Natural Resources Canada | Ressources naturelles Canada

Bedrock geology of the southern Boothia mainland area (Pelly Bay-Rae Strait-Spence Bay map areas), Kitikmeot region, Nunavut

J.J. Ryan, L. Nadeau, A.M. Hinchey, D.T. James, H.A. Sandeman, E.M. Schetselaar, W.J. Davis, and R.G. Berman

Geological Survey of Canada

Current Research 2009-1

2009

Canada

Geological Survey of Canada
Current Research 2009-1

Bedrock geology of the southern Boothia mainland area (Pelly Bay-Rae Strait-Spence Bay map areas), Kitikmeot region, Nunavut

J.J. Ryan, L. Nadeau, A.M. Hinchey, D.T. James, H.A. Sandeman, E.M. Schetselaar, W.J. Davis, and R.G. Berman

2009

ISSN 1701-4387
Catalogue No. M44-2009/1E-PDF
ISBN 978-1-100-11760-7

A copy of this publication is also available for reference in depository libraries across Canada through access to the Depository Services Program's Web site at http://dsp-psd.pwgsc.gc.ca

A free digital download of this publication is available from GeoPub: http://geopub.nrcan.gc.ca/index_e.php

Toll-free (Canada and U.S.A.): 1-888-252-4301

Recommended citation

Ryan, J.J., Nadeau, L., Hinchey, A.M., James, D.T., Sandeman, H.A., Schetselaar, E.M., Davis, W.J., and Berman, R.G., 2009. Bedrock geology of the southern Boothia mainland area (Pelly Bay-Rae Strait-Spence Bay map areas), Kitikmeot region, Nunavut; Geological Survey of Canada, Current Research 2009–1, 18 p.

Critical reviewer
David Corrigan

Authors
J.J. Ryan (jryan@nrcan.gc.ca)
Geological Survey of Canada
625 Robson Street
Vancouver, British Columbia V6B 5J3

L. Nadeau (lnadeau@nrcan.gc.ca)
Geological Survey of Canada
490 rue de la Couronne
Québec, Quebec G1K 9A9

A.M. Hinchey
(alanahinchey@gov.nl.ca)
H.A. Sandeman
(HamishSandeman@gov.nl.ca)
Geological Survey,
Department of Natural Resources
Government of Newfoundland and Labrador
P.O. Box 8700, St. John's,
Newfoundland and Labrador A1B 4J6

D.T. James (djames@nrcan.gc.ca)
Canada-Nunavut Geoscience Office
626 Tumiit Plaza,
Iqaluit, Nunavut X0A 0H0

E.M. Schetselaar (erschets@nrcan.gc.ca)
W.J. Davis (Bill.Davis@nrcan.gc.ca)
R.G. Berman (Rob.Berman@nrcan.gc.ca)
Geological Survey of Canada
601 Booth Street
Ottawa, Ontario, K1A 0E8,

Correction date:

Bedrock geology of the southern Boothia mainland area (Pelly Bay-Rae Strait-Spence Bay map areas), Kitikmeot region, Nunavut

J.J. Ryan, L. Nadeau, A.M. Hinchey, D.T. James, H.A. Sandeman, E.M. Schetselaar, W.J. Davis, and R.G. Berman

Ryan, J.J., Nadeau, L., Hinchey, A.M., James, D.T., Sandeman, H.A., Schetselaar, E.M., Davis, W.J., and Berman, R.G., 2009. Bedrock geology of the southern Boothia mainland area (Pelly Bay-Rae Strait-Spence Bay map areas), Kitikmeot region, Nunavut; Geological Survey of Canada, Current Research 2009–1, 18 p.

Abstract: The Boothia mainland area, part of the north-central Rae Province, comprises a high-grade gneissic terrain dominated by Neoarchean metaplutonic rocks, migmatitic gneiss, Archean supracrustal rocks, and rare Paleoproterozoic supracrustal rocks. The Archean supracrustal rocks are inferred to be correlative with the regionally widespread Prince Albert Group. Granitic rocks and their gneissic equivalents are dominated by meta- to peraluminous, polyphase, commonly porphyritic, biotite- and hornblende-bearing monzogranite to granodiorite. U-Pb zircon ages indicate they are part of a 2.61 to 2.59 Ga magmatic event recognized throughout most of the Rae Province. Lesser 2.67 to 2.66 Ga plutonism represents a previously unknown age of magmatism in the Rae Province. Small outliers of Paleoproterozoic Chantrey Group metasedimentary rocks (Burwash Lake belt) occur as complex infolds in the Archean rocks, and correlate with other Rae Province Paleoproterozoic cover sequences, such as the Amer and Piling groups.

The dominant structural fabric of the study area is a moderately to intensely developed regional transposition foliation (S_1), which is folded about map-scale, northeast-trending, Paleoproterozoic F_4 folds, doubly plunging about less pervasive north-northwest-trending F_5 folds. High-grade (granulite to upper amphibolite facies) metamorphism and migmatization is interpreted to have occurred during 2.6, 2.5, and 1.82 Ga metamorphic events.

The north-central Rae Province has significant exploration potential for diamonds. In addition, the Archean metavolcanic rocks in the area have exploration potential for base and precious metals.

Résumé : La région de la terre continentale de Boothia, dans le centre nord de la Province de Rae, renferme un terrain gneissique de niveau métamorphique élevé, qui se compose en prédominance de roches plutoniques métamorphisées et de gneiss migmatitiques du Néoarchéen, ainsi que de roches supracrustales de l'Archéen et de rares roches supracrustales du Paléoprotérozoïque. On a déduit que les roches supracrustales de l'Archéen sont corrélées à celles du Groupe de Prince Albert, lesquelles sont répandues dans la région. Les roches granitiques et leurs équivalents gneissiques sont composés en prédominance de massifs polyphasés de monzogranite-granodiorite à biotite et à hornblende, métalumineux à hyperalumineux et habituellement porphyriques. La datation U-Pb sur zircon a permis de rattacher ces roches à un événement magmatique survenu entre 2,61 et 2,59 Ga, lequel a laissé des traces dans presque toute la Province de Rae. Une activité plutonique aux effets plus limités datée de 2,67 à 2,66 Ga témoigne d'une période de magmatisme qui était jusqu'alors inconnue dans la Province de Rae. De petites buttes-témoins de roches métasédimentaires du Groupe de Chantrey du Paléoprotérozoïque (ceinture de Burwash Lake) forment des involutions complexes dans les roches de l'Archéen et sont corrélées à d'autres séquences de couverture du Paléoprotérozoïque dans la Province de Rae, notamment celles des groupes d'Amer et de Piling.

La principale fabrique structurale dans la région d'étude est une foliation de transposition régionale (S_1) modérément à intensément développée, déformée par des plis P_4 de direction nord-est du Paléoprotérozoïque qui s'observent à l'échelle de la carte. Ces plis P_4 affichent un double plongement engendré par des plis P_5 de direction nord–nord-ouest moins intensément développés. D'après notre interprétation, le métamorphisme de forte intensité (du faciès des granulites au faciès des amphibolites supérieur) et la migmatisation résultent d'événements métamorphiques survenus à 2,6, 2,5 et 1,82 Ga.

Le centre nord de la Province de Rae présente un potentiel intéressant pour l'exploration diamantifère. En outre, les roches volcaniques métamorphisées de l'Archéen de la région présentent un potentiel pour la recherche des métaux communs et des métaux précieux.

INTRODUCTION

The Boothia Integrated Geoscience Project is a multi-year, collaborative mapping project in the southern Boothia Peninsula area, Kitikmeot Region, Nunavut, jointly funded by Geological Survey of Canada's (GSC) Northern Mineral Resources Development Program, the Canada-Nunavut Geoscience Office (CNGO), the Polar Continental Shelf Project, and university partners. This article reports on 1:250 000-scale bedrock mapping (Ryan et al., 2008) from fieldwork conducted in 2005 in an area covering parts of NTS map areas Pelly Bay (57 A), Rae Strait (57 B), as well as small parts of Spence Bay (57 C), and Harrison Island (57 D). In concert with the bedrock mapping, detailed local surficial mapping and regional ice-flow studies supported a regional update of the Quaternary geology of Boothia mainland area, wherein a complex, four-stage ice-flow history was resolved (Tremblay et al., 2007). Mapping of the northern part of the Boothia mainland area was undertaken during the 2007 field season and will be reported in subsequent articles.

The Boothia mainland project represents the northern continuation of a series of mapping projects initiated in the 2000 field season, intended to unravel the extent, tectonic setting, and mineral potential of supracrustal belts of the north-central Rae Province in the northern Canadian Shield (*see also* Sandeman et al., 2001a, b, 2005; Sanborn-Barrie et al., 2002, 2003; Skulski et al., 2003a, b, c). As a lead up to the 2005 project, mapping was completed by the CNGO in the Darby Lake (NTS 56 N) and Arrowsmith River (NTS 56-O north) region in 2004 (Sandeman et al., 2005) to bridge the region between the Committee Bay Integrated Geoscience Project area (e.g. Skulski et al., 2003b) to the south, and the current study area (*see* Fig. 1). The Boothia mainland project was initiated in 2004 with acquisition of a new aeromagnetic survey data including 101 000 line-kilometres flown at a spacing of 400 m and 150 m elevation (Coyle et al., 2005). This is the first publicly available aeromagnetic data for regions north of 68°N in this part of Nunavut, and is available for download on the GSC's Geoscience Data Repository site (http://gdr.nrcan.gc.ca/index_e.php).

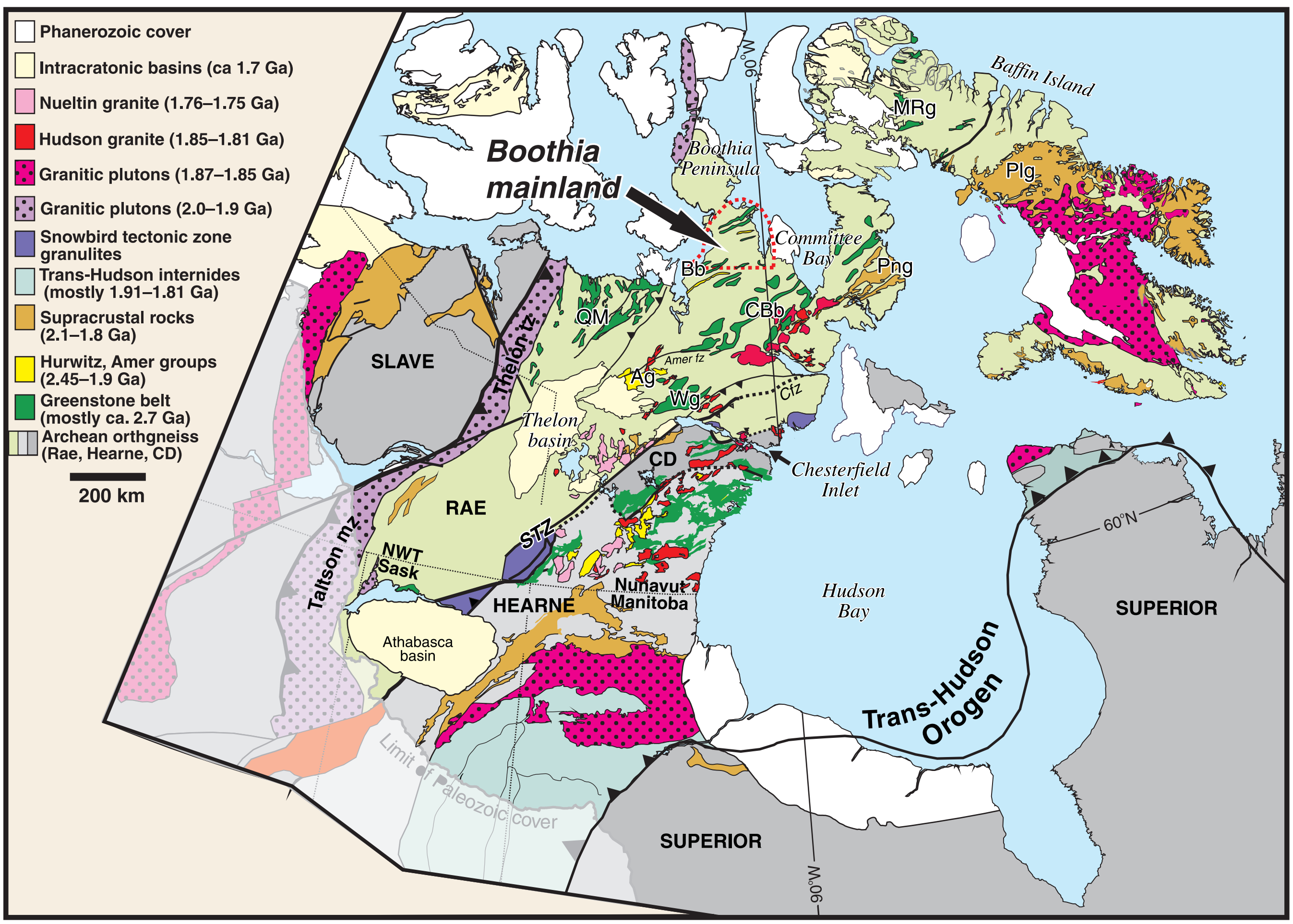

Figure 1. General geology of the north central Laurentian Craton showing the location of the Rae, Hearne, Slave and Superior provinces (modified from Berman et al., 2005). Abbreviations: Ag: Amer Group, Amer fz: Amer fault zone, Bb: Barclay belt, CBb: Committee Bay belt, CD: Chesterfield domain, MRg: Mary River Group, Plg: Piling Group, Png: Penhryn Group, QM: Queen Maud block, STZ: Snowbird tectonic zone, Taltson mz: Taltson magmatic zone, Thelon tz: Thelon tectonic zone, Wg: Woodburn Lake group. The Boothia mainland map area (Fig. 2) is outlined in red dots.

The study area lacks a formal geographic name, and we have adopted the term 'Boothia mainland' following Heywood's (1961) usage to include those areas south of the Isthmus of Boothia, and north of 68°N (Fig. 1). Mapping in 2005 focused on areas covered by NTS map sheets 57 A and 57 B, with reconnaissance mapping in the southern parts of the area covered by NTS map sheets 57 C and 57 D (Ryan et al., 2008). The physiography is characterized by two major lowlands that coincide with the limits of Paleozoic rocks, including carbonates and sandstone, and defined as the Rasmussen Lowlands in the west, and Simpson Lowlands in the east (e.g., Tremblay et al., 2007). Pelly Bay occupies a smaller intervening lowland. Two major uplands divide the lowlands and exhibit exceptionally well exposed bedrock outcrops. The central uplands reach an elevation of about 350 m above sea level (ASL). The lowlands are mainly below 90 m ASL, and commonly host Quaternary surficial sedimentary deposits including marine silts and clays, littoral sands and reworked tills, and have sparse eskers and low hills of Precambrian basement (Tremblay et al., 2007).

Bedrock mapping in 2005 was non-traditional in its approach and methodology. Prior to the 2005 field season, a remote predictive map (RPM) was produced for the region (Schetselaar and Ryan, unpub. data, 2005). The RPM integrated the Heywood (1961) reconnaissance map and field data, the aeromagnetic data (Coyle et al., 2005), Landsat images, features interpreted from air photographs, and data from re-interpretation of archived hand samples from Heywood's 1961 project (*see* Schetselaar and Ryan, 2008). The initial RPM map was derived by interpreting domains having consistent and contrasting magnetic signature, similar spectral reflectance in Landsat imagery, and physical appearance in air photographs considered to be effective discriminants of mappable rock units. A predicted rock type was assigned to each of the RPM units based on combined characteristics. The archived samples were vital for verifying lithological predictions of units as part of the RPM methodology. For some rock samples collected in 1960, thin sections were available for petrographic analysis.

In general, the aeromagnetic data contain abundant, prominent anomalies, and provide a reliable method for predicting the main 'structural grain' of the area. Diabase dyke swarms were the most readily identifiable rock types in the magnetic data. Domains having low magnetic relief were predicted to be underlain by metasedimentary rocks, which, on the basis of the magnetic data and our reinterpretation of archived samples, led us to conclude that supracrustal rocks are less extensive than they are shown to be on Heywood's (1961) map. A vast region of metagranitoid and orthogneiss featuring mid-spectrum, somewhat monotonous magnetic signature was predicted to occur across the southern and central parts of the study area. In contrast, a belt of granulite-facies supracrustal rocks and intervening granitoid bodies outcropping in the southern part of the study area (covered by NTS sheets 57 C and 57 D) was predicted on the basis of its high amplitude and short wavelength magnetic pattern. It was initially tempting to interpret some highly magnetic, narrow anomalies as iron-formation, although samples archived from 1960 demonstrated that these anomalies did not correspond on the ground to iron-formation. Indeed, we noted in some of the archived samples that iron-formation that contained grunerite had very low magnetic susceptibility, and those without it had higher values. In general, these metamorphosed silicate-facies iron-formation units had magnetic-susceptibility values lower than some pyroxenites, mafic granulites, diabase dykes, amphibolites, and some granitoid rocks containing several percent of magnetite porphyroblasts.

The RPM was used in the field to better plan ground traverses and helicopter spot checks in areas having abundant and isolated outcrops, respectively, predicted to be of critical interest. This strategy guided coverage of a large area (20 000 km^2) in a short period of time (7 weeks of mapping), and relied significantly on the RPM for areas between widely spaced traverses (Schetselaar and Ryan, 2008).

OVERVIEW OF THE BOOTHIA MAINLAND AREA

The Boothia mainland area comprises a high-grade gneissic terrain dominated by Neoarchean metaplutonic rocks, lesser Archean and Paleoproterozoic supracrustal sequences, and Archean to Paleoproterozoic migmatitic gneiss. The Archean supracrustal rocks outcrop as narrow, northeast-striking belts, correlated on the basis of rock types with the Barclay belt defined by Frisch (2000), and with the Prince Albert Group. Granitic rocks and their gneissic equivalents are dominated by polyphase, commonly porphyritic, biotite- and hornblende-bearing monzogranite to granodiorite, provisionally correlated with rocks of the ca. 2.61 to 2.59 Ga pan–Rae Province magmatic event (Hinchey et al., unpub. rept.). The Burwash Lake belt comprises small outliers of Paleoproterozoic metasedimentary rocks, occurring as complex infolds in the Archean rocks, and we correlate it with Chantrey Group (Frisch, 2000) and similar Rae Province cover sequences such as the Amer and Piling groups (Kraft, 2006; Hinchey et al., 2007). Detrital zircon U-Pb SHRIMP analyses performed on samples from Archean and Paleoproterozoic sequences (Hinchey et al., 2007) indicate that the Barclay belt is younger than 2.76 Ga and older than the 2.60 Ga granites in the region, and the Chantrey Group is younger than 2.45 Ga. Geochemical analysis of plutonic rocks is currently being undertaken, and quantitative metamorphic and in situ geochronology studies are presented in Berman et al. (2008). Regional geochronology and isotopic models of igneous crust formation are being addressed in Hinchey et al. (unpub. rept.)

GEOLOGY OF THE NORTH-CENTRAL CANADIAN SHIELD

The Boothia mainland area is located in the north-central Rae Province of the north-central Laurentian cratonic core of the Canadian Shield (*see* Fig. 1), in the region historically referred to as the Churchill Province (e.g., Hoffman, 1988). The Rae and Hearne provinces are unique in Laurentia, in that they represent one of the largest tracts of tectonothermally reworked Archean crust on Earth, and are separated by the Snowbird tectonic zone (Gibb and Walcott, 1971; Hoffman, 1988; 1990; Berman et al., 2005; 2007). The Rae Province is separated from the Slave Province to the west and northwest by the 2.0–1.9 Ga Taltson magmatic arc and Thelon tectonic zone, and the Hearne Province is separated from the Superior Province to the south and southeast by the 1.9–1.8 Ga Trans-Hudson Orogen (Hoffman, 1988). The Rae and Hearne provinces (Fig. 1) are characterized principally by northeast- and locally east-trending Neoarchean plutonic and supracrustal rocks with constituent Paleoproterozoic successor sedimentary sequences, igneous suites, and tectonothermal overprints (Hoffman, 1988; Hanmer et al., 2004; Berman et al., 2007).

The Hearne Province can be subdivided into southern, central and northwestern subdomains, based on lithological, metamorphic, structural, and petrochemical characteristics (Tella et al., 2005; Davis et al., 2006). The northwestern Hearne subdomain preserves polydeformed amphibolite-facies assemblages, more abundant Archean metasedimentary rocks, common, ca. 2.60 Ga granodioritic plutons, abundant Paleoproterozoic granitoid rocks and Paleoproterozoic U-Pb titanite ages, and lacks Paleoproterozoic supracrustal sequences (Davis et al., 2006; Berman et al., 2005). Some of its characteristics have recently caused debate about its potential affinity with the Rae Province (Berman et al., 2007).

Neoarchean supracrustal belts in the Rae Province are discontinuously exposed, extending from Woodburn Lake to northern Baffin Island, and include the Woodburn Lake, Prince Albert, and Mary River groups (Fig. 1; Frisch, 1982; Zaleski et al., 2001; Bethune and Scammell, 2003; Skulski et al., 2003b; Sandeman et al., 2005). The Woodburn Lake group formed between 2740 Ma and 2630 Ma (Zaleski et al., 2001) and the Prince Albert group formed during the interval 2730 to 2690 Ma (Skulski et al., 2003b). In contrast, the Mary River Group includes 2.75 to 2.69 Ga rocks and an older, ca. 2.85 Ga group of supracrustal rocks (McNicoll and Young, unpub. data). A characteristic of Rae Province Archean supracrustal belts are occurrences of quartz-rich metasedimentary rocks overlain by a lower, mixed volcanic sequence of basalt, ultramafic flow, sills, and felsic volcanic rocks. These are in turn overlain by composite sedimentary-volcanic sequences including psammite, semipelite, pelite, iron-formation, and quartzite intercalated with intermediate to felsic tuffs (Zaleski et al., 2001; Skulski et al., 2003b). The Woodburn Lake and Prince Albert groups are interpreted to be the result of mantle-derived magmatism in a continental rift setting (Zaleski et al., 2001; Skulski et al., 2003b).

A salient feature of the Rae Province is widespread, metaluminous, and weakly peralkaline I-type granitoid plutons that range in age from 2.64 to 2.58 Ga, and more commonly confined to 2.61 to 2.59 Ga (e.g. LeCheminant and Roddick, 1991; Frisch and Parrish, 1992; Zaleski et al., 2001; Skulski et al., 2003b). These plutons are dominated by granodioritic compositions, and include charnockite (and other orthopyroxene-bearing granitoids) at higher metamorphic grades.

Igneous rocks of the Rae Province characteristically exhibit isotopically evolved crustal-formation signatures (T. Skulski, pers. comm., 2008) commonly having Nd-model ages between 2.75 and 2.85 Ga. At least locally, some igneous rocks have much older Nd-model ages and intrusive ages, including ca. 2.87 Ga plutonic rocks in the Woodburn Lake area (Zaleski et al. (2001); Fig. 1) and 2.88 to 2.75 Ga plutonic rocks in the Eqe Bay region of north Baffin Island (Bethune and Scammell, 2003). On this basis, Neoarchean supracrustal sequences of the Rae Province are interpreted to be founded on Mesoarchean to early Neoarchean basement (Zaleski et al., 2001; Bethune and Scammell, 2003; Skulski et al., 2003b; Hinchey et al., unpub. rept.).

Paleoproterozoic metasedimentary sequences occur throughout the Rae Province (Fig. 1), and are characterized by quartzite, carbonate, and sulphidic black shales. Examples include the >1850 Ma Amer Group (Patterson, 1986; Tella, 1994), the ca. 1880 Ma Penrhyn Group (Henderson, 1983), the Chantrey Group (undated) (Frisch, 2000), and the 2321 Ma and younger Folster Lake Group (Frisch, 1982; Skulski et al., 2003b). These Paleoproterozoic sedimentary sequences have sustained two episodes of deformation and are variably metamorphosed.

Paleoproterozoic intrusive rocks occur sporadically across the Rae Province, are dominated by monzogranite to granodiorite, and range in age between 1.83 and 1.82 Ma (e.g. LeCheminant et al., 1987; Tella, 1994; Skulski et al., 2003a, b). These intrusions are also common to the Hearne Province (Peterson et al., 2002), and are thought to be associated with far field effects of the Trans-Hudson Orogen. Rae Province rocks are also intruded by widespread, northwest-trending diabase dykes belonging to the Mesoproterozoic Mackenzie and the Neoproterozoic Franklin swarms (e.g. Buchan and Ernst, 2004) that have been regionally age dated at ca. 1267 Ma (LeCheminant and Heaman, 1989) and ca. 720 Ma (Heaman et al., 1992), respectively.

In general, the Rae Province is characterized by a prominent northeast-striking structural grain having local deviations from north- to east-striking. The structural grain, which is prominently reflected in the regional aeromagnetic data, approximately mimics the outline of the Trans-Hudson Orogen internides that lies to the southwest (Fig. 1). In detail, the northeast structural grain is a composite fabric developed in the Paleoproterozoic and consisting of Paleoproterozoic fabric elements (e.g. Carson et al. 2004; Berman et al., 2005) and reoriented Archean fabrics (e.g. Zaleski et al., 2001). Distinguishing Paleoproterozoic from Archean fabric elements is difficult in Archean rocks.

The structural history deciphered in the Committee Bay (e.g. Skulski et al., 2003b; Sanborn-Barrie et al., 2003) and Darby Lake–Arrowsmith River (Sandeman et al., 2005) areas has relevance to the Boothia mainland area. The Committee Bay and Darby Lake studies demonstrate three prominent structural features including 1) a strong, northeast-striking foliation, 2) northeast- to east-trending regional folds, and 3) north-trending ‘cross’ folds. There are interpreted to be local occurrences of preserved Archean fabrics near Woodburn Lake (e.g. Zaleski et al., 2001), although most Archean fabrics in the region were overprinted during two main deformation events: D_1 at ca. 2.35 Ga (Berman et al., 2005) and D_2 at 1.85 Ga (Carson et al., 2004; Berman et al., 2005). Monzogranitic dykes which crosscut the main structural fabric elements in the region have been dated at 1.82 Ga (Skulski et al., 2003b). On this basis, the main fabric elements in the region are interpreted to be D_2 structures.

Metamorphic grade during D_1 and D_2 events was mainly amphibolite facies, increasing to the northeast along the Committee Bay belt from greenschist to upper amphibolite facies, and increasing to the north and northwest to lower granulite facies (Berman et al., 2005). The principal, northeast-striking D_2 foliation is folded by north-northeast- and north-northwest-trending regional and mesoscopic open folds, and local conjugate crenulations, that may be synchronous with a regional, apparently static metamorphic event at ca. 1780 Ma (Carson et al., 2004).

GENERAL GEOLOGY OF BOOTHIA MAINLAND

The bedrock geology of the Boothia mainland study area (Fig. 2) comprises four principal lithological associations:

1) Archean supracrustal rocks that crop out as narrow, northeast-striking and highly dismembered belts consisting mainly of psammite, semi-pelite and metabasite, local pelite with rare iron formation (including oxide,

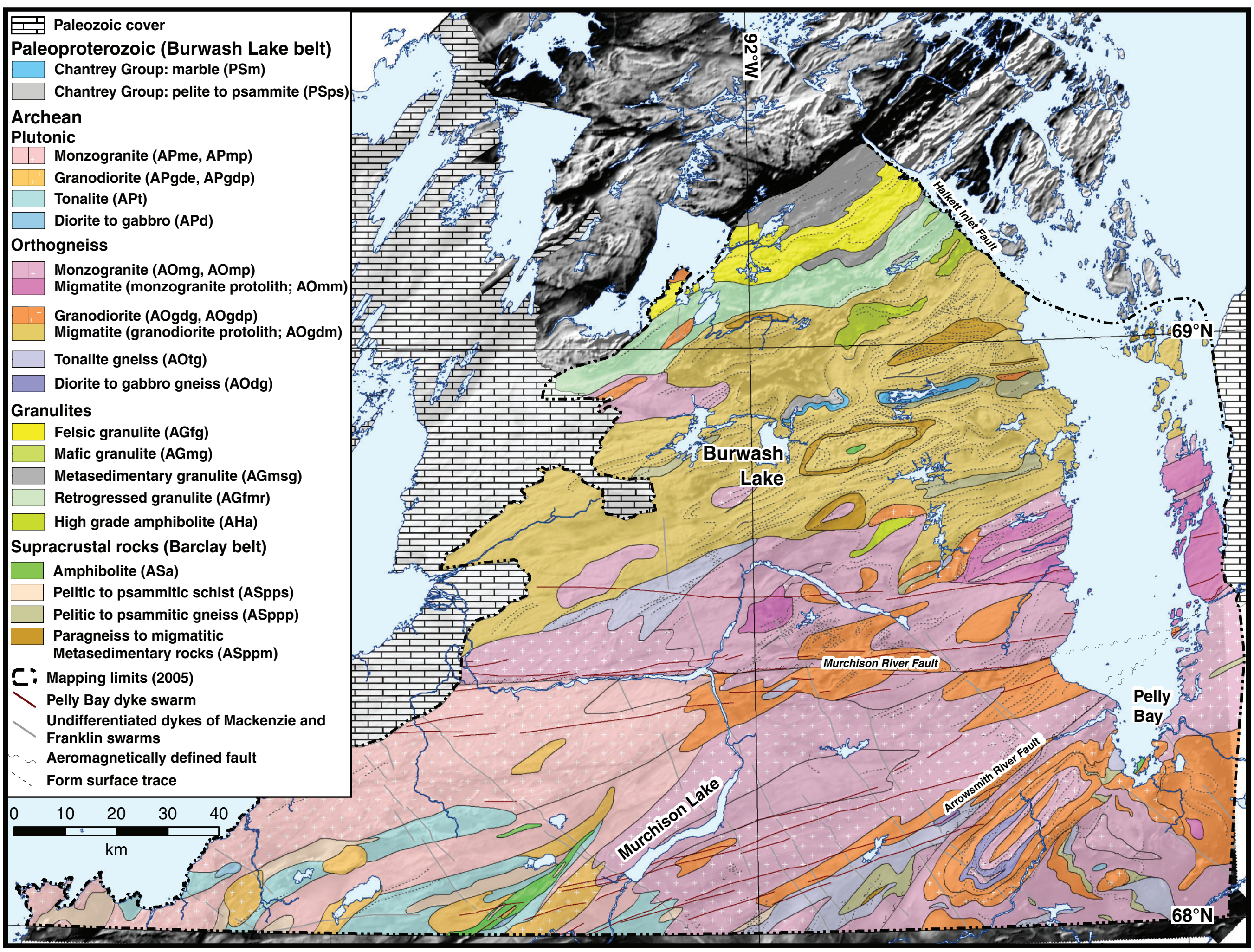

Figure 2. Simplified geology of the Boothia mainland area. Legend corresponds to unit codes in the text.

silicate and sulphide facies), and rare occurrences of meta-ultramafic rocks. On the basis of similarity of rock types, the Archean supracrustal rocks are correlated with the Barclay belt, as defined by Frisch (2000). Based on the youngest detrital zircon age of 2.76 Ga obtained from rocks in the study area (Hinchey et al., 2007), and because the sequence is intruded by Neoarchean granitoid units (*see* subsequent descriptions), the supracrustal rocks are provisionally correlated with the pan–Rae Province Prince Albert Group.

2) A suite of massive to gneissic to migmatitic, Archean granitoid rocks intrudes the aforementioned Archean supracrustal rocks, and forms the most widespread map units. The suite chiefly comprises leucocratic to mesocratic biotite±hornblende-bearing monzogranite and subordinate granodiorite, commonly having K-feldspar porphyritic textures. The suite has an I-type metaluminous to peraluminous geochemical signature (Nadeau et al., unpub. data). Intrusive ages, determined by U-Pb zircon geochronology, indicate the suite is mainly part of a 2.61 to 2.59 Ga pan-Rae magmatic suite. However, it also includes minor amounts of 2.67 to 2.66 Ga rocks, which are previously unknown in the Rae Province (Hinchey et al., 2007; unpub. rept.)

3) Migmatitic rocks underlie extensive portions of the study area, and comprise composite migmatites inferred to be derived from multiple, plutonic injections, and from polymetamorphic remobilisation and partial melting of Archean plutonic and supracrustal rocks (lithological associations 1 and 2 in the previous two paragraphs). The migmatitic character of these rocks resulted from the complex interplay between plutonism, metamorphism and deformation at or near the culmination of regional metamorphism. Contact relationships with protoliths are gradational or cryptic. Migmatites are most abundant in the central portion of the study area.

4) We refer to a belt of Paleoproterozoic supracrustal rocks located near Burwash Lake (Fig. 2) in the northern part of the study area as the Burwash Lake belt, that comprises a sequence dominated by marble and metapelite, with minor amounts of psammitic schist and quartzite. The Burwash Lake belt occurs as complex infolds in the Archean rocks (Kraft et al., 2005; Kraft, 2006). Detrital zircon studies confirm a Paleoproterozoic age (Hinchey et al., 2007). Based on the geochronology, inferred stratigraphy and rock types, the Burwash Lake belt is correlated with the Chantrey Group (Hinchey et al., 2007), that occurs in the Darby Lake area, 120 km to the south-southwest (Sandeman et al., 2005; Frisch, 2000; Heywood, 1961).

The aforementioned associations have been divided into mappable rock units (Fig. 2). Subtle variations in composition and texture of the metaplutonic and migmatitic rocks provide a useful base for subdivision of the units, and help to petrogenetically characterize the parent suite.

Archean rocks

Barclay belt

A volumetrically minor, but important marker unit in the Barclay belt is unit ASa (Fig. 2), which comprises massive to schistose amphibolite, local ultramafic schist and serpentinite. The most continuous exposures of unit ASa occur in the Murchison Lake area (Fig. 2) where amphibolites are interstratified with, and locally grade into, metapsammites and metagreywacke (unit ASpps). The heterogeneous amphibolites of unit ASa are mainly interpreted as metamorphosed mafic and ultramafic volcanic flows and volcaniclastic rocks, whereas some texturally and compositionally uniform ASa rocks may be derived from sills and dykes. Due to pervasive metamorphic recrystallization and local high state of strain, primary volcanic or depositional features and intrusive relationships that could help distinguish the protolith have been masked or obliterated. However, rare examples of relict pillow structures (Fig. 3) were observed in amphibolite southwest of Murchison Lake (Lat. 68.09567833, Long. –92.96299667). At higher strain and regional metamorphic grade, relict pillow selvages are defined by hornblende-rich layers, and pillow interstices by quartz-epidote-hornblende domains (Fig. 4). Less continuous occurrences of ASa are found throughout the study area and occur as metre- to kilometre-scale panels or rafts within younger metagranitoid units. In some places, ASa metavolcanic rocks appear to influence the composition of the granitoids, which tend to have increased mafic content near contacts with the metavolcanic rocks, and may be due to assimilation of the host rock into the granitoid magma. The amphibolites near Murchison Lake trend southwestward into the northwest corner of the Darby Lake map sheet area, where Sandeman et al. (2005) reported exceptionally well preserved examples of pillowed basalt, spinifex-textured komatiitic rocks, and interlayered psammite and pelite.

Figure 3. Relict pillow selvages in dark-weathering, actinolite-hornblende metamorphosed basaltic flows. Hammer is 35 cm long.

The metasedimentary member of the Barclay belt (ASpps) comprises schistose to lesser foliated metapelite to metapsammite, and includes local occurrences of iron-formation that include examples of silicate facies, rusty banded oxide facies, and lean sulphide facies. The rocks commonly preserve bedding (particularly sandstone beds). The ASpps rocks provide a useful indicator of metamorphic grade, which is generally characterized by the mineral assemblage biotite-garnet-staurolite-andalusite±sillimanite. More-mafic occurrences locally grade to hornblende-biotite amphibolite of ASa.

Unit ASppp comprises metapelitic to metapsammitic gneiss (paragneiss) and schist, and is considered to be a more highly metamorphosed equivalent of unit ASpps. It has well developed foliation, which is commonly accentuated by metamorphic segregation and differentiated layering, as well as in situ–derived veins of granitic neosome. The metamorphic assemblage is dominated by biotite-garnet-sillimanite. The unit includes occurrences of banded oxide-facies (Fig. 5) and lean sulphide-facies iron formation, and garnet-rich horizons (Fig. 6) interpreted as either metamorphosed silicate facies iron formation or iron-rich pelite.

Unit ASppm consists of high-grade metasedimentary rocks dominated by migmatitic paragneiss and metatexite, and is inferred to be the higher grade equivalent of unit ASpps. Unit ASppm rocks commonly contain the assemblage garnet-biotite-sillimanite and pods and veinlets of granitic neosome, interpreted to be derived by in situ melting (Fig. 7). Like unit ASppp, occurrences of garnet-rich horizons are interpreted as metamorphosed silicate-facies iron formation, and examples of oxide-facies banded iron formation are preserved. The principal difference between

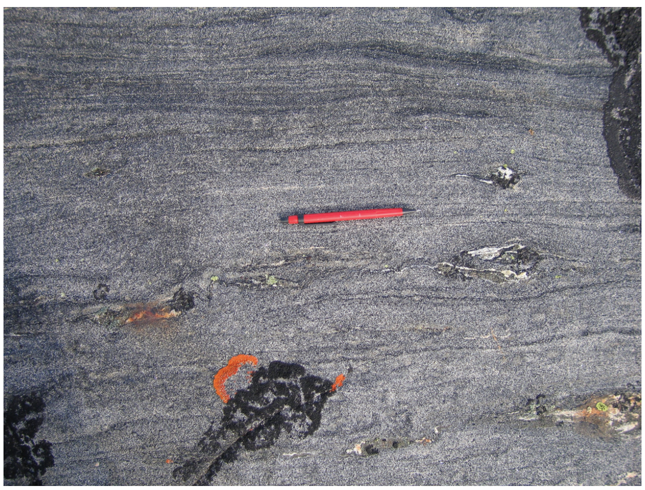

Figure 4. Relict pillow structure in charcoal grey, high-strain amphibolites of unit ASa, wherein hornblende-rich layers define the selvages and pillow interstices are defined by quartz-epidote-hornblende domains. Pencil for scale.

Figure 6. Garnetite-rich horizons, interpreted as metamorphosed silicate-facies iron-formation or iron-rich pelite, in paragneiss of unit ASppp. Pen for scale.

Figure 5. Metamorphically recrystallized oxide-facies banded (with chert laminations) iron-formation in unit ASppp. Pencil for scale.

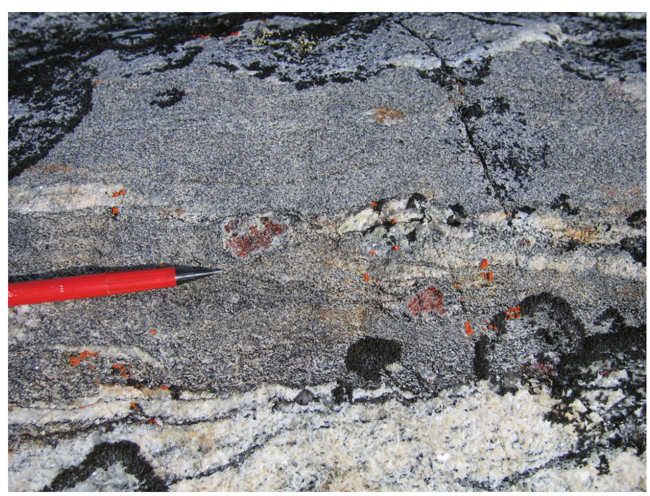

Figure 7. Garnet and leucosome rich migmatitic psammitic paragneiss of unit ASppm; garnet are commonly associated with melt phase. Pencil for scale.

units ASppp and ASppm is that where the foliation in ASppp is generally defined by metamorphic segregation typical of amphibolite facies, unit ASppm are migmatites characterized by partial melts, and the protolith is generally more difficult to ascertain.

Plutonic units

Plutonic rocks in the southwest portion of the map (Fig. 2) exhibit the weakest state of regional strain and metamorphic recrystallization and are better described as plutonic, rather than metaplutonic. The restricted age range thus far determined through geochronology would suggest that the plutonic rocks there represent a single, compositionally varied plutonic suite emplaced between 2.61 and 2.59 Ga (Hinchey et al., unpub. rept). Plutonic rocks were classified in the field based on a modified Streckeisen (1976) scheme, with particular emphasis on the potassic feldspar content, which was relatively easy to estimate visually.

Felsic to intermediate plutonic rocks

Unit APme is characterized by equigranular, grey to pink weathering, mainly massive monzogranite that locally grades to granodiorite. Feldspars and quartz have generally not been recrystallized in this unit. Local xenoliths and larger rafts of unit ASpps metasedimentary rocks demonstrate that APme plutons intrude the Barclay belt although intrusive contacts are not exposed. Unit APme rocks are generally biotite bearing, with local igneous hornblende. An associated unit, APmp, has the same monzogranite to granodiorite composition, but forms a separate mappable unit due to its distinctive K-feldspar porphyritic nature, including phenocrysts as large as 25 mm (Fig. 8).

Unit APgde is similar to APme, but dominated by granodiorite rather than monzogranite. Occurrences of cognate xenoliths of diorite and tonalite (Fig. 9) testify to a compositionally broader suite. The suite comprises variable compositional phases. Unit APgdp comprises K-feldspar porphyritic granodiorite to monzogranite, and is considered a porphyritic equivalent of unit APgde, as it is similar in composition, age and location. K-feldspar phenocrysts in the unit are as large as 25 mm.

Intermediate to mafic plutonic rocks

Unit APt comprises hornblende-biotite-bearing tonalite to granodiorite that is generally massive to moderately foliated. In the field, rocks were classified as tonalite because of apparent low K-feldspar content, relative abundance of hornblende to biotite, and higher colour index relative to felsic granitoid rocks. Unit APt rocks appear to have a spatial association with Barclay belt units. They may signal the presence of tonalite-trondhjemite-granodiorite (TTG) type crust and basement, which could be tested through geochronology. However, preliminary geochemical analyses indicate that most unit APt rocks classify chemically as calcic-sodic granodiorites (Nadeau et al., unpub. data). It is possible that the chemical composition is a function of resorption of mafic components of the supracrustal belts into granodioritic magma that enhanced the mafic content and colour of these rocks locally, leading to a spurious field classification as tonalite.

Unit APd occurs as rare plutons of hornblende-biotite-bearing diorite to quartz diorite, that locally grades to gabbro. They are generally massive to moderately foliated. Petrographically similar rocks were commonly noted as xenoliths in the more felsic to intermediate plutons.

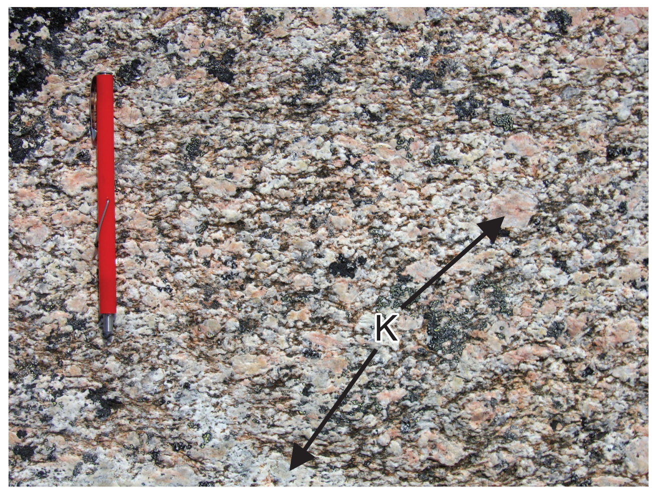

Figure 8. Relatively little deformed, K-feldspar (K) porphyritic monzogranite of unit APmp. Note the 20 mm phenocrysts. Pen magnet for scale.

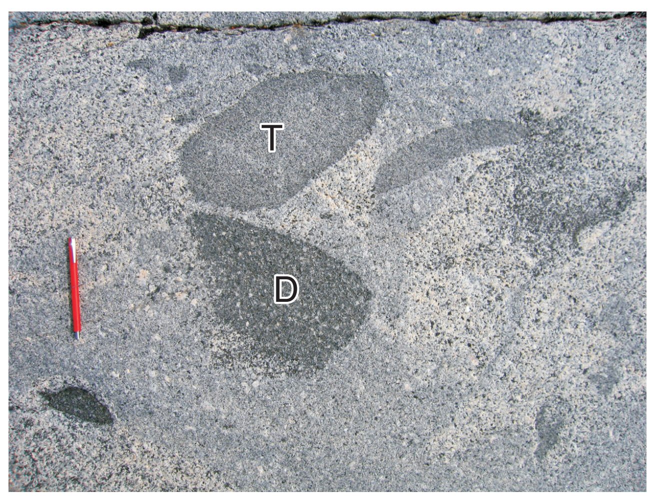

Figure 9. Cognate xenoliths of diorite (D) and tonalite (T) in polyphase hornblende-bearing granodiorite of unit APgde. Pen magnet for scale.

Orthogneiss

Units of orthogneissic rocks are widespread throughout the central, eastern, and northern parts of the study area (Fig. 2). Most of orthogneiss units can be identified as more highly strained and thoroughly recrystallized equivalents of the plutonic phases described in the preceding paragraphs. The orthogneisses have igneous emplacement (protolith) ages of 2.61 to 2.59 Ga, and in the eastern part of the study area, have local, 2.67 to 2.66 Ga emplacement ages (Hinchey et al., unpub. rept.). These two temporally distinct suites are compositionally, texturally, petrographically, and geochemically indistinguishable. Determination of K-feldspar content for field classification of a protolith is difficult due to pervasive recrystallization and strain-enhanced grain size reduction.

Felsic to intermediate orthogneiss

Map unit AOmg comprises monzogranite to granodiorite orthogneiss. In subtle contrast, unit AOgdg comprises granodiorite to monzogranite orthogneiss. Both units are generally fine to medium grained, equigranular, and moderately foliated to gneissic. Based on composition and geochronology, these units are interpreted to be derived from units APme and APgde, respectively. Units AOmp and AOgdp commonly comprise K-feldspar±quartz-porphyritic to augen-textured monzogranite to granodiorite and granodiorite to monzogranite orthogneiss (Fig. 10). Recrystallized K-feldspar aggregates commonly define a stretching lineation in these rocks.

Units AOmm and AOgdm comprise migmatitic varieties of orthogneiss derived from monzogranite to granodiorite and granodiorite to monzogranite protoliths, respectively, that exhibit evidence of having been partially melted. They tend to be highly layered and demonstrate intense ductile deformation and transposition of granitic veins that are either injected or locally derived. We interpret some of the transposed granitic veins as being locally derived (e.g. Fig. 11) and indicate that igneous precursors were partially melted at the latest stage of plutonic emplacement or during high-grade regional metamorphism. Layering in units AOmm and AOgdm commonly exhibit foliation boudinage, wherein pods of granitic melt have mobilized into the boudin necks. Some of the mobilisate is in turn deformed indicating that migmatitization was synchronous with the development of strong transposition foliation.

Unit AOgdg comprises granodiorite to monzogranite orthogneiss. Rocks are gneissic to moderately foliated, and equigranular suggesting derivation from an even-grained plutonic protolith, possibly similar to APgde. Unit AOgdp comprises augen-textured granodiorite to monzogranite orthogneiss. It is moderately foliated to gneissic, with augen of K-feldspar±quartz. Unit AOgdm comprises a migmatitic variety of granodiorite to monzogranite orthogneiss, derived from granodiorite to monzogranite protolith. These rocks are generally well layered due to intense deformation, and like unit AOmm, we interpret them as having undergone partial melting.

Intermediate to mafic orthogneiss

Unit AOtg comprises moderately foliated to gneissic tonalitic orthogneiss whose protolith grades locally to granodiorite or diorite. Like unit APt, it generally has spatial association with occurrences of Barclay belt rocks. Unit AOdg consists of diorite to gabbro orthogneiss.

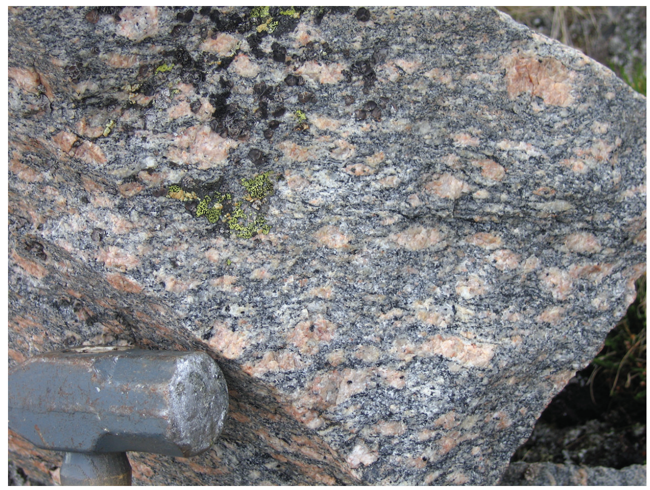

Figure 10. Augen-textured, K-feldspar porphyritic monzogranite orthogneiss of unit AOmp. Note the presence of tiny magnetite within K-feldspar that are interpreted as being primary. Metamorphic magnetite crystals are far more common in the region. Sledge hammer head for scale.

Figure 11. Highly layered and transposed hornblende-bearing, migmatitic orthogneiss of unit AOgdm, derived from a granodiorite protolith. The granitic veins (mobilisate) are interpreted as locally derived partial melt. Rock hammer for scale.

Granulite-facies rocks

The northernmost part of the study area is underlain by granulite-facies rocks derived from a number of different protoliths. The granulite-facies rocks are characterized by the index minerals orthopyroxene in meta-igneous rocks, K-feldspar and cordierite±sillimanite in aluminous metasediments, and orthopyroxene in associated anatectic melts.

The felsic granulite unit (AGfg) is dominated by orthopyroxene-bearing monzogranite, granodiorite, and monzonite, and is inferred to be the granulite-facies equivalent of units AOgdg and AOmg. These rocks are generally granoblastic and have a greasy greenish colour on fresh surfaces. Like the K-feldspars, orthopyroxene is commonly augen shaped (Fig. 12). It is assumed that the orthopyroxene in these rocks is igneous, and formed as a result of emplacement and crystallization under anhydrous, high-grade, regional metamorphic conditions.

The mafic granulite unit (AGmg) is composed of clinopyroxene-orthopyroxene-hornblende metabasite of uncertain protolith. Despite the high metamorphic grade, many of these rocks have fine- to medium-grained mineral assemblages. Some rocks preserve unequivocal igneous (gabbro and pyroxenite) textures. Others, particularly ones interlayered with metasedimentary granulites and associated with metamorphosed iron-formation, may be derived from a mafic volcanic protolith.

Unit AGmsg comprises granulite-facies metasedimentary rocks that are generally described as partially melted metapelites and metapsammites. They commonly have abundant layers of highly garnetiferous leucosome in biotite-rich neosome (Fig. 13). Contacts between leucosome and paleosome are commonly diffuse. Unit AGmsg migmatitic paragneisses locally host thicker sheets (0.5–3 m) of garnet-orthopyroxene-bearing S-type granite having sharp intrusive contacts. Unit AGmsg rocks are characterized by the mineral assemblage garnet–K-feldspar–biotite±orthopyroxene ±cordierite±sillimanite. Local occurrences of rusty-weathering, magnetite-rich rocks are interpreted as metamorphosed iron-formation. Unit AGmsg and the metavolcanic components of unit AGmg are interpreted as being derived from Barclay belt rocks, although there is, as yet, no geochronological or stratigraphic data to support this model. Unit AGmsg rocks are cut by the ca. 2.6 Ga plutonic units confirming that the protolith of AGmsg is Archean.

Unit AGfmr is a mixed (decimetre to decametre scale) unit of retrogressed felsic to intermediate and mafic granulites that lies immediately south of the belt of fresh, granulite-facies rocks. Much of the unit was described in the field as consisting of metatexite or diatexite. Unit AGfmr rocks are characterized by middle to upper amphibolite-facies mineral assemblages, with relict clinopyroxene and orthopyroxene that attest to their prior high metamorphic grade.

Unit AHa makes up a singular unit of hornblende-clinopyroxene-bearing amphibolite, probably derived from retrogressed mafic granulite of uncertain protolith. This unit commonly forms a breccia in monzogranite to granodiorite orthogneiss, and is either synchronous with, or older than, the 2.60 Ga granitoid units.

Paleoproterozoic rocks

Burwash Lake belt (Chantrey Group)

The Burwash Lake belt in the northern part of the study area comprises a supracrustal sequence dominated by marble, pelitic schist, minor amounts of psammitic schist, and quartzite. The metasedimentary rocks occur as complex

Figure 12. Dynamically recrystallized, augen-textured K-feldspar (K) and orthopyroxene (small brown augens in left side of photo marked with an O) in felsic granulite unit (AGfg) derived from granodiorite. Pencil tip for scale.

Figure 13. Granulite-facies metasedimentary rocks of unit AGmsg, derived from partially melted semipelite. Note layer of highly garnetiferous and orthopyroxene bearing leucosome in biotite-rich neosome, wherein the contacts between leucosome and paleosome are diffuse. Pencil tip for scale.

infolds in the Archean rocks. Detrital zircon studies of two quartzite samples indicate a Paleoproterozoic depositional age younger than 2.45 Ga (Hinchey et al., 2007). On the basis of the zircon ages, rock types, and stratigraphy, the Burwash Lake belt is correlated with Chantrey Group (Heywood, 1961; Frisch, 2000; Sandeman et al., 2005). The structurally lower part of the group is characterized by an undifferentiated arenite and marble (Fig. 14) assemblage (PSm), interbedded with quartz arenite and orthoquartzite. The structurally upper part of the group is characterized by metapelitic rocks (PSps), and subordinate layers of banded iron-formation, calc-silicate, quartzite, and garnet amphibolite. Kraft (2006) described the Burwash Lake belt in detail, and estimates the structural thickness in the study area to be ~2000 m. Despite being locally flat-lying, the sequence is highly strained and contains a strong foliation that is tightly folded into upright structures (Fig. 15), adding to the difficulty of estimating its true thickness. In addition, the sequence locally projects below Archean rocks, and may indicate that the Archean basement has been thrust over the Paleoproterozoic cover (Kraft, 2006).

Mesoproterozoic to Neoproterozoic rocks

While the map of Heywood (1961) exhibited very few diabase dykes, the current study has recognized three sets of unmetamorphosed diabase dykes in the Boothia mainland area. The dyke sets, which include two sets of northwest-striking dykes, and one set (collectively) of east- and east-northeast-striking dykes, are more abundant in the southern parts of the study area. Their chemical make up is currently being investigated (Nadeau, unpub. data). Dykes belonging to the three sets are marked by prominent aeromagnetic anomalies with strike length up to 100 km (e.g. Coyle et al., 2005), but have almost no positive topographic expression. In fact, they are commonly located by shallow lineaments left after their fractures surfaces were plucked during glaciation.

The east- and east-northeast-striking dykes have not been previously reported in the north-central Rae Province, and have no known correlatives (Nadeau et al., 2005; Ryan et al., 2007). We have no means yet to subdivide the east-west and east-northeast–west-southwest dykes, and they are collectively, herein informally named the ‘Pelly Bay dyke swarm’. They rarely exceed a few tens of metres in thickness, and exhibit aphanitic to very fine-grained textures, locally having centimetre-size plagioclase phenocrysts and rounded wall-rock inclusions (Fig. 16).

The Pelly Bay dykes are cut by northwest-striking dykes, which are commonly more than 50 m thick (Fig. 17). Geochemical analysis (Nadeau, unpub. data) of the northwest-striking dykes indicate that they form two distinct subsets and probably correlate with ca. 1270 Ma Mackenzie dykes (*see* LeCheminant and Heaman 1989) and ca. 720 Ma Franklin dykes (*see* Heaman et al. 1992). A preliminary zircon age on one northwest-striking dyke from the study area demonstrated a Franklin-equivalent intrusive age (Davis, unpub. data). The regional diabase compilation of Buchan and Ernst (2004) exhibits both Mackenzie and Franklin dykes north and south of the Boothia mainland, consistent with our findings.

Figure 14. Shallowly to moderately dipping interbedded marble and quartzite of the Burwash Lake belt (Chantrey Group).

Figure 15. F_4 folds of S_3 foliation in laminated marble of the Burwash Lake belt (Chantrey Group), illustrating the high internal strain of this Paleoproterozoic succession. Note pencil and hammer for scales.

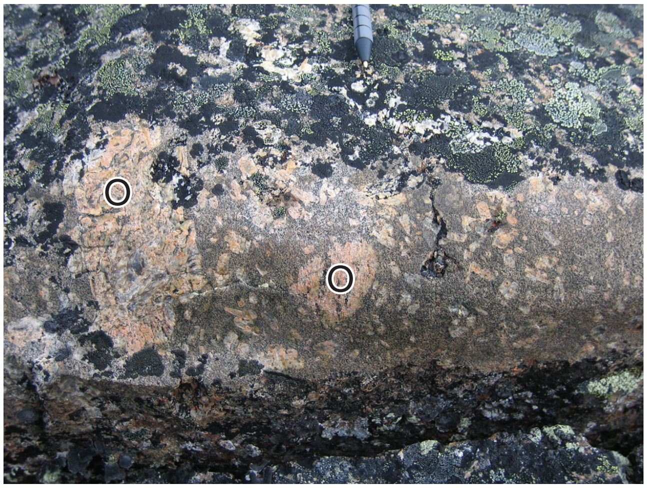

Figure 16. Internal portion of a 2 m thick east-west diabase dyke of the Pelly Bay dyke swarm. The dyke has an aphanitic to very fine-grained matrix with centimetre-size plagioclase phenocrysts and rounded orthogneissic (O) wall-rock inclusions.

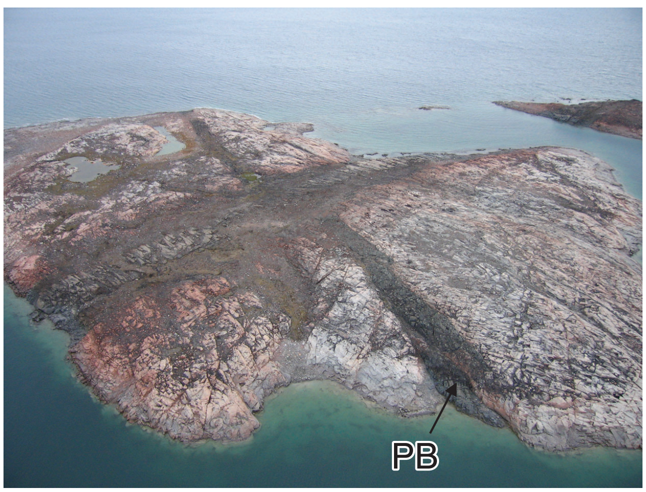

Figure 17. Aerial view (looking east) of >50 m thick northwest-southeast-trending dyke cutting across a Pelly Bay dyke (marked with PB). The northwest-southeast dyke belongs to either the Mackenzie and Franklin dyke swarms, both of which are expected in the area.

Paleozoic rocks

Paleozoic sedimentary rocks, inferred to be Cambrian to Ordovician shallow-water platformal carbonates, occur in the northwest part of Boothia mainland, and cover most of Simpson Peninsula immediately east of the Pelly Bay rise. None were located in situ within the study area. However, preglacial occurrences are demarcated by limestone pavement on glacial till in the low-lying region in the northwestern part of the study area. Paleozoic clasts included in the till include well bedded and interlayered limestone and sandstone, and include yellow to tan, muddy to sandy dolostones, minor quartzose carbonates, and quartz arenite.

STRUCTURAL GEOLOGY AND METAMORPHISM

The state of strain varies significantly across the study area. Rocks are commonly massive in the southwest, whereas they are strongly gneissic, migmatitic, and highly foliated in the eastern and northern parts of the study area. In general, the degree of strain coincides with metamorphic grade, which varies from lower-amphibolite facies andalusite-staurolite-bearing rocks (generally lower strain) in the southwestern volcanic belt (Fig. 2), to granulite-facies rocks (generally higher strain) in the north and northeast. The granulite-facies rocks are characterized by orthopyroxene-clinopyroxene-garnet in metaplutonic rocks, and garnet-K-feldspar-plagioclase, garnet-sillimanite-K-feldspar, and garnet-sillimanite-cordierite in metasedimentary rocks. Quantitative metamorphic analysis of the area is presented in Berman et al. (2008). Apart from the *bona fide*, 'fresh' granulite-facies domain in the north, there is local preservation of granulite-facies assemblages in the central and southern portions of the study area, suggesting the region of high-grade metamorphism was more widespread than the current retrograde overprint. The central area also broadly coincides with a wide region of migmatites derived from both metasedimentary and metaplutonic protoliths, indicating rocks were subjected to high-temperature regional metamorphism. Determining the age of migmatization event(s) is complicated by polyphase regional metamorphism (Berman et al., 2008), although field relationships and preliminary geochronology indicate that it is penecontemporaneous with 2.60 Ga plutonism (Hinchey et al., unpub. rept.; Berman et al., 2008).

Outside of the well exposed north-central part of the area, the combination of brittle fracture, weathering patterns, and glacial cover make it almost impossible to decipher the structural grain across the area from air photographs and satellite imagery. However, a highly variable structural fabric across the area is well exhibited by the first vertical derivative of aeromagnetic data (*see* Coyle et al., 2005), which is consistent with structural measurements recorded at field stations. After filtering the intense magnetic anomalies caused by dyke swarms and faults, a strong, northeast-trending structural grain in evident, which is typical of the north-central Churchill Province (Fig. 1). From a cursory examination of the potential field data, the structural history of the Boothia mainland area appears simple, and similar to that of the Committee Bay belt region to the south, where the main structural fabric is northeast-striking, southeast-dipping, and northwest-verging (Sanborn-Barrie et al., 2002). In contrast, in the Boothia mainland area the northeast-striking fabric is more commonly northwest-dipping, and apparently southeast-verging. In the following summary, episodes of deformation, metamorphism, folding, and foliation development will be designated by the letters D, M, F and S respectively. The reader is also referred to Table 1 of Berman et al. (2008) for a summary of the structural and

Table 1. Structural summary for southern Boothia mainland

Defm	Metm	Element	Description	Orientation	Age
Archean					
D_1	M_1	S_m	main foliation, gneissosity, differentiated layereing	NE-striking	**2.6 Ga**
D_1	M_1	F_2	m-scale, isoclinal folds of S_m	shallow NE-trending fold axes	
Paleoprotrozoic					
	M_2		no deformation		**2.42 Ga**
D_2	M_3	S_3	main, bedding-parallel foliation	NE-striking	**1.82 Ga**
D_3	M_3	F_4	tight to isoclinal, regional folds	shallow NE- to ENE-trending	*1.82–179 Ga*
D_3	M_3	S_4	weak axial-planar, crenulation cleavage	NE-striking	**1.79 Ga**
D_4	M_4	F_5	open folds and warps	shallow NNW- to N-trending	*<1.79 Ga*
D_4	M_4	S_5	weak crenulation cleavage	NNW-striking	*<1.79 Ga*

Defm: deformation event; Metm: metamorphic event; Element: fabric element
Age: determined (bold); inferred (italics)

metamorphic events that are separated into four geological domains, where SHRIMP U-Pb dating of in situ monazite allows some absolute timing of events.

At any location in the study area there is generally one main transposition foliation (S_m), which varies in character from a schistosity in metasedimentary rocks, to shape fabric and strong mineral alignment in metaplutonic rocks, to strong gneissosity at higher grade and higher strain equivalents. The gneissosity is commonly accentuated by injected igneous veinlets. There is local evidence for at least one pre-S_m fabric in migmatitic rocks, although those occurrences are not systematic or prevalent. On this basis, the main planar fabric is designated as a second-generation fabric. S_m occurs only in Archean rocks, and is prevalent in metaplutonic rocks across the entire area. Preliminary geochronology results indicate that S_m was synchronous with M_1, and developed at ca. 2.60 Ga (Hinchey et al., unpub. rept.; Berman et al., 2008). This age is consistent with a model proposed by Hinchey et al. (2006) for the southeast part of the study area, where a pegmatite that cross-cuts S_m is dated at 2.58 Ga (Hinchey et al., unpub. rept.). Local metre-scale, isoclinal F_2 folds of S_m are difficult to link to map-scale folds. It is possible that these folds formed late in the same, progressive deformational event (D_1) or they are a separate deformation.

Berman et al. (2008) distinguished a second metamorphic event (M_2) in the Boothia mainland by SHRIMP U-Pb dating of monazite rim overgrowths and matrix monazite between ca. 2.5 Ga and at 2.35 Ga, probably reflecting the Arrowsmith Orogeny recorded in the Committee Bay region (Berman et al., 2005; Carson et al., 2004). In the Boothia mainland area, no Arrowsmith-age tectonic fabric has been confidently linked to this metamorphism, but it is possible that F_2 folds could be Arrowsmith-age structures.

The next fabric element (S_3) in the area is the first foliation recorded in the folded metasedimentary panels of Paleoproterozoic Burwash Lake belt. This foliation was not recognized in Archean rocks, suggesting it is localized in the Burwash Lake belt. The north-dipping geometry of the Burwash Lake belt indicates that it structurally underlies Archean rocks, possibly indicating that Archean rocks are thrust over the Burwash Lake belt from the north. Thus, the localized S_3 fabric may have formed during a Paleoproterozoic thrusting event.

A regionally pervasive set of northeast- to east-northeast trending folds (F_4), occurring in Archean and Paleoproterozoic rocks, controls the structural geometry and map pattern of the study area. The folds are clearly outlined in the aeromagnetic data. It is difficult to determine the vergence of the F_4 folds, but they appear to verge southward. It is unclear if F_4 folds have caused the principally north-dipping S_m across the area, or if they are simply developed in an already north-dipping S_m. There is generally no axial-planar S_4 foliation developed in the metaplutonic rocks, although a weak crenulation cleavage is seen locally in the Burwash Lake belt and Barclay belt rocks. The F_4 folding is tentatively linked to a ca. 1.82 to 1.79 Ga metamorphism (M_3) identified in monazite in the central and southern portions of the area by Berman et al. (2008). It is possible that the S_3 fabric and F_4 folding are part of a progressive deformation event. F_4 folds in Boothia mainland correlate with D_2 deformation in the Committee Bay area (Berman et al., 2005; Carson et al., 2004).

A weakly developed set of northwest- to north-trending F_5 open folds and warps cause F_4 folds to doubly plunge, creating domains of domes and basins in the tectonostratigraphy. As F_5 folds deform F_4 structures in the Burwash Lake belt rocks, F_5 is also constrained to be Paleoproterozoic. A locally developed north-northwest-striking crenulation cleavage in the Burwash Lake belt (*see* Kraft 2006) is interpreted to be axial planar to F_5 folds, and is designated an S_5 fabric. The F_5 folds may correlate with F_3 folds in the Committee Bay region (*see* Berman et al., 2005; Carson et al., 2004). Evidence for a ca. 1.79 Ga metamorphism (M_4) has been recorded in the area (Berman et al., 2008; Hinchey et al., unpub. rept.), and it may be possible that F_5 folding is synchronous with M_4.

The map area is transected by numerous faults. Some faults of significant scale offset the geology, or even bound structural domains. The Arrowsmith River fault (Fig. 2) appears to bound a region characterized by northeast-striking foliation through the central part of the area, from a region of dome-and-basin structures in the southeast corner of the map area that preserves northwest-trending foliations. The Arrowsmith River fault exhibits spectacular porphyroclastic ultramylonite strands with both sinistral and dextral shear-sense indicators. The east-striking Murchison River fault appears to separate the plutonic rocks in the southwest from their orthogneissic equivalents to the north.

Abundant minor faults occur across the central and northern parts of the map, and are typically defined by narrow topographic lineaments. A northwest set are the most prominent, and the largest of these is the Halkett Inlet fault, which has approximately 250 m of sinistral offset. The age of deformation along the faults is not known.

The Paleoproterozoic and Archean rocks, and the structures they carry, are cut by the three sets of undeformed Meso- to Neoproterozoic diabase dykes described earlier in the paper. This dates all the penetrative regional deformation and metamorphism as being older than the 720 Ma Franklin dykes, and probably older than the 1267 Ma Mackenzie dykes.

ECONOMIC GEOLOGY

The Boothia mainland area has exploration potential for 1) base- and precious-metal mineralization in Archean metavolcanic rocks (e.g. Barclay belt and other correlatives of the Prince Albert and Woodburn Lake groups), and 2) diamondiferous kimberlites.

Regionally, the Prince Albert and Woodburn groups have significant, proven base- and precious-metal mineralization (Skulski et al., 2003a; Zaleski et al., 2001). Sandeman et al. (2005) identified rare, greenschist-facies metavolcanic rocks in the northwestern Darby Lake map area, which they inferred to represent the Barclay supracrustal belt, and thus correlated them with the Prince Albert Group. Bedrock samples from the Darby Lake area did not yield anomalous mineral values (Little et al., 2005), although Sandeman et al. (2005) suggest that the extent of Barclay belt and its potential for base- and precious-metal mineralization likely increases to the north, and into the Boothia mainland study area. The present study demonstrates that Barclay belt rocks are far less extensive and of much higher metamorphic grade than was indicated by Heywood (1961). Of these, only a small proportion represent metavolcanic rocks. On this basis, gold and base-metal potential is interpreted to be low across the granitoid-dominated units. Though not widespread, the supracrustal rocks do contain some prominent, rusty gossan zones (e.g. Lat. 68.04977833, Long. -93.21321667; Lat. 68.89155977, Long.-91.21085961; Lat. 68.92054825, Long. -90.61115897), commonly associated with recognizable sulphide- and silicate-facies iron formation, or garnetite horizons that may be high metamorphic grade equivalents. Disseminated sulphides (pyrite±chalcopyrite) were observed at some of these localities.

Forty samples were collected in 2005 for mineral assay. Some samples contain anomalous gold, copper, lead, zinc, and nickel values (Nadeau et al., 2008). The area is likely to have poor potential in terms of syngenetic gold, because much of the area has experienced granulite-facies metamorphic conditions. However, post-peak metamorphic quartz veins may be prospective targets for gold. Some anomalous gold values were obtained from Burwash Lake belt rocks (Chantrey Group). The Burwash Lake belt is provisionally correlated with the Piling Group, known to host significant gold mineralization on Baffin Island (Stacey and Pattison, 2003).

The most significant economic interest in the area centres on diamond potential. Upon initiation of the Boothia mainland project, most of the study area was staked for land permits by Diamonds North Resources, BHP and Indicator Minerals Inc., ostensibly on speculation for diamond potential resulting from regional till geochemistry, kimberlite indicator mineral surveys, and in anticipation of the new aeromagnetic survey released in April, 2005. During the 2005 field season, kimberlite boulder debris was discovered during a routine traverse by two of our field geologists, and follow-up at the locality yielded a significant amount of kimberlite rubble in glacial till. The results of analysis of this discovery are reported in more detail in Sandeman and Ryan (2008). The discovery was reported in July 2005 to the permit holders (Diamonds North Resources and operating partner BHP). In a September 2005 Diamonds North Resources (http://www.diamondsnorthresources.com) press release, it was announced that that 14 other kimberlite float occurrences were discovered by company geologists and one in situ kimberlite had been located, and they referred to the prospect as Amaruk. Further press releases have indicated that almost all of the kimberlitic material thus far analyzed is diamondiferous, and has an abundance of high-quality, small stones indicating that this region is Canada's newest diamond field.

The antiquity of the Archean crust in the study area has been determined using Nd-isotopic analysis on some of the main plutonic units. Most results have yielded Nd-model ages (DePaolo, 1981) of between 2.7 and 2.8 Ga, indicating interaction with crust that was probably only 100 to 200 Ma older than pluton emplacement ages. Several samples in the southeastern part of the study area, in the vicinity of the Amaruk diamond play, yielded 2.8 to 2.9 Ga, broadly Mesoarchean Nd-model ages (Nadeau et al., unpub. data), which may be significant in defining the presence of older subcontinental mantle lithosphere (SCML) that may be fertile for sourcing diamonds. It may be the case that Paleoproterozoic tectonothermal reworking did not destroy a deep, 'diamond reservoir' below the Boothia mainland area. A couple of samples in the northeast part of the map area, in the granulite belt near Halkett Inlet, yielded similar model ages, giving hints that there may be at least a small domain in that region also underlain by old SCML.

ACKNOWLEDGMENTS

The 2005 Boothia project field season was funded by the Geological Survey of Canada's Northern Resources Development Program, the Canada-Nunavut Geoscience Office, the Government of Nunavut (with funds from Strategic Initiatives in Northern Economic Development), and the Polar Continental Shelf Project. Special thanks to geological assistants Jamie Kraft, Crystal LaFlamme, Jenrene Martel, James Rae, Kate Rubingh, Andrew Smye, Roxanne Takpanie-Brière, and Nesha Trenholm. A field visit by Dave Scott was greatly appreciated. Thank you to Mike Young for helping to set up a Geodatabase for the project, and for assisting in map development.

Thanks to Dorothy Edwards for culinary services in the field. Helicopter pilots Terry Halton and Colin Lavalle of Universal Helicopters of Newfoundland provided skilled and reliable helicopter support. Excellent Twin Otter service was supplied by Kenn Borek Air under contract to the Polar Continental Shelf Project. Charlie Cahill of Cap Enterprises provided expediting services in Gjoa Haven. We thank David Corrigan for a thoughtful review of the manuscript.

REFERENCES

Berman, R.G., Sanborn-Barrie, M., Stern, R.A., and Carson, C.J., 2005. Tectonometamorphism at ca. 2.35 and 1.85 Ga in the Rae Domain, western Churchill Province, Nunavut, Canada; insights from structural, metamorphic and in situ geochronological analysis of the southwestern Committee Bay Belt; Canadian Mineralogist, v. 43, p. 409–442. doi:10.2113/gscanmin.43.1.409

Berman, R.G., Davis, W.J., and Pehrsson, S., 2007. Collisional Snowbird tectonic zone resurrected: Growth of Laurentia during the 1.9 Ga accretionary phase of the Hudsonian orogeny; Geology, v. 35, p. 911–914. doi:10.1130/G23771A.1

Berman, R.G., Ryan, J.J., Davis, W.J., and Nadeau, L., 2008. Preliminary results of linked in-situ SHRIMP dating and thermobarometry of the Boothia mainland area, north-central Rae Province, Nunavut; Geological Survey of Canada, Current Research 2008–2, 13 p.

Bethune, K. and Scammell, R.J., 2003. Geology, geochronology, and geochemistry of Archean rocks in the Eqe Bay area, north-central Baffin Island, Canada: constraints on the depositional and tectonic history of the Mary River Group of northeastern Rae Province; Canadian Journal of Earth Sciences, v. 40, p. 1137–1167. doi:10.1139/e03-028

Buchan, K.L. and Ernst, R.E., 2004. Diabase dyke swarms and related units of Canada and adjacent regions. Geological Survey of Canada Map 2022A, scale 1:5 000 000.

Carson, C.J., Berman, R.G., Stern, R.A., Sanborn-Barrie, M., Skulski, T., and Sandeman, H.A.I., 2004. Paleoproterozoic tectono-metamorphic evolution of the Committee Bay region, western Churchill Province, Canada: evidence from in-situ monazite SHRIMP geochronology; Canadian Journal of Earth Sciences, v. 41, p. 1049–1076. doi:10.1139/e04-054

Coyle, M., Dumont, R., Kiss, F., and Potvin, J., 2005. High-resolution maps of the shaded residual total magnetic field and shaded magnetic first vertical derivative with Keating correlation coefficients, Boothia Peninsula area, Nunavut (NTS 57A/SW, 57 A/NW, 57 B/SW, 57 B/SE, 57 B/NW, 57 B/NE, 57 C/SW, 57 C/SE, 57 C/NE, 57 D/SW, 57 D/NW); 22 colour maps, scale 1:100 000, April 2005. http://gdr.nrcan.gc.ca/aeromag/surveys/316_boothia_peninsula_e.php

Davis, W.J., Hanmer, S., Tella, S., Sandeman, H.A., and Ryan, J.J., 2006. U–Pb geochronology of the MacQuoid supracrustal belt and Cross Bay plutonic complex: Key components of the northwestern Hearne subdomain, western Churchill Province, Nunavut, Canada; Precambrian Research, v. 145, p. 53–80. doi:10.1016/j.precamres.2005.11.016

DePaolo, D.J., 1981. Neodymium isotopes in the Colorado Front Range and crust-mantle evolution in the Proterozoic: Nature, v. 291, p. 193–196.

Frisch, T., 1982. Precambrian geology of the Prince Albert Hills, western Melville Peninsula, Northwest Territories; Geological Survey of Canada, Bulletin 346, 70 p.

Frisch, T., 2000. Precambrian geology of Ian Calder Lake, Cape Barclay, and part of Darby Lake map areas, south-central Nunavut; Geological Survey of Canada, Bulletin 542, 51 p.

Frisch, T. and Parrish, R.R., 1992. U-Pb zircon ages from the Chantrey Inlet area, northern District of Keewatin, Northwest Territories; *in* Radiogenic Age and Isotopic Studies: Report 5; Geological Survey of Canada, Paper 91–2, p. 35–41.

Gibb, R.A. and Walcott, R.I., 1971. A Precambrian suture in the Canadian Shield; Earth and Planetary Science Letters, v. 10, p. 417–422. doi:10.1016/0012-821X(71)90090-2

Hanmer, S., Sandeman, H.A., Davis, W.J., Aspler, L.B., Rainbird, R.H., Ryan, J.J., Relf, C., and Peterson, T.D., 2004. Geology and Neoarchean tectonic setting of the Central Hearne supracrustal belt, Western Churchill Province, Nunavut, Canada; Precambrian Research, v. 134, p. 63–83. doi:10.1016/j.precamres.2004.04.005

Heaman, L.M., LeCheminant, A.N., and Rainbird, R.H., 1992. Nature and timing of Franklin igneous events, Canada: implications for a Late Proterozoic mantle plume and the break-up of Laurentia; Earth and Planetary Science Letters, v. 109, p. 117–131. doi:10.1016/0012-821X(92)90078-A

Henderson, J.R., 1983. Structure and metamorphism of the Aphebian Penrhyn Group and its Archean basement complex in the Lyon Inlet area, Melville Peninsula, District of Franklin; Geological Survey of Canada, Bulletin 324, 50 p.

Heywood, W.W., 1961. Geological Notes, northern District of Keewatin; Geological Survey of Canada, Paper 61–18, 9 p.

Hinchey, A.M., Ryan, J.J., Davis, W.J., Nadeau, L., and James, D.T., 2007. Detrital zircon geochronology of the Archean volcano-sedimentary sequence of the Barclay belt and the Paleoproterozoic marble-quartzite sequence of the Northern Chantrey Group, Boothia mainland area, Kitikmeot region, Nunavut; Geological Survey of Canada, Current Research 2007-C1, 19 p.

Hinchey, A.M., Davis, W.J., Ryan, J.J., Nadeau, L., and James, D.T., 2006. Timing of magmatism, granulite-facies metamorphism and deformation in the Archean metaplutonic rocks of the Boothia mainland area within the Rea domain, Northwest Churchill Province, Nunavut; Geological Association of Canada – Mineralogical Association of Canada, Program with Abstracts, v. 31, p. 67.

Hoffman, P.F., 1988. United plates of America, the birth of a craton; early Proterozoic assembly and growth of Laurentia; Annual Review of Earth and Planetary Sciences, v. 16, p. 543–603. doi:10.1146/annurev.ea.16.050188.002551

Hoffman, P.F., 1990. Subdivision of the Churchill Province and extent of the Trans-Hudson Orogen; *in* The early Proterozoic Trans-Hudson Orogen of North America, (ed.) J.F. Lewry, and M.R. Stauffer, Geological Association of Canada, Special Paper 37, p. 5–39.

Kraft, J., 2006. Petrology, geochronology and tectonometamorphism of the Paleoproterozoic Northern Chantrey Group, northern Rae Domain, Churchill Province, Nunavut, B.Sc. thesis, University of Alberta, Edmonton, Alberta, 66 pp.

Kraft, J., James, D.T., Ryan, J.J., and Chacko, T., 2005. Preliminary data from a metasedimentary succession in the Rae Domain, South Boothia Peninsula, Nunavut; (comp.) E. Palmer, 33rd Annual Yellowknife Geoscience Forum Abstracts, v. 2005, p. 107.

LeCheminant, A.N. and Heaman, L.M., 1989. Mackenzie igneous events, Canada; middle Proterozoic hotspot magmatism associated with ocean opening; Earth and Planetary Science Letters, v. 96, p. 38–48. doi:10.1016/0012-821X(89)90122-2

LeCheminant, A.N. and Roddick, J.C., 1991. U-Pb zircon evidence for widespread 2.6 Ga felsic magmatism in the central District of Keewatin, N.W.T.; in Radiogenic Age and Isotopic studies, Report 4: Geological Survey of Canada, Paper 90–2, p. 91–99.

LeCheminant, A.N., Roddick, J.C., Tessier, A.C., and Bethune, K.M., 1987. Geology and U/Pb ages of early Proterozoic calc-alkaline plutons northwest of Wager Bay, District of Keewatin; *in* Current Research, Part A; Geological Survey of Canada, Paper 87–1A, p. 773–782.

Little, E., Sandeman, H., Ozyer, C., Young, M., and Utting, D., 2005. Preliminary Bedrock Geochemistry and Drift Prospecting results from the Committee Bay North Project (NTS 56N and 56-O/north), mainland Nunavut, Geological Survey of Canada, Open File 5003, 82 p.

Nadeau, L., Ryan, J.J., Brouillette, P. and James, D.T., 2008. Mineral assay results for the 2005 and 2007 field seasons, Boothia mainland area, Kitikmeot region, Nunavut; Geological Survey of Canada, Open File 5907, 33 p.

Nadeau, L., Schetselaar, E.M., Ryan, J.J., and James, D.T., 2005. Fracture patterns of the Boothia mainland, Nunavut: an analysis of dykes, faults, fractures and lineaments; (comp.) E. Palmer, 33rd Annual Yellowknife Geoscience Forum Abstracts, Northwest Territories Geoscience Office, Yellowknife, NT; YKGSF Abstracts, v. 2005, p. 114–115.

Patterson, J.G., 1986. The Amer Belt; remnant of an Aphebian foreland fold and thrust belt; Canadian Journal of Earth Sciences, v. 23, p. 2012–2023.

Peterson, T.D., Van Breemen, O., Sandeman, H., and Cousens, B., 2002. Proterozoic (1.85–1.75 Ga) igneous suites of the Western Churchill Province: granitoid and ultrapotassic magmatism in a reworked Archean hinterland; Precambrian Research, v. 119, p. 73–100. doi:10.1016/S0301-9268(02)00118-3

Ryan, J.J., Nadeau, L., Hinchey, A.M., James, D.T., Sandeman, H.A., Berman, R.G., Davis, W.J., and Young, M.D., 2007. Archean to Proterozoic evolution of high-grade terrain in the Boothia Mainland area, Kitikmeot region, Nunavut; Geological Association of Canada—Mineralogical Association of Canada; Program with Abstracts, v. 32, p. 70.

Ryan, J.J., Nadeau, L., Hinchey, A.M., James, D.T., Young, M.D., Williams, S.P., and Schetselaar, E.M., 2008. Geology, southern Boothia mainland area, Pelly Bay-Rae Strait-Harrison Island map area, Nunavut; Geological Survey of Canada, Open File 5808, scale 1:250 000.

Sanborn-Barrie, M., Skulski, T., Sandeman, H., Berman, R., Johnstone, S., MacHattie, T., and Hyde, D., 2002. Structural and metamorphic geology of the Walker Lake Arrowsmith River area, Committee Bay Belt, Nunavut; Geological Survey of Canada, Current Research 2002-C12, 13 p.

Sanborn-Barrie, M., Sandeman, H., Skulski, T., Brown, J., Young, M., MacHattie, T., Deyell, C., Carson, C., Panagapko, D., and Byrne, D., 2003. Structural geology of the northeastern Committee Bay belt, Ellice Hills area, central Nunavut; Geological Survey of Canada, Current Research 2003-C23, 13 p.

Sandeman, H.A. and Ryan, J.J., 2008. Petrology of kimberlite debris from the GSC showing, Pelly Bay kimberlite field (NTS 57/A03), Nunavut, Canada; Geological Survey of Canada, Open File 5876, 20 p.

Sandeman, H.A., Brown, J., Studnicki-Gizbert, C., MacHattie, T., Hyde, D., Johnstone, S., Greiner, E., and Plaza, D., 2001a. Bedrock mapping in the Committee Bay Belt, Laughland Lake area central mainland, Nunavut; Geological Survey of Canada, Current Research 2001-C12, 20 p.

Sandeman, H.A., Studnicki-Gizbert, C., Brown, J., and Johnstone, S., 2001b. Regional structural and metamorphic geology of the Committee Bay Belt, Laughland Lake area, central mainland, Nunavut; Geological Survey of Canada, Current Research 2001-C13, 11 p.

Sandeman, H.A., Schultz, M., and Rubingh, K., 2005. Results of bedrock mapping of the Darby Lake - Arrowsmith River north map areas, central Rae Domain, Nunavut; Geological Survey of Canada, Current Research 2005-C2, 11 p.

Schetselaar, E.M. and Ryan, J.J., 2008. A remote predictive mapping case study of the Boothia mainland area, Nunavut Canada, Case Study 9; *in* Remote Predictive Mapping: An Aid for Northern Mapping, (ed.) J. R. Harris; Geological Survey of Canada, Open File 5643, p. 261-281.

Skulski, T., Sandeman, H., and MacHattie, T., Sanborn-Barrie, M., Rayner, N., and Byrne, D. 2003a. Tectonic setting of the 2.73–2.70 Ga Prince Albert Group, Rae domain, Nunavut; in Geological Association of Canada–Mineralogical Association of Canada–Society of Economic Geologists Joint Annual Meeting, Vancouver, British Columbia, Abstracts Volume 28, p. 158.

Skulski, T., Sandeman, H., Sanborn-Barrie, M., MacHattie, T., Young, M., Carson, C., Berman, R., Brown, J., Rayner, N., Panagapko, D., Byrne, D., and Deyell, C., 2003b. Bedrock geology of the Ellice Hills area and new constraints on the regional geology of the Committee Bay area, Nunavut; Geological Survey of Canada, Current Research 2003-C22, 11 p.

Skulski, T., Sanborn-Barrie, M., and Sandeman, H., 2003c. Geology, Walker Lake and Arrowsmith River area, Nunavut; Geological Survey of Canada, Open File 3777, 2 sheets, scale 1:100 000.

Stacey, J.R. and Pattison, D.R., 2003. Stratigraphy, structure, and petrology of a representative klippe of the Bravo Lake Formation, Piling Group, central Baffin Island, Nunavut; Geological Survey of Canada, Current Research 2003-C13, 11 p.

Streckeisen, A., 1976. To each plutonic rock its proper name; Earth-Science Reviews, v. 12, p. 1–33. doi:10.1016/0012-8252(76)90052-0

Tella, S., 1994. Geology, Amer Lake (66H), Deep Rose Lake (66G) and parts of Pelly Lake (66F); Geological Survey of Canada, Open File 2969, scale 1:250 000.

Tella, S., Paul, D., Davis, W.J., Berman, R.G., Sandeman, H.A., Peterson, T.D., Pehrsson, S.J., and Kerswill, J.A., 2005. Bedrock geology compilation and regional synthesis, parts of Hearne domain, Nunavut; Geological Survey of Canada, Open File 4729, 2005; scale 1: 250 000, 2 sheets, 1 CD-ROM.

Tremblay, T., Ryan, J.J., and James, D.T., 2007. Ice flow studies in Boothia Mainland (NTS 57A and 57B), Kitikmeot region, Nunavut, Geological Survey of Canada, Open File 5554, 16 p.

Zaleski, E., Davis, W.J., and Sandeman, H.A., 2001. Continental extension, mantle magmas & basement/cover relationships; in Extended Abstracts, 4th International Archean Symposium 2001; (eds.) K.F. Cassidy, J.M. Dunphy, and M.J. van Kranendonk; Australian Geological Survey Organisation, Report 2001/37, p. 374–376.

Geological Survey of Canada Project NMRD-Booth