitalized for the generic part of lithostructural feature names (formal stratigraphic and biostratigraphic nomenclature being the exceptions).

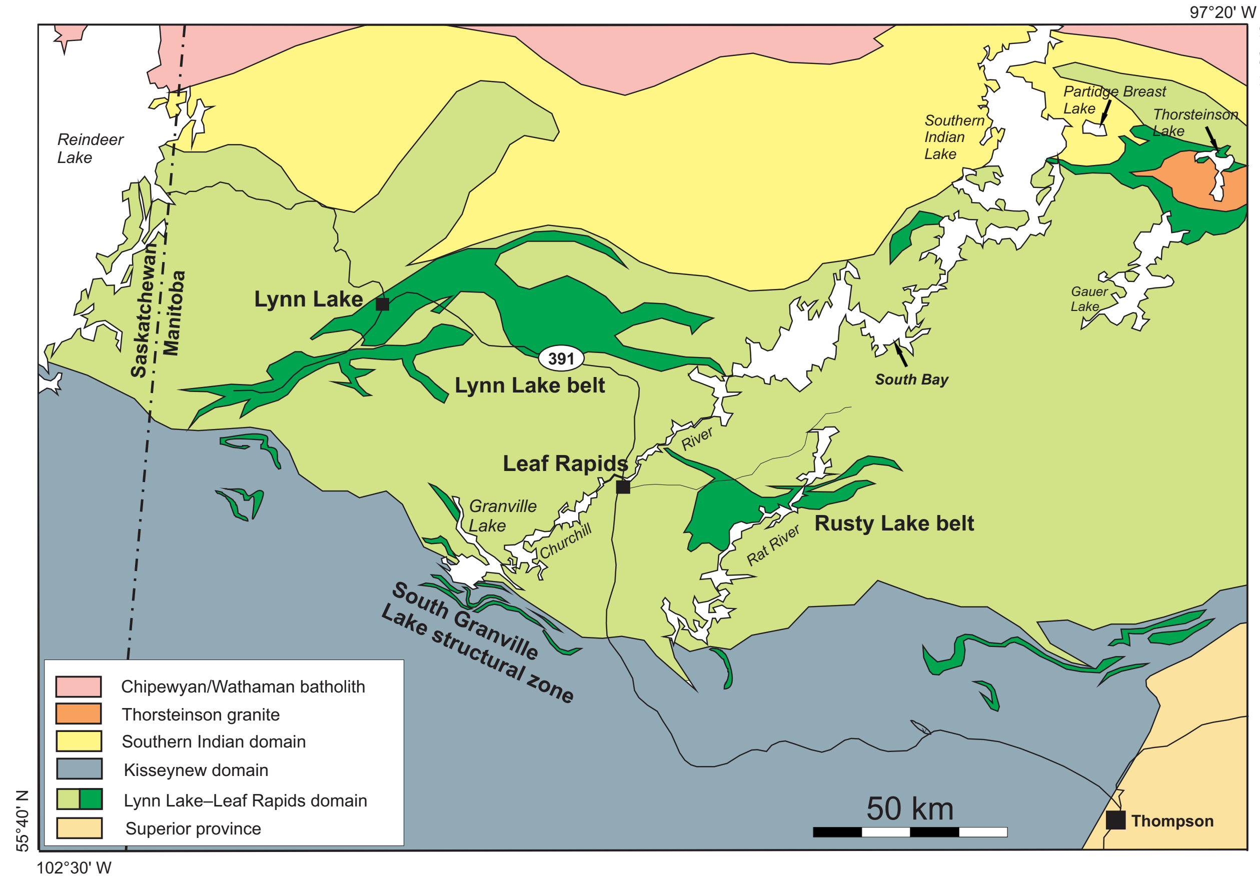

***Figure GS-10-1:** Simplified regional geology showing the three main tectonic subdivisions of the Trans-Hudson orogen in Manitoba and the locations mentioned in the text.*

distinct lithotectonic assemblages (Kremer, 2008, Kremer et al., 2009a). The Pukatawakan Bay assemblage is composed of semipelitic to pelitic metasedimentary rocks interbedded with juvenile, massive to pillowed metabasalt flows and minor calcsilicate and exhalative metasedimentary rocks. The Partridge Breast Lake–Whyme Bay assemblage is dominated by ca. 1.89–1.88 Ga mafic to felsic metavolcaniclastic and lesser metavolcanic rocks with contaminated isotopic signatures and trace-element geochemical profiles similar to modern arc magmas. These assemblages are unconformably overlain by ca. 1.86–1.83 Ga sequence(s) of clastic sedimentary rocks composed of quartz and feldspathic arenite and polymictic conglomerate (Rayner and Corrigan, 2004; Kremer et al., 2009a). All lithotectonic assemblages in the Southern Indian domain have been flooded with voluminous granitic intrusions with known ages ranging from 1.86 to 1.80 Ga.

Pegmatites at Southern Indian and Partridge Breast lakes

Pegmatite occurrences in these areas have been previously described (Corrigan et al., 2001; Corrigan and Rayner, 2002; Kremer, 2008; Kremer et al., 2009) but no detailed study was dedicated to these bodies. Most of these pegmatite bodies have simple mineralogy (mostly quartz, albite, K-feldspar, muscovite and biotite) but tourmaline, beryl and columbite group minerals were observed in some exposures. Pegmatites mostly intrude the metasedimentary and metavolcanic rocks of the Pukatawakan Bay assemblage and have sharp contacts with little to no contact aureoles. At Southern Indian Lake, the simpler pegmatites have variable thicknesses (<30 cm to >4 m), and generally strike 120º, subvertical. Mineralogy identified in hand sample is commonly albite, K-feldspar, quartz, muscovite, garnet, apatite and minor biotite. Margins can be straight or bulbous (Figure GS-10-2a), intruding migmatitic sedimentary rocks (Figure GS-10-2b). One of the examples with a clear differentiated border zone is a roughly subvertical, northeast-southwest–oriented body more than 10 m in width (apparent width). It intrudes metasedimentary and metabasaltic rocks of the Pukatawakan Bay assemblage. The body has a main central area with abundant K-feldspar, quartz, plagioclase, muscovite and minor biotite, tourmaline and garnet (Figure GS-10-2c). This simplest part of the pegmatite contains graphic texture and booklets of muscovite. The margins are mostly composed of sugary albite and very fine grained quartz. A peculiar texture consisting of garnet

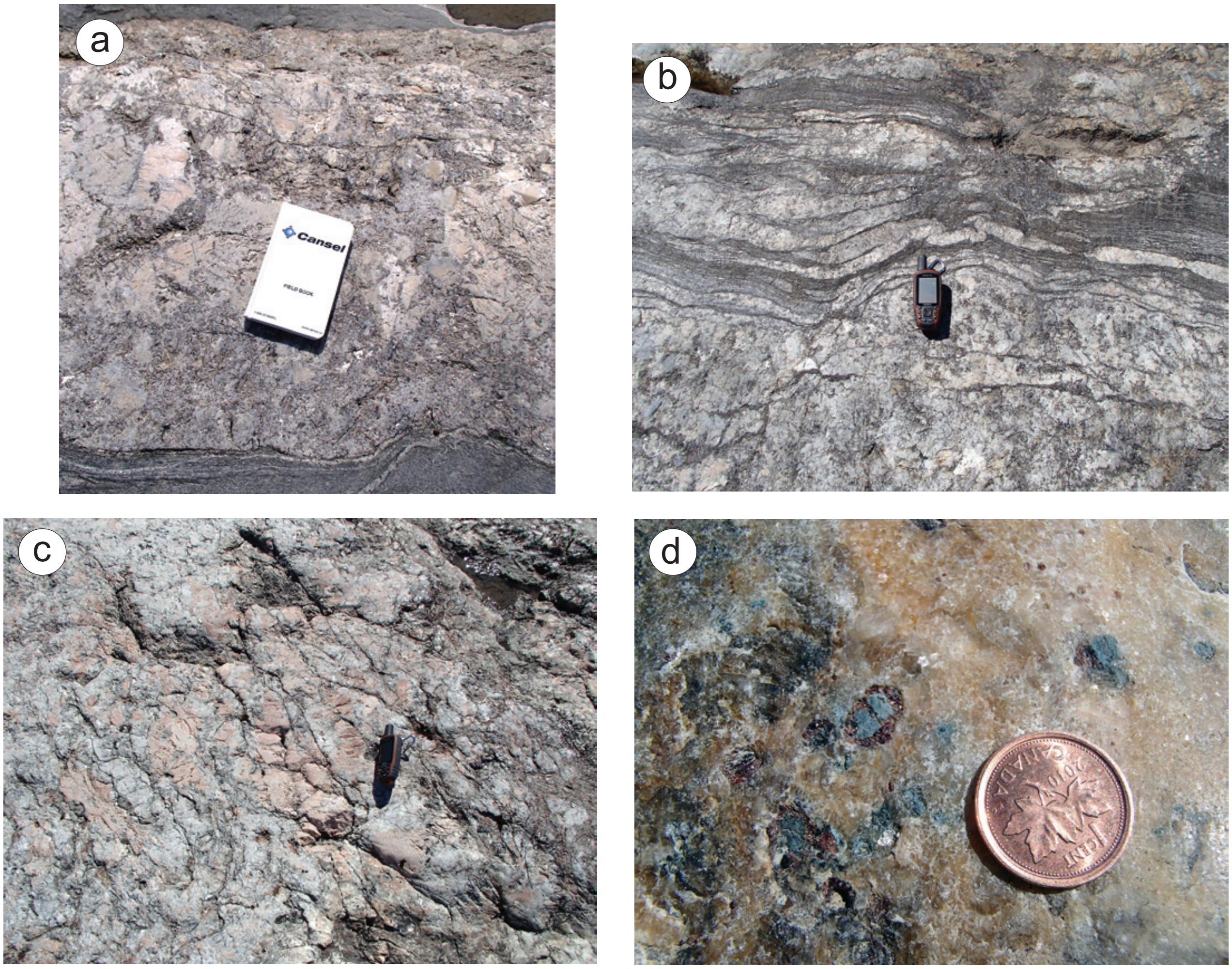

Figure GS-10-2: *Examples of pegmatites intruding the Pukatawakan Bay assemblage:* ***a)*** *detail of a simple pegmatite with bulbous contacts and minor metasomatic aureole imposed in the country rock (notebook is 18 cm long);* ***b)*** *detail of pegmatite hosted by migmatitic metasedimentary rocks (GPS is 15 cm long);* ***c)*** *homogeneous and mineralogically simpler main area of the pegmatite;* ***d)*** *detail of apatite replaced by garnet in the aplitic border zone of the same pegmatite.*

surrounding blue apatite can be recognized in the margin zone of this pegmatite (Figure GS-10-2d). Also observed is epidote surrounding garnet. Layering within the very fine grained margin is present; pyrite, chalcopyrite and a calcareous crust coating part of the pegmatite margins occur locally.

A very distinct and unusual pegmatite containing beryl and auriferous sulphide mineralization was visited and sampled on Turtle Island. The sulphide mineralization is restricted to the altered contact zone with the basalt hostrocks, and occurs as a band of semi-massive to massive pyrite and chalcopyrite (5–10 cm thick) within the pegmatite (Figure GS-10-3a). The semi-massive sulphide is bounded by a zone containing abundant white to pale-green beryl crystals (1–3 cm) in a groundmass of sulphide (Figure GS-10-3b). Geochemistry and assay results of samples collected in 2009 reveal 2130–2865 ppm Be, 1.53–1.55 g/t Au, 2 g/t Ag, 458–681 ppm Bi, 3970–4100 ppm Zn, 62.4 ppm Nb and 17.2 ppm Ta (Kremer et al., 2009b, c). It is possible that one or a combination of the following processes were responsible for this very unusual association: differentiation of the pegmatitic melt, interaction of the late-stage pegmatitic melt with the country rock, or overprinting by one or more generations of a hydrothermal fluid. Further investigation will be conducted to clarify the origins of this polymetallic mineralization.

In the Partridge Breast Lake area, the pegmatites intrude volcanic, volcaniclastic and sedimentary rocks assigned to the Partridge Breast Lake–Whyme Bay assemblage. Pegmatites have variable thicknesses (approximately 5–30 m), with graphic texture and predominantly sharp, straight and bulbous contacts. Metasomatic aureoles in the country rock, when present, are minor and manifest by slight enrichment in biotite, tourmaline or garnet. The dikes are subvertical and strike between 240º and 330º. The main mineralogy consists of quartz, K-feldspar, plagioclase, biotite, muscovite, apatite, tourmaline,

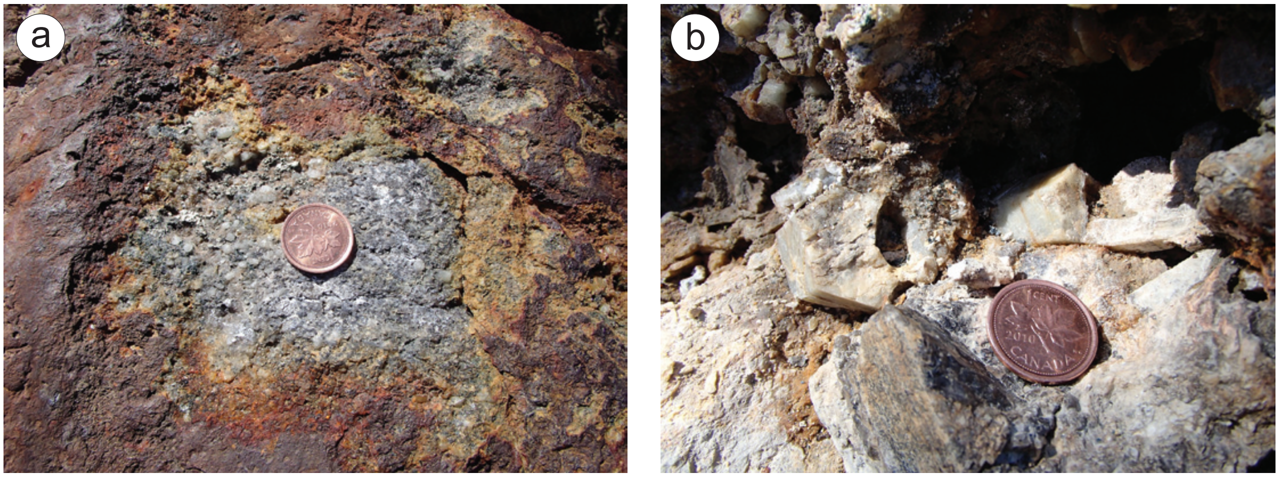

Figure GS-10-3: *Detail of beryl and sulphide semi-massive mineralized contact area of the pegmatite. Different morphologies of beryl may indicate different phases of Be mineralization:* ***a)*** *centimetre-scale white beryl with sulphide crust;* ***b)*** *detail of beryl crystals in a vuggy area of the contact.*

garnet, columbite group minerals and zircon. Booklets of mica are common and part of the pegmatite bodies contain euhedral garnet up to 2 mm associated with megacrystic feldspar up to 60 cm; a quartz core measuring 0.5–3 m is locally observed. Tourmaline tends to be found associated with quartz, although in one of the pegmatites, coarse tourmaline crystals are concentrated around the margin of very large feldspar crystals (Figure GS-10-4).

Thorsteinson Lake granite

The Thorsteinson Lake granite is a large granitic intrusion located between the Chipewyan and the Baldock batholiths. Previous workers described this granitic body as a biotite-hornblende–bearing granite containing fluorite (Halden et al., 1990). Age determination by Rb-Sr geochronology indicates an age of 1740 Ma with an initial ratio of 0.7013 (Clarke, 1981). Later work using Rb-Sr whole-rock geochemistry gives an age of 1713 ±19 Ma (Halden et al., 1990).

Figure GS-10-4: *Detail of tourmaline crystals concentrated at the margins of feldspar in a pegmatite at Partridge Breast Lake.*

The Thorsteinson Lake granite is medium to coarse grained, locally weakly to moderately magnetic and has no deformation fabrics. It is mainly composed of quartz, K-feldspar, albite, garnet, biotite, magnetite and fluorite (Figure GS-10-5a). Locally it is intruded by a pegmatite with the same composition as the granite, interpreted as late-stage crystallization (Figure GS-10-5b). A syenitic phase located in the southern margin of Thorsteinson Lake is interpreted as a more evolved phase of the same granite, with less Si and possible enrichment in incompatible elements (e.g., F, Nb, Y), is medium to coarse grained, massive, undeformed and nonmagnetic. Preliminary petrographic studies have identified the following mineralogy: plagioclase, K-feldspar, quartz, biotite and hornblende, with minor titanite, zircon, apatite, ilmenite, fluorite, allanite and rare muscovite. Fluorite is found throughout the thin section with a maximum length of 2 mm. It occurs as isolated grains and in association with ilmenite, biotite and amphibole. Titanite has similar associations as those described for fluorite and it is locally found surrounding ilmenite. Association of titanite and ilmenite locally replace biotite and amphibole. Zircon is found associated with biotite and amphibole, measuring up to 1 mm. Both metamict and crystalline zircon grains are evident. Geochemistry and geochronology results are pending.

Pegmatites at South Bay

The pegmatites at South Bay were first described by Mumin and Corriveau (2004). Since then, the Tantalum Mining Corporation of Canada Ltd. performed an enzyme leach soil geochemical survey over the area (Assessment File 74323, Manitoba Mineral Resources, Winnipeg) and

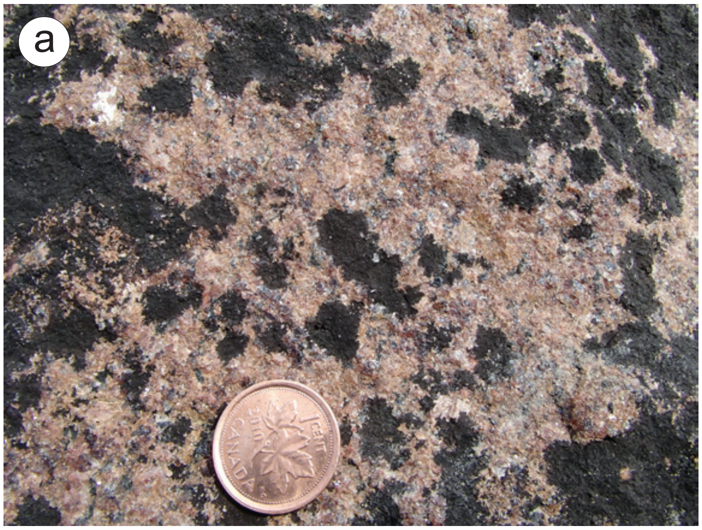

Figure GS-10-5: *Outcrop photographs of the Thorsteinson Lake fluorite-bearing granite:* ***a)*** *more syenitic phase of the fluorite-bearing granite located in the southern margin of Thorsteinson Lake;* ***b)*** *pegmatite dike intruding the fluorite-bearing granite.*

exploration work was carried out by Wildwood Geological Services in 2010 (confidential Assessment File 74028, Manitoba Mineral Resources, Winnipeg; reproduced by permission of R. Bezys).

During this study, the main pegmatite exposures were described and sampled. These include the outcrop exposures along the roadcut and short distances off-road, and those exposed on the southwestern shore of Southern Indian Lake. The main goal of this study is to characterize the pegmatite bodies in terms of their mineralogy, relationship with the country rock, whole-rock geochemistry and rare-metal potential. Geochronological studies will be carried out if suitable minerals can be separated.

Different types of pegmatites were observed at South Bay, including simple quartz-feldspar-garnet bodies, layered aplitic and pegmatitic bodies and beryl-Nb-Ta–bearing bodies. The pegmatites intrude diorite composed of quartz, plagioclase, biotite and hornblende, and highly metamorphosed metasedimentary rocks with migmatite injections.

Quartz-feldspar-garnet pegmatites

These pegmatite bodies are composed mostly of plagioclase, quartz, biotite, garnet, apatite, muscovite and dark oxides. They vary in thickness from 2 to 12 m and intrude both the metasedimentary unit and diorite. For the most part, the contacts are irregular but sharp, and straight contacts are also observed. The orientation of the pegmatites varies but most trend 230º and are subvertical. Graphic texture (Figure GS-10-6a) and booklets of biotite and muscovite are common, as well as K-feldspar with a comb structure (Figure GS-10-6b). A pronounced mineralogical layering known as ‘line rock’ (fine-grained, garnet-rich bands alternating with albite- and quartz-rich bands) is also common in the aplitic portions of the pegmatite (Figure GS-10-6c).

Zonation is not readily visible, although there are some examples where a crude zonation is observed, which includes i) chilled margin (usually varying from 1 to 2 cm; Figure GS-10-6b), ii) zone of quartz and comb structure feldspar, iii) aplitic zone and iv) quartz core. In other examples, the differences between adjacent zones are marked by minor variations in the concentration of feldspar+quartz+muscovite (up to 40 cm in thickness).

Layered pegmatites

These pegmatite bodies consist of alternating layers of aplite and pegmatite. The pegmatitic texture is characterized by the existence of comb structure and abundant garnet (Figure GS-10-6d). Pegmatites have sharp contacts, strike northeast and have apparent thicknesses of approximately 4.5 m. Minerals identified in hand sample are quartz, K-feldspar, plagioclase, garnet, garnet and dark oxides.

Beryl-bearing pegmatites

This is by far the most evolved pegmatite type found in this area. The main exposure is a near-vertical body striking 210º found along the roadcut that extends approximately 16.5 m along strike. More pegmatites of this type were found along the lakeshore but are not as well exposed. The true thickness of the roadcut exposure

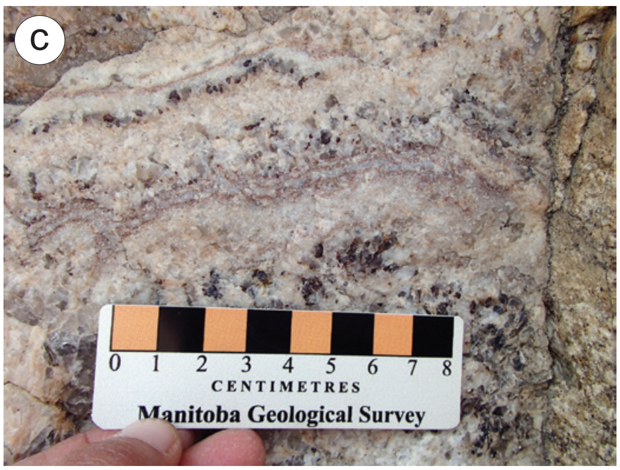

***Figure GS-10-6:** Pegmatite types at South Bay: **a)** detail of graphic texture in quartz-feldspar-garnet pegmatite; **b)** pegmatite dike showing chilled margins, comb structure of K-feldspar and booklets of muscovite; **c)** detail of garnet line rock; **d)** detail of layered pegmatite.*

is unknown but it is estimated that it only represents perhaps half or even less of the entire pegmatite. Most of the pegmatite was cut and removed for road construction. As with many of the examples observed in this area, it intrudes diorite and the alteration aureole in the country rock is minor or nonexistent.

Four zones were identified in the field: i) aplitic zone, ii) intermediate zone, iii) beryl-rich zone and iv) minor quartz core (Figure GS-10-7a).

The aplitic zone is usually located close to the margin of the pegmatite and is mainly composed of very fine grained, almost sugary albite, garnet, apatite, columbite group minerals and rare beryl. Locally, garnet is found in the groundmass or surrounding larger grains of albite or quartz (Figure GS-10-7b). The intermediate zone is essentially composed of coarse- to very coarse grained quartz and albite; garnet is also observed. The beryl zone is characterized by the presence of very large crystals of quartz, albite and beryl (up to 2 cm across; Figure GS-10-7c). Columbite group minerals are also observed (maximum length of 1 cm), as well as rare biotite.

Economic considerations

From an economic perspective, the most interesting pegmatite is the Be-Au-Zn-Bi–bearing body at Southern Indian Lake. Descriptions of this type of rare-element and

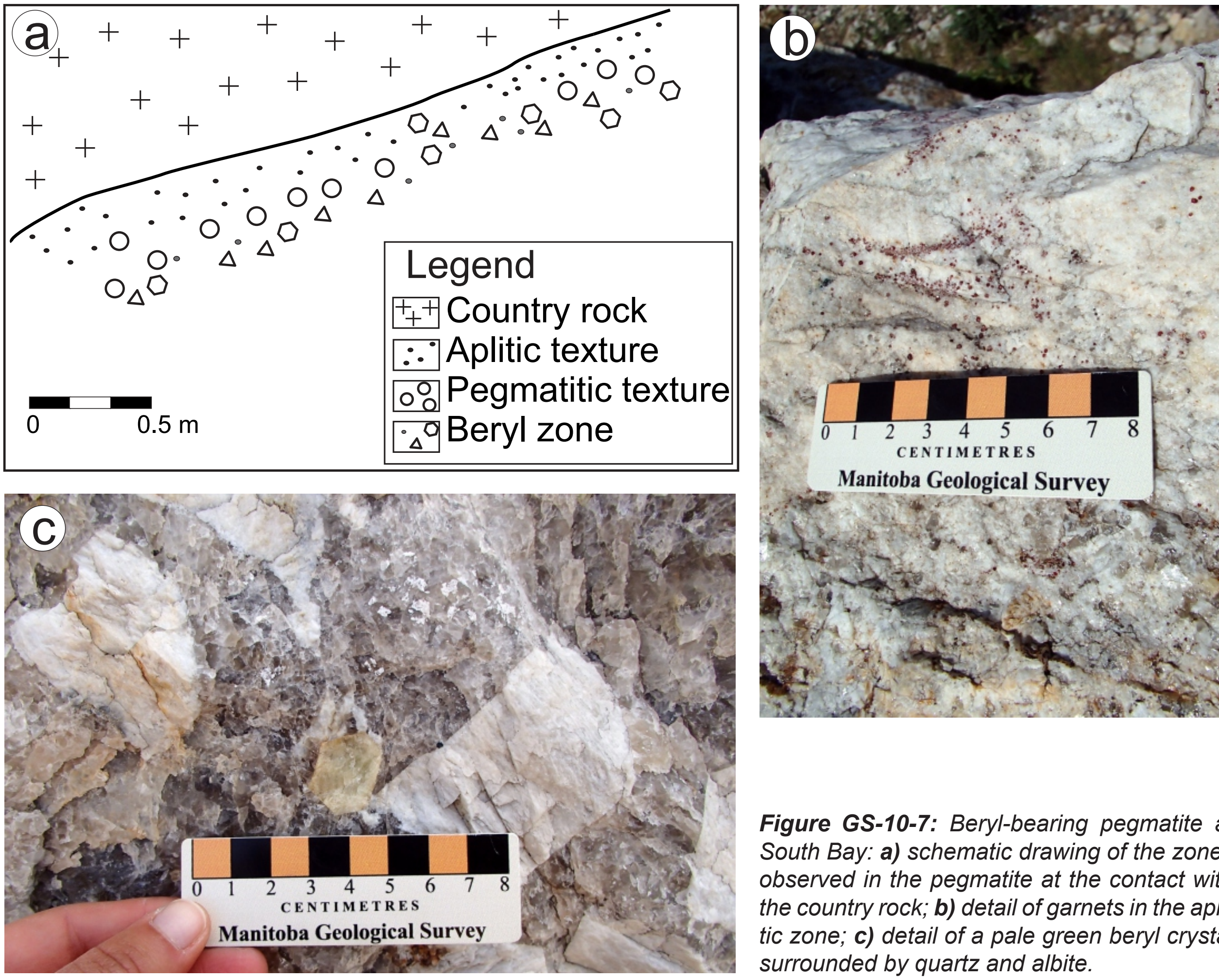

Figure GS-10-7: *Beryl-bearing pegmatite at South Bay:* ***a)*** *schematic drawing of the zones observed in the pegmatite at the contact with the country rock;* ***b)*** *detail of garnets in the aplitic zone;* ***c)*** *detail of a pale green beryl crystal surrounded by quartz and albite.*

base-metal association are rare in the literature. This association may indicate an analogy to the Fort Knox mine in Alaska, where the gold deposit is associated with a granitic environment and pegmatites (Quandt et al., 2008). Other examples of polymetallic deposits are described in the Gold Hill mining district, United States, where Au, As, Pb, Zn, Cu, Mo and W were produced from its numerous mines (Robinson, 2006).

The pegmatites investigated at Partridge Breast Lake during this scoping study show significant B, Nb and Ta mineralization (i.e., the presence of tourmaline and columbite group minerals). Geochemical analyses will be completed to determine if other elements usually found in association with B, Nb and Ta are also present in these pegmatites, thereby indicating a more evolved granitic-pegmatitic system. Geochemistry and mineralogical studies of the granitoid bodies found in this area could also help identify the parental granite for these pegmatitic bodies and constrain the limits of the pegmatite field.

Based on field observations and preliminary petrographic study, the Thorsteinson Lake granite has the potential to host columbite group minerals, in addition to the already identified fluorite. Geochemistry results from Lenton and Corkery (1981) indicate that F ranges from 500 to 3150 ppm, which could indicate a Nb, Y, F (NYF) signature. Further mineral studies and whole-rock geochemistry will provide more information on the economic potential of this granitic body.

The more evolved pegmatites (i.e., the ones with highest economic potential) found at South Bay belong to the rare-element (REL) class, subclass REL-Li, beryl type, beryl-columbite subtype according to the classification of Černý and Ercit (2005). It has been proposed that pegmatites with LCT mineralization could be found in the area after enrichment in Be, Nb, Ta and Cs was reported (Mumin and Courriveau, 2004; Assessment File 74323). This would suggest that there is a pegmatite family with LCT association that displays a distinctive pattern of regional zoning of different types and subtypes of pegmatites. Regional zoning occurs ideally as a concentric aureole around an inferred parental pluton (Trueman and Černý, 1982; Černý, 1989). The least fractionated pegmatites are located close to the parental pluton, and the most fractionated pegmatites are distal to the parental pluton. The following spatial distribution has been defined with increasing distance from the source pluton:

1) barren, 2) beryl subtype, 3) beryl-columbite subtype, 4) beryl-columbite-phosphate subtype, 5) spodumene or petalite±amblygonite subtypes, 6) lepidolite subtype, 7) albite-spodumene type and 8) albite type. According to the same authors, magmas with enrichment in H_2O, F, B, P, Li, Rb, Cs and Be can travel further from the parental granite because they have low viscosity and are capable of more mobility. In the case of South Bay, the present-day exposure only allows the identification of barren and beryl-columbite–subtype pegmatites. This may indicate that the more evolved pegmatites were lost to erosion. Alternatively, they could occur at depth or simply have not been found yet. The source for these pegmatites is currently unknown. It has been speculated that the pegmatitic granite found in the area could be the source of these pegmatites but geochemical results and field relationships are lacking to support this hypothesis. Granitoid and pegmatitic granite bodies in the vicinity were sampled and geochemistry, geochronology and mineral studies are pending. Petrography, geochemistry results and mineralogical studies will shed light in understanding the types of pegmatites found in the South Bay area.

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