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M. Sanborn-Barrie and D. Regis

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Introduction

The Boothia Peninsula – Somerset Island area is an under-explored frontier region of the western Churchill Province, Canadian Shield (Fig. 1) where, until recently, knowledge has stemmed from 1962 (Blackadar, 1967) and 1986-1992 (Frisch, 2011) geological mapping, undertaken without benefit of aeromagnetic constraints and with only limited U-Pb geochronology (Frisch and Hunt, 1993). Geomapping for Energy and Minerals (GEM) built upon this historical foundation through modern-concept bedrock mapping supported by high-resolution geophysical and geochronological data sets. To date, reports of field findings (Sanborn-Barrie et al., 2018, 2019), value-added assay data (Regis et al., 2019), new geological maps (Sanborn-Barrie and Regis, in press; Regis and Sanborn-Barrie, in prep.) and journal papers (Drayson et al., 2022; Regis and Sanborn-Barrie, 2023) are ensuring that relevant data and knowledge are accessible for this region. This report contains a broad overview of the geochemical character of the major rock units recognized as comprising fundamental crustal components of the Boothia-Somerset region (Fig. 2), based on major, minor and trace-element data for select samples (Appendix 1).

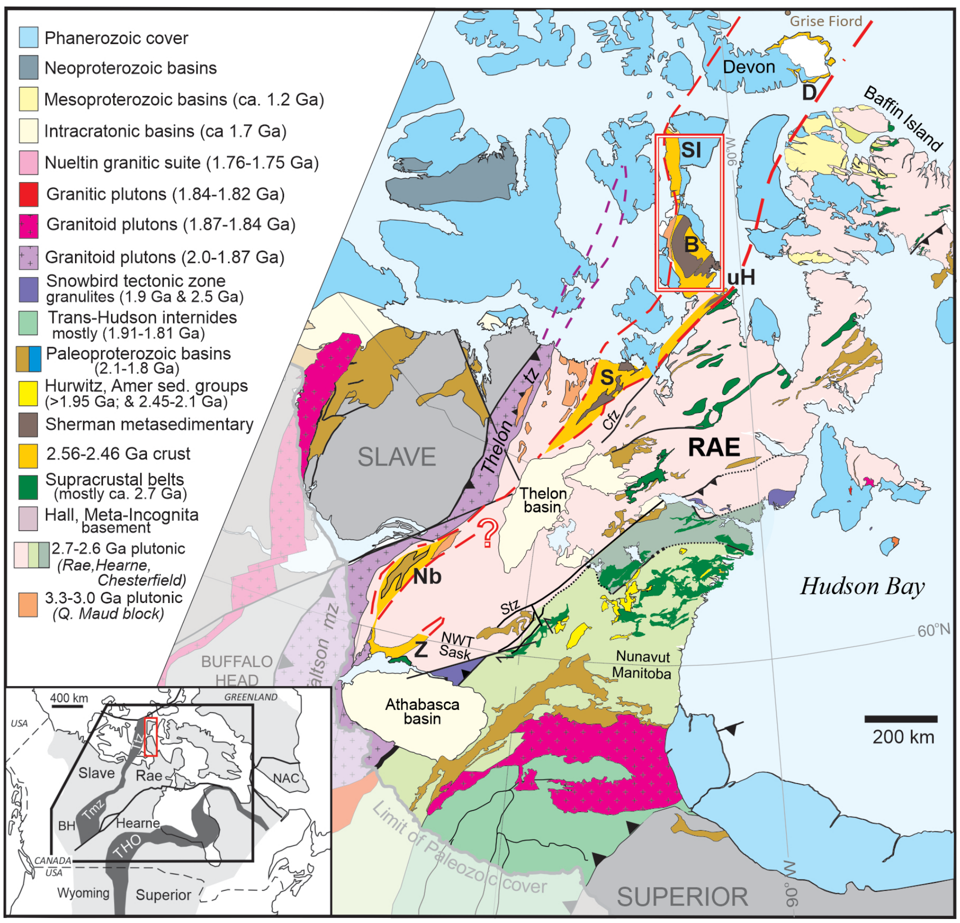

Figure 1: Regional geological map of the Canadian Shield showing main lithotectonic units, select structures, and localities of units discussed in the text. Note that Boothia-Somerset is now recognized as underlain largely by ca. 2.56-2.51 Ga crust whose extent (red dash line) along the western margin of Rae craton has been established from SE Devon Island to Saskatchewan (*see* Regis and Sanborn-Barrie, 2022 *and references therein*). Purple dash line denotes geophysically defined extent of Thelon arc.
Abbreviations: B-Boothia Peninsula; Cfz-Chantrey fault zone; D-Devon Island basement; mz-magmatic zone; Nb-basement to Nonacho group; NWT-Northwest Territorial border; S-Sherman domain; Sask-Saskatchewan provincial border, SI-Somerset Island, Stz-Snowbird tectonic zone; tz-tectonic zone; uH-upper Halkett Inlet belt; Z-Zemlak domain. Red rectangle bounds the Boothia-Somerset region for which an updated geological map is shown in Figure 2.

Geological Overview

Field observations and supporting isotopic data acquired for this region collectively highlight a tonalite-trondjemite-granodiorite (TTG) suite, known to be neoArchean (ca. 2.55-2.51 Ga; Sanborn-Barrie and Regis, in prep.) intrusive into slightly older ca. 2.56 Ga peraluminous porphyroclastic granodiorite-quartz monzonite (Osinchuk, 2021) with a ca. 2.85 Ga ancestry (i.e., Sm-Nd model ages) and locally into ca. 2.71 Ga tonalite (Wrottesley Inlet, NW Boothia Peninsula). Unconformably overlying and tectonically interleaved clastic metasedimentary rocks (sequence 1 of Regis and Sanborn-Barrie, 2023), derived from the Neoarchean basement complex, are extensively cut by a dioritic suite emplaced at ca. 2.49-2.48 Ga (Regis and Sanborn-Barrie, 2023) likely in an extensional setting, in advance of ca. 2.45 and 2.39 Ga Arrowsmith tectonometamorphism. Following the Arrowsmith orogeny, a quiescent setting (e.g., passive margin) from ca. 2.29-2.02 Ga is reflected by deposition of quartzite (sequence 2 of Regis and Sanborn-Barrie, 2023) and overlying marble ± calc-silicate strata (lower sequence 3 of Regis and Sanborn-Barrie, 2023). An influx of ca. 2.02-1.97 Ga detritus in the < 1.96 Ga upper clastic component of sequence 3 (Regis and Sanborn-Barrie, 2023) is believed to reflect unroofing of Thelon magmatic arc rocks following collision of Slave craton (Thelon Orogeny) to the west. On northwestern Boothia Peninsula and along the length of Somerset Island, clastic-carbonate sequence 3 rocks (yellow unit in Fig. 2) are extensively cut by mafic, intermediate to felsic plutonic rocks, currently represented by 2-pyroxene diorite-gabbro±gabbroic anorthosite, orthopyroxene-bearing granodiorite-tonalite and monzogranite. These plutonic rocks yield crystallization ages of 1.95-1.93 Ga (Regis and Sanborn-Barrie, 2023; unpublished U-Pb data 2021). Ultra-high temperatures recorded in metamorphic assemblages at this time, together with lithogeochemistry (this report) point to production of compositionally variable plutonic rocks in a back-arc environment at 1.95 to 1.93 Ga. Given that the locus of subduction-generated Thelon arc magmatism is established from 2.01 to 1.97 Ga (Whalen et al., 2018; Berman et al., 2023, in press), our data suggest a back-arc environment was active during the waning stages of the orogen (i.e., 1.95-1.93 Ga). Thelon plutonic rocks dated at 2.01-1.97 Ga with an arc affinity, so dominant across the central Thelon tectonic zone to the southwest (Berman et al., 2023, in press), are not recognized on Boothia Peninsula or Somerset Island. Their distribution supports an orogenic architecture wherein the Thelon magmatic arc is to the west (see Fig. 1) with its back-arc region represented on Somerset Island.

Peraluminous leucogranite (homogeneous diatexite) derived from melted metasedimentary precursors are widespread across both Boothia Peninsula and along western Somerset Island (Fig. 2). On the basis of cross-cutting relationships, these leucogranitic rocks are recognized to be multi-generational, formed: 1) locally in response to ca. 2.49-2.48 Ga contact metamorphism; 2) during ca. 2.45 and 2.39 Ga granulite-facies Arrowsmith tectonometamorphism; and 3) as products of the ca. 1.96-1.94 Ga Thelon high-heat (back-arc) environment. In this report, different generations of leucogranite are not discriminated, such that differences in lithogeochemistry of S-type melts during the evolution of the region are not assessed in this report.

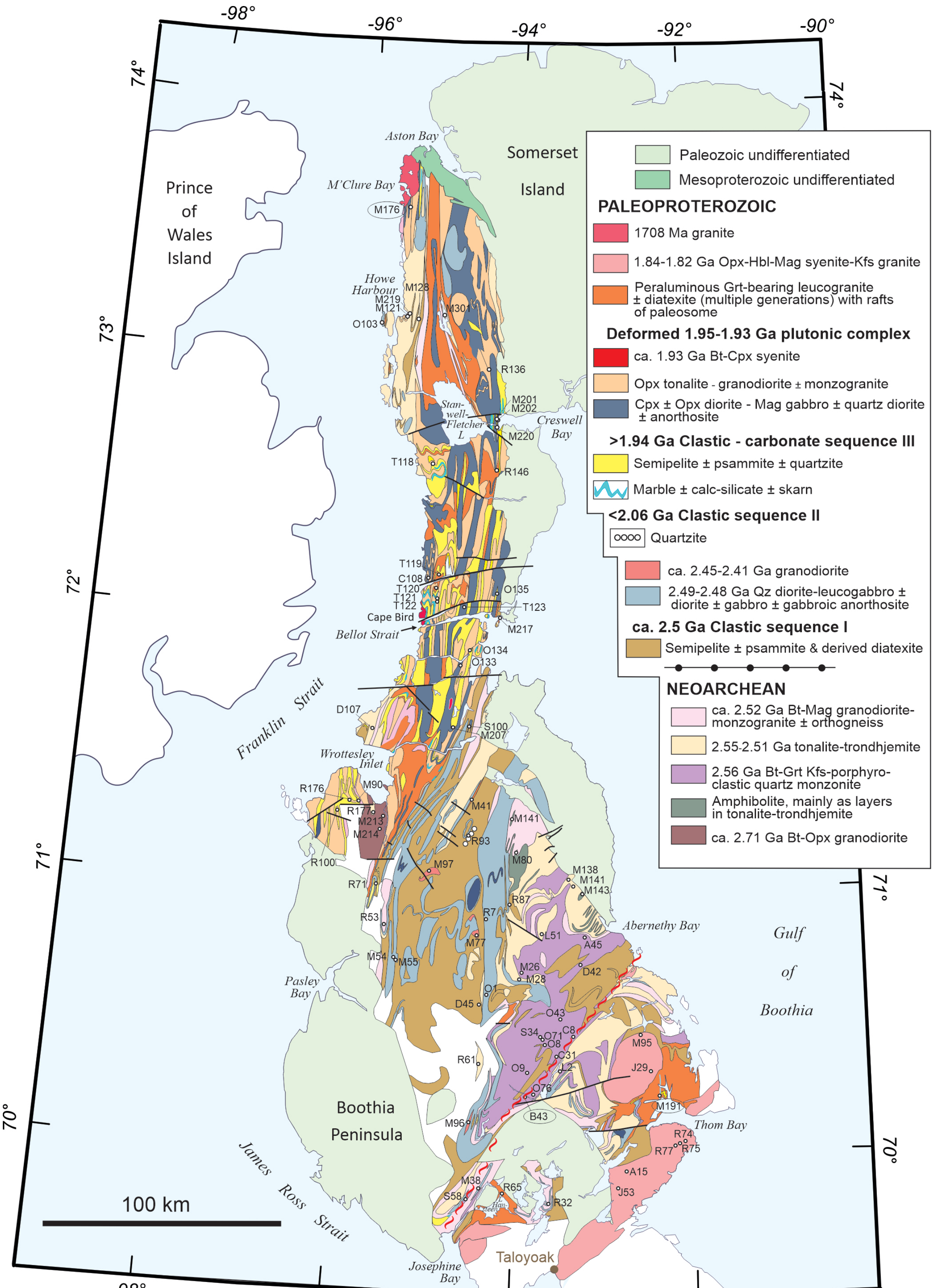

Figure 2: Geological map of Boothia Peninsula and Somerset Island showing distribution of major Precambrian crustal units, the ductile Sanagak Lake shear zone (red symbols), some major faults (heavy black lines), and the location (white circles) of plutonic rocks analysed for lithogeochemistry (Appendix 1) and discussed in this report. Abbreviated sample numbers (see text) are circled where new U-Pb data is available (Appendix 3, 4). White areas are unmapped.

Variably deformed magnetite-bearing, quartz-poor monzonitic dykes and salmon-weathering aplitic granite dykes, dated at 1.89 and 1.87 Ga respectively (Appendix 3), cut Neoarchean porphyroclastic granodiorite preferentially along the Sanagak Lake shear zone, such that the shear zone appears to have localized syn-tectonic magmatic melts.

Late to post-tectonic units include weakly foliated to massive orthopyroxene alkali-feldspar granite, and hornblende syenogranite - monzogranite plutons that underlie southeastern Boothia Peninsula (Fig. 2). Undeformed gabbroic (diabasic) dykes, 1-30 m wide, transect the region (not shown in Figure 2, *see* Sanborn-Barrie and Regis CGM430, in press). SE-trending gabbro dykes are most common and belong to the ca. 1270 Ma Mackenzie swarm (LeCheminant and Heaman, 1989). North- and east-striking gabbro-gabbroic anorthosite dykes are now recognized as part of the ca. 723 Ma Franklin swarm (Appendix 4).

Nature and Geochemical Characterization of Major Plutonic Suites

Field relationships and supporting U-Pb geochronology (e.g., Regis and Sanborn-Barrie, 2023; unpublished data) have established the chronology of lithological units synthesized above. These units are characterized in terms of their lithogeochemistry below, from oldest to youngest (except for undated mafic enclaves in Neoarchean TTG suite, described after TTG). The lithologic unit code on new geological maps of the region (Sanborn-Barrie and Regis, in press; Regis and Sanborn-Barrie, in prep.) is provided in brackets below to facilitate cross referencing between the maps and the data presented in this report. Only samples representative of the freshest, homogeneous, unaltered portions of major map units were collected for geochemical analyses and lithogeochemical characterization. However, it should be noted that U-Pb monazite and zircon rim data (not presented here) have provided insight into the region's polyphase tectonometamorphic history through relatively precise calibration of three significant tectonometamorphic events. Such widespread medium- to high-grade metamorphism may have affected the primary geochemical character of the plutonic rocks analyzed and should be considered in the development of models of the evolving tectonic setting for this region. In addition, multiple intrusive phases, partial melting and polyphase deformation combine to disrupt, inflate and modify most exposures.

The geochemical analyses are organized into lithological groups with selected metadata (location, ratios) in the accompanying spreadsheet (Appendix 1). Portions of selected samples were trimmed and cleaned in Ottawa to remove weathered surfaces, and alteration bands or patches. Samples were then crushed and pulverized (<75 µm) by Activation Laboratories Limited in Ancaster, Ontario, using a mild-steel mill and analyzed using a combination of their standard analytical methods, the details of which can be found at http://www.actlabs.com. All major and trace elements were obtained by total digestion - inductively coupled optical emission spectrometry (ICP) (ActLAB codes: 4LITHOSRES and 4B1 – Assay traces). Methods for U-Pb geochronology are presented in Appendix 2. The sample prefix 17SRB- (collected in 2017 from Boothia

Peninsula) and 18SRB- (collected in 2018 from northern Boothia Peninsula and Somerset Island) appear in Appendix 1, 3 and 4, but are omitted from the figures and text of this report for clarity and simplicity.

Neoarchean Basement Complex

Ca. 2.71 Ga Tonalite

Isolated exposures of foliated orthopyroxene-bearing tonalite and clinopyroxene-biotite granodiorite (Fig. 3a; map unit nAgg) underlie the Wrottesley River valley of northwestern Boothia Peninsula (Fig. 2) and constitute the oldest rock unit recognized. Two samples of this oldest phase, represented by granodiorite (M214) and tonalite (M213), have between 67 and 69 wt.% SiO_2 (Fig. 4), 14.6 to 15.5 wt.% Na_2O, 1.3 to 2 wt.% K_2O, and are metaluminous to weakly peraluminous (Fig. 6). In terms of their trace elements, ca. 2.71 Ga granodiorite is enriched in light rare earth elements (LREE) at 110-120 times chondrite, relative to heavy rare earth elements (HREE) at 3 to 4 times chondrite (Fig. 5) with La_N/Lu_N ratios of 39 and 47. They show minor fractionation of HREE (Gd_N/Lu_N= 2.7-2.9), lack a Eu anomaly, and have a small negative Nb-Ta anomaly.

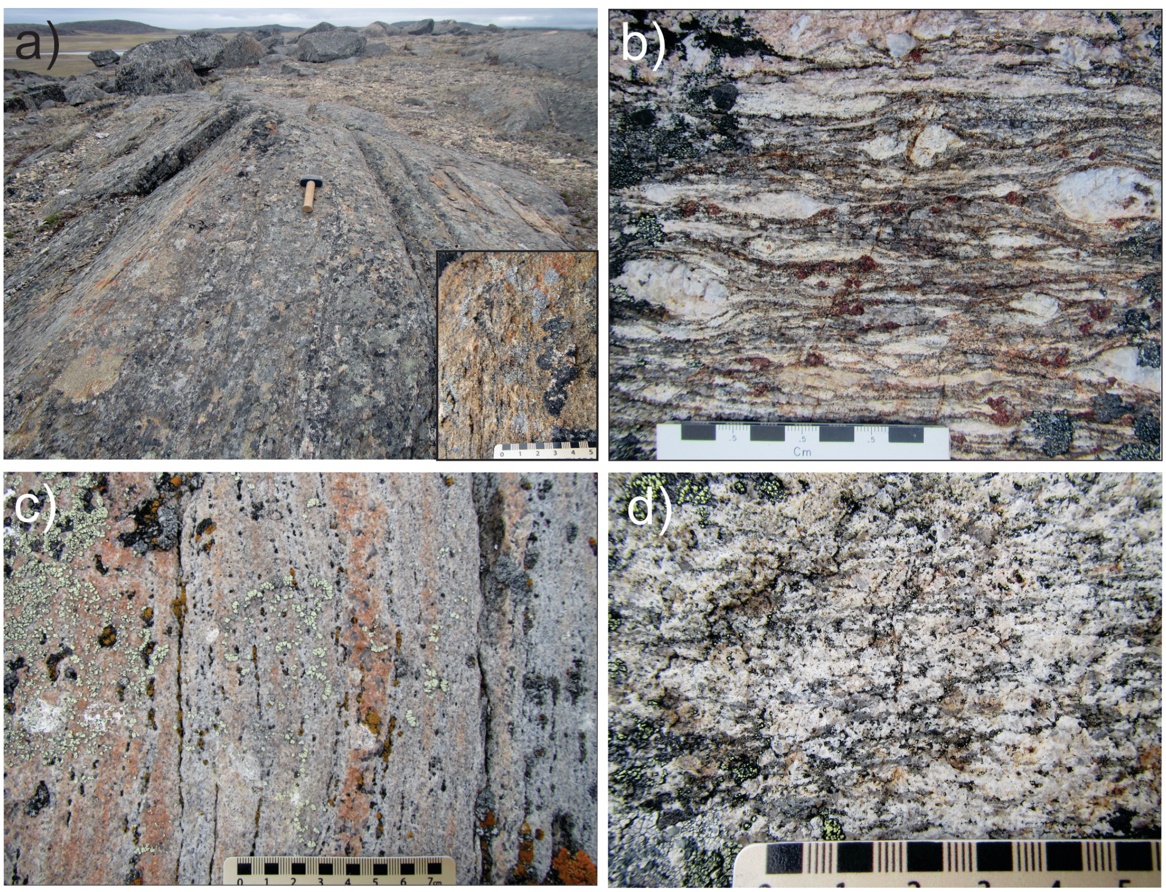

Figure 3: Neoarchean plutonic rocks of Boothia-Somerset. a) View to south of cpx-bt-mt granodiorite (18SRB-M214) in the drift-covered Wrottesley River valley. 26-cm long hammer parallel to L=S foliation oriented 326/30°NE with mineral lineation plunging shallowly (10°) to the SE. Photograph by M. Sanborn-Barrie. NRCan photo 2023-001; Inset shows relatively lichen free, weathered surface. Photograph by M. Sanborn-Barrie. NRCan photo 2023-002; b) ca. 2.56 Ga feldspar porphyroclastic, garnet-bearing granodiorite. Photograph by M. Sanborn-Barrie. NRCan photo 2023-003 ; c) fine-grained grey weathering biotite tonalite-trondhjemite cut by pink granodiorite veins typical of ca. 2.55-2.52 Ga TTG suite. Photograph by M. Sanborn-Barrie. NRCan photo 2023-004; d) detail of weathered surface of granodiorite, Wrottesley River valley (locality 18SRB-R177). Photograph by D. Regis. NRCan photo 2023-005.

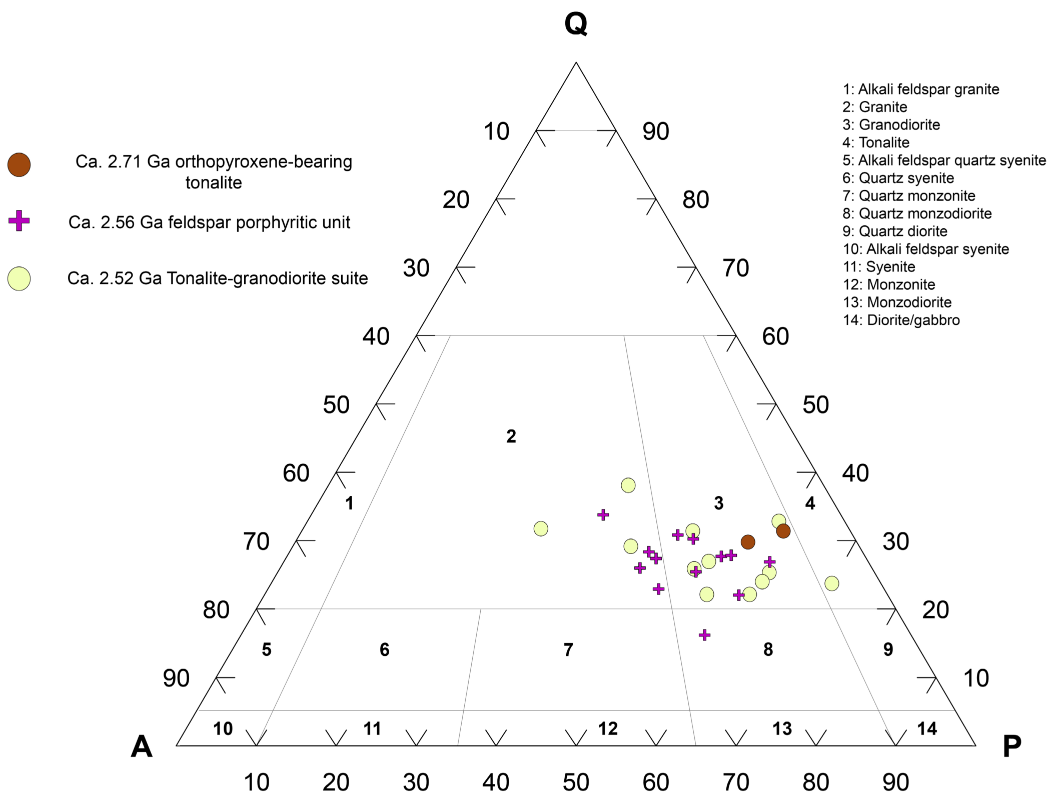

Figure 4: QAP diagram of Neoarchean plutonic rocks of the Boothia-Somerset region.

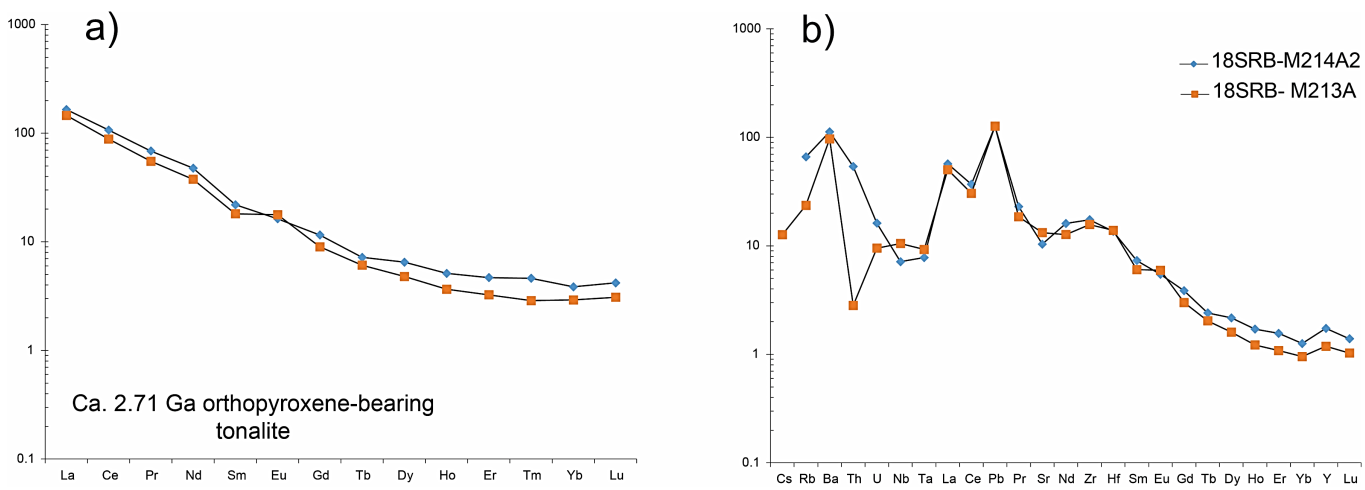

Figure 5: REE for 2.71 Ga tonalitic rocks exposed in Wrottesley River valley, northwest Boothia Peninsula. a) chondrite normalized values of McDonough and Sun (1995); b) primitive mantle normalized values of Sun and McDonough (1989).

Ca. 2.56 Ga Feldspar Porphyroclastic Unit

Widespread, moderately to strongly foliated feldspar porphyritic biotite-garnet granodiorite-quartz monzodiorite (map unit nA**gr**) exposed throughout east-central Boothia Peninsula (Fig. 2), constitutes a major component of the Neoarchean basement complex. Where highly strained, this unit is distinctly and spectacularly porphyroclastic (Fig. 3b) with isolated feldspar porphyroclasts surrounded by fine strongly foliated dark biotite±orthopyroxene matrix phases. Thirteen samples of the porphyroclastic unit, analyzed as part of a MSc research project (Osinchuk, 2021), typically contain between 60 and 69 wt.% SiO_2 (i.e., low compared to I-type suites), 15 to 17.4 wt.% Al_2O_3 and 1.75 to 4.4 wt.% K_2O (high-K), and magnesian to ferroan signatures. Their weakly to moderately peraluminous character is reflected by aluminum index values between 1.0 and 1.1 (Fig. 6) and by 5-10% modal garnet. Accordingly, a sedimentary component is suspected to have been involved (e.g., sourced and/or assimilated) in the production of this plutonic phase.

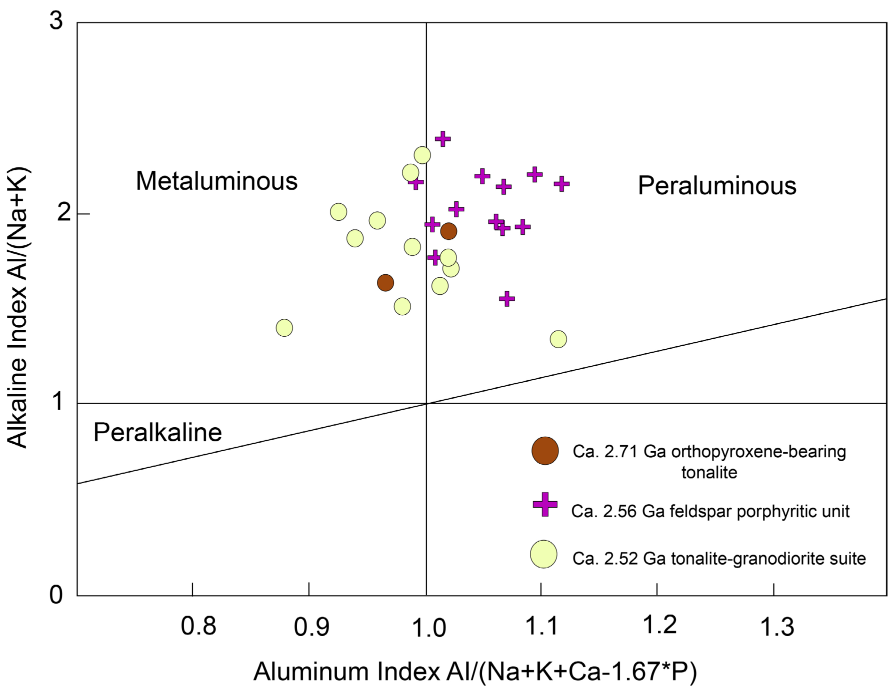

Figure 6: Aluminum versus total alkalis binary diagram for Neoarchean plutonic rocks high-lighting the more peraluminous character of the ca. 2.56 Ga feldspar porphyroclastic - garnet granodiorite relative to the 2.55-2.52 TTG suite.

In terms of trace elements, the porphyroclastic samples are LREE enriched at 105 to 130 times chondrite and HREE enriched at 4 to 30 times chondrite (Fig. 7), corresponding to La_N/Lu_N ratios typically between 11 and 60, averaging 35 (Appendix 1). O43 is the most fractionated with La_N/Lu_N = 70. The porphyroclastic granodiorites are characterized by small negative Eu anomalies (Eu*=0.6-1.0), contrary to the substantial positive Eu anomaly expected for these feldspar porphyritic/porphyroclastic rocks. This may be due to the presence of 5-10% garnet in these rocks. Their HREE show considerable variation from uniformly enriched (Gd_N/Lu_N = 1.52) at 30 times chondrite (e.g., M26a-2) to progressively depleted (Gd_N/Lu_N ~7) at 4 times chondrite (e.g., C31a and O76a). Variation in HREE is attributed, in part, to the proportion of garnet in the analyzed sample. For instance, C31a with no evident garnet is most strongly depleted in the HREE, whereas, M26 with the highest modal garnet (~10%) has a Gd/Lu= 1.52 and is most enriched. These rocks display negative Nb-Ta and Sr anomalies, with positive Pb (Fig. 7b).

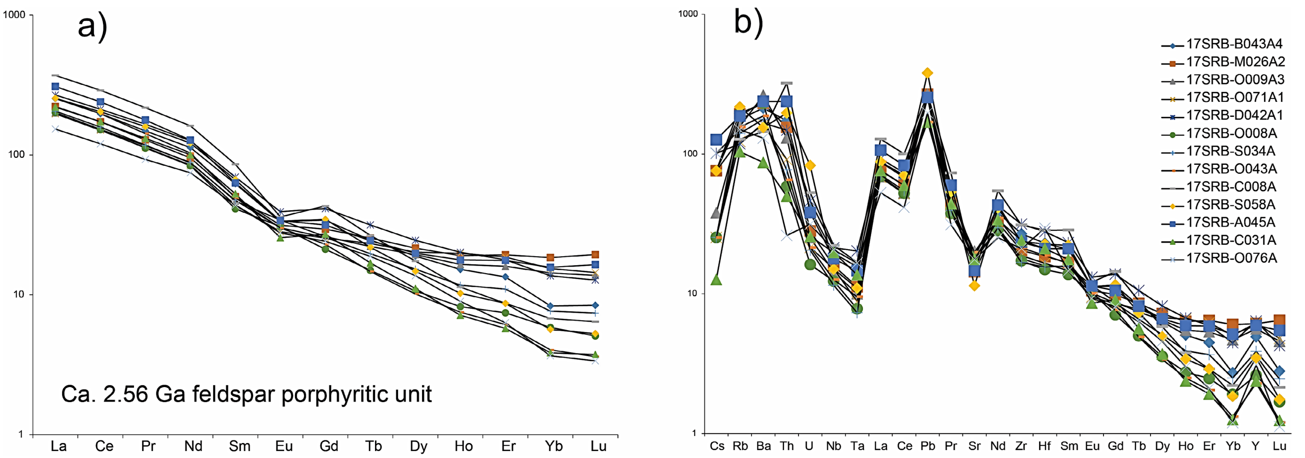

Figure 7: REE data for samples from the 2.56 Ga feldspar pophyroclastic garnet-bearing granodiorite. a) chondrite normalized values of McDonough and Sun (1995); b) primitive mantle normalized values of Sun and McDonough (1989).

Ca. 2.55-2.52 Ga TTG suite

Spatially associated with, and commonly structurally overlying the porphyroclastic unit is strongly foliated to gneissic, medium- to fine-grained, grey, biotite-magnetite tonalite-trondhjemite (map unit n**A**tn) locally associated with pink-white weathered granodiorite-monzogranite (map unit n**A**gd; Fig. 3c). At several localities across Boothia Peninsula and on western Somerset Island (i.e., Howe Harbour, Fig. 2) these rocks are dated at ca. 2.55-2.51 Ga (Sanborn-Barrie and Regis, in prep.) establishing a TTG suite that is slightly younger than the porphyroclastic basement unit described above. Granodiorite R177 (Fig. 3d) is undated but is geochemically similar to the dated TTG suite and suspected to be of similar age. The ca. 2.55-2.52 Ga TTG suite (Fig. 4) has between 64 and 70 wt.% SiO_2, typically between 1 and 4.46 wt.% K_2O (medium-K), between 2.09 and 3.89 wt.% Na_2O, and is generally metaluminous (AI<1.0; Fig. 6). REE contents are progressively depleted with LREE enrichment at 80 to 145 times chondrite to HREE at 8 to 30 times chondrite (Fig. 8), corresponding to La_N/Lu_N ratios typically between 10 and 34. Two tonalitic to granodioritic samples (M219 and D107, respect-

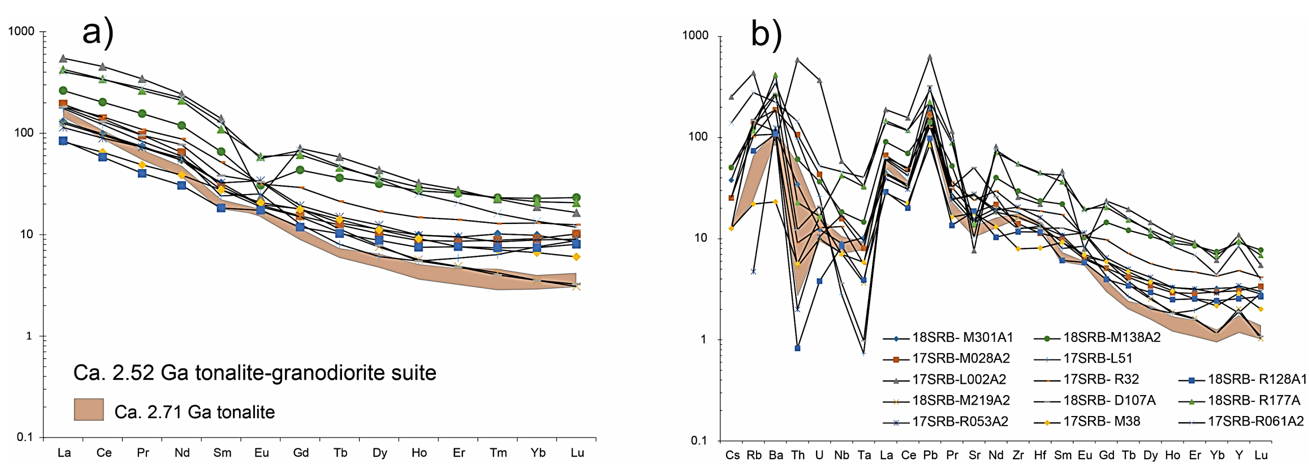

Figure 8: REE for 2.55-2.52 Ga tonalite-trondhjemite-granodiorite suite. a) chondrite normalized values of McDonough and Sun (1995); b) primitive mantle normalized values of Sun and McDonough (1989).

ively) are more fractionated with La_N/Lu_N ratios of 56 and 40, respectively. The HREE in the TTG suite is typically flat to concave up (dish-shaped) corresponding to Gd_N/Lu_N ratios of 1.5 to 5.7. They contain variable Eu contents resulting in both slight positive (Eu* between 1.26-1.44 for L51, D107a, R53a2) or negative (Eu* between 0.24-0.61 for M138, R177, L2) anomalies. Several samples (L51, D107a) are depleted (<1x chondrite) in Th and Ta (Fig. 8b). These rocks possess variable Sr contents resulting in Sr anomalies that are either strongly negative (e.g., R61, L2, R177, M138) or slightly (R128a, L51) to moderately positive (D107, R53). They all possess a moderately to strongly negative Nb-Ta anomaly.

Older enclaves and inclusions

The TTG suite locally contains mafic layers and inclusions (map unit **Adr**) composed of dark green-black hornblende-gabbro/amphibolite with lesser gabbroic anorthosite and anorthosite. These mafic enclaves are particularly abundant on northeastern Boothia Peninsula (Fig. 2). Although undated, these layers and inclusions are suspected to constitute an older mafic substrate into which the Neoarchean TTG suite intruded. Sm-Nd data (unpublished) and only very rare ca. 2.85 Ga xenocrystic zircon in dated Neoarchean rocks, suggest a ca. 2850 Ma substrate that is both mafic and juvenile. Three leucogabbroic to gabbroic anorthositic samples (M80, M143, M144: Appendix 1) from these enclaves contain between 47 and 48 wt.% SiO_2 (dark green filled circles in Fig. 11). They have relatively low REE abundances with LREE enriched values at 25 to 70 times chondrite to HREE values of 3 to 5 times chondrite (Fig. 9), corresponding to La_N/Lu_N ratios between 7 and 16. Their negative Zr anomaly supports/reflects the lack of zircon in these rocks.

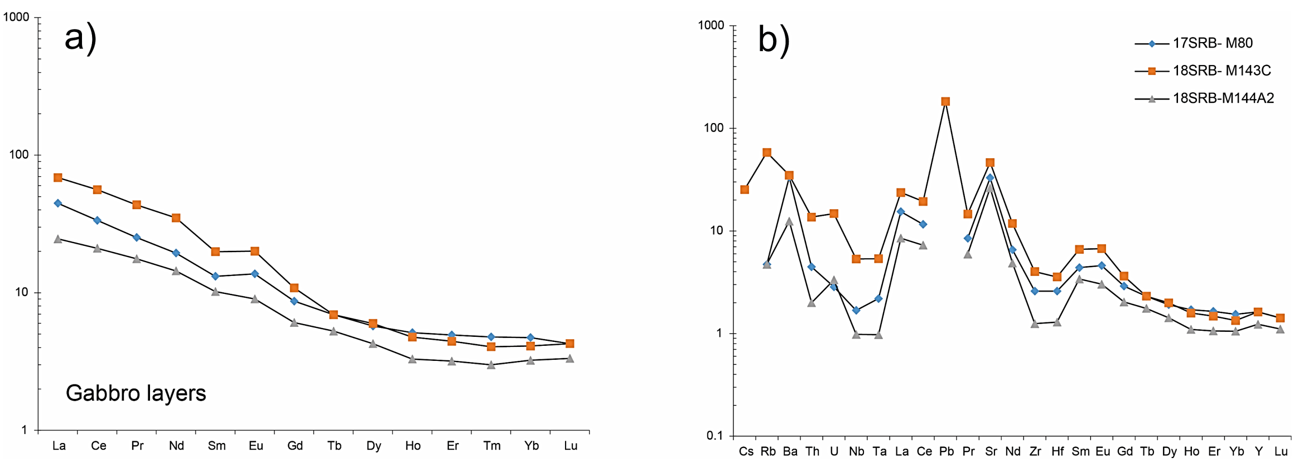

Figure 9: REE for dioritic to gabbroic anorthositic layers and inclusion within Neoarachean tonalite-trondhjemite-granodiorite suite. a) chondrite normalized values of McDonough and Sun (1995); b) primitive mantle normalized values of Sun and McDonough (1989).

Paleoproterozoic Plutonic Rocks

Ca. 2.49-2.48 Ga Intermediate to Mafic Plutonic Suite

Paleoproterozoic intermediate to mafic plutonic rocks (map unit **pPqd**) dominated by orthopyroxene-magnetite±clinopyroxene±hornblende quartz diorite (Fig. 10) ± diorite (Fig. 11) cut both the basement complex and oldest clastic rocks (sequence 1 of Regis and Sanborn-Barrie, 2023). Several samples of this intermediate to mafic suite were dated (U-Pb sensitive high-resolution ion microprobe (SHRIMP)) at various localities across Boothia Peninsula (i.e., 18SRB-R7 in Regis and Sanborn-Barrie, 2023) and all yielded consistent 2.48-2.49 Ga U-Pb zircon ages. Gabbro (map unit **p**Pgb) and anorthositic (i.e., 17SRB-M55A2, -M55B2 Appendix 1 not plotted) rocks (**p**P**an**) are locally associated with the dioritic rocks, with subtle transitional contact relationships consistent with co-genetic, contemporaneous crystallization.

Figure 10: Weathered surface of quartz diorite (17SRB-M54) with moderate foliation oriented 182/76°W. Photograph by M. Sanborn-Barrie. NRCan photo 2023-006

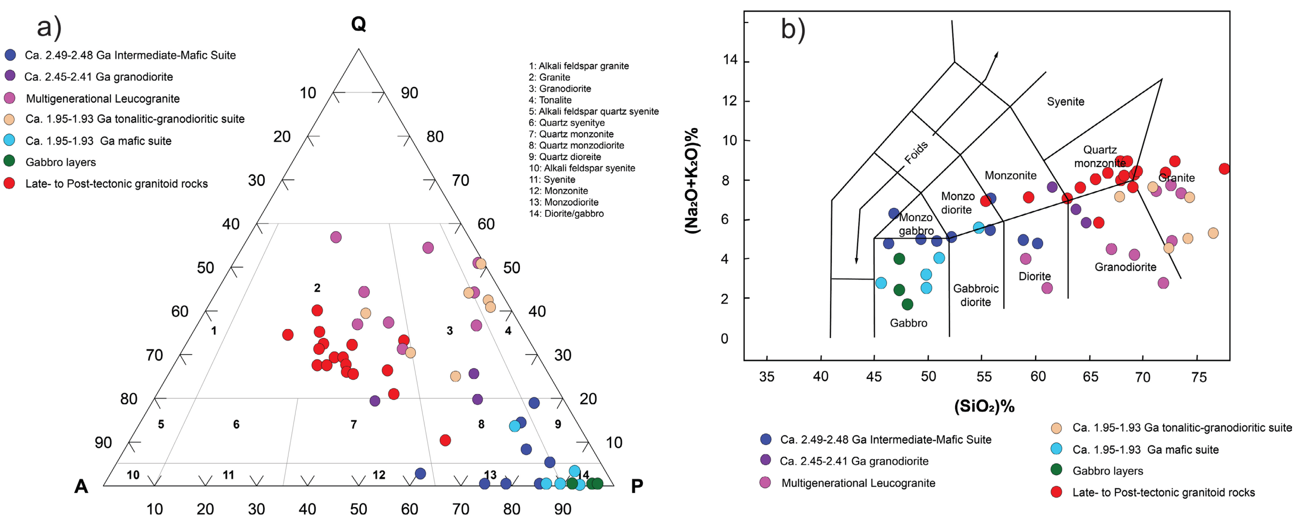

Figure 11: Major element character of Paleoproterozoic plutonic rocks (and undated, >2.5 Ga mafic layers – green filled circles) of Boothia Peninsula and Somerset Island. a) QAP ternary diagram; b) total alkali (Na_2O+K_2O) silica (TAS) diagram.

This opx ± cpx bearing suite of dioritic rocks contains between 46 and 60 wt.% SiO_2, 14.6 to 19.7 wt.% Al_2O_3, 0.6 to 4.08 wt.% K_2O (medium K) and 2.6 to 4.2 wt.% Na_2O. Most samples contain 0.6 to 1.7 wt.% TiO_2, although two samples (M141, R49a) have TiO_2 >2 wt.%. Mg numbers ($MgO/(MgO+FeO_{total})$) for the ca.

2.49-2.48 Ga suite are generally <0.75 (0.18 to 0.69), indicating they are not representative of mantle melts, but rather reflect significant fractionation and/or crustal assimilation. One exception is R136 with Mg number of 0.81.

Significant fractionation is reflected in the trace element contents of this group with LREE values at 105 to 140 times chondrite and HREE at 8 to 18 times chondrite (Fig. 12), corresponding to La_N/Lu_N ratios generally between 8 and 20 and Gd_N/Lu_N ratios averaging 2.6. Two samples show a higher degree of fractionation (R136 and M217) with La/Lu_N ratios of 32 and 47, respectively. Diorite M217 has the highest P_2O_5 contents (1.09 wt.%) such that its enrichment in LREE (and therefore steeper La/Lu) may reflect the presence of apatite (which generally has higher L/MREE). They all lack an europium anomaly (Fig. 12a), display a small negative Nb-Ta anomaly, contain a range of Th contents, and are elevated in the mobile element Ba (Fig. 12b).

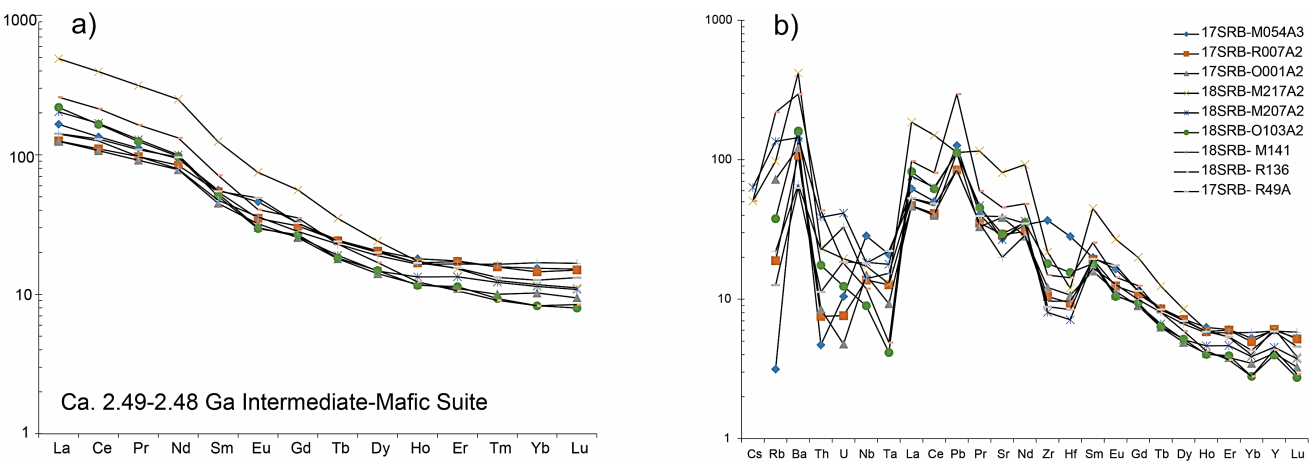

Figure 12: Trace element data for the 2.49-2.48 Ga mafic-intermediate suite. a) chondrite normalized values of McDonough and Sun (1995); b) primitive mantle normalized values of Sun and McDonough (1989).

This intermediate to mafic suite may correlate with the Queen Maud granitoid suite (Schultz et al. 2007) for which dated mafic rocks include amphibolite (NT-3) with an ID-TIMS U/Pb age of 2483±1.4 Ma, and amphibolite (ST-1) and mafic granulite (NT-8a) with LA-MC-ICPMS ages of 2475±15 Ma and ca. 2480 Ma, respectively (Schultz, 2007).

Ca. 2.45-2.41 Ga granodiorite

Minor granodiorite – quartz monzodiorite-monzonite (map unit **pPgr**) is spatially associated with the 2.48-2.49 Ga intermediate -mafic suite. Isotopic and textural information reveals that monzodiorite (M97; unit 3 granite of Blackadar, 1967) is ca. 2.44 Ga (unpublished LA-ICPMS U-Pb zircon data, Osinchuk 2021), and that granodiorite (M96) is >2.41-2.45 Ga (D. Regis unpublished data, 2023). Accordingly, these two granodioritic rocks and a geochemically similar, undated granodiorite (M77) appear to have crystallized during the early stage of the Arrowsmith orogeny. Their ca. 2.60 Ga Sm-Nd model ages suggest derivation by crustal melting of Neoarchean rocks. These 3 samples (purple-filled circles in Fig. 11) contain between 62 and 65 wt.% SiO_2, 15.7 to 16.5 wt.% Al_2O_3, 2.1 to 5.2 wt.% K_2O (medium K) and 2.4 to 4.0 wt.% Na_2O. They exhibit moderate fractionation with LREE values at 110 to 130 times chondrite and HREE at 10 times chondrite (Fig. 13) corresponding to La_N/Lu_N ratios of 30 (M96 and M77) and 14 (M97). M97 has a slight positive Eu anomaly, consistent with the presence of feldspar phenocrysts. Similarity in REE and high field strength element contents for these granodiorites and the Neoarchean TTG suite (*see* Fig. 8) is consistent with TTG basement as source rocks that were partially melted during early Arrowsmith metamorphism to generate ca. 2.45-2.41 Ga granodioritic-monzonite melts.

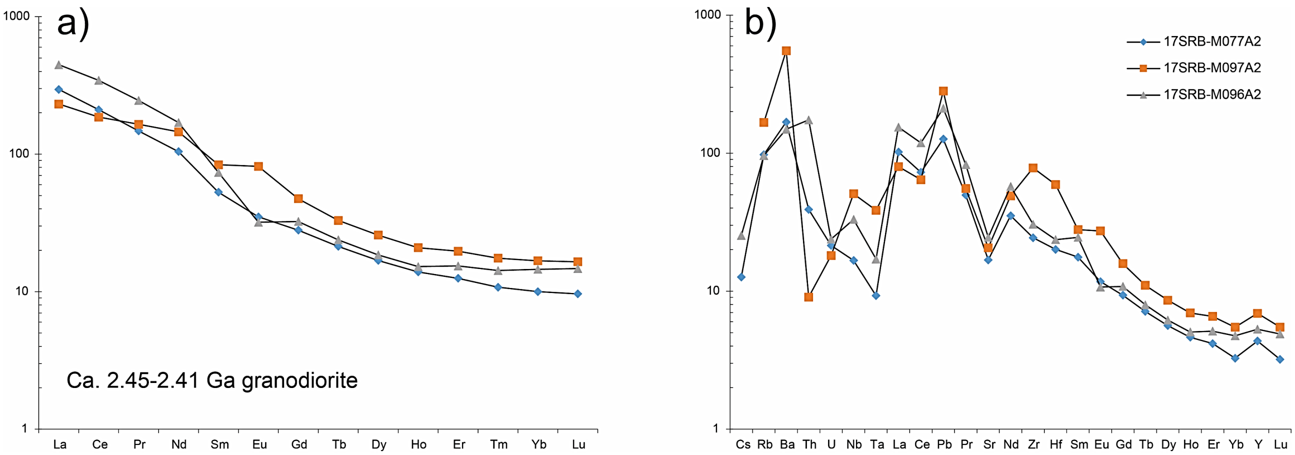

Figure 13: Trace element data for the ca. 2.4 Ga granodiorites generated at an early stage of the Arrowsmith orogeny. a) chondrite normalized values of McDonough and Sun (1995); b) primitive mantle normalized values of Sun and McDonough (1989).

Tectonized ca. 1.95-1.93 Ga Tonalitic-Diorite-Granodiorite suite

Buff-weathered orthopyroxene-bearing tonalite±diorite (map unit **pPtn**) occurs throughout northwestern Boothia Peninsula and along the length of western Somerset Island (Fig. 2). These rocks are commonly observed to cut a younger carbonate (marble ±calc-silicate rocks)-clastic succession (sequence 3 of Regis and Sanborn-Barrie, 2023), whose <1.97 Ga clastic portion contains a prominent mode of ca. 2.02-1.97 Ga "Thelon-arc age" detritus. Foliated to gneissic granodiorite (map unit **pPgd**) is commonly associated with this dioritic-tonalitic suite as interlayered injection gneiss layers (Fig. 14).

Figure 14: 1.95-1.93 Ga plutonic complex characterized by dioritic host cut by granodiorite. Photograph by M. Sanborn-Barrie. NRCan photo 2023-007

Mafic rocks belonging to the 1.95-1.93 Ga plutonic complex are gabbroic in composition (Fig. 11) and contain between 45 and 54 wt.% SiO_2, 14.9 to 17.3 wt.% Al_2O_3, and 0.6 to 1.6 wt.% K_2O. They show variation in Mg number ranging from 0.3 (T122, O135) to 0.85 (S100) and TiO_2 contents of 0.6 to 1.4 wt.% (Appendix 1). They exhibit only slight fractionation in their trace elements with LREE at 40 to 70 times chondrite and HREE enrichment at 6 to 13 times chondrite (Fig. 15), corresponding to La_N/Lu_N ratios between 2 and 10. They constitute the least fractionated suite of rocks in the region (except for post-tectonic dykes) with chemistry comparable to enriched mid-ocean ridge basalt (Fig. 15a). These mafic rocks lack a Eu anomaly, display moderate negative Zr, Hf, and Nb-Ta anomalies, and have prominent positive Pb (Fig. 15b).

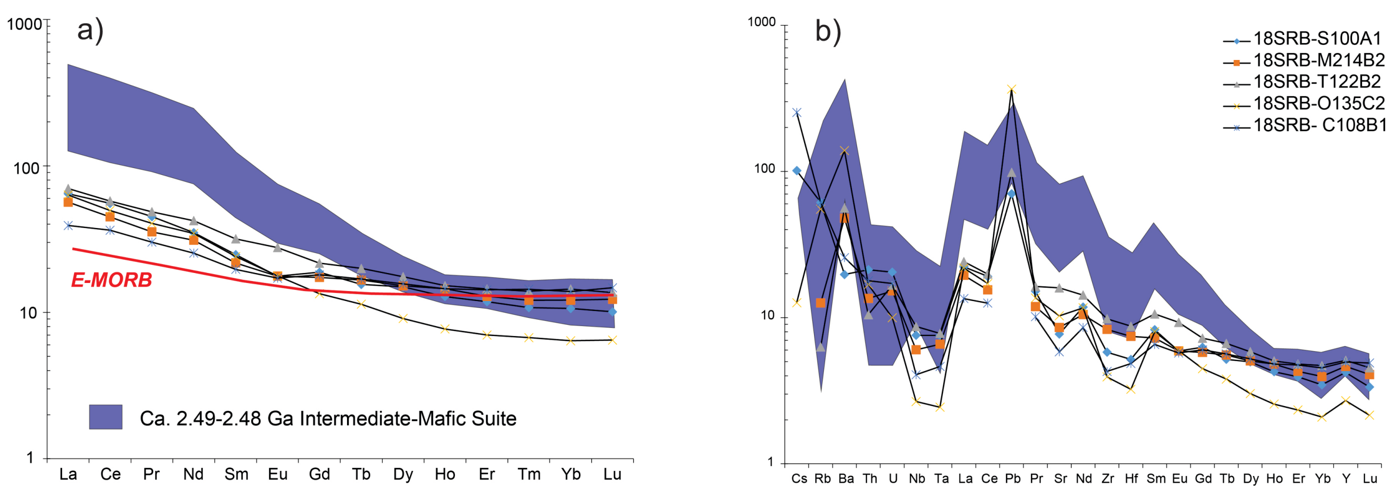

Figure 15: Trace element data for the ca. 1.95-1.93 Ga mafic plutonic suite that cuts sequence 3 metasedimentary rocks of northwestern Boothia Peninsula and along the length of Somerset Island. Field of 2.49-2.48 Ga dioritic suite (see Fig. 12) shown for comparison. a) chondrite normalized values of McDonough and Sun (1995) with average enriched - mid ocean ridge basalt (*E-MORB*) shown in red; b) primitive mantle normalized values of Sun and McDonough (1989).

Intermediate to felsic rocks of the 1.95-1.93 Ga plutonic complex are tonalitic to granitic in composition (Fig. 11) and contain between 67 and 77 wt.% SiO_2, 12.3 to 15.4 wt.% Al_2O_3, 2.4 to 4.6 wt.% Na_2O, and 0.6 to 4.6 wt.% K_2O. They typically have AI values of 0.96 to 1.05 reflecting a metaluminous to very weakly peraluminous character, with the exception of O133 (not plotted) whose AI value of 6.92 is a result of sodium depletion (0.18wt.% Na_2O; Appendix 1), likely due to hydrothermal alteration. Intermediate to felsic rocks of 1.95-1.93 Ga age have LREE at 22 to 108 times chondrite and HREE enrichment at generally only 1.5 to 3 times chondrite, with one sample (M201a2) depleted in the HREE (Fig. 16). La_N/Lu_N ratios range from 13 to 56, with the exception of M201a2 whose HREE depletion corresponds to a La_N/Lu_N ratio of 511. The intermediate to felsic samples are characterized by positive Eu anomalies (Fig. 16a), and moderately positive Zr-Hf anomalies, very prominent positive Pb, and strongly negative Nb-Ta anomalies (Fig. 16b).

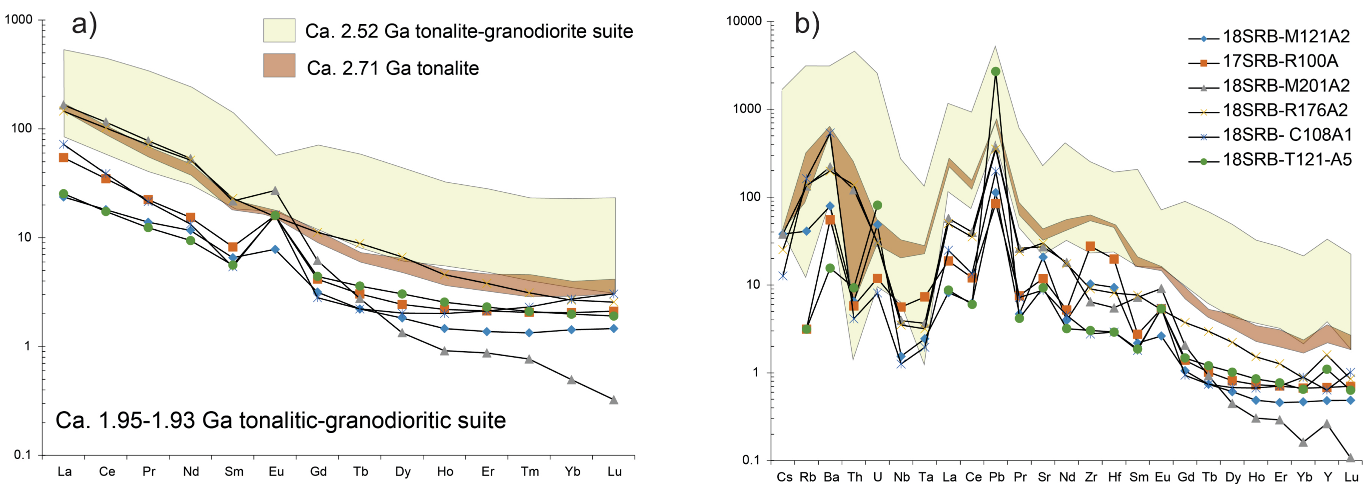

Figure 16: Trace element data for the ca. 1.95-1.93 Ga intermediate to felsic plutonic suite that typically cuts ca. 1.95-1.93 Ga dioritic rocks of northwestern Boothia Peninsula and along the length of Somerset Island. a) chondrite normalized values of McDonough and Sun (1995); b) primitive mantle normalized values of Sun and McDonough (1989).

Multigenerational Leucogranite

Peraluminous garnet±sillimanite±cordierite leucogranite with <5% paleosome (map unit **pPl-gr**), also known as homogeneous diatexite, commonly occurs as veins, dykes and sills. S-type leucogranites cut both the older clastic sequence and the youngest carbonate-clastic sequence (Regis and Sanborn-Barrie, 2023), and occur as discrete plutons (see Fig. 2). They are especially voluminous surrounding Lake Hansteen (R65 in Fig. 2, Fig. 17a) on southern Boothia, and surrounding Thom Bay (eastern Boothia Peninsula; Fig. 17b) where they host gossanous enclaves with elevated Au, Pt, Cr and Ni contents (Regis et al., 2019). On Somerset Island, these rocks cut sequence 3 metasedimentary rocks (Regis and Sanborn-Barrie, 2023) and the 1.95-1.93 Ga plutonic complex (Fig. 17c) and are also commonly gossanous (Fig. 17d). They appear, on the basis of low magnetic response, to underlie the poorly exposed central corridor of Somerset Island on which Stanwell-Fletcher Lake is located (Fig. 2). Leucogranite may display less strain than the rocks it cuts (i.e., Fig. 17c), suggesting emplacement during elevated geotherms, relatively late with respect to deformation.

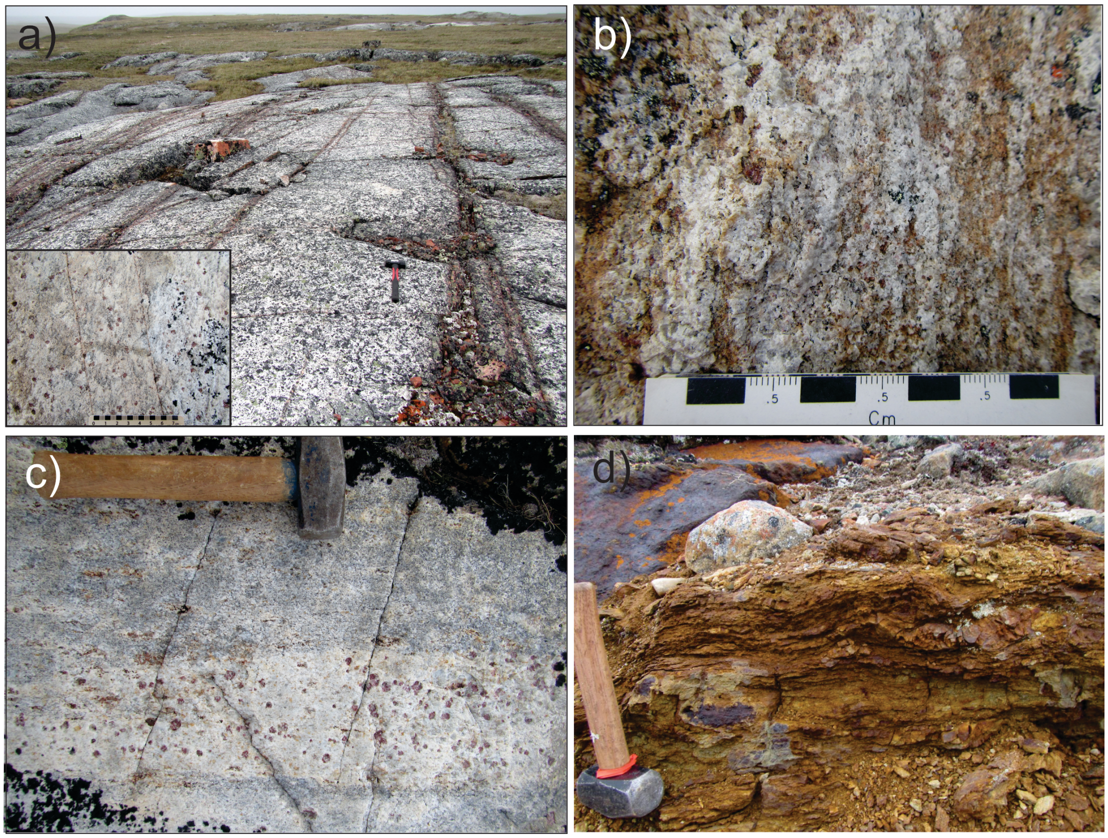

Figure 17: Multigenerational peraluminous (S-type) Grt-Sil leucogranite. a) southern Boothia Peninsula (locality 17SRB-R65). Photograph by D. Regis. NRCan photo 2023-008; inset shows close-up of weathered surface. Photograph by D. Regis. NRCan photo 2023-009 b) 4 km west of Thom Bay, SE Boothia Peninsula (locality 17SRB-M63). Photograph by M. Sanborn-Barrie. NRCan photo 2023-010; c) weakly foliated, garnet-porphyroblastic leucogranite vein, 10 cm wide, cutting foliated 1941.5±5.7 Ma monzogranite host rock (*see* Regis and Sanborn-Barrie 2023) on Creswell Bay, eastern Somerset Island (locality 18SRB-M202). Photograph by M. Sanborn-Barrie. NRCan photo 2023-011; d) gossanous, fissile leucogranite SW of Stanwell-Fletcher Lake, Somerset Island (locality 18SRB-T118). Photograph by T. Moum. NRCan photo 2023-012

The leucogranites typically contain between 67 and 73 wt.% SiO_2, with the exception of gossanous T118a2 (*see* Fig. 17c) with 58 wt.% SiO_2 and T119a2 with 61 wt.% SiO_2, samples that are on tectonic strike but separated by 47 km (Fig. 2). These garnet-bearing, locally sillimanite-bearing leucocratic rocks contain between 13 to 16 wt.% Al_2O_3 (except T118a2 with 20.01 wt.% Al_2O_3), 1.2 to 3.45 wt.% Na_2O, 0.2 to 5.0 wt.% K_2O (Appendix 1), and are strongly peraluminous with AI values of 1.1 – 3.

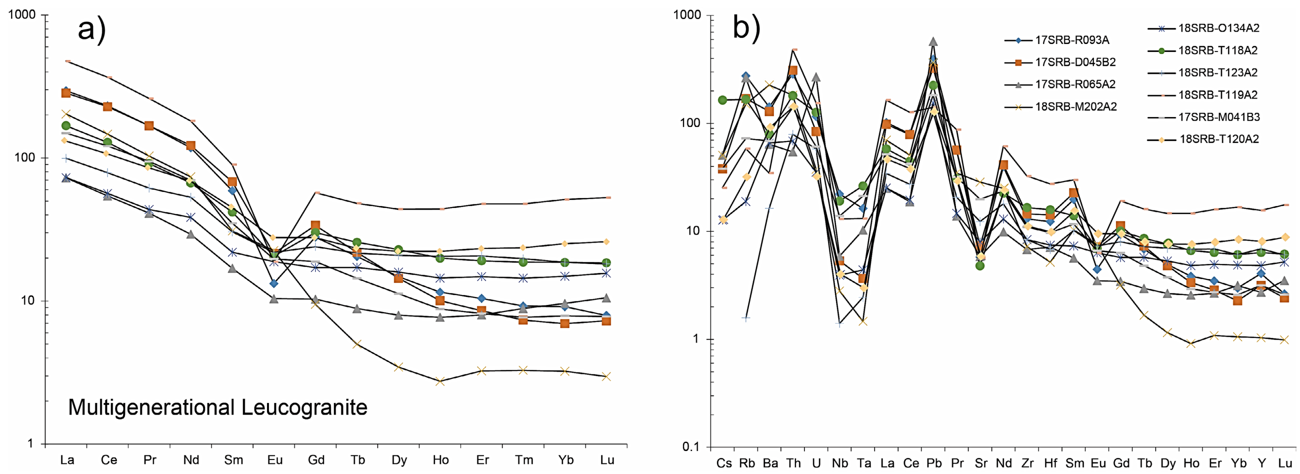

Figure 18: Trace element data for multigenerational leucogranites. a) chondrite normalized values of McDonough and Sun (1995); b) primitive mantle normalized values of Sun and McDonough (1989).

Leucogranite rocks are enriched in LREE (70 to 500 times chondrite) and, with the exception of M202 and T119, have HREE at 7 to 20 times chondrite, with La_N/Lu_N ratios typically between 4.6 and 39. Most samples have a significant to slight negative Eu anomaly (Fig. 18a) corresponding to Eu* values of 0.26 to 0.81 (Appendix 1). In contrast to the fractionation shown by LREE, the HREE are typically flat (note T119 is flat at 60x chondrite) with Gd_N/Lu_N ratios between 0.98 and 4.6. The trace element profile of M202a2 (Fig. 17c), which cuts granodiorite dated at 1.93 Ga (Regis and Sanborn-Barrie, 2023) differs from the other leucogranites analyzed, in that it shows most LREE enrichment (500 times chondrite), least HREE enrichment (3 times chondrite; Fig. 18), with a La_N/Lu_N ratio of 68 and no Eu anomaly (Eu* = 1.32).

Ca. 1.89-1.87 Ga Dykes

Magnetite-bearing, quartz-poor monzonitic rocks occurring as dykes (map unit **pPmnd**) and salmon-weathering aplitic dykes (code **pPgrd**) cut the porphyroclastic unit where it is transected by the Sanagak Lake shear zone. A sheared quartz monzonite dyke sampled for geochemical analysis, yielded a U-Pb age of 1894.4±3.1 Ma (Appendix 3). This quartz monzonite (B43b) contains 69.3 wt.% SiO_2, 13.78 wt.% Al_2O_3, 1.95 wt.% Na_2O and 6.33 wt.% K_2O (Appendix 1), with an AI value of 1.08. It is enriched in REE and strongly fractionated (La_N/Lu_N = 219; Gd_N/Lu_N = 9.2), with a significant negative Eu anomaly (Eu* = 0.22). A folded aplite dyke, for which there is no geochemical data, cuts the 1.89 Ga quartz monzonite dyke and yielded a U-Pb zircon age of 1866.0 ± 4.5 Ma (Appendix 3).

Ca. 1.84-1.82 Ga Late- to Post-tectonic Syenitic Granitoid Rocks

Weakly foliated to massive orthopyroxene alkali-feldspar granite (map unit **pPch**) and hornblende syenogranite (map unit **pPsy**) to monzogranite (map unit **pPsy**) underlie southernmost Boothia Peninsula (Fig. 2; red-filled circles in Fig. 11). These plutons were collectively designated the Boothia Ferroan Granite Complex by Osinchuk (2021) who completed a comprehensive isotopic and geochemical study of these dominantly ferroan (high Fe/Mg) potassic rocks. Lithogeochemical data for sixteen samples from the 1840-1820 Ma late- to post-tectonic Boothia Ferroan Granite Complex is contained in Appendix 1 and described in detail by Osinchuk (2021).

Meso- to Neoproterozoic Mafic Dykes

Gabbro (diabasic) dykes

Undeformed gabbroic (diabasic) dykes (Fig. 19a), 1-30 m wide, transect the region (not shown in Figure 2, *see* Sanborn-Barrie and Regis CGM map 2023). At least 2 swarms are recognized. SE-trending dykes are most common and are likely part of the ca. 1270 Ma Mackenzie swarm (LeCheminant and Heaman, 1989), which includes a sill in the Aston Bay area of northern Somerset Island (Fig. 2) for which paleomagnetic measurements and K-Ar data (Jones and Fahrig, 1978) establish linkage to the Mackenzie igneous event. Sample 18SRB-M128a2 is representative of this dyke swarm and displays relatively flat, slightly concave downwards REE pattern at 25x chondrite (Fig. 19b).

N-striking gabbroic anorthositic dykes (i.e., M191; Appendix 1) and E-striking gabbroic dykes (Fig. 19a), now recognized as belonging to the ca. 723 Ma Franklin swarm (Appendix 4), have more fractionated trends (Fig. 19b).

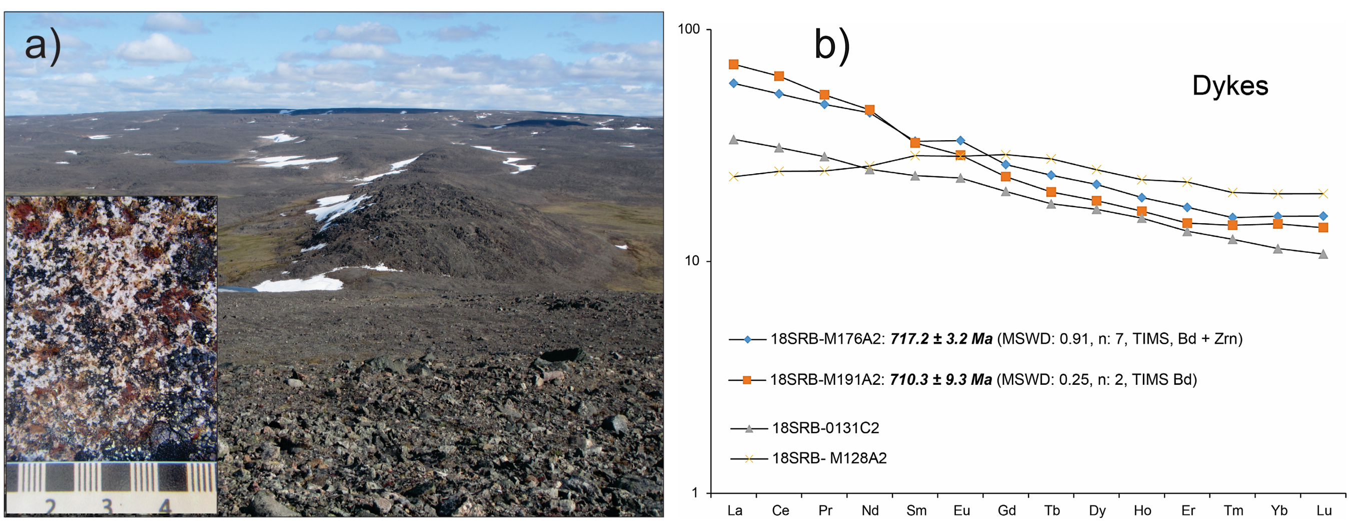

Figure 19: Meso- and Neoproterozoic mafic dykes. a) View to ENE of E-trending gabbroic dyke (locality 18SRB-M176) south of M'Clure Bay, northern Somerset Island. Photograph by M. Sanborn-Barrie. NRCan photo 2023-013; Inset is weathered surface showing equigranular, medium-grained cpx-opx-hb-plag. Photograph by M. Sanborn-Barrie. NRCan photo 2023-014; b) Trace element data for post-tectonic mafic (diabasic) dykes, two of which are dated (see also Appendix 4), chondrite normalized values of McDonough and Sun (1995). Bd: Baddeleyite, Zrn: Zircon.

Tectonometamorphism and Continuity of Lithological Units

The deformational history of Boothia Peninsula is polyphase with at least two, and typically three, penetrative deformation events reflected in most units, with the exception of late-to post-tectonic granitoid rocks (e.g., pPch, pPsy) that are typically weakly foliated to massive. In general, rocks across Boothia Peninsula display strongly developed, shallow to flat-lying fabrics. Lower strain 'windows' preserve folded layering with an axial planar S_1 foliation indicating that the prominent shallow tectonic fabric observed throughout much of the map area is a composite S_1+S_2 transposition foliation.

F_2 folds and fabrics are refolded by upright F_3 folds, creating dome and basin (Type-2) and mushroom geometry (Type-3) interference patterns of 10-20 km scale. N-trending D3 structures are prevelant along the length of Somerset Island. On southern Boothia Peninsula, folds and fabrics are sinistrally deflected by a regional southwest-striking, moderately northwest-dipping shear zone (Sanborn-Barrie et al., 2018; Drayson et al., 2022) that extends at least 160 km (red symbols in Fig. 2), with apparent offset of ~30 km. This structure is marked by a number of northeast-trending linear lakes disposed along it including Sanagak Lake, such that it is designated the Sanagak Lake shear zone.

Relevant to interpretation of the lithogeochemical character of these rocks, the Boothia-Somerset region has been subject to multiple metamorphic events including two regional events and local contact thermal metamorphism. Regional granulite-facies assemblages include monazite and metamorphic zircon dated at 2.45 and 2.39 Ga (Regis unpublished data 2020), and attributed to the Arrowsmith Orogeny (Berman et al., 2013). Subsequent granulite-facies metamorphism, recognized at ca. 1920 Ma (Frisch and Hunt, 1993) to have attained conditions of 740-850°C and 6-8 kbar, locally up to 960°C and 8.7 kbar (Kitsul et al., 2000), are now distinguished as two stages of Thelon orogenesis at ca. 1.93 and 1.91 Ga (Regis, unpublished data, 2020). U-Pb titanite ages of ca. 1.87 Ga across the region were interpreted to reflect cooling through ~600°C (U-Pb titanite closure) by Frisch and Hunt (1993), but associated high-temperature assemblages, zircon and monazite recrystallization (Regis, unpublished data, 2020) point to re-heating at this time. The complex deformational and metamorphic history of the Boothia-Somerset region is consistent with a complex compressional and extensional evolution that likely evolved from Neoarchean compressional arc environment (Fig. 20a), through an extensional stage at 2.49-2.48 Ga (Fig. 20b) to a potential back-arc setting at 1.95-1.93 Ga related to the Thelon orogeny.

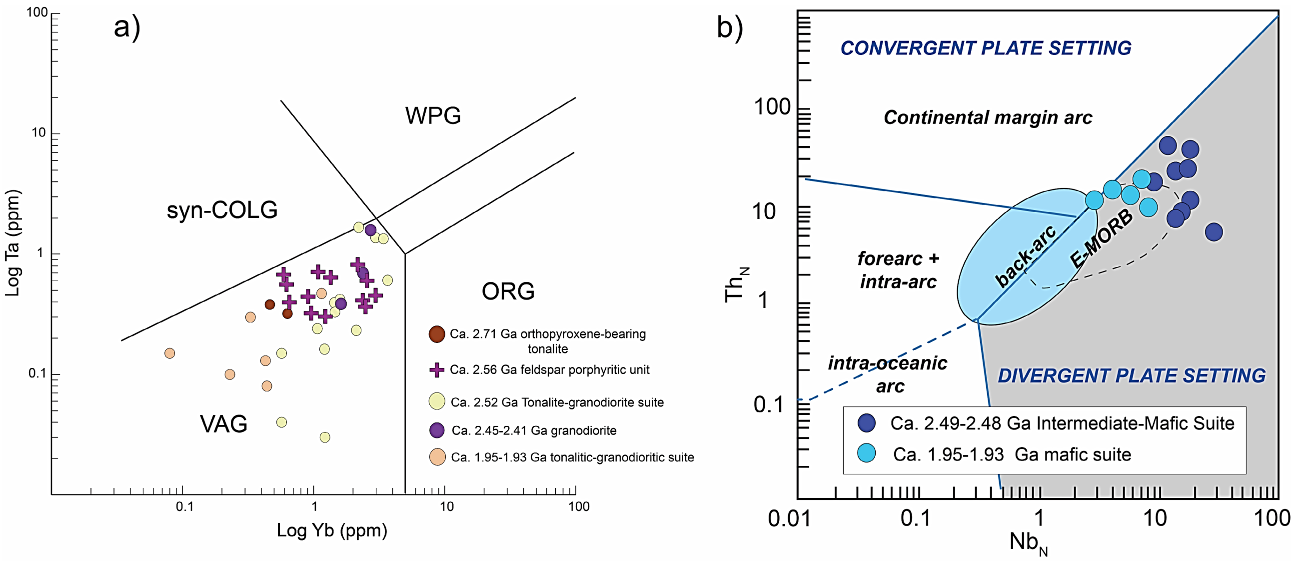

Figure 20: Tectonic setting discrimination diagrams for the plutonic rocks on Boothia Peninsula and Somerset Island. a) Neoarchean and Paleoproterozoic felsic units plotted on the Ta-Yb tectonic discrimination diagram of Pearce et al. (1984); WPG: within plate granite, syn-COLG: syn-collisional granite, VAG: volcanic-arc granite, ORG: ocean ridge-type granite; b) Paleoproterozoic mafic units plotted on the Th_N-Nb_N tectonic discrimination diagram of Saccani (2015).

Mineral Prospectivity

Boothia Peninsula contains numerous scattered sulphide occurrences associated with clastic supracrustal sequences and their melted derivatives. Whereas an earlier report for this area stated "On closer examination, superficially exciting gossan zones proved to be devoid of any significant metallic minerals and are seen to be the result of weathering of garnet-graphite-biotite-quartz feldspar schists and gneisses" (Blackadar 1967, p. 14), many of the gossans sampled yielded anomalous polymetallic mineral values (Regis et al., 2019) which, while generally modest, demonstrate some economic mineral potential for base-metals across the region. More than half of the samples collected for mineral assay in 2017 and 2018 returned polymetallic anomalous values for copper, nickel, chromium, cobalt, molybdenum, sulfur, gold, and palladium (Regis et al., 2019). Results indicate that metasedimentary rocks of clastic sequence 1 and upper sequence 3 (Regis and Sanborn-Barrie, 2023) host gossans that signal base- and precious metal prospectivity. High-grade regional metamorphism of the region, possibly linked to a back-arc setting, may have played an important role in base-metal distribution, by driving remobilization and secondary re-concentration of sulphides.

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