GS2024-9

Spodumene-bearing pegmatites from the Cross Lake pegmatite field, east-central Manitoba: mineralogy and petrography descriptions (parts of NTS 63I12, 63J9)

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In Brief:

- Petrographic descriptions from spodumene-bearing pegmatites from the Cross Lake pegmatite field are presented
- Archival detailed maps, geochemistry and station descriptions are also released with this report

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Summary

The Cross Lake pegmatite field in central Manitoba is a well-documented, lithium-rich pegmatite field of Archean age in the western Superior Province. This pegmatite field provides an excellent opportunity for the exploration and study of rare-element-bearing pegmatites, particularly the Li-enriched kind. Recently-cut polished thin sections of spodumene-bearing pegmatites from the Cross Lake pegmatite field were examined and are described in this report. Archival descriptions and outcrop maps of pegmatites from the Cross Lake pegmatite field are also being released in association with this report.

Introduction

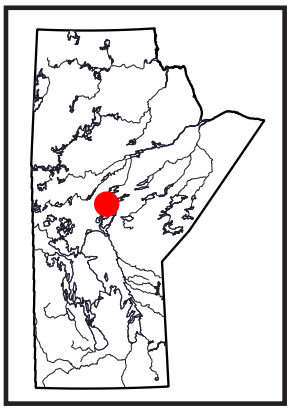
The Cross Lake greenstone belt was studied by the MGS in the 1980s (e.g., Corkery, 1983; Corkery et al., 1992). The Cross Lake pegmatite field was studied in detail by A. Anderson (1984) as part of an MSc. thesis, which was included in the MGS regional greenstone belt mapping project (Corkery, 1983; Corkery et al., 1992). Work by Anderson (1984) focused on the regional distribution and the geochemical, paragenetic and textural variations in the pegmatites and pegmatitic granites throughout the pegmatite field.

During the last few years, and due to increasing interest in hard-rock lithium resources associated with pegmatites (e.g., Kesler 2012; Gardiner et al., 2024; U.S. Geological Survey, 2024), the area has been the target of mineral exploration (e.g., Leeuwin Metals, 2024; Assessment File 63I8629, Manitoba Economic Development, Investment, Trade and Natural Resources). Lithium is considered critical for the green-energy transition and is included in the list of critical elements released by Canada (Government of Canada, 2024). Currently, Leeuwin Metals owns the rights to explore in this area (Leeuwin Metals, 2024).

This report summarizes the current knowledge of the Cross Lake pegmatite field and a detailed petrographic description of recently cut thin sections of the spodumene-bearing pegmatites. The associated Data Repository Item (Martins et al., 2024) includes unpublished detailed maps of selected pegmatite outcrops, along with station descriptions of MGS work from the 1980s.

Geological setting

The Cross Lake greenstone belt is flanked by the metaplutonic Molson Lake domain to the south and a largely metaplutonic terrane to the northwest (Figure GS2024-9-1). The northern contact is a major northeast-trending fault system with dextral strike-slip and a vertical component indicative of relative uplift of the northwest side (Breedveld, 1988). The southern contact is a much broader zone of deformation in which a number of east-southeast-trending dextral fault zones imbricate supracrustal rocks of the Pipestone Lake and Gunpoint groups and, to a lesser extent, Molson Lake domain plutonic rocks. This dextral strike-slip zone has a vertical component of south side up (Breedveld, 1988).



The Cross Lake greenstone belt is composed of supracrustal rocks and plutonic complexes. The supracrustal rocks in the belt can be subdivided into three groups: an older metavolcanic series, the Pipestone Lake group, is unconformably overlain by the metasedimentary-metavolcanic Gunpoint group, which is in turn overlain by the Cross Lake group. A more detailed description of the regional geology of this area, along with a relative sequence of geological events, is outlined in Corkery et al. (1992).

Cross Lake pegmatite field

The Cross Lake pegmatite field is located in the Cross Lake greenstone belt and contains numerous pegmatites of diverse geochemical affinity. This pegmatite field covers an area of about 200 km^2

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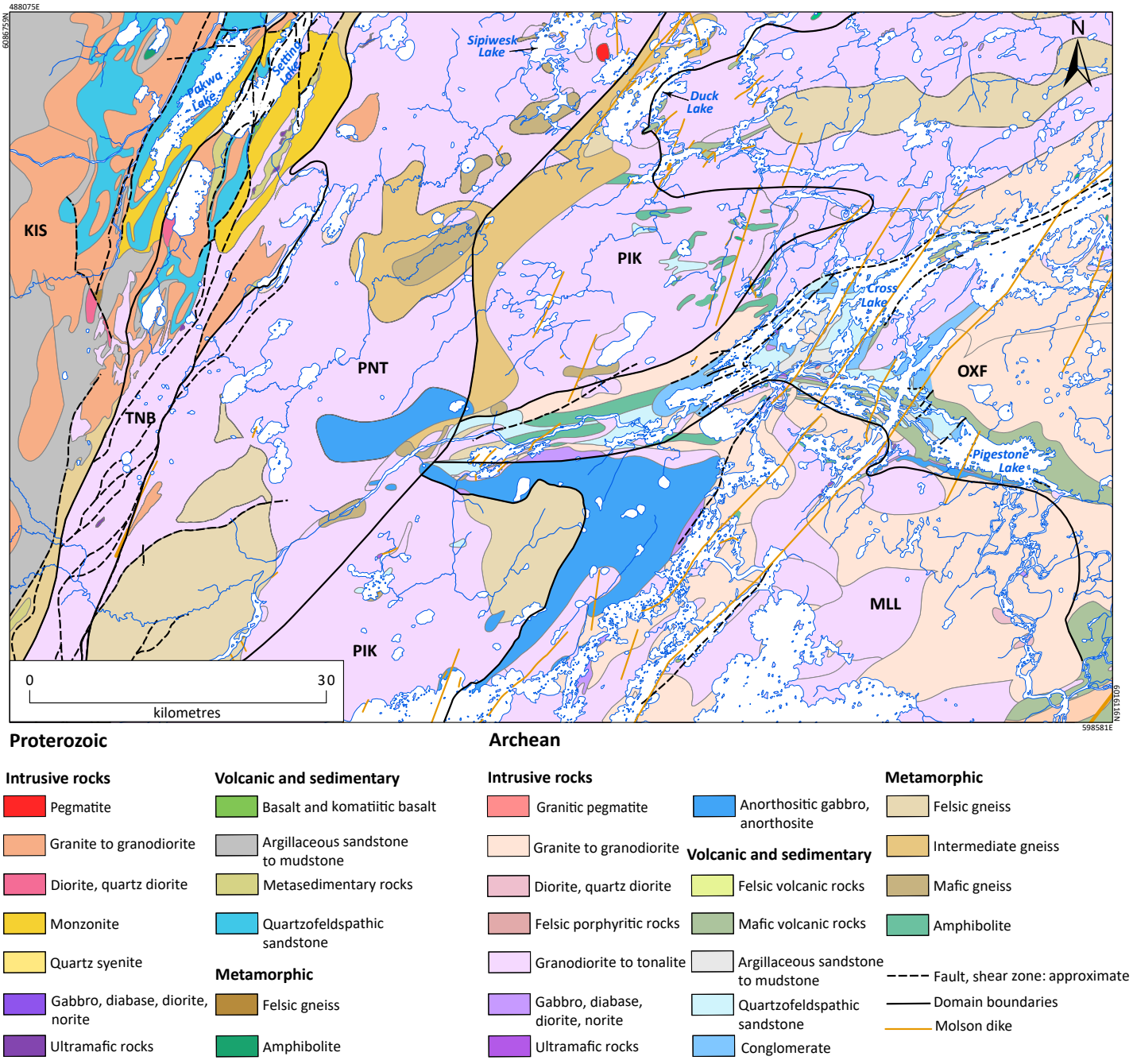

Figure GS2024-9-1: *Regional geology of the Cross Lake greenstone belt at 1:250 000 scale (geology from Manitoba Geological Survey, 2022). Domain abbreviations: KIS, Kisseynew; MLL, Molson Lake; OXF, Oxford; PIK, Pikwitonei; PNT, Paint Lake; TNB, Thompson nickel belt.*

that extends from the Minago River in the south to north of Cross Island (Figure GS2024-9-2). The pegmatites intrude amphibolite-facies supracrustal rocks, which parallel the axial trend of the belt. The pegmatites are en échelon and comprise narrow, linear, east- and northeast-trending zones parallel to the axial trend of the greenstone belt. A garnet-muscovite-tourmaline granite, interpreted to be comagmatic with the rare-element pegmatites, provided a U-Pb age between 2653 and 2634 Ma, interpreted as a likely age of intrusion (Corkery et al., 1992).

Anderson (1984) divided the pegmatite field into four major series. Each series consists of spatially and structurally related pegmatite bodies that present similar geochemical, paragenetic and textural characteristics. The same author suggested a progressive fractionation in an easterly direction, parallel to decreasing metamorphic grade of the hostrocks. Geochemical data indicate that the Minago and Southern series are genetically related (probably to a common source at depth) to mineralized Li-Be-Nb-Ta-Sn pegmatites recognized in the Southern series. The Northern series is geochemically distinct, interpreted to be derived from a separate source, and includes Be-Nb-Ta–mineralized pegmatites. The Nelson series was interpreted as consisting of anatectic bodies. Anderson et al. (2004) added that two petro-

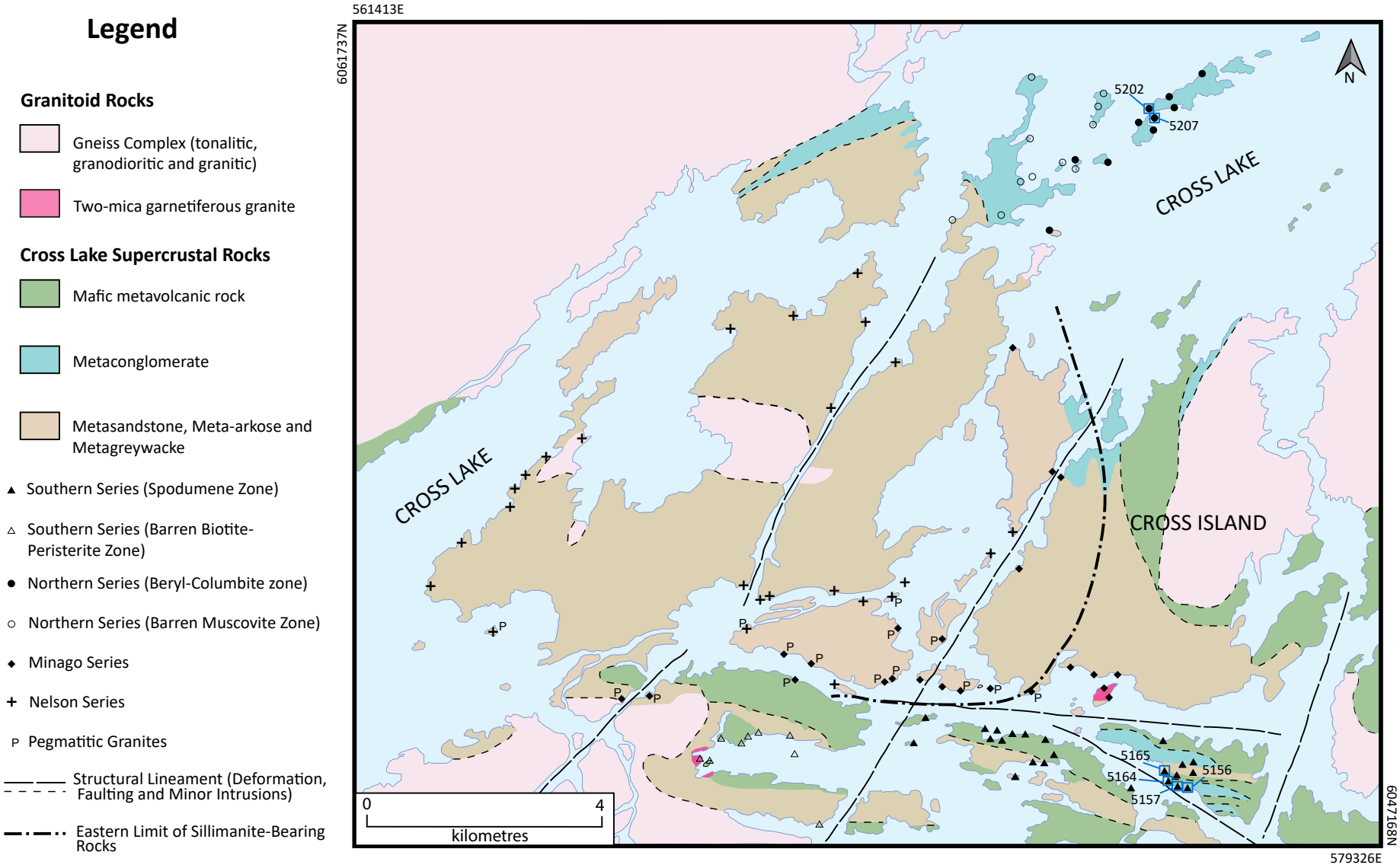

Figure GS2024-9-2: *Simplified geology of the Cross Lake pegmatite field, showing the different pegmatite groups defined by Anderson (1984). Locations of detailed pegmatite outcrop maps are marked by blue squares. Modified from Anderson (1984).*

genetic models are equally plausible: the series are the products of distinct granitic sources, or they are comagmatic and developed geochemical distinctions because of the heterogeneity of the parent melt.

Below is a summary of the characteristics of the pegmatites from each series. Detailed descriptions of the dikes' internal structure, mineral distribution, paragenesis and chemistry can be found in Anderson (1984).

Nelson series

This series consists of barren biotite-oligoclase-microcline-quartz-garnet pegmatite dikes. These pegmatites intrude the metapsammitic–pelitic rocks west of Cross Island (Figure GS2024-9-2). Additional minerals present include accessory blue apatite and schorl (black tourmaline).

Minago series

This group of pegmatites consists of a narrow linear zone of pegmatitic granite bodies (i.e., granite bodies composed mainly of quartz, feldspar and mica with a pegmatite texture, but lacking some features typical of other pegmatites in the area, such as graphic texture or internal zonation) and barren pegmatite dikes that outcrop intermittently from the Minago River to the southwestern shore of Cross Island (Figure GS2024-9-2). The main mineral assemblage of the pegmatitic granites and related pegmatites is microcline perthite, quartz, albite-oligoclase, biotite and muscovite. Graphic microcline perthite is most prevalent in the pegmatites and pegmatitic granites that constitute the eastern end of the Minago series but is absent or weakly developed in the bodies that lie farther west. Prevalent accessory mineral phases are garnet and schorl (black tourmaline), along with rare apatite, arsenopyrite and beryl.

Northern series

This series is composed of muscovite-bearing pegmatites that intruded the metasedimentary rocks north of Cross Island (Figure GS2024-9-2). The Northern series has been subdivided into a beryl-columbite pegmatite zone (Figure GS2024-9-3a) and a barren muscovite pegmatite zone (more common; Figure GS2024-9-3b). The internal zoning in the pegmatites of the Northern series is weakly developed. However, Anderson (1984) noted that the internal structure of the pegmatites of the barren muscovite zone evolves from a near texturally homogeneous muscovite+K-feldspar+quartz+plagioclase pegmatite to concentrically zoned bodies containing quartz cores. Figure GS2024-9-3b is a representation of the intermediate stage in the textural evolution of the barren muscovite pegmatite zone of the Northern series. Detailed description of this textural evolution can be found in Anderson (1984). The beryl-columbite pegmatites are the most fractionated members known in the Northern series.

Southern series

The pegmatites of the Southern series form an 8 km long belt south of Cross Island (Figure GS2024-9-2). They intrude the metavolcanic rocks and metasedimentary rocks south and east of the sillimanite zone of metamorphism. The series has been subdivided into two zones that are texturally and paragenetically distinct but spatially, structurally and geochemically related. These are the biotite-peristerite pegmatite zone and the spodumene pegmatite zone.

The biotite-peristerite pegmatite zone forms the western third of the southern series (Figure GS2024-9-2). Albitization and internal zonation are absent or weakly developed in the pegmatites of this zone. Figure GS2024-9-3c illustrates the mineral distribution and simple internal texture of the most evolved pegmatites in the biotite-peristerite zone of the Southern series. The characteristic mineral assemblage is biotite, peristerite, pale green apatite and rare ferrocolumbite.

The spodumene-bearing pegmatites are in a 5 km long, east-trending zone south of Cross Island that represents about two-thirds of the Southern pegmatite series (Anderson, 1984; Figure GS2024-9-2). These pegmatites are texturally complex, extensively albitized and paragenetically diverse. An idealized textural section of the spodumene-bearing pegmatites, representing zonation and characteristic mineralogy, can be found in Figure GS2024-9-3d. The spodumene pegmatites were fractured and boudinaged due to tensional stress, with fractures within the pegmatite that do not continue into the less competent hostrock. These pegmatites are irregular with complex apophyses (Anderson, 1984).

Pegmatite outcrop maps

P. Lenton (MGS emeritus, deceased) carried out detailed outcrop mapping of several of the pegmatite dikes from the Cross Lake pegmatite field (Figure GS2024-9-4) as part of an MGS regional mapping project in the 1980s (e.g., Corkery, 1983). Samples of mineral separates were also collected and will be studied at a later stage. Locations of the detailed maps are indicated in Figure GS2024-9-2. One example of a detailed pegmatite outcrop map is provided in this report (Figure GS2024-9-4). The complete set of detailed outcrop maps can be found in MGS Data Repository Item DRI2024013[2], together with a full collection of station maps and outcrop descriptions (Martins et al., 2024).

Petrographic descriptions

Recently made polished thin sections of the spodumene-bearing pegmatites (Southern series) from archival drillcore

[2] MGS Data Repository Item DRI2024013, containing the data or other information sources used to compile this report, is available online to download free of charge at https://manitoba.ca/iem/info/library/downloads/index.html, or on request from minesinfo@gov.mb.ca, or by contacting the Resource Centre, Manitoba Economic Development, Investment, Trade and Natural Resources, 360-1395 Ellice Avenue, Winnipeg, Manitoba R3G 3P2, Canada.

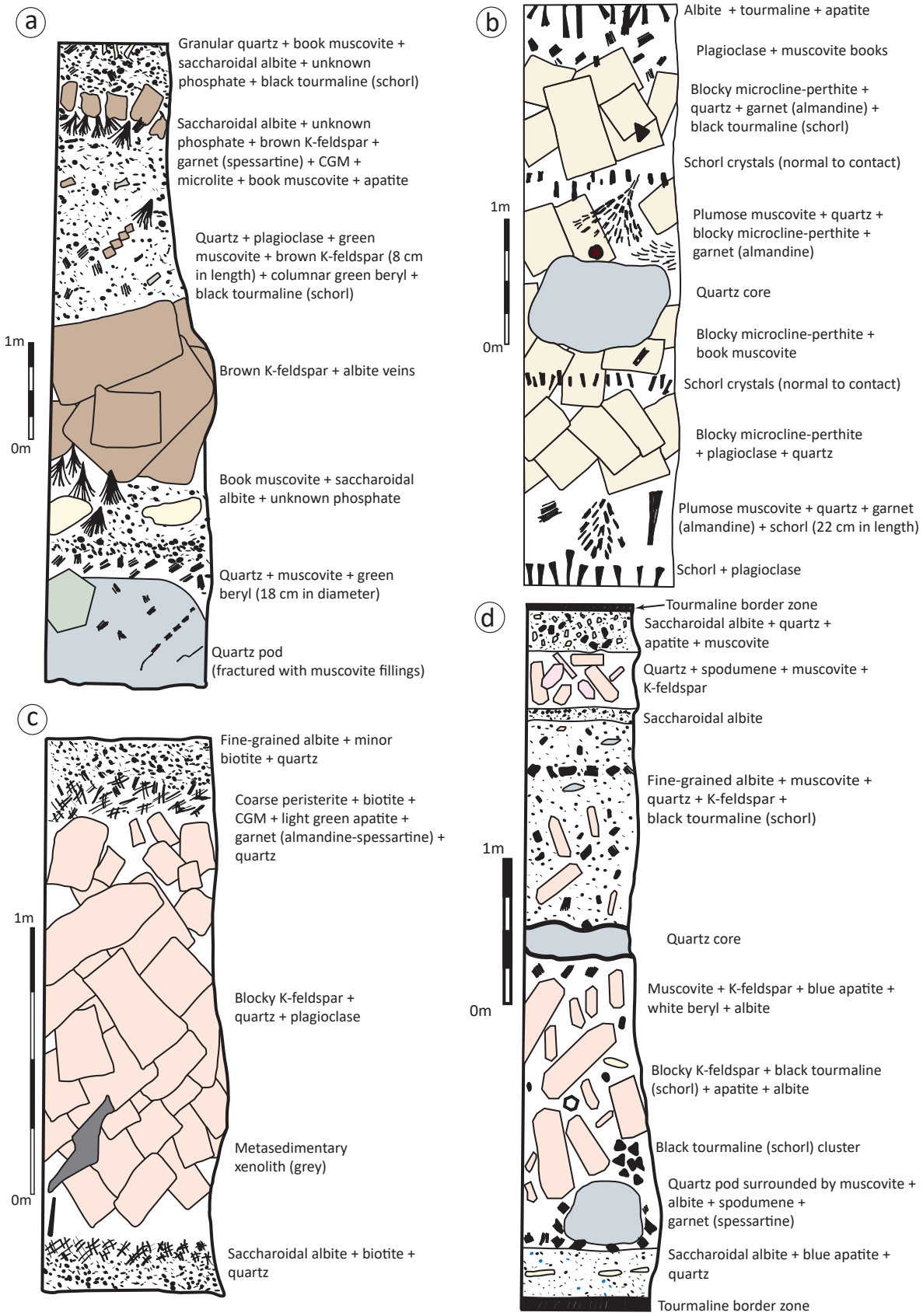

Figure GS2024-9-3*: Interpreted textural sections of the different pegmatite types at Cross Lake after Anderson (1984):* ***a)*** *beryl-columbite pegmatite of the Northern series, the most fractionated example;* ***b)*** *barren muscovite pegmatite of the Northern series, representing the intermediate stage in the textural evolution of the series;* ***c)*** *internal texture of the most evolved biotite-peristerite pegmatite of the Southern series;* ***d)*** *internal structure of a highly fractionated spodumene-bearing pegmatite of the Southern series. Abbreviations: CGM, columbite group mineral.*

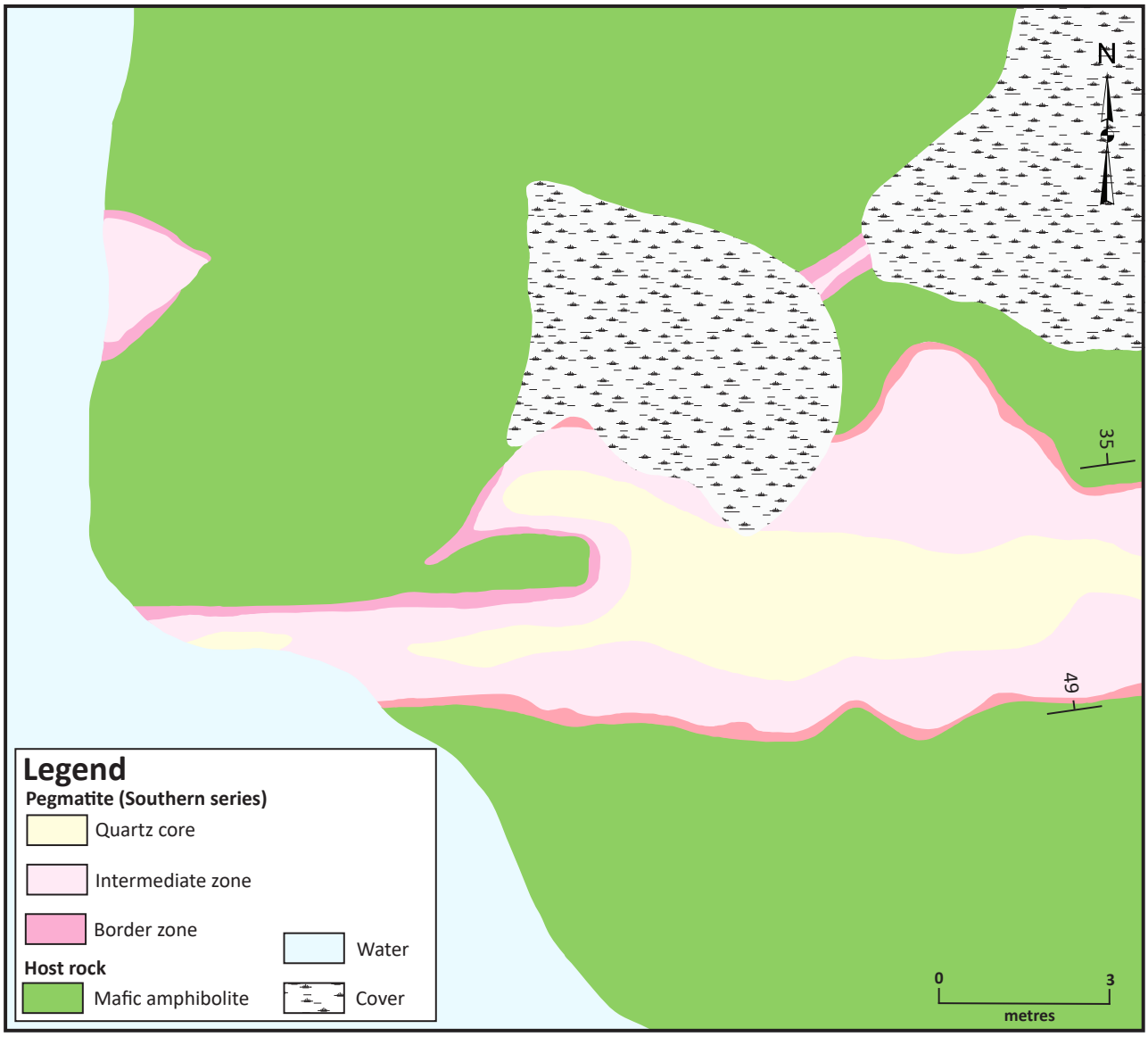

***Figure GS2024-9-4**: Example of a detailed outcrop map of a spodumene-bearing pegmatite dike from Cross Lake (station 5165 in Figure GS2024-9-2; UTM Zone 14, 575762E, 6048356N; map from DRI2024013).*

are described in detail in this section. Major minerals are quartz, plagioclase feldspar, K-feldspar, spodumene and muscovite. Accessory phases include a range of Ta-Nb-Mn-Fe oxides (columbite-group minerals [CGM], wodginite, ixiolite, tapiolite), tourmaline (unknown composition), apatite, zircon, amblygonite-montebrasite (Li-Al-F-OH phosphate series), triphylite-lithiophilite (Li-Fe-Mn phosphate series), garnet (unknown composition) and calcite. Beryl, arsenopyrite and löllingite were described by Anderson (1984) but were not observed during the current petrographic observations.

Quartz is interstitial to the other primary phases and often has undulatory extinction. Locally, it occurs in spodumene-quartz intergrowths, particularly at the edges of spodumene crystals. Plagioclase feldspar is present in all of the observed thin sections, occurring interstitially between the other primary phases. Anderson (1984) described albite of the cleavelandite habit occurring in the wall and intermediate zones of the spodumene-bearing pegmatites, associated with quartz, K-feldspar, pale green muscovite, spodumene, beryl, apatite and CGM. Very fine grained saccharoidal albite was recognized predominantly in association with quartz, muscovite and CGM, and locally replacing other primary mineral phases. Potassium-feldspar is interstitial with other major primary mineral phases. Locally, they can be perthitic, cloudy and have inclusions of other minerals (e.g., apatite, quartz). No graphic texture was observed in the current petrographic work.

Spodumene occurs as large laths with local fractures filled with late mica and plagioclase feldspar minerals. Very fine grained needles of spodumene occur throughout the thin section, growing at the edges of other minerals or surrounding and crosscutting earlier mineral phases (Figure GS2024-9-5a). Also observed are vermicular textures (Figure GS2024-9-5b) of spodumene and

quartz intergrowth, similar to what is described at the Tanco pegmatite as micro-SQUI by Breasley et al. (2022). Muscovite occurs in large crystals associated with spodumene, quartz and feldspar, and local kink bands are observed. Late fine-grained mica occurs in fractures of spodumene and feldspar. The large muscovite grains are zoned in backscattered electron (BSE) imagery, primarily due to variations in Cs and Rb contents (Figure GS2024-9-5c).

Columbite group minerals occur throughout the pegmatite but were more noticeable in the saccharoidal albite units. These minerals usually appear as needles or pear-shaped grains and can be found associated with other oxides (i.e., cassiterite, uraninite) only observed in BSE imagery (Figure GS2024-9-5d). Cassiterite can be found isolated or in association with CGMs, albite, quartz or muscovite. Bluish-green zoned tourmaline can form discrete grains or occur in association with apatite. Tourmaline is also observed as inclusions in spodumene. Tourmaline is more abundant in proximity to the country rock contacts but can be found in other areas of the pegmatite.

Apatite occurs as isolated crystals or associated with tourmaline, as described above (Figure GS2024-9-5a), and is most abundant near the pegmatite contacts. Zircon is metamict with radiation damage haloes in the surrounding minerals. Triphylite-lithiophilite and amblygonite-montebrasite are the main Li-bearing phosphate phases observed. Locally, amblygonite-montebrasite is replaced by calcite. Garnet is rare but was also observed in thin section, locally close to the contact with the country rock. Rare calcite occurs interstitially with quartz and feldspar. Late calcite, replacing other mineral phases and in veins in quartz, was also observed.

Economic considerations

Lithium is among the 34 minerals and elements that Canada considers critical for its potential to support Canada's economic growth and because of its direct role in the green revolution (Government of Canada, 2022). Rare-element pegmatites are a

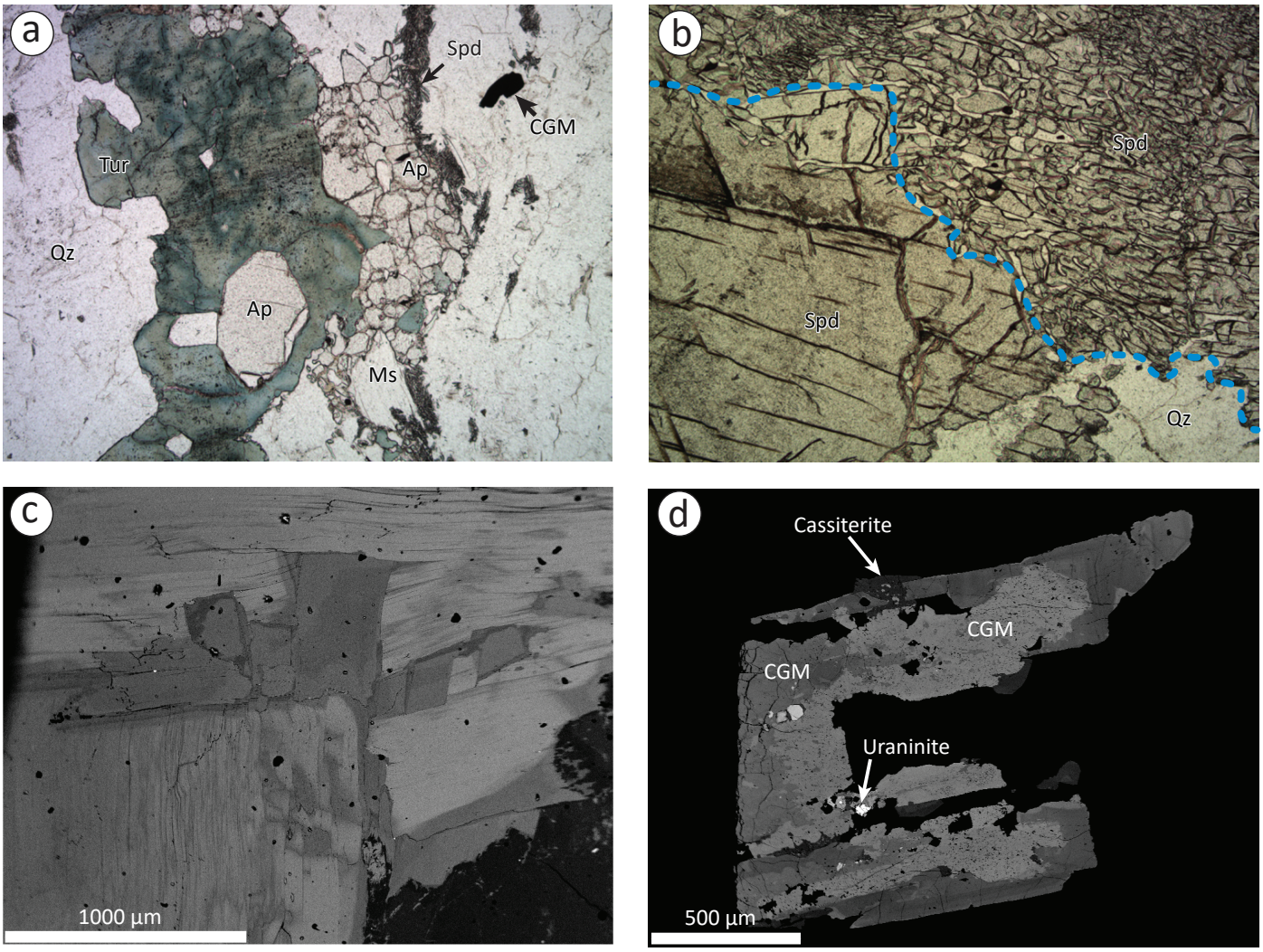

Figure GS2024-9-5*: Photo and electron micrographs of the studied thin sections of Li-bearing pegmatites:* ***a)*** *zoned tourmaline (Tur) associated with apatite (Ap), quartz (Qz) and muscovite (Ms). Fine grained spodumene (Spd) needles are observed surrounding feldspars, muscovite and quartz. Also visible is a columbite group mineral (CGM); plane polarized light;* ***b)*** *large spodumene (Spd) crystal (left) and vermicular intergrowth of spodumene and quartz (right); blue line highlights the difference between the two textures; plane polarized light;* ***c)*** *BSE image of a zoned muscovite, with lighter grey areas enriched in Rb and Cs;* ***d)*** *BSE image of a CGM in association with other oxides.*

source of hard-rock Li and are expected to continue to grow as an important source of this resource (U.S. Geological Survey, 2024). Manitoba plays an increasingly important role in the production of hard-rock Li because of the extraction and concentration of spodumene at the Tanco mine in the southeastern part of the province.

Based on mineral-chemistry indicators and element ratios, Anderson (1984) suggested that the most promising area for undiscovered mineralized pegmatites in the Cross Lake pegmatite field is on strike with, and east of, the spodumene pegmatite zone of the Southern series (Figure GS2024-9-2). The same author added that, if the aplite dikes on the north shore of Pipestone Lake are related to the Southern pegmatite series, more undiscovered pegmatites could exist between the known eastern limit of the spodumene-bearing pegmatites and Pipestone Lake. Given the possible easterly fractionation trend of the Southern pegmatite series, any additional pegmatites in the proposed target area would potentially be highly differentiated. However, this mineralization potential was not drill-tested. To the best of the current authors' knowledge, there are no surface exposures of pegmatites of the Southern series east of the current known extent.

Future work focusing on the lithium-bearing pegmatites includes detailed mineral characterization of mica and CGM, and multimineral geochronology studies. A better understanding and characterization of Li-bearing pegmatites in the Archean Superior Province further enhances Manitoba's potential as a Li producer.

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