GS2023-2

Preliminary results from field investigations in the Bird River domain of the Archean Superior province, Manitoba (parts of NTS 52L5, 6, 11, 12)

by T. Martins, M.L. Rinne, C. Breasley[1] and H. Adediran

In Brief:

- The Bird River domain is an area with well-established potential for critical minerals
- Structural and emplacement controls of rare-metal–bearing pegmatites at the regional level were noted
- Results from the Mineral Deposits Database compilation show spatial distributions that reflect geological controls on mineralization

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Summary

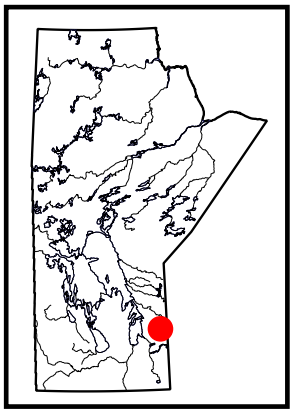
In 2023, the Manitoba Geological Survey began work on a new compilation and mapping project in the Bird River domain, an area with well-established potential for critical minerals including lithium, cesium, platinum, nickel and chromium. Bedrock geology fieldwork in 2023 was carried out to investigate a number of known rare-element–bearing pegmatites throughout the Cat Lake–Winnipeg River pegmatite field, and also to verify and document various mineral occurrences uncovered during compilation work. Preliminary structural observations indicate that an episode of late lithium mineralization was partly controlled by northeast- or north-northeast-striking sinistral shears. An update on mineral-occurrence data in the Bird River domain is also provided.

Introduction

The Manitoba Geological Survey (MGS) initiated a multidisciplinary geoscientific mapping and compilation project focusing on the Bird River domain of the Superior province of Manitoba, with the Bird River greenstone belt and the Cat Creek–Euclid Lake areas being the focus of the 2023 field season. This report highlights the preliminary results from bedrock mapping. For surficial study results, the reader is referred to Hodder and Martins (2023).

The study area has seen almost 20 years of bedrock mapping activity by the MGS. Projects led by P. Gilbert (e.g., Gilbert, 2006; Gilbert et al., 2008) focused on the southern side of the Bird River domain. Most recently, work by X.M. Yang was focused on the Cat Creek–Euclid Lake area (e.g., Yang et al., 2013; Yang and Houlé, 2020), which is part of the northern side of the Bird River domain. The bedrock-mapping results from these projects were incorporated in the 1:250 000 scale (Manitoba Geological Survey, 2022b) and 1:1 000 000 scale compilation (Manitoba Geological Survey, 2022a) maps, but were not integrated at a smaller regional scale into a seamless geological map.

The Bird River area is also the focus of much interest and exploration activity, particularly related to rare-element–bearing pegmatite bodies and mafic to ultramafic intrusive rocks containing base metals, Cr, Co and platinum-group elements (PGE). Many of these elements are viewed as critical for the economy (Government of Canada, 2021; Government of Manitoba, 2023), so the MGS identified this project as a priority. Given the enormous exploration potential and long history of the region (ongoing for more than 120 years; cf. Tyrrell, 1900), a compilation of mineral occurrences from assessment files and MGS data is also ongoing. The final aim of this bedrock geoscience project is to create a digital ArcGIS product that encompasses all publicly available geological information for the region, together with a compilation release of all the mineral occurrences in the area. The bulk of bedrock geology fieldwork for 2023 was focused around selected pegmatites outcropping in the Bird River greenstone belt area and in the Cat Lake area.



Geological setting

This project focuses on the vast area of the Bird River domain of the Superior province (Figure GS2023-2-1). The Bird River domain is flanked to the north by the English River domain (bounded by the Cat Lake–Euclid Lake fault) and by the Winnipeg River domain to the south (bounded by the Winnipeg River fault). In this report, the domain nomenclature of the Superior province is used as per the domain map in Manitoba Geological Survey (2022a).

An integral part of the Bird River domain is the Bird River greenstone belt (BRGB; Figure GS2023-2-2), an east-trending supracrustal belt that extends for 150 km from Lac du Bonnet in the west to Separation Lake (Ontario) in the east. The BRGB comprises a northern part (Cat Creek–Euclid Lake

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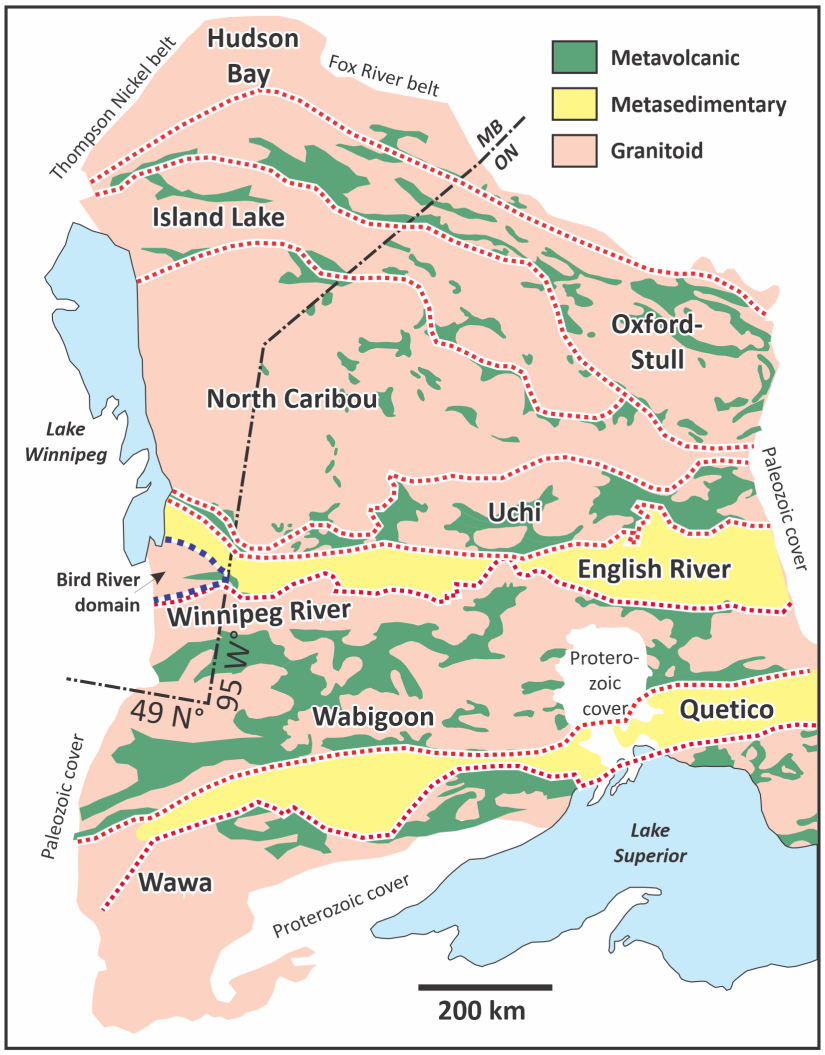


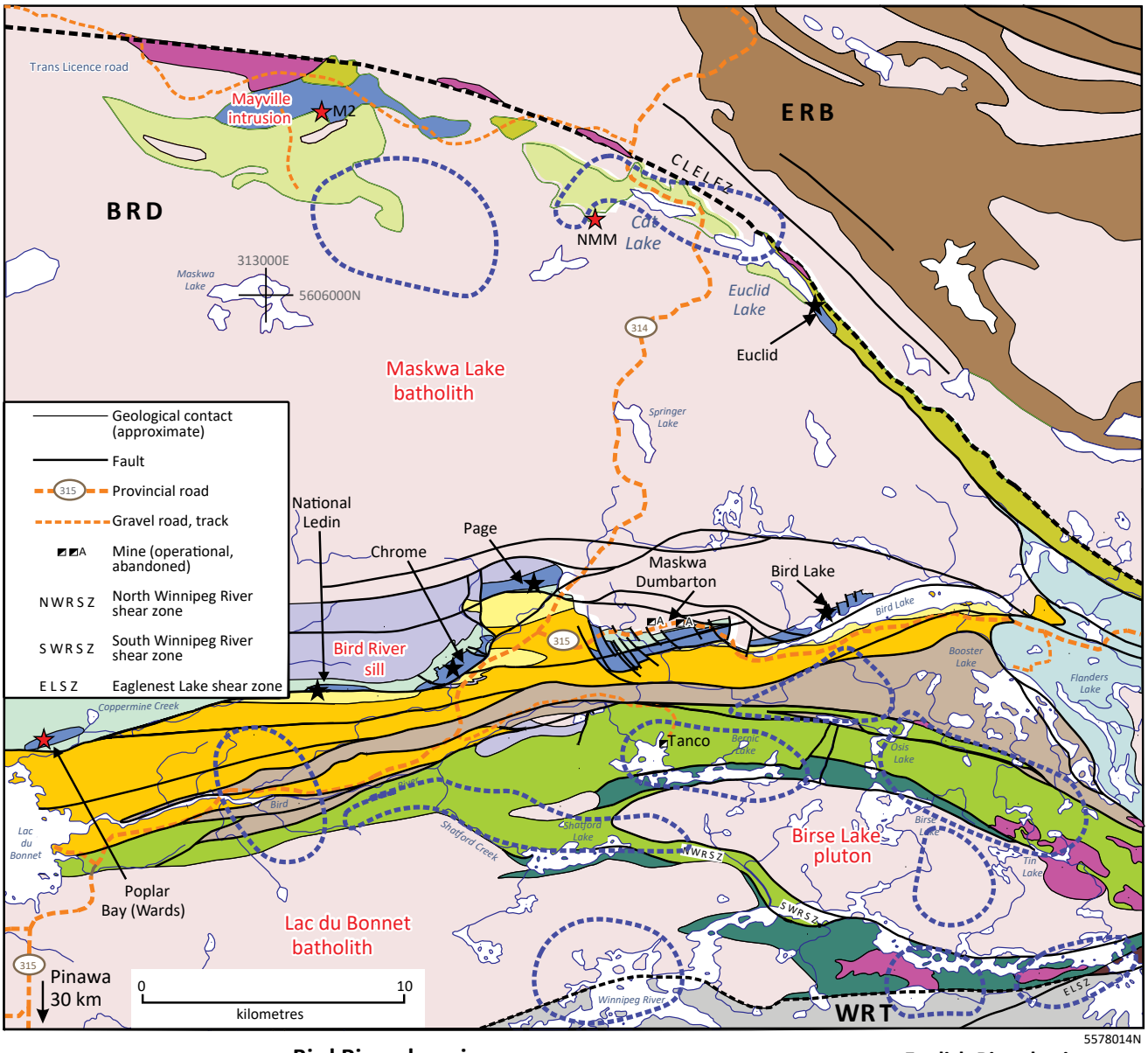
***Figure GS2023-2-1**: Simplified geology of the northwestern Superior province, showing the location of the Bird River domain in Manitoba (blue dashed line). Terrain nomenclature after Percival et al. (2006) and Stott et al. (2010). Bird River domain after Manitoba Geological Survey (2022a). Abbreviations: MB, Manitoba; ON, Ontario.*

area; Yang and Houlé, 2020) and a southern part. The southern part has been subdivided into two geochemically distinct sequences (northern and southern panels), both of which are composed of ca. 2.75–2.72 Ga juvenile, arc-type metavolcanic and associated metasedimentary rocks. These two panels are separated by the Booster Lake formation (<2712 ±17 Ma; Gilbert, 2006), a turbiditic sequence with classic Bouma-type features that is penecontemporaneous with clastic sedimentary rocks of the fluvial-alluvial deposits of the Flanders Lake formation immediately to the east (Gilbert, 2006; Figure GS2023-2-2). The BRGB was historically described as a large synclinal keel (Trueman, 1980; Černý et al., 1981); however, mapping by the MGS has led to a reinterpretation of the volcanostratigraphic framework of this belt (e.g., Gilbert, 2006; Gilbert et al., 2008). For a detailed geological description of the southern part of the BRGB, the reader is referred to work by Gilbert and co-authors (e.g., Gilbert, 2006; Gilbert et al., 2008).

To the north of the southern part of the BRGB, the Bird River domain consists of a granitoid terrane (Maskwa Lake batholith) that contains intrusive phases ranging from 2.85 to 2.73 Ga (Gilbert et al., 2008) and contains the Cat Creek–Euclid Lake area (Figure GS2023-2-2). This northern part of the Bird River domain was interpreted as part of the northern limb of the BRGB by Yang and Houlé (2020). They described the Cat Creek–Euclid Lake area as underlain by a suite of greenstone assemblages formed in a continental-margin setting adjacent to the Mesoarchean Maskwa Lake batholith. The greenstone assemblages consist mainly of mafic–felsic volcanic and related intrusive rocks, and epiclastic and minor volcaniclastic rocks; and mafic–ultramafic layered intrusions. These were intruded by younger phases of tonalite-trondhjemite rocks from a granodiorite suite (i.e., Maskwa Lake batholith II of Yang and Houlé, 2020), late peraluminous granitoid rocks and pegmatites.

Updated mineral occurrence data in the Bird River domain

The Bird River domain is host to a wide range of mineralization styles and critical mineral occurrences, including previously



Bird River domain

Intrusive rocks

- S-type granite
- Granite, granodiorite, tonalite
- Gabbro, diorite, quartz diorite
- Pyroxenite, anorthosite, gabbro

Late sedimentary rocks

Flanders Lake formation

- Arenite, polymictic conglomerate

Booster Lake formation

- Greywacke, siltstone

Volcanic and sedimentary rocks

Bird River belt South Panel

Bernic Lake formation

- Heterolithic volcanic breccia, rhyolite, basalt, andesite

Eaglenest Lake formation

- Greywacke, siltstone

Southern MORB-type formation

- Basalt, aphyric; gabbro

Bird River belt North Panel

- Massive to fragmental, mafic to felsic volcanic and sedimentary rocks

Peterson Creek formation

- Massive to fragmental felsic volcanic rocks

Northern MORB-type formation

- Basalt, aphyric; gabbro

Cat Lake area

- Sedimentary and volcanic rocks, related gneiss
- Tholeiitic basalt

English River basin

- Paragneiss, granitoid intrusive rocks, migmatite, pegmatite

Winnipeg River terrane

- Tonalite, granodiorite, granitoid gneiss

- Ni-Cu-PGE deposit/occurrence
- Cr-PGE deposit/occurrence
- Domain or terrane boundary

***Figure GS2023-2-2**: Tectonic assemblages of the Bird River domain, southeastern Manitoba (modified from Gilbert et al., 2008, 2013; Yang et al., 2013). Abbreviations: BRD, Bird River domain; CLELFZ, Cat Lake–Euclid Lake fault zone (indicated by the bold dashed line); ERB, English River basin; M2, Mayville deposit; MORB, mid-ocean–ridge basalt; NMM, New Manitoba mine; WRT, Winnipeg River terrane. Blue dashed lines represent location of the pegmatite groups from the Cat Lake–Winnipeg River pegmatite field (after Černý et al., 1981).*

mined deposits hosted by ultramafic intrusions (e.g., Maskwa, Dumbarton), as well as the currently-producing Tanco mine. As part of this project, recent updates to Manitoba's Mineral Deposits Database (MDD), described by Rinne (2023), were partly targeted to include the Bird River domain. The resulting compilation of new mineral-occurrence data shows spatial distributions that reflect geological controls on mineralization (Figure GS2023-2-3).

The new mineral-occurrence data reveal potentially important features that saw little or no reference in past studies or compilations of the area. Highlights include the following:

- The Little Bear Lake gold occurrences, located in the centre of the Maskwa Lake batholith, trace a belt of gold mineralization approximately 6 km long, with some reported assays of around 300 ppm Au (e.g., Assessment Files 73960, 52L1182, Manitoba Economic Development, Investment,

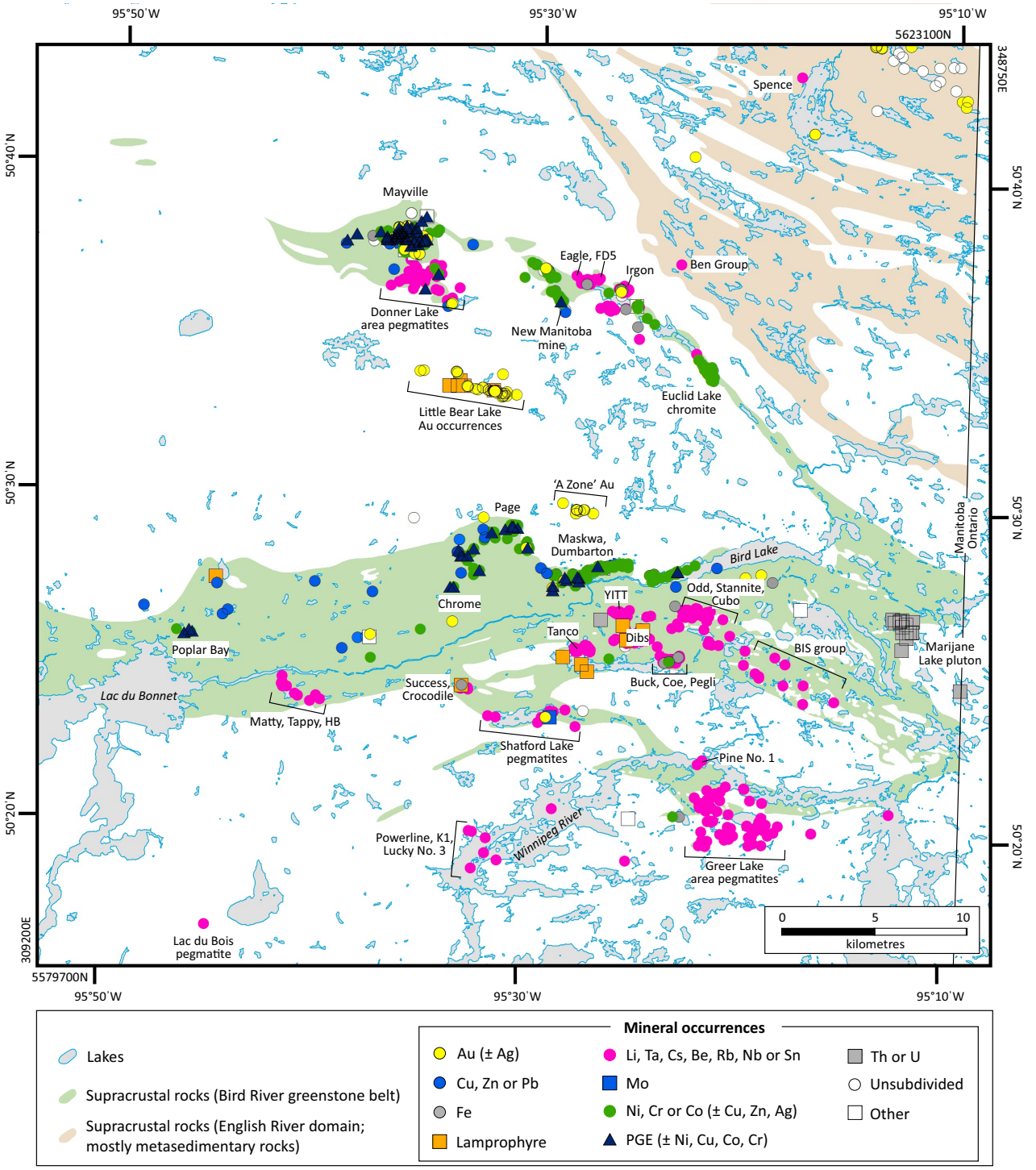


Figure GS2023-2-3: *Simplified map of mineral occurrences in the Bird River area, part of a recent update to the Manitoba Mineral Deposits Database. For clarity, the background geology has been simplified to show only supracrustal-dominant and mafic-intrusive units (i.e., approximate greenstone belt outlines). Corner co-ordinates are in UTM Zone 15 (NAD83).*

Trade and Natural Resources, Winnipeg). An apparently smaller zone of gold mineralization—the "A zone" occurrence—also occurs along a similar eastward trend and could represent an offset of the Little Bear Lake gold trend (Figure GS2023-2-3).

- More comprehensive geochemical data reveal a wider footprint of enrichment in PGE, Ni and other elements around known deposits hosted by mafic to ultramafic intrusions such as Chrome, Maskwa and Mayville.
- Drillcore intersections of lamprophyre dikes were reported by several industry workers in the vicinity of both the Tanco deposit and the Little Bear Lake gold occurrences. Near Little Bear Lake, gold mineralization is reportedly focused along sheared lamprophyre-dike contacts exposed in outcrop (Assessment File 74096). As none of these lamprophyre findings have yet been independently confirmed, they may require further investigation.
- Compiled data show a slightly more widespread distribution of rare-element–bearing pegmatite intrusions than indicated in previous compilations, including two sets of dikes in the English River domain (Figure GS2023-2-3). The Spence pegmatites are weakly uranium-mineralized dikes, perhaps related to later mineralization in the Marijane Lake pluton to the southeast. The Ben Group pegmatites were reported to contain spodumene in several drillcore intersections near or at surface (Assessment File 91309). Such findings would be significant, as they would prove that lithium-bearing pegmatite mineralization extends into the English River domain. An attempt by the MGS geologists to find spodumene reported for the Ben Group dikes in 2023 proved unsuccessful.

Structural observations

Rocks of the Bird River domain were subjected to a complex structural history that has been summarized by several workers, including Duguet et al. (2005), Gilbert et al. (2008), Kremer and Lin (2006) and Kremer (2010). Although regional structural trends vary by location, most workers describe a general sequence of events involving:

1) an early (D_1) episode of north-side-up ductile deformation, resulting in a strong pervasive planar fabric evident in supracrustal outcrops both north and south of the Maskwa Lake batholith;
2) a later (D_2) episode of strike-slip deformation, characterized mostly by northeast-trending sinistral (and south-side-up) shears, and southeast-trending dextral shears; and
3) a possible later (D_2 or D_3?) episode of transpressive deformation, expressed mostly by dextral shears. In the southern part of the BRGB, the later strike-slip events are proposed to have been coeval with the emplacement of at least some pegmatite intrusions at ca. 2640 Ma (Duguet et al., 2005; Gilbert et al., 2008).

Fieldwork in 2023 was undertaken partly to investigate structural controls on pegmatite-dike emplacement and related rare-element mineralization. Preliminary field structural observations throughout the study area revealed features broadly consistent with the early (D_1) foliation and later (D_2 and possibly D_3) strike-slip shears, including a set of dominantly northeast- or north-northeast-trending sinistral shears that are, in places, expressed as a late sinistral spaced cleavage. At the outcrops of the Eagle pegmatite and other pegmatites in the Cat Creek area, rare examples of late lithium mineralization were found to be associated with these late (D_2 or D_3) sinistral brittle-ductile shears (Figure GS2023-2-4). These preliminary findings indicate that late transpressional structures in the Bird River domain were involved in some episode of late lithium remobilization, or possibly later mineralized-pegmatite emplacement.

Detailed pegmatite descriptions

All pegmatite dikes visited during fieldwork were described as belonging to the Cat Lake–Winnipeg River pegmatite field as defined by Černý et al. (1981). This vast pegmatite field has been subdivided into two pegmatite districts (the Cat Lake–Maskwa Lake district and the Winnipeg River district), and subsequently into several different pegmatite groups according to their mineralogy, geochemistry and location (Černý et al., 1981). Martins et al. (2013) presented a summary table of the main characteristics of the different groups of pegmatites within this pegmatite field. The pegmatite outcrops visited and described below were selected by taking into account location, exploration interest and accessibility.

High Grade dike

The High Grade dike is located in the Donner Lake area (part of the Cat Lake–Maskwa Lake district; Figure GS2023-2-3) and was described by both Černý et al., (1981) and Bannatyne (1985). The best exposure visited consists of a 1.5 m wide pegmatite dike intruding pillowed basalt. The dike is oriented roughly north-south and extends for more than 10 m, crosscutting the main foliation in the basalt. Contacts are variable and sharp with the hangingwall (Figure GS2023-2-5a) and irregular and bulbous with the footwall. Black tourmaline occurs in sprays along the dike margin (tourmaline basal sections measure about 0.5 cm with lengths of 1.5 cm). The pegmatite is zoned and is subdivided into a border zone, lepidolite fringe, central zone and core.

The border zone is about 5–7 cm thick (Figure GS2023-2-5a) on both the hangingwall and footwall of the pegmatite dike but better developed on the hangingwall. Main mineralogy is feldspar, quartz, muscovite, cleavelandite (a form of albite) and local apatite. Cleavelandite blades or sprays grew perpendicular to the country rock and can be >7 cm long. The cleavelandite locally extends into the next zone, the lepidolite fringe. The lepidolite fringe is an irregular and discontinuous, 1–3 cm thick lepidolite layer that occurs along the border zone at the hangingwall but

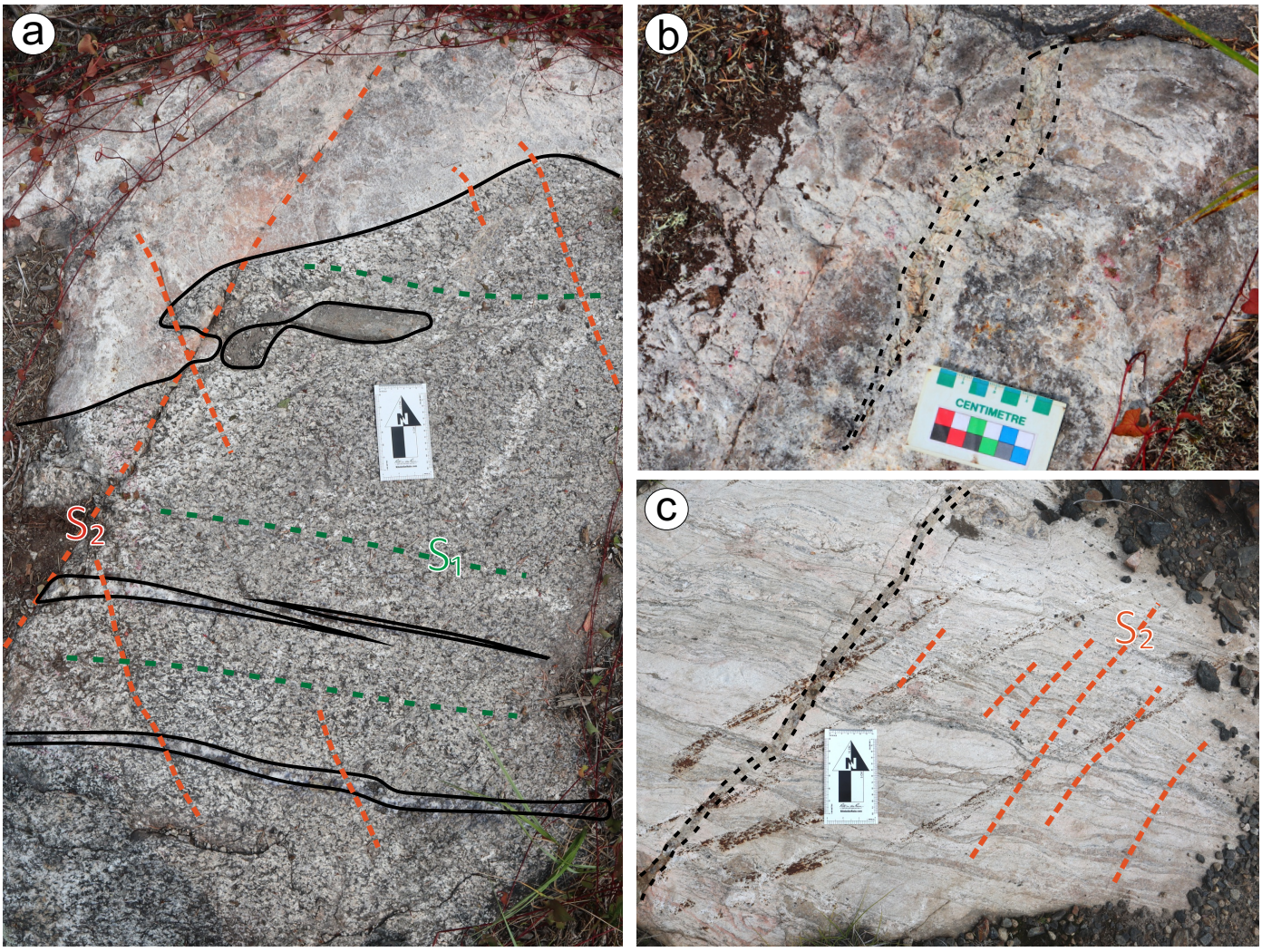


Figure GS2023-2-4: *Outcrop photographs of structural features related to lithium-bearing pegmatites in the northern part of the Bird River greenstone belt, showing:* ***a)*** *Eagle pegmatite (top of image, outlined in black) within a granite overprinted by an early east-striking foliation (S_1) and quartz-holmquistite veins (outlined, bottom of image), with late brittle-ductile shears (labeled S_2) that crosscut both the pegmatite and the quartz veins;* ***b)*** *Eagle pegmatite crosscut by a vein of green spodumene (outlined, centre of image) parallel to north-northeast-striking S_2 shears, located approximately 2 m from the location of panel A;* ***c)*** *late spodumene vein (outlined at centre left) parallel to north-northeast-striking S_2 shears and spaced sinistral cleavage in the pegmatite from the Cat Creek area.*

is not observed at the footwall. This zone is composed mainly of lepidolite, quartz and feldspar.

The central zone is the largest subdivision and makes up almost the entire width of the dike. It contains both aplitic and pegmatitic portions with complex textures and mineralogy, indicating that this is the most fractionated portion of the pegmatite. The aplitic portion is generally very fine grained (almost sugary), white and purple. It consists mainly of lepidolite and albite, with local, medium- to coarse-grained aquamarine. This aplitic portion can be found throughout most of the central zone, except for areas dominated by pegmatitic textures. The pegmatitic section is composed of quartz, albite, spodumene, light pink tourmaline (as locally developed sprays; Figure GS2023-2-5b), various phosphate phases and petalite. Part of this central zone is intensely albitized and probably caused by a later metasomatic event (Figure GS2023-2-5c). This area is chalk white with veins or 'diatreme' of a grey/green-coloured mineral referred to as greenish pollucite alteration, a mixed-layer silicate (Bannatyne, 1985). Petalite in this zone is rimmed by a combination of clay minerals (montmorillonite), tourmaline and phosphate minerals. Local wisps and veinlets of lepidolite, oriented 225°/20°, were also observed in both pegmatitic and aplitic phases. An 8 cm x 25 cm piece of country rock was observed in the central zone.

The core zone developed immediately after the lepidolite fringe and is composed of quartz and massive, blocky feldspar (Figure GS2023-2-5d). Blue tourmaline and beryl (1 cm basal section, 2 cm length) occur locally within this zone.

Eagle, F.D. No. 5 and Tappy pegmatite dikes

The Eagle and F.D. No. 5 pegmatite dikes are located in the Cat Lake–Maskwa Lake district of the Cat Lake–Winnipeg River

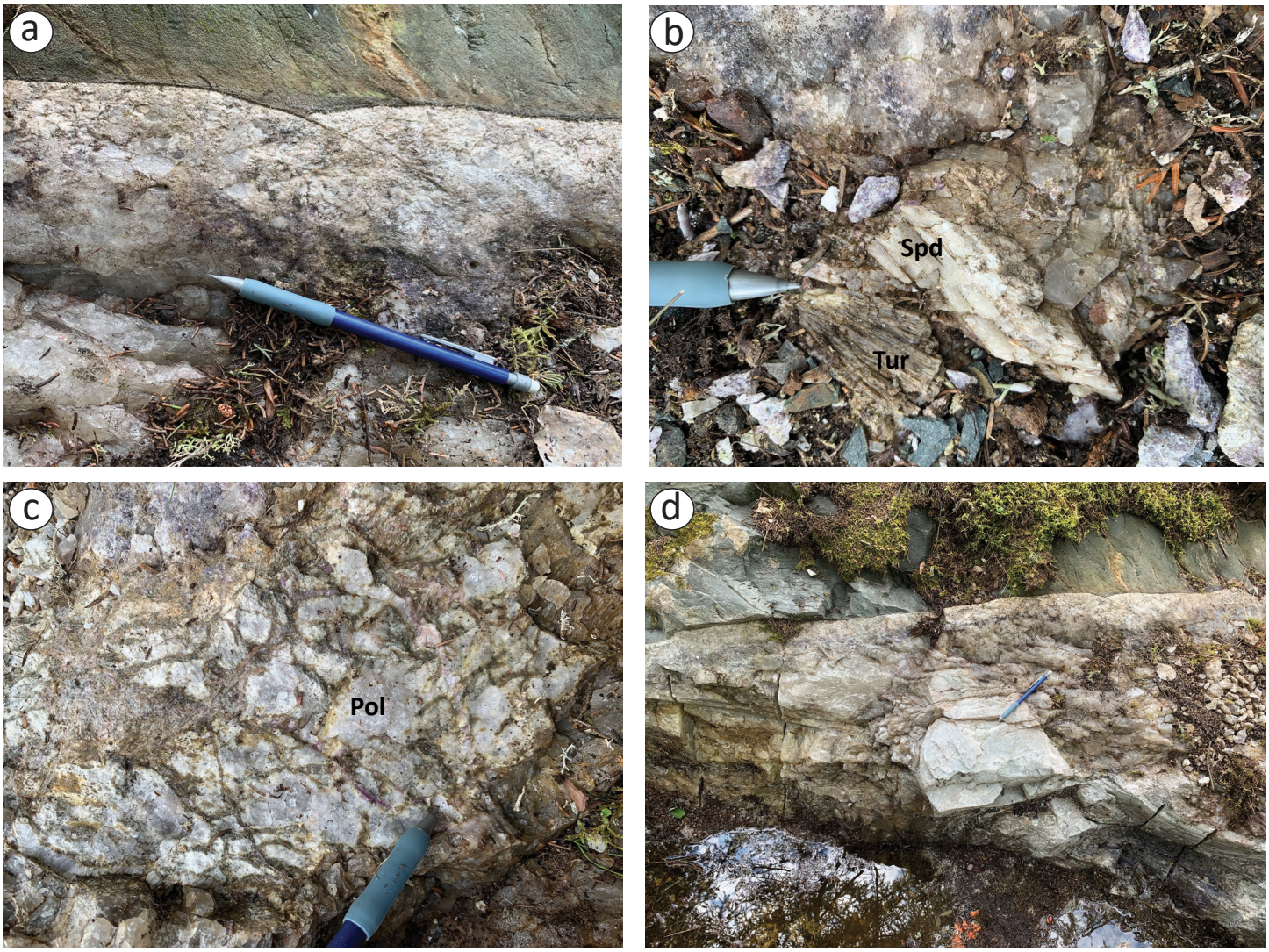


Figure GS2023-2-5*: Outcrop photos of the High Grade dike:* ***a)*** *sharp contact of pegmatite dike with basalt country rock;* ***b)*** *detail of light grey-pink tourmaline (Tur) sprays and spodumene (Spd);* ***c)*** *albitized portion of the central zone with remnants of glassy pollucite (Pol);* ***d)*** *detail of the white blocky feldspar and quartz of the core zone.*

pegmatite field, whereas the Tappy pegmatite is located in the Winnipeg River district (Figure GS2023-2-3). An M.Sc. project was initiated this year at the University of New Brunswick in collaboration with the MGS to map and document these three pegmatite dikes in detail. Refer to Roush et al. (2023) for descriptions of the pegmatite bodies.

YITT-B pegmatite swarm

The YITT-B pegmatite swarm, located northwest of the Tanco mine (Figure GS2023-2-3), was discovered in the late 1980s as a result of regional exploration efforts by the Tantalum Mining Corporation of Canada Ltd. (Assessment File 72418). This exploration work was followed by the research of Anderson (1992) and Anderson et al. (1998), which outlined several zones in the pegmatites, based on textural features and mineral associations: wall zone, intermediate zone (that is subdivided into 1, 2a and 2b subzones) and core zone. Their work also included a detailed mineralogical and paragenetic description of the Yitt-B pegmatite swarm, with descriptions of the following minerals (not listed in order of abundance): quartz, K-feldspar, albite, muscovite, beryl, tourmaline, garnet, columbite-group minerals, cassiterite, phosphates (beusite, triplite, alluaudite, triphylite, phosphophyllite, parascholzite and different varieties of apatite), and sulphides (arsenopyrite löllingite and bismuthinite). Anderson et al. (1998) interpreted the YITT-B pegmatite dikes to be geochemically unique from other pegmatite bodies in the southern part of the Cat Lake–Winnipeg River pegmatite field. The YITT-B pegmatite dikes are enriched in Ta, Nb and Sn, but are very poor in Li, Be, B, P, S and F. The fractionation level of Fe-Mn is considered moderate, whereas the Nb-Ta is evolved. The same authors interpreted the broad geochemical diversity of this pegmatite field to be related to different sources. Specifically, the fertile leucogranites that were parental to the individual pegmatite groups required anatectic melts derived from different lithological sources.

Two outcrops were examined that contained YITT-B pegmatite dikes intruding into cordierite-bearing turbiditic sandstone-mudstone of the Booster Lake formation. In both outcrops the predominant mineral phases are very coarse-grained quartz, K-feldspar, albite and muscovite. In one of the outcrops, an accumulation of quartz about 20 cm thick could be described as a quartz core. In one outcrop, a localized zone of quartz and muscovite intergrowth was interpreted as a greisen. In both outcrops, a very fine grained aplitic unit (saccharoidal texture) of greyish-bluish colour was observed. Albite, quartz, columbite-group minerals, sulphides (possibly arsenopyrite, löllingite and bismuthinite measuring up to 0.5 cm in width) and phosphate phases (predominantly blue apatite) were identified in hand sample.

Coe and Buck claims, pegmatites 7, 8 and 9

The Coe and Buck claims are located at the eastern end of Bernic Lake (Figure GS2023-2-3; Bannatyne, 1985; Lenton, 1979) and consist of a series of pegmatite dikes, of which pegmatites 7, 8 and 9 were mapped in detail. Six major zones were described for pegmatites 7, 8 and 9: 1) a simple pegmatite with chilled margin; 2) a wall zone that consists of quartz, mica and tourmaline in a comb structure; 3) an aplitic zone that hosts a sugary texture of fine-grained feldspar, tourmaline and apatite; 4) intermediate zone 1, a quartz-dominated unit that hosts abundant beryl and phosphate mineralization; 5) intermediate zone 2, a lithium-enriched zone that hosts large 15 cm laths of petalite, which is partially broken down into spodumene and quartz, the spodumene, in turn, being locally broken down into a clay product; and 6) intermediate zone 3, a feldspar-dominated zone containing metre-scale feldspar crystals that are crosscut by veins of albitization. Intermediate zone 3 also contains phosphate-rich bands containing purpurite and apatite.

Pegmatite 7 is a lithium-rich pegmatite dike that intruded foliated pillow basalt (main elongation of pillows is in a northeasterly direction). The intrusion displays bulbous contacts in the western and eastern parts, and brittle contacts in the northern and southern parts. The wall zone hosts quartz, mica and tourmaline parallel to the bulbous country rock contact. Intermediate zone 1 forms the bulk of the intrusion, containing abundant quartz and phosphates such as amblygonite. Intermediate zone 2 is present as a petalite and spodumene mass in the southern part of the intrusion. A separate intrusion, located proximal to pegmatite 7, hosts a granodioritic assemblage and texture (consisting of equigranular orthoclase, quartz and albite).

Pegmatite 8 is exposed along two main outcrops. It has undulatory bulbous contacts with the foliated pillowed basalt and is oriented approximately 098° with a subvertical dip (Figure GS2023-2-6). This pegmatite hosts multiple fragmented xenoliths of basaltic country rock. The xenoliths are surrounded by the wall zone, which is composed of comb-textured mica and quartz in a pink-feldspar groundmass. A distinct band of purpurite and a single crystal of spodumene were identified within intermediate zone 1 (massive quartz zone with abundant amblygonite and beryl). Green mica is common in this pegmatite as accreted clots that appear to be metasomatic in origin (potential late-stage accumulation of hydrous fluid). Cleavelandite is commonly found surrounding the green mica. The northeastern contact of the intrusion is a mix of small-scale fragments of country rock (averaging 2–30 cm).

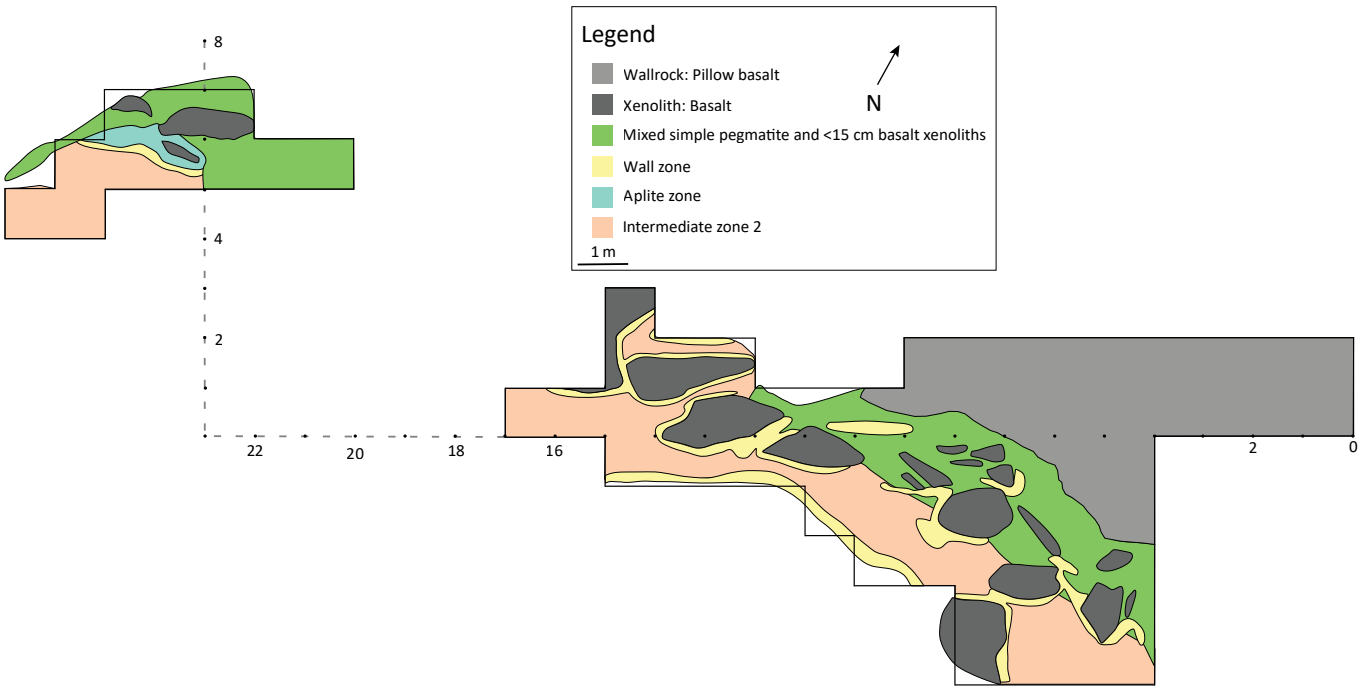


Figure GS2023-2-6*: Sketch of pegmatite 8, part of the Buck group on the eastern shore of Bernic Lake.*

Pegmatite 9 intruded pillowed basalt, which contains abundant holmquistite close to the pegmatite contact. This pegmatite contains a zone of massive metre-scale primary pink orthoclase, termed intermediate zone 3, that was not identified in pegmatites 7 and 8. Intermediate zone 3 also contains clots of green mica and bands enriched in phosphates (70% modal abundances of purpurite and apatite along with an unidentified brown-weathered phosphate phase). Wall-zone rocks are present along the northeastern bulbous contacts of the pegmatite. The wall zone consists of comb-structured mica, quartz and a significant amount of black tourmaline. Intermediate zone 3 (feldspar zone) appears to gradationally change into intermediate zone 1 (quartz zone), which is exposed beneath the cliff outcrop beside the swamp. An offset dike to the west hosts a classic pegmatite zonation of the wall zone transitioning into the aplite zone.

Economic considerations

The Bird River domain of the Archean Superior province in Manitoba is prospective for base metals (nickel, copper, chromium), precious metals (platinum-group elements, gold) and rare elements (e.g., lithium, cesium, tantalum, niobium). A significant number of these elements are now considered critical for Manitoba (Government of Manitoba, 2023) and for Canada (Government of Canada, 2021). Rare-element–bearing pegmatites in particular, such as those of the Cat Lake–Winnipeg River pegmatite field, are becoming increasingly important in the context of a transition to a lower-carbon economy.

Preliminary findings of late, structurally-controlled lithium mineralization in the Cat Lake area imply there may be common structural controls between lode gold and pegmatite dike emplacement in the area. In practical terms, this suggests that some exploration techniques applied to lode gold could be applied to lithium exploration in parts of the Bird River domain. Such techniques could include the detection of controlling structures through mapping and remote-sensing methods (e.g., displacements traced via topographic lineaments, particularly in high-resolution LiDAR data, jogs in landforms or stream trends), followed by targeting of splays, major deflections, zones of likely dilation along regional and secondary shear structures, or targeting of areas where major structures interact with rheological contrasts such as batholith margins.

Manitoba's critical minerals strategy (Government of Manitoba, 2023) highlights the need to provide high-quality geoscience information in support of new critical minerals discoveries. The remarkable extent and variety of critical-mineral occurrences in the Bird River area continues to warrant further data compilation and field investigations in support of this mandate.

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