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ISLAND HARBOUR BAY PLUTONIC SUITE, LABRADOR

A.M. Hinchey, J.P. Butler and S. Serna-Ortiz[1]
Regional Geology Section
[1]Department of Earth Sciences, Memorial University of Newfoundland, St. John's, NL, A1B 3X5

ABSTRACT

Research this past summer (2021) represented the initiation of fieldwork for the Geological Survey of Canada–Geological Survey of Newfoundland and Labrador–Nunatsiavut collaborative project aimed at upgrading the geoscientific knowledge of, and stimulating mineral exploration in, the Saglek to Makkovik region of Labrador. This project is supported by the GeoNorth program at Natural Resources, Canada, and the Geological Survey of Newfoundland and Labrador. The objectives of the GeoNorth program are to assist in completing surveys of regional-scale geological maps across Canada's north, and to enhance the geological knowledge of key areas of the Canadian Shield. The GeoNorth project addresses the latter objective by targeting specific areas in the Nain and Makkovik provinces.

*This study is of the Paleoproterozoic Island Harbour Bay Plutonic Suite, which intrudes the reworked margin on the Archean North Atlantic Craton (Nain Province). This intrusive suite is composed of dominantly granodiorite and lesser granite (*ss*). The intrusions are variably foliated as a result of syn-kinematic to post-kinematic emplacement under amphibolite-facies conditions. This project aims to resolve many outstanding questions as to the nature, timing and tectonic history of the Island Harbour Bay plutonic suite by examining its geochronology, magmatic history, geochemistry, as well as its mineral potential.*

INTRODUCTION

Targeted areas in the Nain and Makkovik provinces are the focus of a joint Geological Survey of Canada–Geological Survey of Newfoundland and Labrador–Nunatsiavut project. The study region is tectonically complex, located at the junction of four tectonic domains bounded by Archean to Paleoproterozoic orogens (Figure 1). These domains include the 3.3–2.8 Ga Hopedale Block, the 4.0–3.2 Ga Saglek Block, the 2.8–2.3 Ga Core Zone and the 1.88–1.74 Ga Makkovik Province (James *et al.*, 2002; Wardle *et al.*, 2002; Ketchum *et al.*, 2002; Corrigan *et al.*, 2018; Hinchey *et al.*, 2020). Part of the current project includes the acquisition of new aeromagnetic maps for the Makkovik Province, the results of which are expected to be published in the fall of 2022.

In Labrador, the Archean Hopedale and Saglek blocks form the Nain Province and are part of the larger North Atlantic Craton (NAC), which extends through Greenland to northwest Scotland (Connelly and Ryan, 1996). These two major Archean crustal fragments are inferred to have been juxtaposed in the late Archean (Wasteneys *et al.*, 1996; James *et al.*, 2002) along a poorly defined, north-northeast-trending high-strain zone. The Makkovik Province formed during the assembly of the supercontinent Nuna, also known as Columbia (Hinchey, 2021a). Part of this crustal assembly is recorded in the Makkovik orogeny, which reworked the southern margin of the NAC together with accreted juvenile terranes, during a period of protracted collision, broadly coeval with the Ketilidian orogeny in southern Greenland (Bagas *et al.*, 2020; Hinchey, 2021b, d). The southern margin of the NAC was a passive continental margin at *ca.* 2.24–2.13 Ga, and later became the locus of subduction, arc-magmatism and juvenile crustal accretion between *ca.* 1.90 and 1.79 Ga (Kerr *et al.*, 1996; Ketchum *et al.,* 2002; Hinchey *et al.*, 2020).

Subduction beneath the southern margin of the NAC led to emplacement of the voluminous, calc-alkaline Island Harbour Bay Plutonic Suite (IHBPS) between 1895 and 1870 Ma (Culshaw *et al.*, 2000; Barr *et al.*, 2001, 2007). Fieldwork included several visits to the IHBPS, to further refine its age, tectonic affinity, and mineral potentional. The focus of this report is field observations and sampling methodology during the summer of 2021. Additional litho-geochemistry, thin-section analysis, isotopic analysis and U–Pb geochronological studies will be conducted during 2022, to complement this initial report. These additional data will enhance our understanding of the complex,

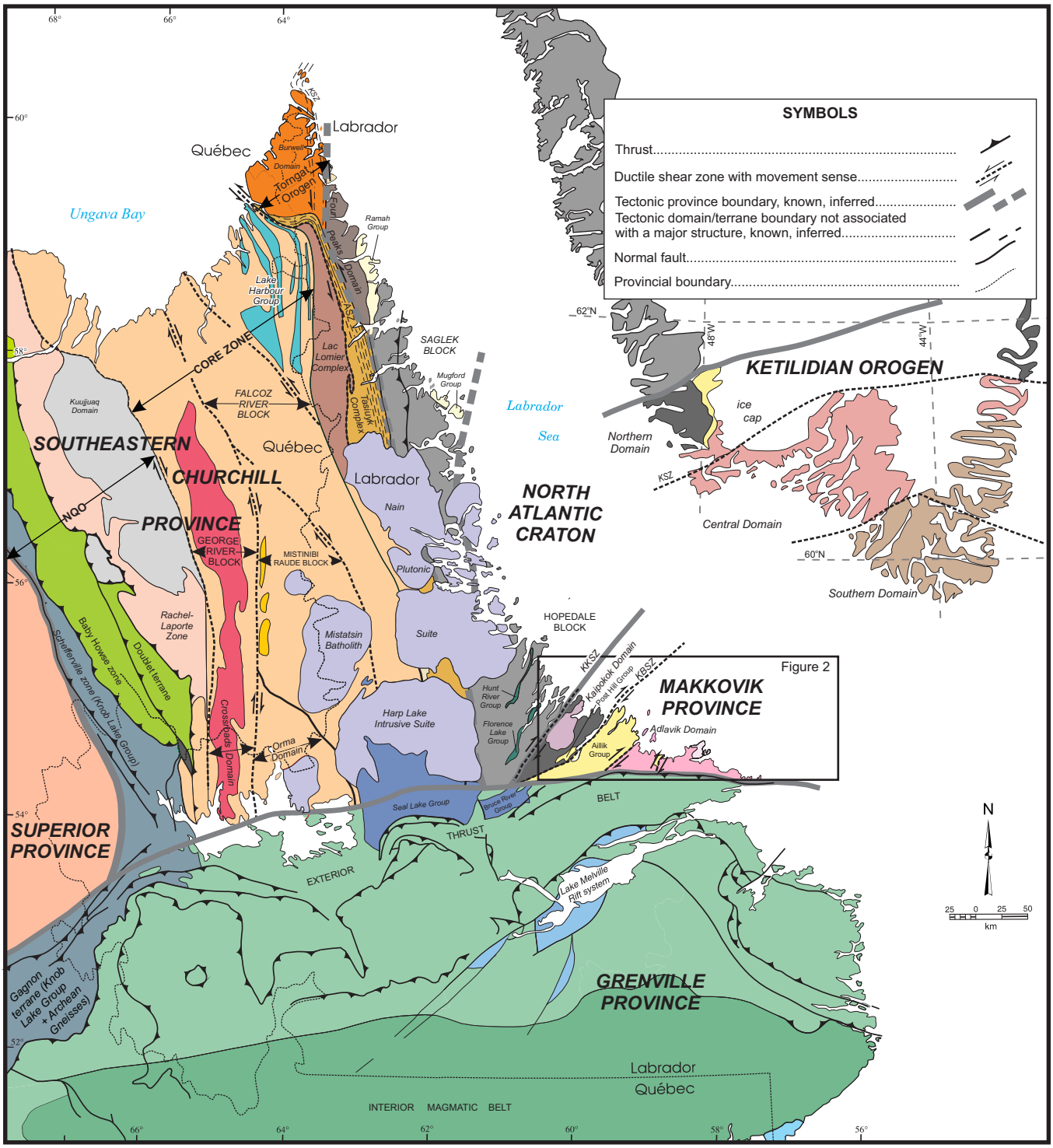


Figure 1. *The Makkovik Province and Ketilidian Orogen in a restored configuration (prior to complete Mesozoic opening of the Labrador Sea). Modified after Hinchey* et al. *(2020), Bagas* et al. *(2020), Ketchum* et al. *(2002), St-Onge* et al. *(2009) and Corrigan* et al. *(2021). KSZ = Kobberminebugt Shear Zone; KBSZ = Kaipokok Bay Shear Zone; KKSZ = Kanairiktok Shear Zone; ASZ = Abloviak Shear Zone; NQO = New Québec Orogen.*

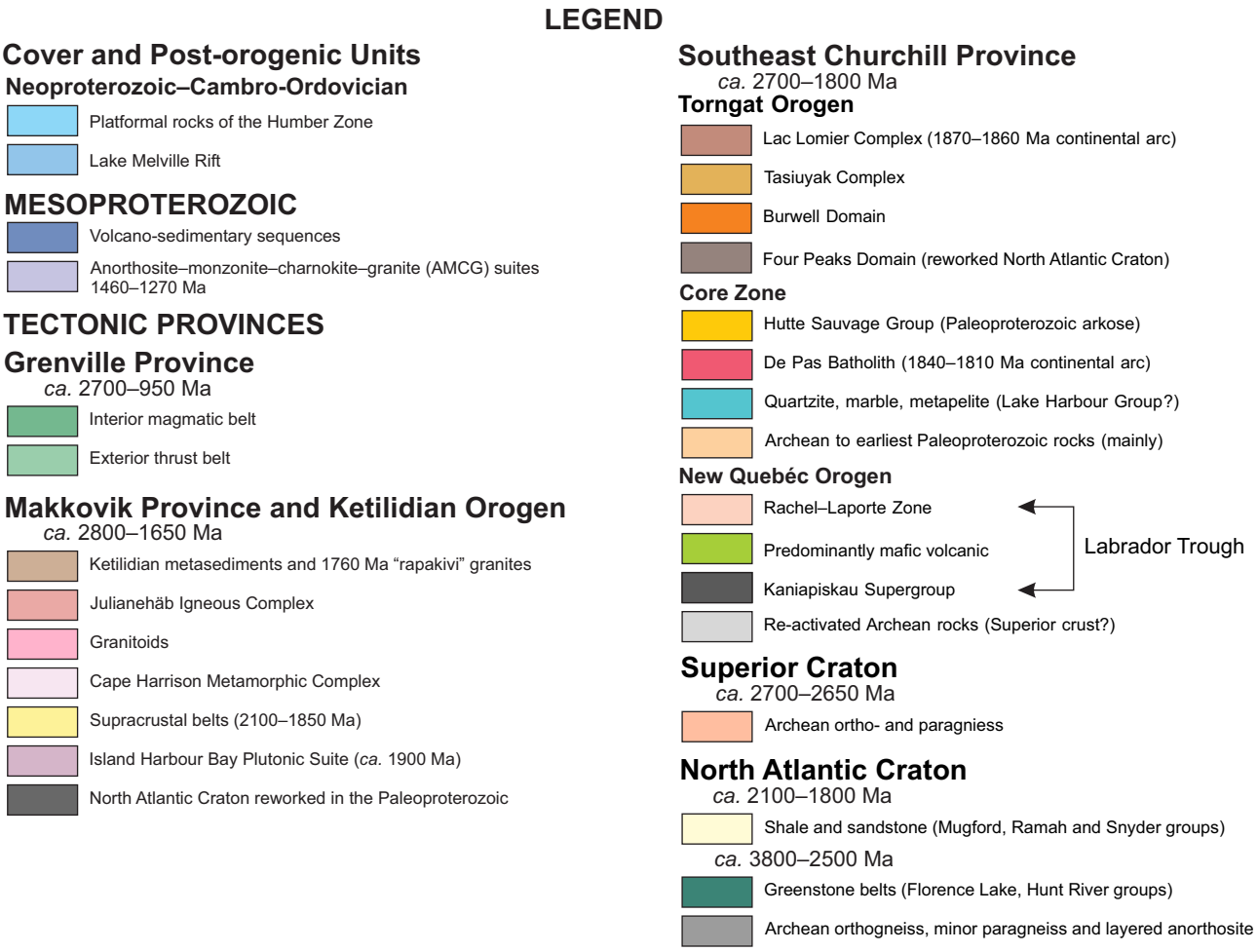


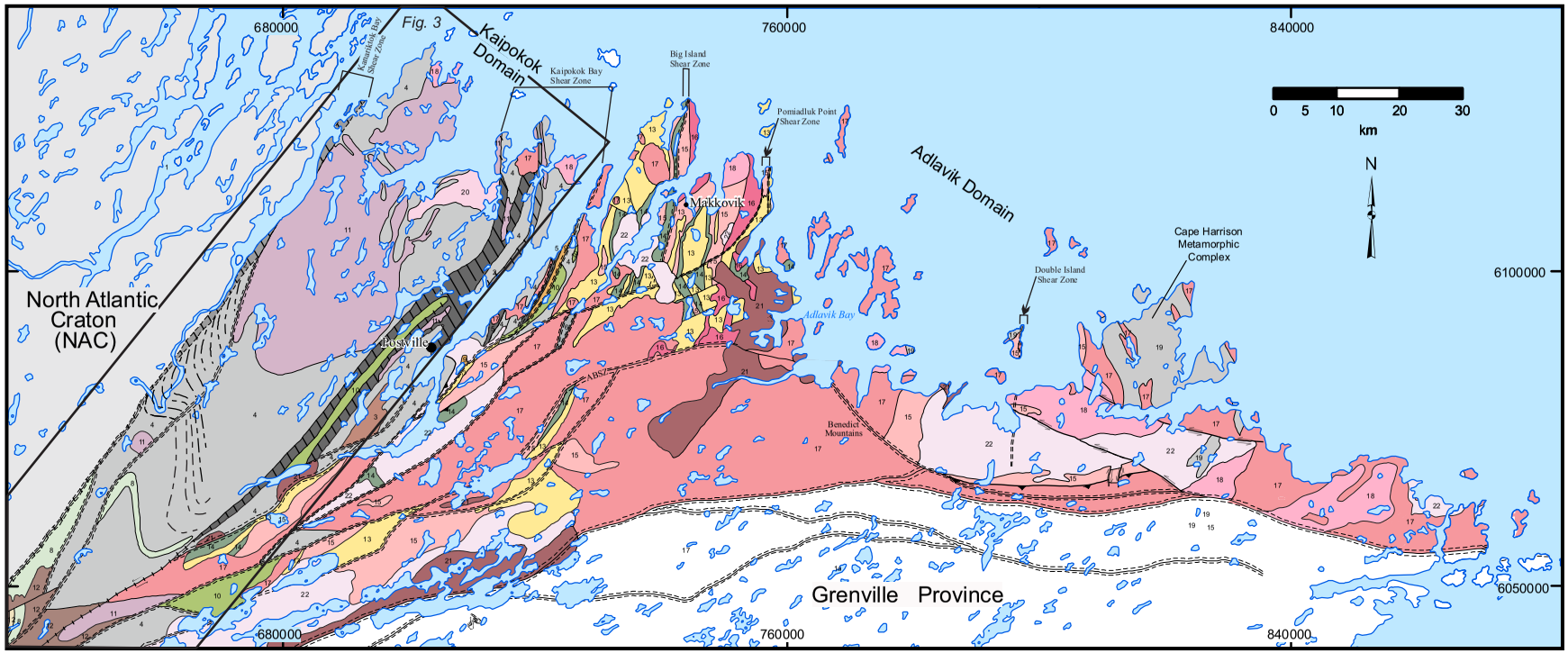
Figure 1. *Legend.*

diachronous assembly of the Makkovik Province having important implications on supercontinent assembly and metallogenic tenor of the region.

REGIONAL GEOLOGY

During the Makkovikian Orogen, juvenile terranes accreted to the NAC through protracted collisional events along this active margin (Hinchey, 2021b), contemporaneous with the Ketilidian Orogen of southern Greenland (Figure 1). The southern margin of the NAC was a passive continental margin from *ca.* 2240 to 2130 Ma (Ketchum *et al.*, 2001b) and there is a lack of preserved rock record until the rifted related volcanism at 2178 Ma documented in the Post Hill amphibolite (Ketchum *et al.*, 2002). Following this, a drift phase dominated until *ca.* 2000 Ma; although, there is little evidence of the >165 Ma drift phase in the rock record (Ketchum *et al.*, 2002). Sometime after 2013 Ma, a Paleoproterozoic passive margin developed (Culshaw *et al.*, 2000b; Ketchum *et al.*, 2002), during which, foredeep psammite and semipelite of the Post Hill and Moran Lake groups were inferred to be deposited on NAC's margin. Subsequently, the region became the locus of subduction, arc-magmatism, and juvenile crustal accretion in an overall transpressional setting between *ca.* 1900 and 1790 Ma (Ketchum *et al.*, 2002; Hinchey *et al.*, 2020; Hinchey, 2021a, b).

Traditionally, the Makkovik Province has been divided into three domains, from northwest to southeast, the Kaipokok, Aillik and Cape Harrison domains (Kerr *et al.*, 1996). However, recent bedrock mapping, in combination with geochronological, petrological, lithogeochemical and isotopic data (Hinchey, 2021b, c) indicate that the boundary between the Aillik and Cape Harrison domains is likely arbitrary and that the domains should be merged. Hinchey (*op. cit.*) recommended that the Makkovik Province should maintain the division of the Kaipokok Domain, which correlates with the Northern Domain of the Ketilidian Orogen (Bagas *et al.*, 2020). The Aillik and Cape Harrison domains are now considered as one domain, the Adlavik Domain (Figure 2).



LEGEND

PALEOPROTEROZOIC

Stathenian (P_4 *ca.* 1800–1600 Ma)

Late Intrusions (P_4 *ca.* 1650–1635 Ma)

- 22 Granitic suites
- 21 Gabbroic suites

Mid Intrusions (P_4 *ca.* 1720 Ma)

- 20 Granitic suites

Orosirian (P_3 ca. 2150–1800 Ma)

Late Metamorphic Complexes (*ca.* 1810 Ma)

- 19 Cape Harrison Metamorphic Complex

Late Intrusions (*ca.* 1810–1780 Ma)

- 18 Unfoliated granitic suites
- 17 Foliated granitic suites

Mid Intrusions (*ca.* 1885–1840 Ma)

- 16 Synvolcanic porphyries (MPGS)

Mid Supracrustals (*ca.* 1883–1848 Ma)

Aillik Group

- 15 Felsic volcanic rocks (rhyolite + felsic tuff)
- 14 Mafic volcanic rocks (basalt, minor mafic tuff)
- 13 Clastic sedimentary rocks

Unknown Group

- 12 Haggart Lake Formation (*ca.* 1850 Ma) (Previously part of the Bruce River Group)

Early Intrusions (*ca.* 1890–1870 Ma)

- 11 Island Harbour Bay Plutonic Suite

Early Supracrustals (PHG *ca.* <2013 Ma)

Post Hill Group (PHG)

- 10 Metabasalt rocks
- 9 Psammitic to pelitic rocks

Moran Lake Group (age uncertain, assumed coeval with the PHG)

- 8 Basalt
- 7 Metamorphosed sedimentary rocks (shale + sandstone)

ARCHEAN

Paleoarchean (*ca.* 3800–3200 Ma) reworked in the Paleoproterozoic

Kaipokok Domain

- 6 Affinity unknown
- 5 Mylonitic + migmatitic orthogneiss (deformed (deformed *ca.* 1870–1780 Ma)
- 4 Reworked North Atlantic Craton (deformed *ca.* 1900–1870 Ma)
- 3 Banded amphibolite, reworked North Atlantic Craton
- 2 Mylonitic North Atlantic Craton (shear zone re-activated *ca.* 1900–1870 + *ca.* 1870–1780 Ma)
- 1 Orthogneiss (minor amphibolite + paragneiss of North Atlantic Craton)

SYMBOLS

- Geological contact
- Geophysical lineament
- Limit of mapping
- Shear zone > 1 km wide
- Dextral shear zone <1 km wide
- Sinistral shear zone <1 km wide
- Shear zone (sense unknown) <1 km wide
- Dextral fault
- Sinistral fault
- Thrust fault

Figure 2. *Principal lithological and lithotectonic units of the Makkovik Province based on a 1:250 000 compilation map (modified from Hinchey, 2021a).*

The Kaipokok Domain comprises: a) reworked, *ca.* 3300–2830 Ma Archean gneiss of the NAC (Ermanovics, 1993); b) Paleoproterozoic metavolcanic and metasedimentary supracrustal sequences (2178–~2000 Ma Post Hill and >1850 Ma Moran Lake groups); and, c) Paleoproterozoic (1895–1870 Ma IHBPS), and various (*ca.* 1800 and *ca.* 1720 Ma) granitoid intrusions (Kerr *et al.*, 1996; Ketchum *et al.*, 2001a; Barr *et al.*, 2007). The Kaipokok Domain is interpreted as a relict passive margin and the foreland basin of the Makkovik Province (Kerr *et al.*, 1996; Ketchum *et al.*, 2002). Multiple high-strain shear zones mark the boundary between the Kaipokok and Adlavik domains, and collectively comprise the Kaipokok Bay Shear Zone (Culshaw *et al.*, 2000; Ketchum *et al.*, 2002).

The Adlavik Domain preserves Paleoproterozoic metasedimentary and metavolcanic sequences (1883–1848 Ma Aillik Group), Paleoproterozoic intrusive suites (various suites of *ca.* 1800, *ca.* 1720 and *ca.* 1650–1640 Ma), and a package of polydeformed orthogneiss (1815–1800 Ma Cape Harrison Metamorphic Complex; Figure 2; Hinchey *et al.*, 2020). The Adlavik Domain is interpreted to represent a rifted, composite arc/back-arc (Hinchey, 2021a, b, c). Historically, only two major shear zones were interpreted to have accommodated strain within the Adlavik Domain, namely the Big Island Shear Zone and the Pomiadluk Point shear zone (Figure 2). However, mapping during the 2021 field season recognized an additional shear zone to the east of the Benedict Mountains, on Double Island. This shear zone likely accommodated thrusting during the final compressional events of the Makkovik Province and is herein termed the Dog Island shear zone.

ISLAND HARBOUR BAYPLUTONIC SUITE

Regional bedrock mapping in the late 1970s to early 1980s produced the most recent geological maps of the region (Ryan, 1982; Ryan *et al.*, 1983a; Figure 3). Much of the subsequent research on the IHBPS is from Barr *et al.* (2001), which focused on the well-exposed coastal section from the Hares Islands area around the shoreline of Island Harbour Bay to Drunken Harbour Point (Figure 4). There has been limited systematic lithogeochemical, isotopic, or geochronological research on the aerially expansive suite outside of this study area. Much of what is reported here combines the early work of Ryan *et al.* (1983a) and Barr *et al.* (2001), with field observations from the 2021 field season.

LITHOLOGIES

The IHBPS is a polyphase, granitic body that intrudes the reworked Archean NAC in the Kaipokok Domain. The intrusions are variably foliated, and structural analysis indicates that the dominant fabric in the suite is an amphibolite-facies, solid-state, S>L foliation interpreted to have developed during emplacement of the IHBPS in a dextral transpressive regime (Culshaw *et al.*, 2000). The intrusive contact of the pluton(s) is marked by a zone of intermingled migmatitic orthogneiss of the Hopedale Block with varying amounts (15–50%) of IHBPS granitoids. This zone is illustrated on Figure 3 as the boarder zone (Unit 11). Ryan *et al.* (1983b) divided the intrusion into two main components: a) a predominately grey, biotite granodiorite; and, b) a pink, biotite granite. The granodiorite phase was interpreted as the main component of the intrusion and could be further subdivided into eight phases, which are often intermingled at the outcrop scale.

The granodiorite phase varies from equigranular to porphyritic and ranges in composition from diorite to granite. Igneous layering is preserved locally, as are abundant rafts of country rock. Based on detailed mapping along the coastline, Ryan *et al.* (1983b) distinguished eight phases: a) diorite; b) hornblende, appinite and diorite; c) fine-grained, dark-grey, quartz diorite and tonalite; d) medium-grained, non-porphyritic, dark-grey quartz diorite to granodiorite; e) coarse, grey, layered granodiorite/granite locally characterized by pink microcline phenocrysts; f) medium- to coarse-grained granodiorite with rare Kfs phenocrysts; g) homogenous, pink Kfs phenocryst-rich granodiorite; and, h) banded leucocratic dykes.

Along the coast of Island Harbour Bay, Barr *et al.* (2001) divided the IHBPS into 6 distinct plutonic phases (Figure 4). These include: a) *ca.* 1886 Ma Antons Island quartz diorite–monzodiorite; b) Northwest Bight granodiorite–tonalite; c) *ca.* 1880 Ma Abels Harbour granite; d) porphyritic biotite granite dykes; e) Groovy Island granodiorite; and, f) Philips Point granite–granodiorite. In addition to the mapped plutons, a range of dioritic to granodioritic dykes and sills intrude gneissic screens within the IHBPS and in the host gneiss of the Hopedale Block (Barr *et al.*, 2001). There are also enclaves of diorite, hornblendite and hornblende–pyroxene gabbro that can preserve very coarse-grained (pegmatoid) textures, dominated by amphibole (Ryan *et al.*, 1983b).

AGE CONSTRAINTS

The timing of emplacement of the IHBPS is based on three U–Pb ages from coastal outcrops, which constrain the intrusion to between 1895 and 1870 Ma (Barr *et al.*, 2001). These U–Pb zircon dates include: a) an 1886 +5/-3 Ma sample from the Antons Island quartz diorite–monzodiorite; b) a 1880 ± 2 Ma sample from the Abels Harbour granite; and, c)

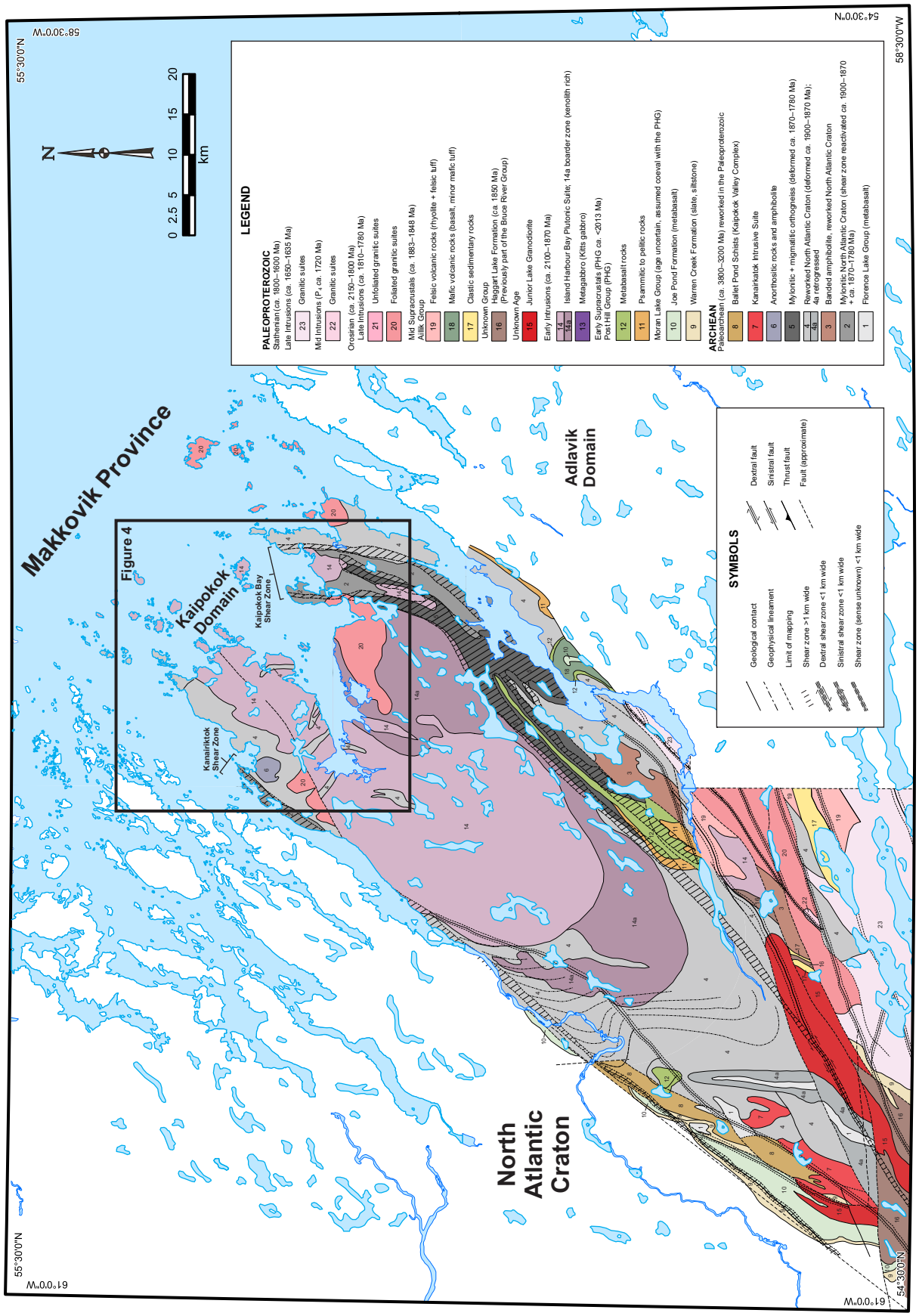


Figure 3. *Compilation of the geology of the Kaipokok Bay based on 1:50 000 mapping by Ryan (1982, 1983).*

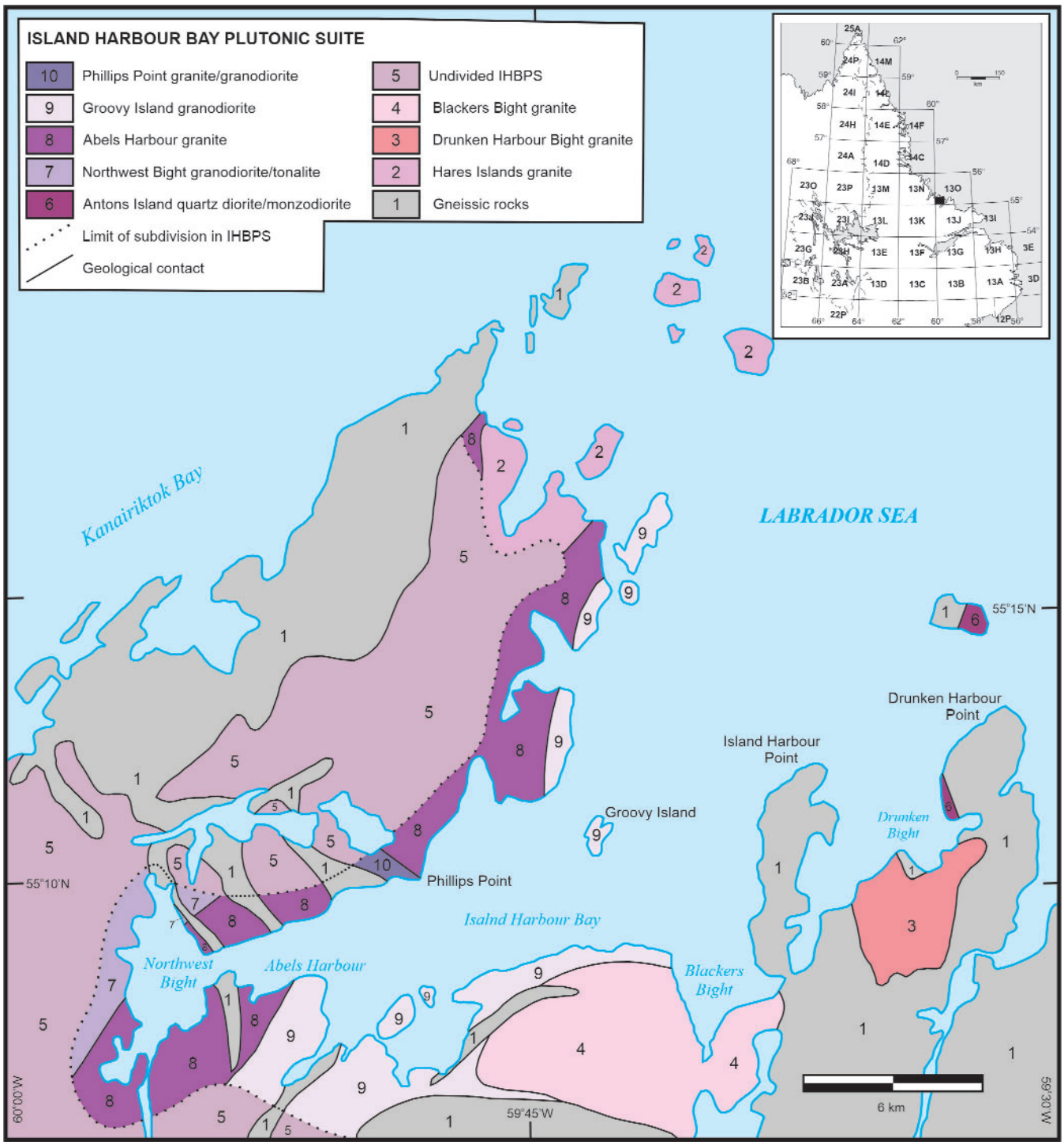


Figure 4. *Geological map of the Island Harbour Bay area (modified from Barr* et al.*, 2001). Inland extent of units mapped in the coastal section is unknown, except for the Drunken Harbour and Blacklers Bight granites as inferred from Ryan* et al. *(1983).*

a 1870 ± 2 Ma sample from a presumably co-genetic granodioritic sheet in the Kaipokok Bay area (Ketchum *et al.*, 1997, 2001b). This range of ages is known to occur in sills and intrusions throughout the Kaipokok Domain (*see* Barr *et al.*, 2001).

Several metamorphic ages also support a major thermal and plutonic event during this time period. A *ca.* 2235 Ma Kikkertavak mafic dyke intruding gneiss contains zircon dated at 1896 ± 6 Ma; interpreted to represent the timing of metamorphism in the Kaipokok Domain. In addition, the sil-

limanite paragneiss on Drunken Harbour Point preserves monazite grains with an age of 1871 ± 3 Ma that are interpreted to have formed during emplacement of the IHBPS (Ketchum *et al.*, 1997).

CURRENT INVESTIGATIONS

This research program addresses several knowledge gaps in our current understanding of the evolution of the IHBPS, and consequently the evolution of the Makkovik Province during the assembly of the supercontinent Nuna. Whereas the IHBPS occurs inland, and is mapped as covering a >4 km^2 area, there is limited research beyond the mapped margins of the intrusions along coastal outcrops. In addition, there has been only limited complete lithogeochemical analysis (including rare-earth elements) and isotopic studies. This program presents the opportunity to further investigate the magmatic history of this complex intrusion. The authors have extensively sampled the entire intrusion for lithogeochemistry, isotopic and geochronological studies. In addition, an outcrop has been identified that preserves three distinct phases of the IHBPS, a granodiorite having plagioclase pseudomorphs, intruded by a foliated monzogranite, intruded by cm-scale feldspar phenocrystic (rapakivi) monzogranite (Plate 1). All phases were sampled for further geochemical, isotopic and geochronological studies with the objective of constraining this magmatic event.

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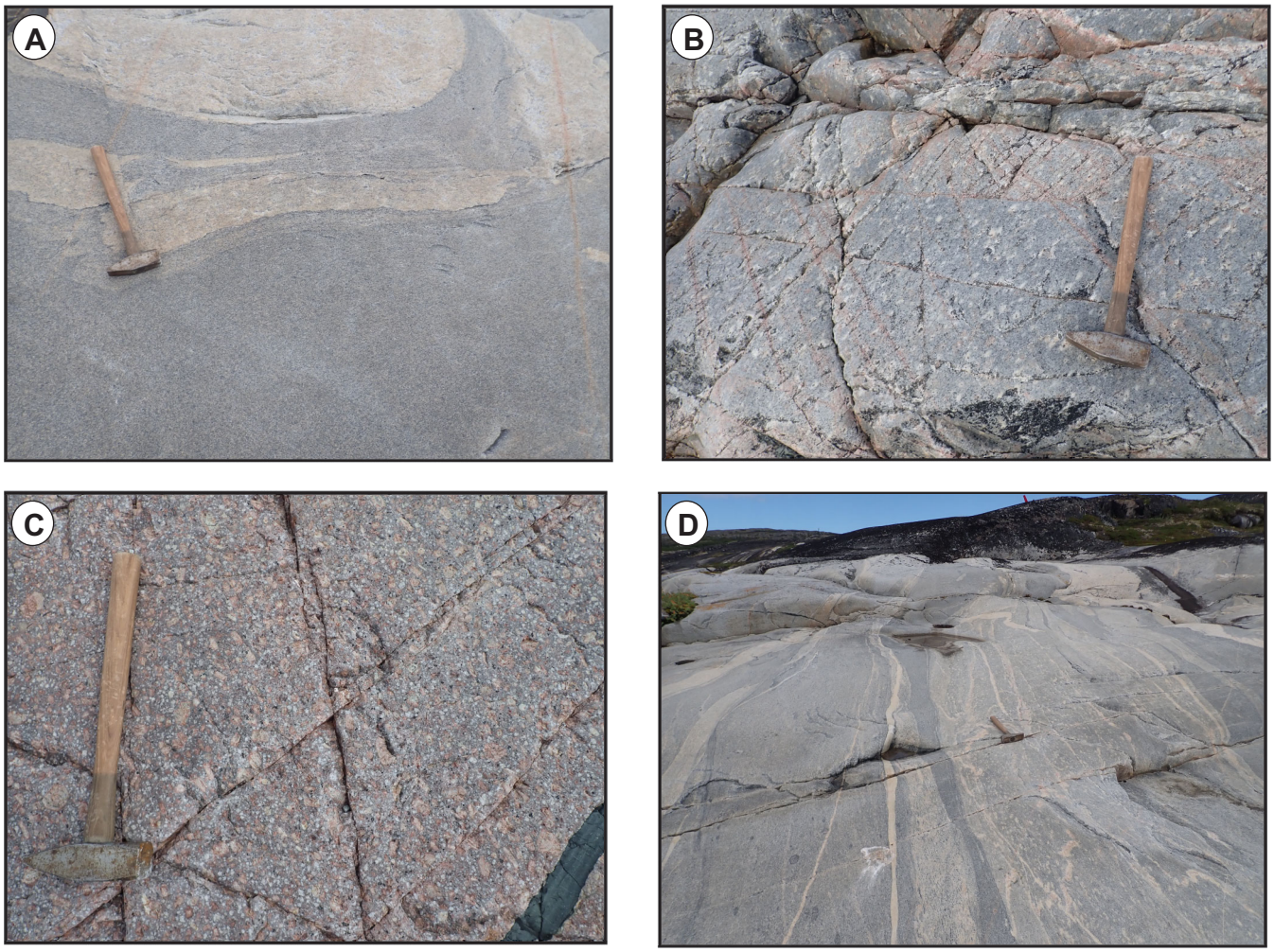

Plate 1. *Field photographs of the IHBPS. A) Foliated, granodiorite displaying magma mixing textures with a leucogranitic phase; B) Granodiorite with pseudomorphs of plagioclase surrounding titanite; C) Porphyritic rapakivi monzogranite phases; D) Complexity of magma phases/mixing at the outcrop scale.*

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