GS2024-12

Research activities at the Lalor mine, Snow Lake, west-central Manitoba (part of NTS 63K16)

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In Brief:

- New geological studies are underway on the Snow Lake volcanogenic massive ore deposits as part of a doctoral study
- Summer 2024 fieldwork goals were to establish spatial and lithogeochemical relationships between the Lalor and 1901 deposits
- Results of this work will be incorporated into a 3-D geological model

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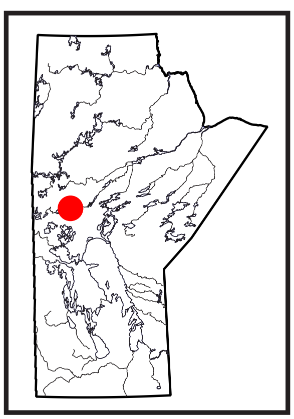

Summary

New geological studies on the volcanogenic massive sulphide orebodies of the Snow Lake area are underway as part of a doctoral study investigating the processes, geochemical signatures and resulting architecture of metal and sulphide remobilization in metamorphosed and deformed VMS deposits. This report summarizes the work done to date, with focus on fieldwork conducted in August 2024. The goals of the fieldwork included establishing the spatial relationships of the orebodies of the Lalor and 1901 deposits with hosting and neighbouring lithologies and deposit-scale faults, particularly the inferred Lalor-Chisel fault. Samples were collected for planned geochemical characterization of faults, detailed ore petrological work and geochronological uranium-lead dating. The results of this work will be incorporated into a 3-D geological model.

Introduction

The volcanogenic massive sulphide (VMS) deposits of the Snow Lake district in west-central Manitoba, owned and operated by Hudbay Minerals, have been the subject of many geological and economic studies (e.g., Bailes and Galley, 1999; Caté, 2016; Stewart, 2018). The wealth of base-metal deposits, active mining and mineral exploration, and complex geology with many open questions related to formation and postdepositional events continues to entice researchers pushing the envelope on our understanding of metamorphosed and deformed ancient VMS deposits. The Snow Lake arc assemblage (SLA) provides an ideal case study in understanding the geological controls on primary VMS mineralization and remobilization.

A doctoral study is being undertaken at the University of Toronto, in collaboration with Mount Royal University, the Manitoba Geological Survey and Hudbay Minerals Inc. This project is focused on understanding the processes, geochemical signatures and resulting architecture of metal and sulphide remobilization in metamorphosed and deformed VMS deposits. It seeks to determine the controls on grade and tonnage of mineralization, including primary mineralizing and upgrading processes and post-VMS deposit formation modifications related to metamorphism and deformation. The VMS deposits of the Snow Lake district are ideal case studies for exploring the proposed research questions. These orebodies are typical of ancient, modified VMS deposits, with excellent underground rock exposures and access to drillcore, and a substantial database replete with spatial data and geochemical results. This report summarizes the fieldwork completed in August of 2024, including drillcore stratigraphic logging and sampling, underground mapping and sampling, and surface sampling. Preliminary results are discussed, along with the next steps for this research project.

Geology of the Snow Lake arc assemblage

The Snow Lake arc assemblage (SLA) is part of the eastern Flin Flon belt in the Reindeer zone of the Trans-Hudson orogen in Manitoba (Figure GS2024-12-1). The SLA hosts eight known VMS deposits, interpreted to have formed from a single synvolcanic metalliferous hydrothermal system (Galley et al., 2007). The SLA is divided into the Chisel sequence, a series of mature arc-related volcanic rocks, and the Anderson sequence, which consists of primitive arc-related volcanics (Percival et al., 2004; Corrigan et al., 2009). This research project focuses mainly on the Chisel sequence and the VMS orebodies hosted within it. The Chisel sequence is divided into lower and upper sequences, and the VMS ore interval coincides with the transition between these units, marking a period of volcanic inactivity, subsidence, metal precipitation and ore accumulation (Bailes and Galley, 1996;

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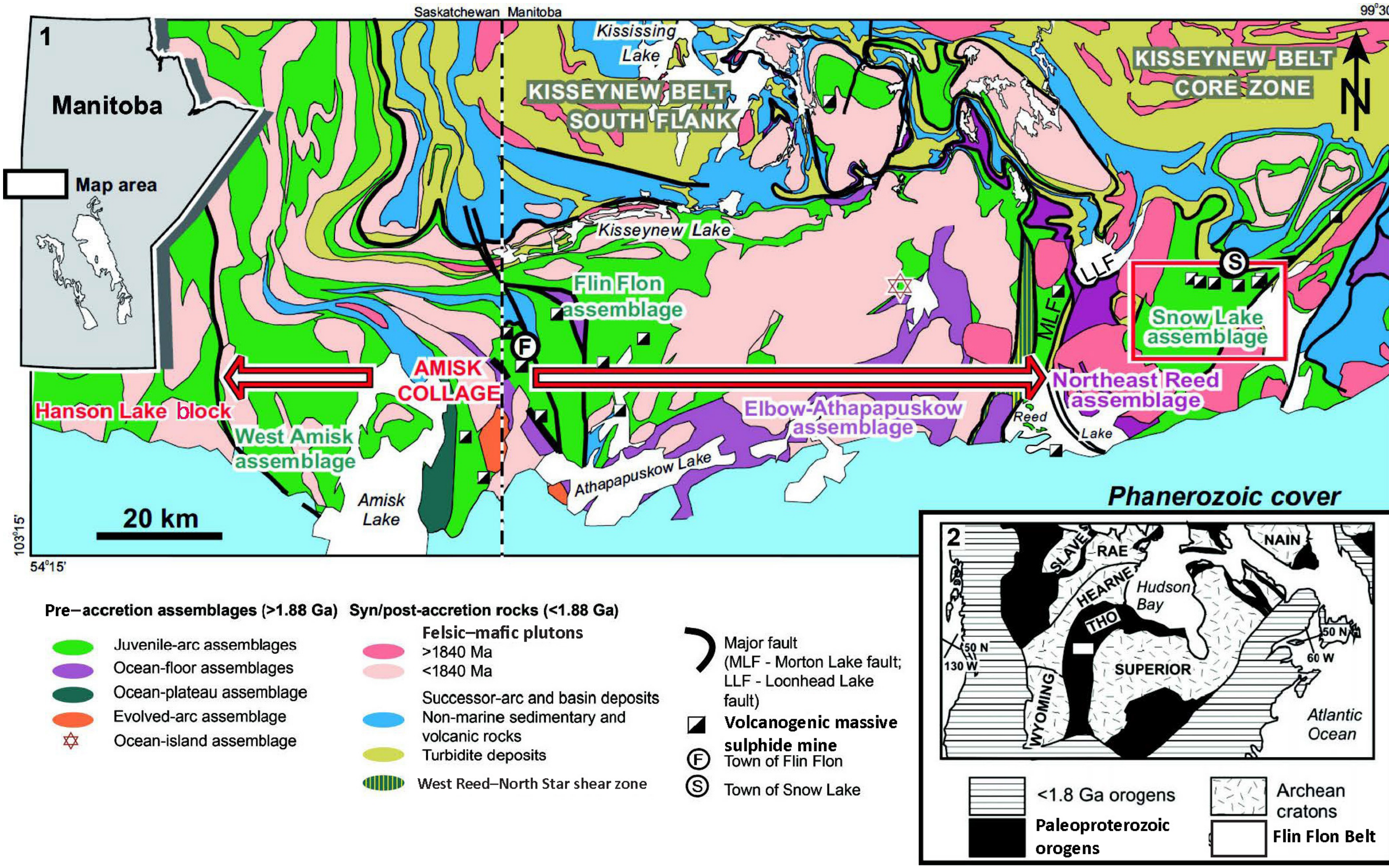

Figure GS2024-12-1: *Tectonostratigraphic assemblages of the Flin Flon Glennie complex, showing the Hanson Lake block in the west, the Amisk collage in the centre and the Snow Lake assemblage in the east. Inset map 1 indicates the map location within the province of Manitoba. Inset map 2 shows the location of the Flin Flon belt within the Trans-Hudson Orogen (modified by Stewart et al, 2018, after Syme et al., 1999).*

1999; Friesen et al, 2021). The rock assemblages and VMS mineralization formed via processes associated with volcanism and related hydrothermal activity as a pericratonic arc outboard of the Superior Craton ca. 1.92–1.88 Ga (David et al., 1996; Lucas et al., 1996; Corrigan et al., 2009). One of the goals of this study is to understand the depositional settings of the VMS ore lenses, comparing differences in the primary alteration, nature of remobilization and metal grades. This study focuses on the Lalor and 1901 deposits, as well as areas distal to these ore lenses at the same stratigraphic level.

Following VMS deposit formation, the SLA underwent four deformation events related to the closure of the Manikewan ocean and the Hudsonian orogen from 1.84 to 1.77 Ga (Kraus and Williams, 1998, 2001; Stewart et al., 2018). Phase equilibrium modelling indicates metamorphic conditions of 550–600°C and 4.5–5.5 kbar in the Snow Lake area (Lazzarotto et al., 2023), or peak almandine-amphibolite facies metamorphism, associated with the second deformation event ca. 1.81 Ga (Menard and Gordon, 1997). The spatial distribution of ore lenses in the SLA is interpreted to be primarily the result of isoclinal folding during transposition and thrust faulting that caused stacking of ore bodies (Caté et al., 2014; Caté, 2016; Stewart et al., 2018). Differentiating between primary and later faults related to accretion of VMS-hosting belts can reveal temporospatial relationships in ore-deposit formation, preservation and modification (Gibson et al., 1999; DeWolfe and Pittmann, 2018; Friesen et al., 2021). Characterizing faults in the SLA and the associations with ore lenses is a primary focus of this study.

2024 Fieldwork

Stratigraphic core logging and drillcore sampling

Preselected sections of five drillholes were stratigraphically logged and a total of 86 intervals were split, sampled and shipped to laboratories at the University of Toronto. The drillcore intersected several district-scale faults and shear zones, and targeted areas believed to intersect the inferred Lalor-Chisel fault (Figure GS2024-12-2). Characterizing this fault has remained elusive, despite numerous studies and its important spatial association to the VMS orebodies hosted in the SLA, which are generally in the footwall of the Lalor-Chisel fault. Orebodies of the 1901 deposit were also sampled, with the goal of comparing differences in metal content and mineral associations, and the nature of deformation (Figure GS2024-12-2a, b, c). The Lalor, 1901 and Chisel ore deposits appear similar in host rock, mineralization and alteration, although additional planned analyses will establish any similarities. Ore petrography of the samples collected from the 1901 deposit will be compared to previous studies on core from the Lalor deposit and from ore samples collected in this study from underground. Drillholes between the 1901 and Lalor deposit were also logged and sampled to aid in understanding the depositional setting distal to hydrothermal activity and the effects of metamorphism and deformation in regions with less alteration and sulphide content.

Underground mapping and sampling

A drift at the 950 level of the Lalor mine was mapped and sampled. This drift intersects several shear zones, metavolca-

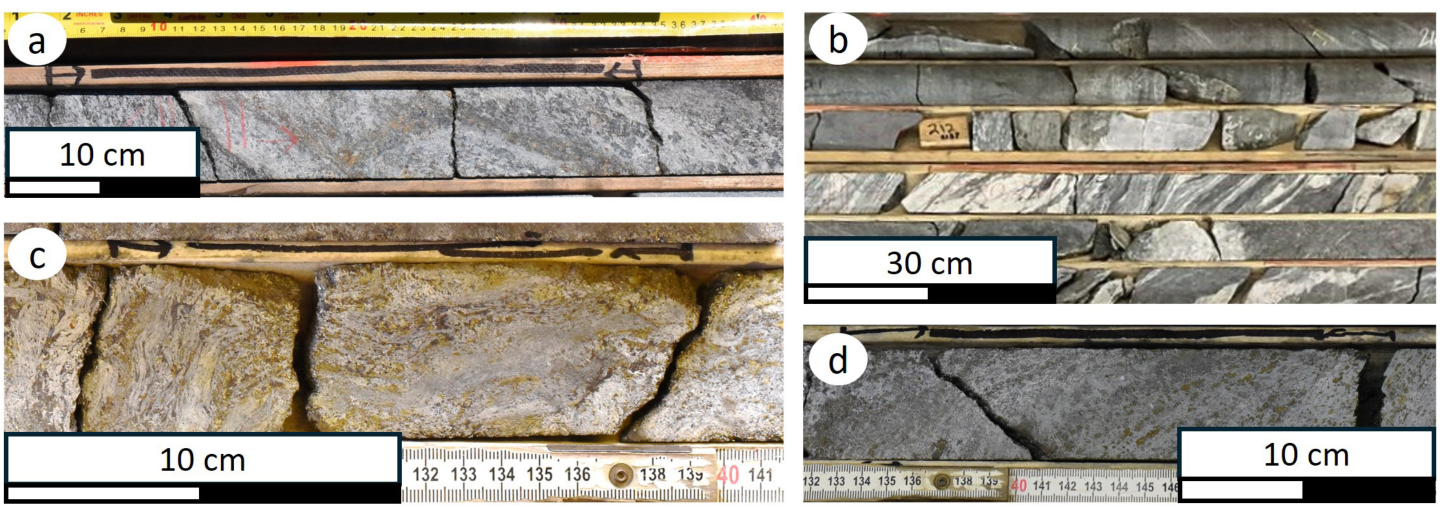

Figure GS2024-12-2: *Examples of the core that was relogged and sampled from Snow Lake, Manitoba; samples were collected and shipped to the University of Toronto for detailed description, petrographic work and additional analytical work:* ***a)*** *from drillhole NUX001, highly deformed sulphides plus gahnite that is likely part of the footwall to the 1901 deposit;* ***b)*** *from drillhole CH1925, shear zone distal to hydrothermal alteration, possibly the Lalor Chisel fault (to be confirmed with additional analyses and integration into the 3-D geological model);* ***c)*** *from drillhole CH1975, deformed and recrystallized sulphides in strongly altered and foliated rocks;* ***d)*** *examples of large grains of recrystallized pyrite and fine layers of deformed sulphides along foliation. Ore petrography on samples such as this, supplemented with electron backscatter diffraction (EBSD), is planned to investigate the timing and element distribution in remobilized sulphides.*

nic lithologies and five ore lenses. The foliation, contacts and shear zones are generally parallel and steeply (60–70 degrees) dipping toward the northeast. This drift runs approximately perpendicular to the strike of these features, allowing the spatial relationships and changes across section to be observed. In total, 19 samples were collected and their structural features recorded (examples shown in Figure GS2024-12-3). Sampling focused on testing variations in metal content through each of the lenses, and characterizing the hangingwall, footwall and deformed central parts of a large shear zone.

Sampling for U-Pb geochronology

Despite several attempts by previous researchers, a robust framework for the ages and duration of the ore-bearing volcanic sequences at Snow Lake has remained elusive, largely due to the low abundance of high-field-strength elements in the volcanic assemblages and the consequent lack of primary zircon (e.g., Stewart, 2018). To date, the only constraints available are from U-Pb zircon ages of two synvolcanic intrusions: Sneath Lake at 1886 +17/–9 Ma and the Richard Lake intrusive complex (RLIC) at 1889 +8/–9 Ma (Bailes et al., 1991). Xenocrystic zircons of the Stroud Lake felsic breccia, at the base of the Chisel sequence, have been dated at 1892 ±3 Ma (David et al., 1996). New surface samples from the RLIC were collected this year, with one targeting the same location as the published data of Bailes et al. (1991), and the other 1 km northeast. The collected RLIC samples are quartz-phyric tonalites (Figure GS2024-12-4). The Manitoba Geological Survey also collected samples for geochronological work during the summer of 2024. The first is a new surface sample of the Sneath Lake tonalite. The second consists of two intervals of core intersecting a relatively fresh gabbro intrusion, the Chisel pluton, thought to postdate volcanism but predate later deformation.

These samples have been sent to the University of Toronto's Jack Satterly Geochronology Laboratory. Under the guidance of Professor M. Hamilton, improved zircon-recovery techniques developed at the Satterly Lab since the last radiometric dating attempts at Snow Lake (methods that have proven highly successful in the Flin Flon district), and application of refined chemical-abrasion techniques in zircon dating for improved accuracy and precision, will be employed. The presence of other accessory phase chronometers (e.g., rutile, titanite, xenotime) will be assessed within selected assemblages to better constrain the thermal history of the district as it relates to the potential ore

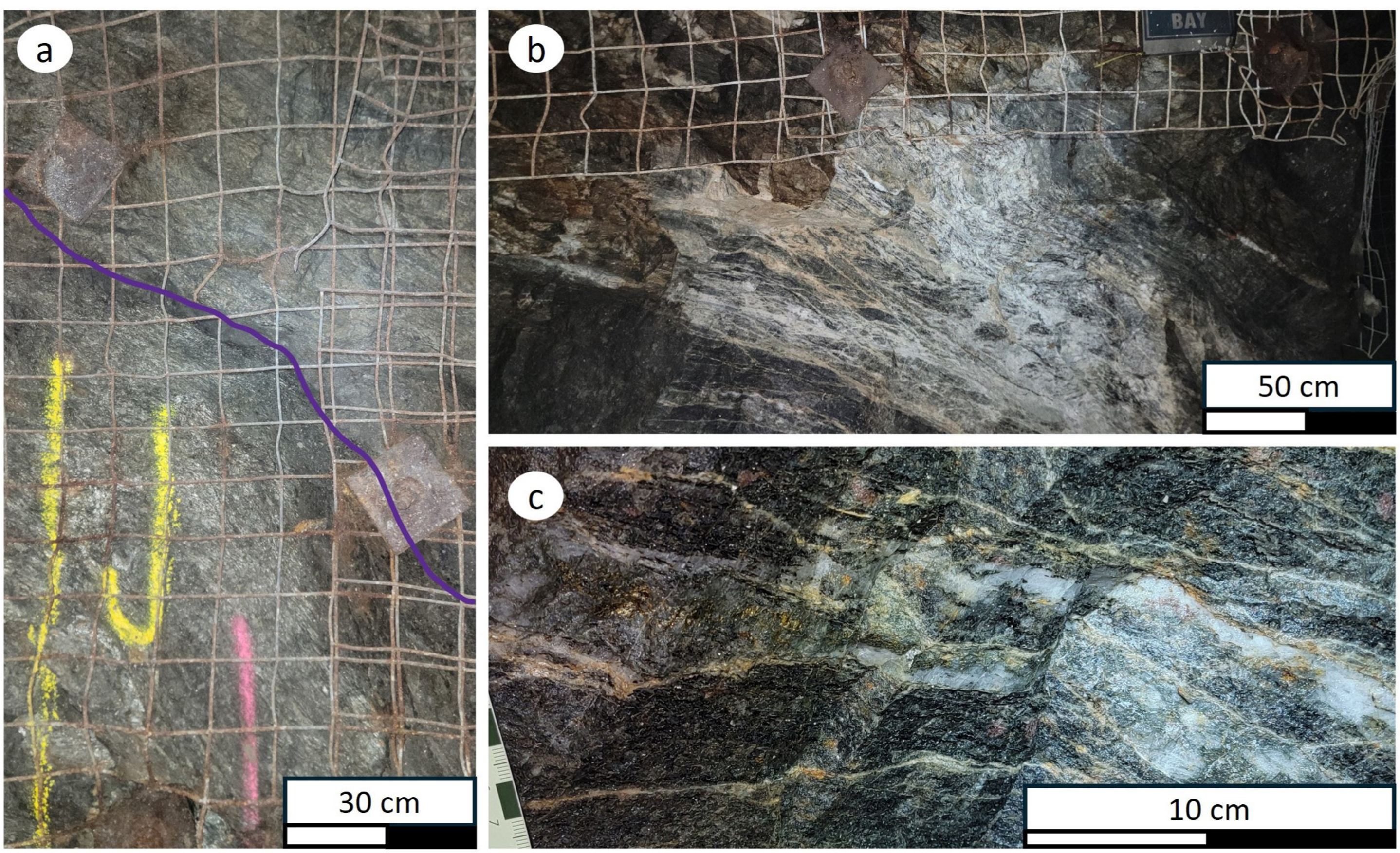

Figure GS2024-12-3: *Examples of the sample locations from a drift on the 950 level at the Lalor mine. Samples were collected and shipped to the University of Toronto for detailed description, petrographic work and additional analytical work:* ***a)*** *looking northwest, a sheared and undulating contact (purple line) between two ore lenses with significantly different metal grades;* ***b)*** *looking northwest, a wide (1–2 m) quartz-healed shear zone within one of the ore lenses; significant sulphide material occurs along the fractures, with evidence of recrystallization;* ***c)*** *close-up of the shear zone from image b, showing the sulphide-filled fractures.*

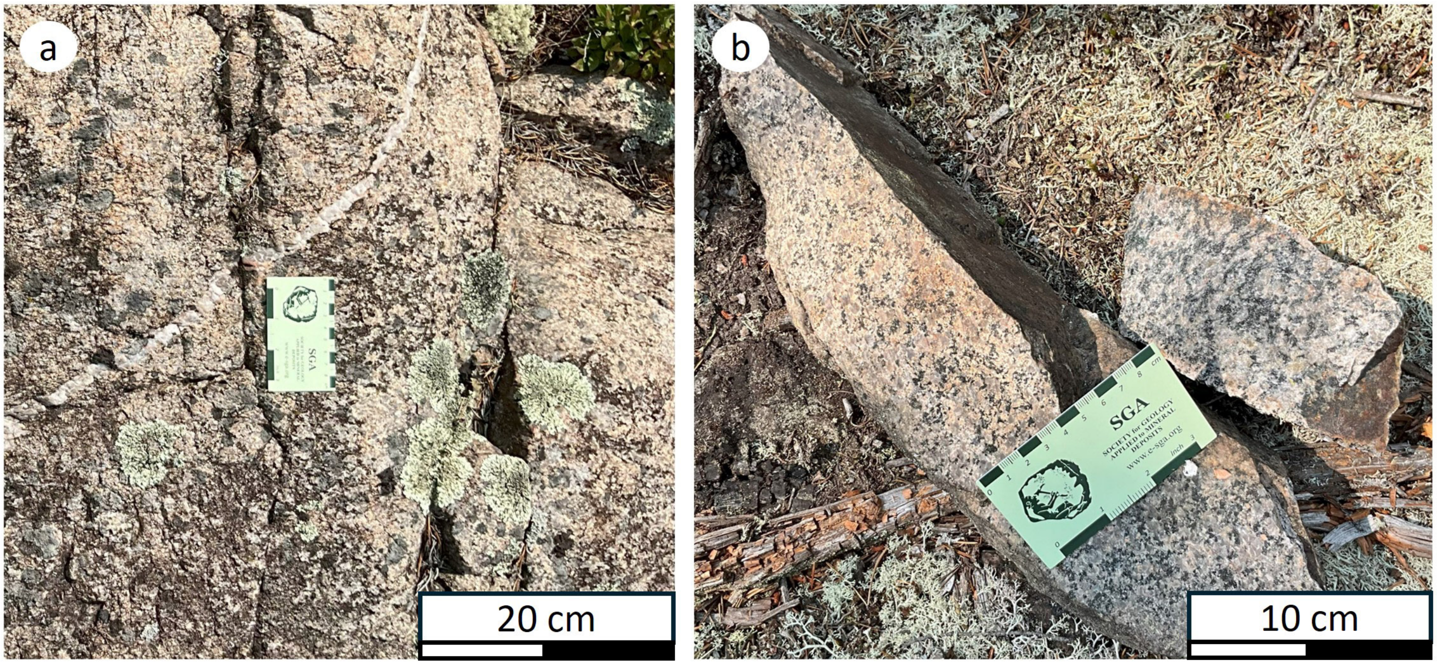

Figure GS2024-12-4: *Surface-sample locations in the Richard Lake intrusive complex, from* ***a)*** *near the existing data from Bailes 1886 +8/-9 Ma (Bailes et al., 1991), and* ***b)*** *1 km northeast of this location. New U-Pb dating may constrain the age of these synvolcanic tonalites.*

remobilization and upgrading process. The goal is to better constrain the existing dates for the RLIC and the Stroud Lake felsic breccia, and determine an age for the Chisel pluton.

Next steps

The 112 rock samples collected in the August 2024 site visit will be described in detail. Samples will be selected for thin-section petrography, and scanning electron microscopy (SEM) will be employed for understanding the gold chemical and mineral associations. Selected samples will be analyzed by electron microprobe and laser-ablation inductively coupled plasma–mass spectrometry (LA-ICP-MS) to examine microscale distributions and associations for gold, with the ultimate goal of linking a paragenetic sequence to primary metal enrichment and postdepositional upgrading and remobilization. Remobilization sequences under varying stress regimes, along with associated mineral and chemical changes, will be determined on some of the ore samples using electron backscatter diffraction (EBSD). The results will be integrated into a new 3-D geological model of the Snow Lake camp, often referred to as the Chisel basin. This geological model will incorporate a large drillcore database with geochemistry, produced by Hudbay Minerals, and new multivariate statistical analyses, with the goal of revealing novel spatial lithogeochemical associations. The findings from this work will verify and constrain the 3-D geological model.

Economic considerations

Volcanogenic massive sulphide deposits are significant sources of base metals, including zinc, copper and lead, as well as precious metals such as gold and silver. The development and deployment of electrified transportation and energy technologies is creating an ever-increasing demand for these metals from safe, reliable sources. The Snow Lake district has undergone continual VMS-related mineral exploration since the 1950s and has had seven producing VMS mines. The currently active Lalor mine produced 8.8 million tonnes of ore between 2012 and 2021 (Tavchandjian, 2021). A new deposit in the Snow Lake area, the 1901, is in currently the development phase. Expanding the understanding of the primary and postdepositional geological controls on spatial distribution, metal concentrations and associations, and of lithogeochemical signatures, could aid in creating new mineral exploration targets for VMS orebodies in the Snow Lake area, as well as other similar lithotectonic settings in Manitoba.

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