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2023

Canada

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2023

Permanent link: https://doi.org/10.4095/331537

This publication is available for free download through GEOSCAN (https://geoscan.nrcan.gc.ca/).

Recommended citation

McClenaghan, M.B., Brushett, D.M., Paulen, R.C., Beckett-Brown, C.E., Rice, J.M., Haji Egeh, A., and Nissen, A. 2023. Critical metal indicator mineral studies of till samples collected around the Brazil Lake LCT pegmatite, southwest Nova Scotia; Geological Survey of Canada, Open File 8960, 12 p. https://doi.org/10.4095/331537

Publications in this series have not been edited; they are released as submitted by the author

ISSN 2816-7155
ISBN 978-0-660-47853-1
Catalogue No. M183-2/8960E-PDF

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Abstract
This report describes field work carried out as part of the Geological Survey of Canada's Targeted Geoscience Initiative indicator mineral research activities at the Brazil Lake Li-Cs-Ta pegmatites in southwest Nova Scotia. This research is being undertaken in partnership with the Nova Scotia Department of Natural Resources and Renewables (NSDNRR). In the fall of 2022, 44 till samples were collected around and down-ice of the Brazil Lake Li-Cs-Ta pegmatites to document the geochemical and indicator mineral signatures of the pegmatites in the till. In 2020, 2021, and earlier in the summer of 2022, 105 till samples were collected across southwest Nova Scotia by the NSDNRR to provide regional context for the interpretation of the 44 case study samples. Till samples were also collected at the Salmon River beach section ~25 km north of Yarmouth where a thick coastal exposure (> 20 m) contains multiple till units that reflect several phases of glacial deposition and shifting ice-flow directions across southwest Nova Scotia. These section samples will provide insight and additional details on the regional glacial context.

Introduction

In 2022, the Geological Survey of Canada (GSC), in partnership with the Nova Scotia Department of Natural Resources and Renewables (NSDNRR), collected till samples around the Brazil Lake Li-Cs-Ta (LCT) pegmatites in southwest Nova Scotia (Fig. 1). This field work is was carried out as part of critical mineral exploration research funded by the GSC's Targeted Geoscience Research Initiative (TGI). TGI is a national, collaborative, multidisciplinary geoscience research program that aims to improve mineral exploration effectiveness. It will achieve these goals by developing next-generation geological models and knowledge, as well as leading-edge tools and methods, to understand the processes that formed Canada's mineral deposits and identify and develop novel indicators and parameters to guide exploration in emerging and existing mining areas. https://www.nrcan.gc.ca/earth-sciences/earth-sciences-resources/targeted-geoscience-initiative-tgi/10907

A detailed glacial sediment and bedrock study is being conducted around the Brazil Lake pegmatite to: (1) determine the geochemical and indicator mineral signatures in till from this style of mineralization; (2) define local geochemical and glacial dispersal patterns and parameters; and, (3) define the appropriate sampling protocols and analytical techniques that can be used for lithium exploration not only in southwest Nova Scotia, but in glaciated terrain in general. In support of this research, regional-scale surficial geological mapping, sediment thickness modelling, till fabric and clast lithology analyses, till geochemistry, and studies of glacial stratigraphy are being carried out in order to provide the regional context for interpreting results from the Brazil Lake case study. Previous till sampling carried out in the Brazil Lake region by the NSDNRR in 2020 and 2021 are reported in Brushett and Tupper (2021) and Brushett et al. (2022) and sample locations are shown in Figure 2a and b.

Location and Access

The Brazil Lake pegmatites are in southwest Nova Scotia, approximately 25 km northeast of Yarmouth. The topography consists of gently rolling hills with near continuous cover of glacial sediments that is characterized by drumlin fields. Bedrock is only exposed in only a few places along stream beds and around the edges of bedrock quarries. Sample sites were accessed by truck along local roads, resource-access roads, and trails.

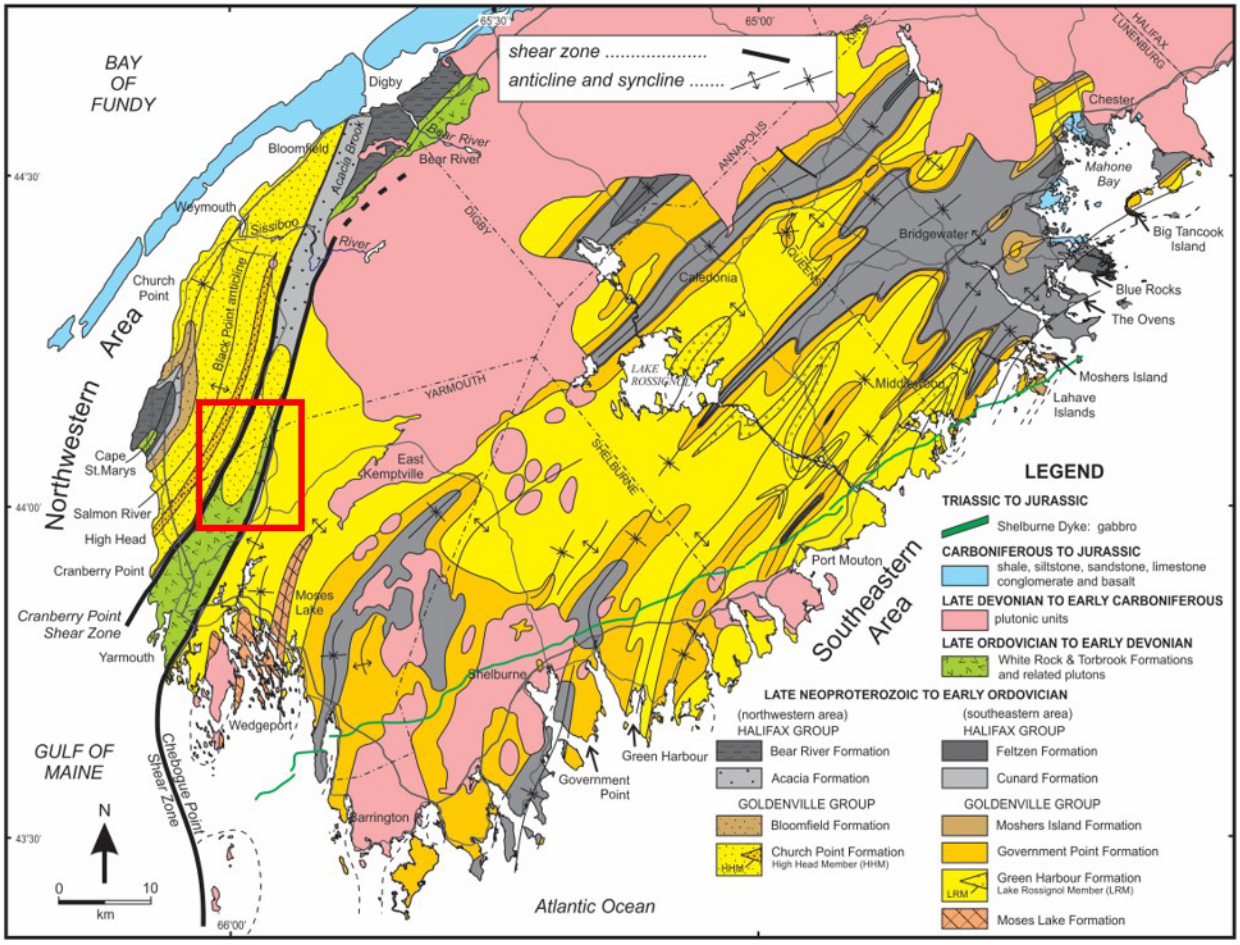

Figure 1. Bedrock geology of southwestern Nova Scotia (modified from White, 2010; White et al., 2012, 2018). Location of study area is indicated by the red box.

Geology

Bedrock geology

The study area is underlain by rocks of the Meguma terrane and consists of Early Cambrian to Early Ordovician metasedimentary rocks comprising metasandstone-dominated Goldenville Group and the overlying siltstone- and slate-dominated Halifax Group (White, 2010). Locally, the Meguma Group is unconformably overlain by a thin sequence of Silurian to Early Devonian slate, quartzite, and volcanic rocks of the Rockville Notch Group (White and Barr, 2017; White et al., 2018). Subsequent deformation and variable metamorphism (greenschist to amphibolite facies) occurred during the Early to Middle Devonian Neoacadian orogeny (ca. 405–365 Ma) resulting in NE- to NNE-trending, upright regional-scale folds. These rocks were intruded by numerous late syntectonic to post-tectonic, Middle to Late Devonian, peraluminous granitic plutons, such as the South Mountain Batholith (SMB; White, 2010); the western edge of which occurs some 20 km east of the Brazil Lake area (Fig. 2a).

The Brazil Lake pegmatites consist of two separate NE-trending, steeply-dipping pegmatite sheets, each ≤20–25 m in width and a few hundred metres in length. They have been described in detail by Kontak (2004, 2006) and Kontak et al. (2003, 2005), Barr and Cullen (2010), and Cullen et al. (2022), and are described with respect

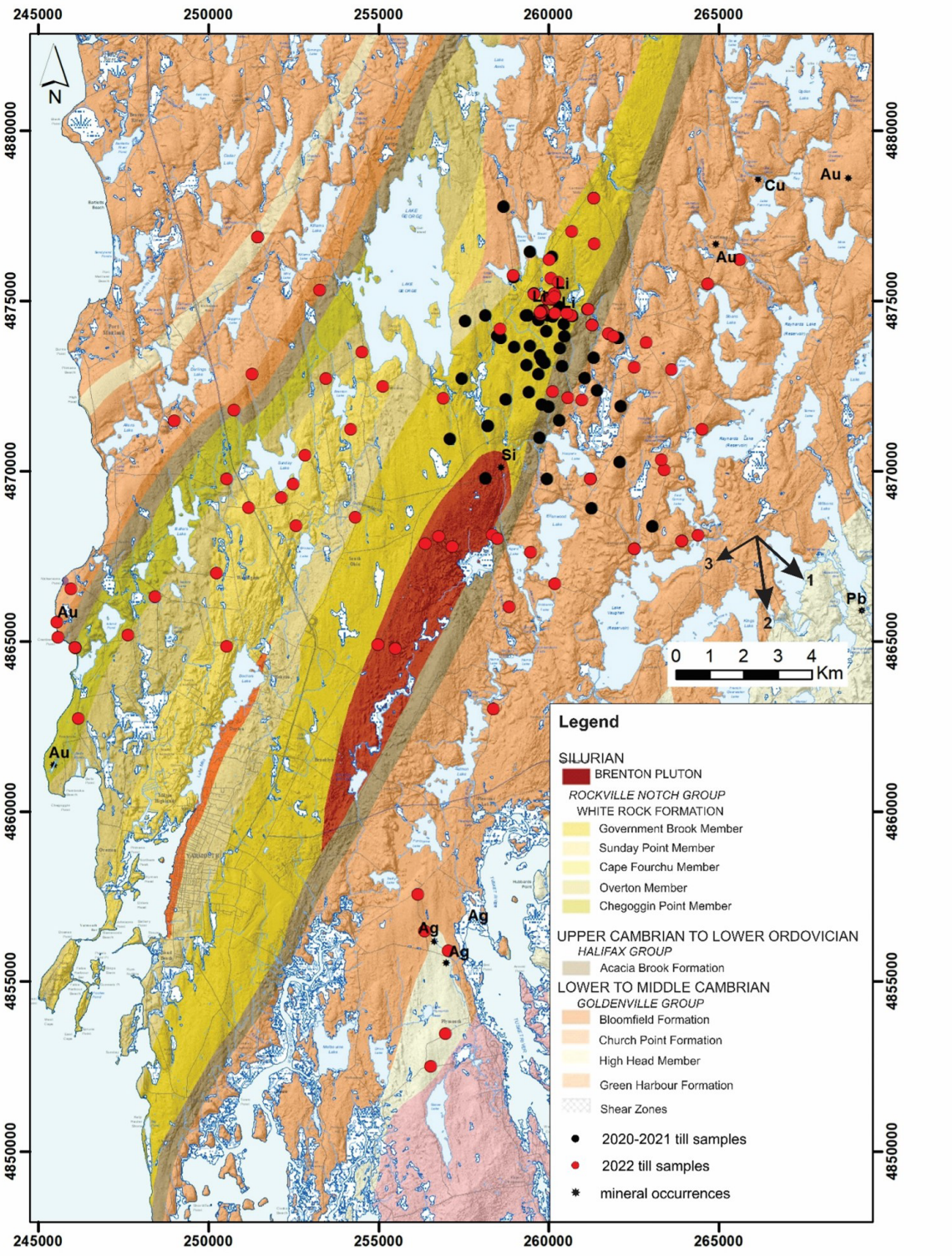

Figure 2a. Bedrock geology of southwest Nova Scotia (White et al., 2012) superimposed on LiDAR hillshade image (azimuth of 315°) showing the location of till samples collected for matrix geochemistry analysis in 2021 (red dots) and 2022 (black dots). Mineral occurrences (small black dots). The Brazil Lake pegmatites are marked by the Li symbol.

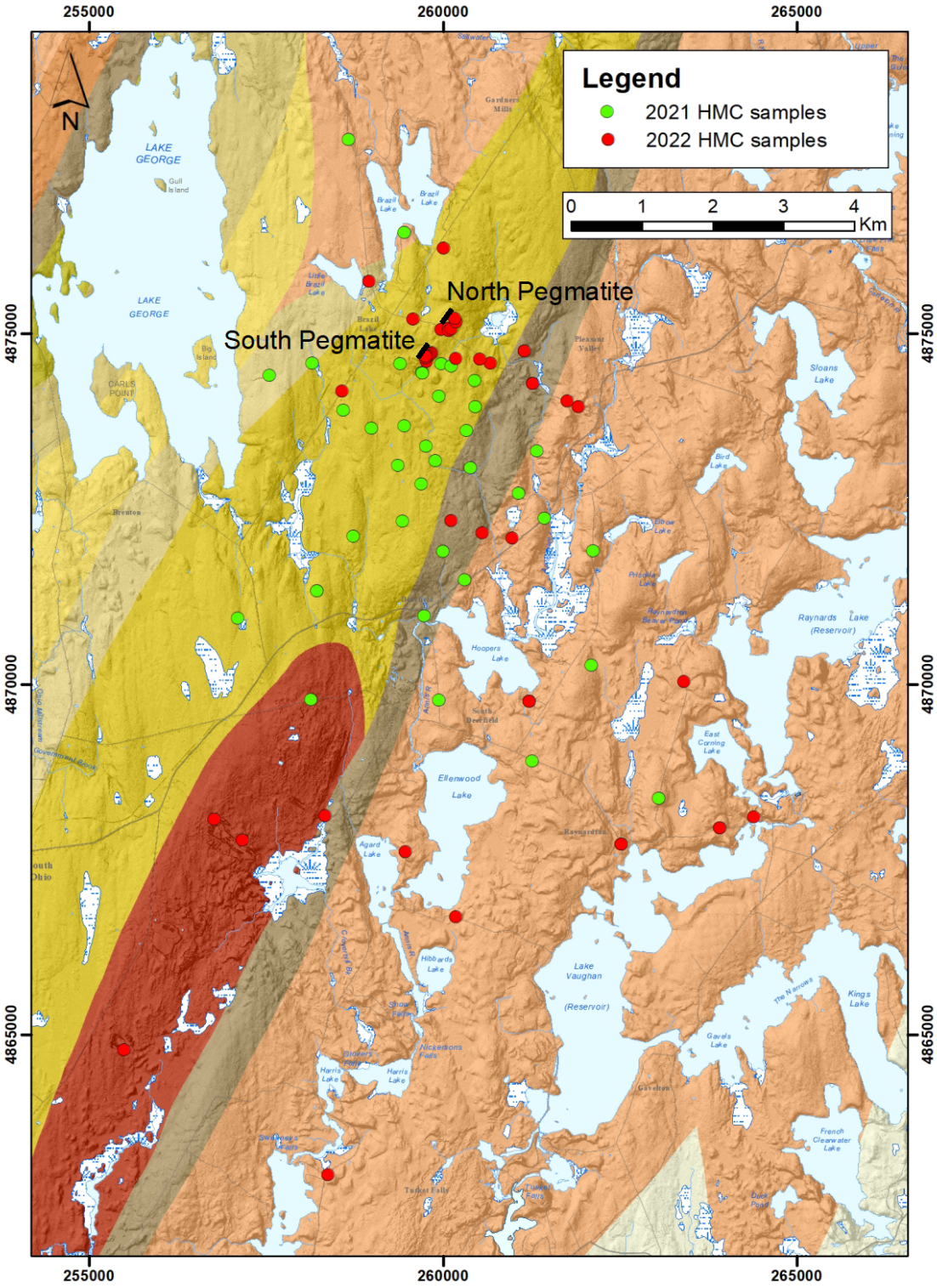

Figure 2b. Bedrock geology of the Brazil Lake study area (White et al., 2012) superimposed on LiDAR hillshade image (azimuth of 315°) showing the location of till samples collected for recovery and counting of indicator mineral in 2021 (green dots) and in 2022 (red dots) around the Brazil Lake pegmatites (black lines).

to their location. The “North pegmatite” is on the north side of an NW-SE trending gravel road and the “South pegmatite” is on the south side of the road. The South pegmatite outcrops in an area of ~720 m^2. The pegmatites are composed of coarse (up to 2.0 m in length crystals) spodumene (Fig. 3a), K-feldspar, quartz, and two varieties of albite occurring as fine-grained albite or euhedral platy cleavelandite. Muscovite occurs throughout the pegmatite, most of which is of secondary origin and generally associated with albitized zones (Kontak, 2004; Kontak et al., 2005). Key minerals in the pegmatites that could be useful indicator minerals for drift prospecting include black tourmaline, black columbite-tantalite (Fig. 3b), red garnet, blue apatite, green beryl, cassiterite, wolframite, sphalerite, zircon, epidote, topaz, titanite, and phosphate minerals. Age dates of tantalite (U-Pb) from the South pegmatite indicate that pegmatite crystallization occurred at 395 Ma (Kontak et al., 2005; Kontak and Keyser, 2009).

The pegmatites have been the focus of exploration since they were discovered in 1960 by tracing the source of a pegmatite float boulder near what was later discovered to be the north pegmatite (Taylor, 1967; Barr and Cullen, 2010). Subsequent geological mapping and prospecting in the local area have identified additional spodumene-bearing float boulders on surface and resulted in the discovery of a third pegmatite, the “Army Road pegmatite”, 300 m east of the South pegmatite, described as a cleavelandite muscovite pegmatite in which no spodumene has been reported. Overburden was stripped and the bedrock surfaces of the North and South pegmatites were exposed in the early 2000s (Barr and Cullen, 2010). Diamond drilling by the Nova Scotia Department of Energy and Mines in 1993 (Corey, 1995; Barr and Cullen, 2010) and by Champlain Resources (2002-2011) have reported on the nature of the pegmatites at depth (Barr and Cullen, 2010; Black, 2011).

Surficial Geology

South- to southeast-trending streamlined drumlins are the predominant landform over much of the region. Till thickness is variable, ranging from thin veneers (<2 m) over the pegmatites to drumlin ridges over 40 m thick (Brushett et al., 2022). The area between the till ridges is characterized by shallow bedrock with sediment cover of <5 m. Glaciofluvial deposits commonly occur in topographic lows, which are now occupied by modern rivers and wetlands. Previous till or soil sampling around the Brazil Lake pegmatites has been reported by Palma et al. (1982), MacDonald et al. (1992), Lundrigan (2008), Black (2012), and Wightman (2020).

The current state of knowledge about the glacial history of southwestern Nova Scotia is largely derived from previous regional-scale (1:100 000) surficial mapping and till sampling conducted by Stea and Grant (1982) and Finck and Stea (1995). This mapping and sampling, together with stratigraphic studies by Grant (1976), Grant and King (1984), and Stea et al. (1992), has led to a broad framework of regional glacial history. A drift thickness model and new regional surficial mapping, aided by LiDAR data, are ongoing by NSDNRR.

Engagement

Two site visits were made to the Brazil Lake pegmatites with First Nation representatives in 2022. GSC and NSDNRR scientists met with Jeff Purdy (Councillor, Acadia First Nation), Greg Hart (NSPI Early Engagement Coordinator, Kwilmu'kw Maw-klusuaqn Negotiation Office), and Patrick Butler (Mi’kmaq Energy & Mines Advisor, Kwilmu'kw Maw-klusuaqn Negotiation Office) to explain the collaborative GSC-NSDNRR research at the site, the geology of the local lithium occurrence, answer questions, and address potential concerns about the impact of the field work (Fig. 4a, b).

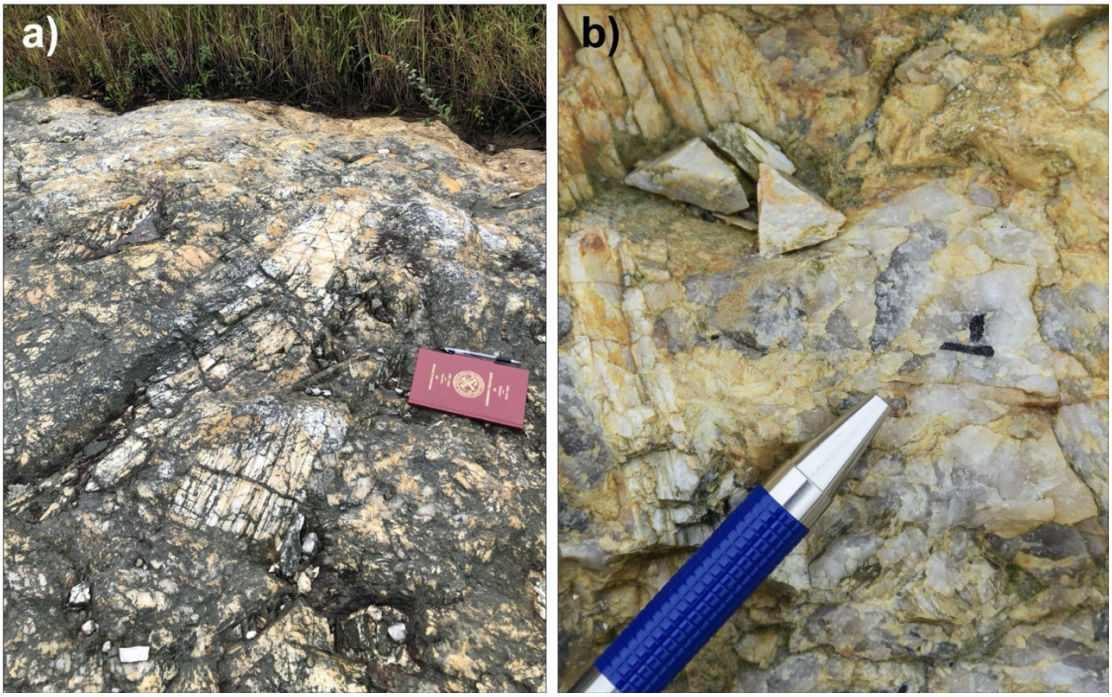

Figure 3. a) Coarse (up to 0.5 m in length) white spodumene crystals exposed on the subcropping surface of the South pegmatite (Photograph by M.B. McClenaghan; NRCan photo 2022-571); b) tantalite (black) crystals in quartz at the North pegmatite (Photograph courtesy of D. Archibald, St. Francis Xavier University).

Figure 4. a) Abeer Haji Egeh (GSC) showing Greg Hart and Patrick Butler (Kwilmu'kw Maw-klusuaqn Negotiation Office) sample material used to study the lithium in soils around the pegmatites (Photograph by M.B. McClenaghan, NRCan photo 2022-573); b) L-R Jeff Purdy (Acadia First Nation), Denise Brushett (NSDNRR), Greg Hart and Patrick Butler (Kwilmu'kw Maw-klusuaqn Negotiation Office) and Beth McClenaghan (GSC) standing beside large spodumene-rich boulder (Photograph by R.C. Paulen. NRCan photo 2022-574).

Till sampling methods

A total of 44 till samples were collected from 41 sites that consisted of hand-dug holes, till exposures in borrow pits (Fig. 5a), exposures along local roads, or backhoe trenches dug on the down-ice (south-southeast) side of both North and South pegmatites. Three of the samples were field duplicates. Till samples were collected following the Geological Survey of Canada till sampling protocols described in Spirito et al. (2011), Plouffe et al. (2013), and McClenaghan et al. (2020). At each site, two till samples were collected from moderately oxidized till: i) small sample (~6 kg) for geochemical analysis of till matrix and for archiving; and ii) large bulk (~15 kg) sample for recovery of indicator minerals of Li-bearing pegmatite and the recovery of pebbles for lithological analysis. During till sampling in trenches close to the pegmatite, pebbles and cobbles of spodumene (white mineral) were observed in the till (Fig. 6).

A total of 15 bedrock samples from the north and south pegmatites (Fig. 5b) were collected to document the mineralogy and mineral chemistry of both pegmatites. Four bedrock samples were submitted for heavy mineral processing to identify the Li-pegmatite indicator mineral signature.

Also, during the 2022 field season, the NSDNRR collected 50 3-kg till samples in a broad region between Brazil Lake and Tuskett Falls to characterize the regional composition of the surface till. These till samples will provide the context for interpreting the Brazil Lake pegmatite test site data.

At the ocean beach section at Salmon River, ~25 km north of Yarmouth, seven 3-kg till samples and accompanying bags of pebbles (1 to 4 cm in size) were collected from a 19 m vertical section to document the geochemical and textural characteristics of the multiple till units exposed. Data from these till samples and pebbles will be compared to the regional till samples and samples from the Brazil Lake area to further our understanding of the regional glacial history. An additional three sand samples were collected from a large shelly sand bed that occurs between the till layers. These sand beds are known as the ‘Salmon River sand’, but with very limited previous research (Grant, 1976), and have been subjected to mixed interpretations as to their age, which ranges from the last interglacial time (Stea et al., 1992) to a younger interstadial deposit (Grant, 1987).

Field data collected at each till and bedrock sample site included GPS coordinates, general site description, sample description (texture, colour, clast types, relative percentages of clasts, matrix texture, and sample depth). Several colour photos were taken at each site.

Sample processing and analysis

Till geochemistry

The 3 and 6 kg samples were shipped to the GSC Sedimentology Lab in Ottawa where they were prepared and analyzed using the following methods:

1. Aqua regia digestion, ICP-ES, -MS of the <0.063 mm and 1-2 mm fractions;
2. Na-peroxide fusion of the <0.063 mm and 1-2 mm fractions;
3. 4-Acid digestion, ICP-MS of the <0.063 mm and 1-2 mm fractions;
4. Loss on ignition (LOI);
5. Munsell colour (moist);
6. Matrix grain size analysis (% sand, silt and clay);
7. pH; and
8. pXRF lab-based analysis on sieved and unsieved fractions.

Figure 5. a) Collecting samples from a vertical till section for matrix geochemistry and indicator mineral analysis (Photograph by M.B. McClenaghan. NRCan photo 2022-575); b) collecting a bedrock sample for recovery of indicator minerals at the North pegmatite (Photograph by M.B. McClenaghan. NRCan photo 2022-576).

Figure 6. Spodumene pebble recovered from till within 20 m down ice of the pegmatite (Photograph by M.B. McClenaghan. NRCan photo 2022-577).

Indicator Minerals

The large bulk (15 kg) till samples and bedrock samples were shipped to Overburden Drilling Management Limited, Ottawa for sample processing to produce 0.25-2.0 mm mid-density (2.8-3.2 specific gravity) and heavy-density (>3.2 specific gravity) mineral concentrates from which indicator minerals are being counted and selected minerals removed for mineral chemistry. Bedrock samples are being processed and examined first to establish the suite of indicator minerals that best reflect the Li pegmatites. The till samples will then be examined for the Li indicator mineral suite, as well as gold grains and other indicator minerals that may be derived from other rocks in the region.

Optically Stimulated Luminescence (OSL)

The three sand samples were shipped to the University of the Fraser Valley, School of Land Use and Environmental Change, Abbotsford, British Columbia to be analyzed for optically stimulated luminescence (OSL) age dating. This dating method provides a measure of time since the sand grains were last exposed to sunlight, and dates when those grains were deposited and buried.

Acknowledgements

The authors thank John Wightman and Cliff Stanley for access to the property, field visits, and advice that guided the field work. Staff at the Carleton Country Outfitters store are thanked for excellent service and support during the Fall 2022 field work. P-M Godbout (GSC) is thanked for his review of the report.

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