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Overview of the GEM Multiple Metals — Melville Peninsula project, central Melville Peninsula, Nunavut

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Abstract: Recent work in the Melville Peninsula area of the Rae Craton provides new constraints on the lithotectonic framework of Archean supracrustal rocks and associated Archean intrusions, as well as Paleoproterozoic cover sequences. The region is subdivided into four lithologically distinctive crustal blocks that include from north to south: the Northern Granulite Block; the Prince Albert Block; on which lies the Penrhyn Group; and the Repulse Bay Block. The Prince Albert belt is redefined as a ca. 3.20 Ga to 2.77 Ga greenstone belt, much older than the Committee Bay belt to which it was historically linked and collectively named the Prince Albert Group. On the eastern side of the Peninsula, the Roche Bay greenstone belt appears to be linked — at least in age — to the Prince Albert belt. Penetrative Paleoproterozoic deformation can be confidently documented northwesterly to the Roche Bay greenstone belt. Beyond this, it is less well defined although the Folster Lake Formation suggests moderate deformation under upper-greenschist metamorphic conditions.

Résumé : De récents travaux effectués dans la région de la péninsule Melville, dans le craton de Rae, fournissent de nouvelles contraintes au cadre lithotectonique des roches supracrustales de l'Archéen et des intrusions associées du même âge, ainsi que des séquences de couvertures du Paléoprotérozoïque. La région peut être subdivisée en quatre blocs crustaux à lithologie caractéristique, à savoir, du nord au sud, le bloc de granulites du Nord, le bloc de Prince Albert, le Groupe de Penrhyn, qui repose sur le bloc précédent, et le bloc de Repulse Bay. La ceinture de Prince Albert est redéfinie comme étant une ceinture de roches vertes âgée de 3,20 à 2,77 Ga. Elle est beaucoup plus ancienne que la ceinture de Committee Bay à laquelle on l'associait par le passé et que, collectivement, l'on désignait sous le nom de Groupe de Prince Albert. Sur le côté est de la péninsule, la ceinture de roches vertes de Roche Bay semble être reliée - du moins en âge - à la ceinture de Prince Albert. Une déformation pénétrative d'âge paléoprotérozoïque peut être observée vers le nord-ouest avec certitude jusqu'à la ceinture de roches vertes de Roche Bay. Au-delà de ce point, elle est plus discrète, bien que la Formation de Folster Lake suggère une déformation modérée dans les conditions métamorphiques du faciès des schistes verts supérieur.

INTRODUCTION

Melville Peninsula in central Nunavut was the focus of one of a number of multidisciplinary, northern geoscience projects that were initiated by the Geological Survey of Canada as part of the five-year Geo-mapping for Energy and Minerals (GEM) program (Fig. 1). The main objective of this project was to improve geoscience knowledge of Melville Peninsula, an area of approximately 50 000 km^2, in order to better understand the bedrock and surficial geological evolution and mineral potential of the area. This improvement on general geoscience knowledge was deemed necessary to ascertain along-strike correlations with more recently studied, mineral-rich supracrustal belts to the southwest (Committee Bay Belt), to the west (Barclay and Halkett Inlet belts), to the north-northeast (Mary River Group), and east-northeast (Eqe Bay belt and Piling Group) (e.g. Scammell and Bethune, 1995; Corrigan et al., 2000; Scott et al., 2003; Skulski et al., 2003; Johns and Young, 2006; Ryan et al., 2009).

One of the numerous hypotheses that are being tested in the Melville project is whether the Archean and Paleoproterozoic rocks on Melville Peninsula are as economically endowed as those that occur along strike (e.g. Woodburn Group; Meadowbank mine (Au), Committee Bay belt; Three Bluff (Au), Mary River Group; Baffinland Iron (Fe) and Piling Group; Bravo formation (Au)). The preferred approach here was to invest as much effort as possible in understanding the geology in terms of tectonometamorphic history, tectonic environment of deposition, volcanism, and magmatism; and to link these environments to metallogenic models comprising a broad range of possible deposit types. In order to help attain these goals the program leaders designed a scientifically integrated research program aimed at understanding crustal evolution in time and space.

Quaternary studies were carried out together with bedrock mapping in order to provide more detail to existing glacial dynamic models and to evaluate economic mineral potential by improving the database on till geochemistry, kimberlite and base-metal indicator mineral analysis, and gold-grain counts (Tremblay et al., 2010; Tremblay and Paulen, 2012).

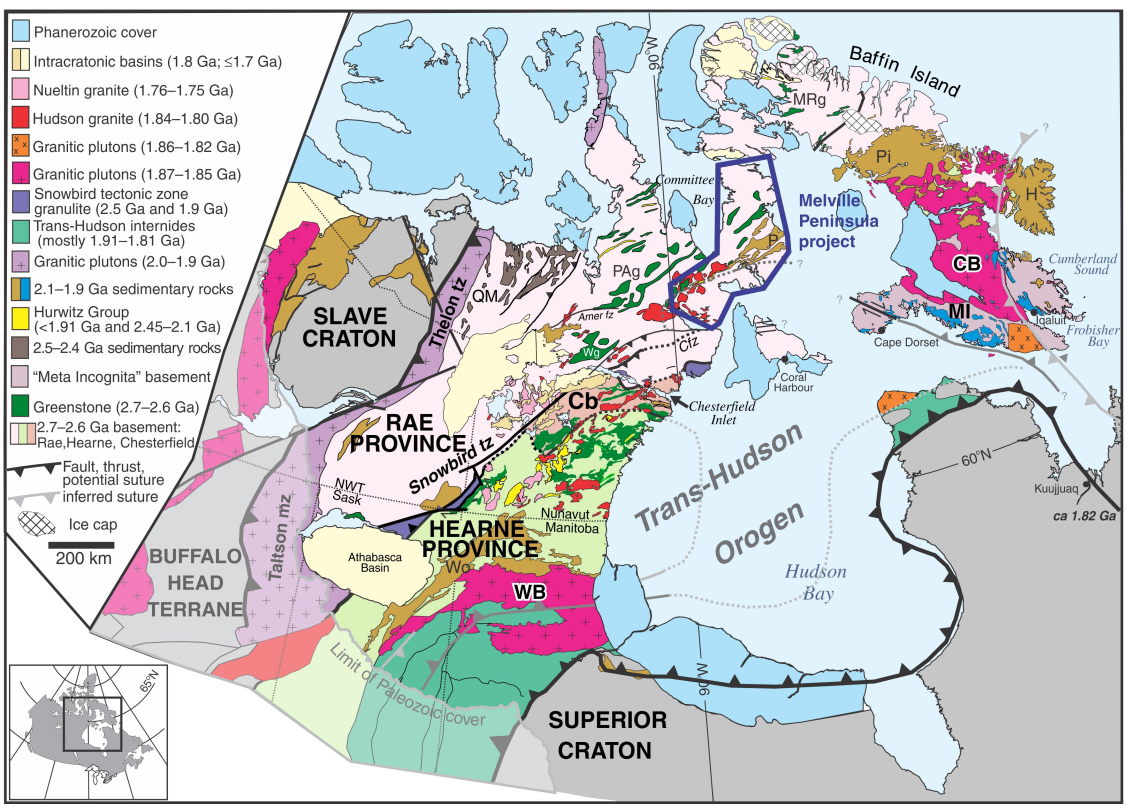

Figure 1. Simplified geological map of Melville Peninsula, (*modified from* Berman et al., 2005). The area shown within the thick blue line outlines the greater Melville Peninsula project area, although the bedrock geology mapping component is limited to Melville Peninsula only. The Quaternary component includes the area southwest of Melville Peninsula. Cb = Chesterfield Block, CB = Cumberland batholith, Cfz = Chesterfield fault zone, fz = fault zone, H = Hoare Bay Group, MI = Meta-Incognita micro-continent, MRg = Mary River Group, mz = magmatic zone, P = Penrhyn Group, Pi = Piling Group, PAg = Prince Albert Group, QM = Queen Maud Block, tz = tectonic zone, Wb = Wathaman batholith, Wg = Woodburn Group, Wo = Wollaston Group.

This contribution represents a summary of field observations, resulting from variable-scale geological mapping in NTS map areas 47-A and 47-B (Fig. 2). A subsequent report will highlight the main observations from Melville Peninsula south of 68°N.

PREVIOUS WORK

Prior to 1960, sporadic geological observations had been made along segments of the Melville Peninsula coast, but it was not until helicopter-supported mapping in the early 1960s during Operation Wager that the bedrock geology of Melville Peninsula was first investigated at reconnaissance scale (Heywood, 1967). Following preliminary findings by Heywood (1967), the geology of selected areas was mapped in greater detail in the 1970s and early 1980s (e.g. Schau, 1973, 1975, 1984, 1993, 1997; Frisch and Jenner, 1975, Frisch and Goulet, 1975; Henderson and Turay, 1977; Henderson and Vrona, 1977; Henderson et al., 1977, 1978; Schau and McGrath, 1981; Frisch, 1982; Henderson, 1983; Schau and Heywood, 1984 and references therein; Schau and Digel, 1989). This early mapping succeeded in outlining the main lithological subdivisions with identification of the main Archean greenstone belts, expanses of gneissic terranes, plutonic rocks, and Proterozoic cover. Published mineral potential studies have focused on iron (Wilson and Underhill, 1971), nickel (Eckstrand, 1975), base–metal deposits (Cameron, 1979), and uraniferous granite (Maurice, 1979; Delpierre, 1982). The first comprehensive account of the physiography and Quaternary geology of the interior of Melville Peninsula was produced by V.W. Sim (unpub. Geographical Branch memoir, 1960). Dredge (1995 and references therein) added significantly to this earlier work. Previous geophysical surveys covering Melville Peninsula include low-resolution (800 m flight-line spacing) analogue aeromagnetic data as well as an early low-resolution analogue radiometric survey flown in the 1970s as part of the NatGam program. Despite these early studies there still remained large parts of the peninsula with relatively little information, a lack of conformity between adjacent 1:250 000 scale map sheets, and an absence of modern radiogenic isotope data, all hindering the postulation of regional correlation models.

MELVILLE PENINSULA PROJECT

The fieldwork component of the Melville Peninsula project consisted of three field seasons, with the first season in 2009 concentrated in the northern half of the peninsula within the Archean dominated terrains in NTS map areas 47-A and 47-B, and the second season in 2010 concentrated on the southern half in map areas 46-J, -K, -N and -O within Proterozoic-dominated terrains (Fig. 2). During the summer of 2011, a third, shorter field season was completed in the western part of map sheet 47-B, in order to acquire a better understanding of the stratigraphy of the Prince Albert Group in its type locality within the Prince Albert Hills. Surficial studies were extended to the southwest of the main bedrock focus area to include the vast, poorly known area on the mainland located between Repulse Bay and Wager Bay (Campbell and McMartin, 2011).

Prior to commencement of fieldwork in the summer 2009, regional airborne geophysical surveys were carried out in order to improve on low-resolution analogue data acquired in the 1970s and provide more detailed resolution of rock magnetic and radiometric properties over two areas dominated by supracrustal rocks (Fig. 3a, b). The Sarcpa Lake survey collected 43 000 line-kilometres of aeromagnetic data over the Archean supracrustal rocks, mostly in map areas NTS 47-A and 47-B, at 400 m line spacing and 150 m nominal terrain clearance (Coyle, 2010a, b; Fortin et al., 2010). The Miertsching Lake survey, consisting of 47 000 line-kilometres acquired at the same resolution as the Sarcpa Lake survey, comprised both aeromagnetic and radiometric data (Fortin et al., 2010, 2011). It was collected mostly over the Paleoproterozoic Penrhyn Group, which correlates with the Piling Group on Baffin Island (Jackson and Taylor, 1972; Rainbird et al., 2010). During the summer of 2009, a 300 km long magnetotelluric survey was acquired along a north-south transect across most of the peninsula (Spratt et al., 2013). Some 2341 lake-sediment samples that were collected during an earlier survey (originally analyzed for 12 elements by XRF and published as GSC Open Files 521A, B and 522A, B; Hornbrooke 1978a, b, c, d), were reanalyzed for 36 elements by inductively coupled plasma mass spectrometry (ICP-MS) and 25 elements by instrumental neutron analysis (INA), and published as GSC Open File 6269 (Day et al., 2009). In order to extend surficial sediment analytical coverage in the north half of Melville Peninsula, 508 unprocessed till samples from GSC archives were also analyzed and published as GSC Open File 6285 (Dredge, 2009).

REGIONAL CONTEXT

Melville Peninsula is located in the Western Churchill Province, which is essentially a large mobile belt that formed during assembly of the supercontinent Nuna between approximately 1.98 Ga and 1.80 Ga (e.g. Hoffman, 1990; Lewry and Collerson, 1990). The Western Churchill Province consists predominantly of distinct, variably reactivated Archean crustal blocks (predominantly remnants of the Rae and Hearne cratons) with voluminous Paleoproterozoic intrusions and sedimentary cover sequences. Melville Peninsula sits entirely within the Rae Craton, which consists largely of Meso- to Neoarchean crust and Paleoproterozoic cover that were variably reactivated during the Paleoproterozoic (Jackson and Berman, 2000; Berman et al., 2005). The main regional structural fabric strikes in an easterly to northeasterly direction. From north to south on Melville Peninsula, four main lithotectonic domains are identified: the Northern Granulite Block consisting of granulite facies orthogneiss and

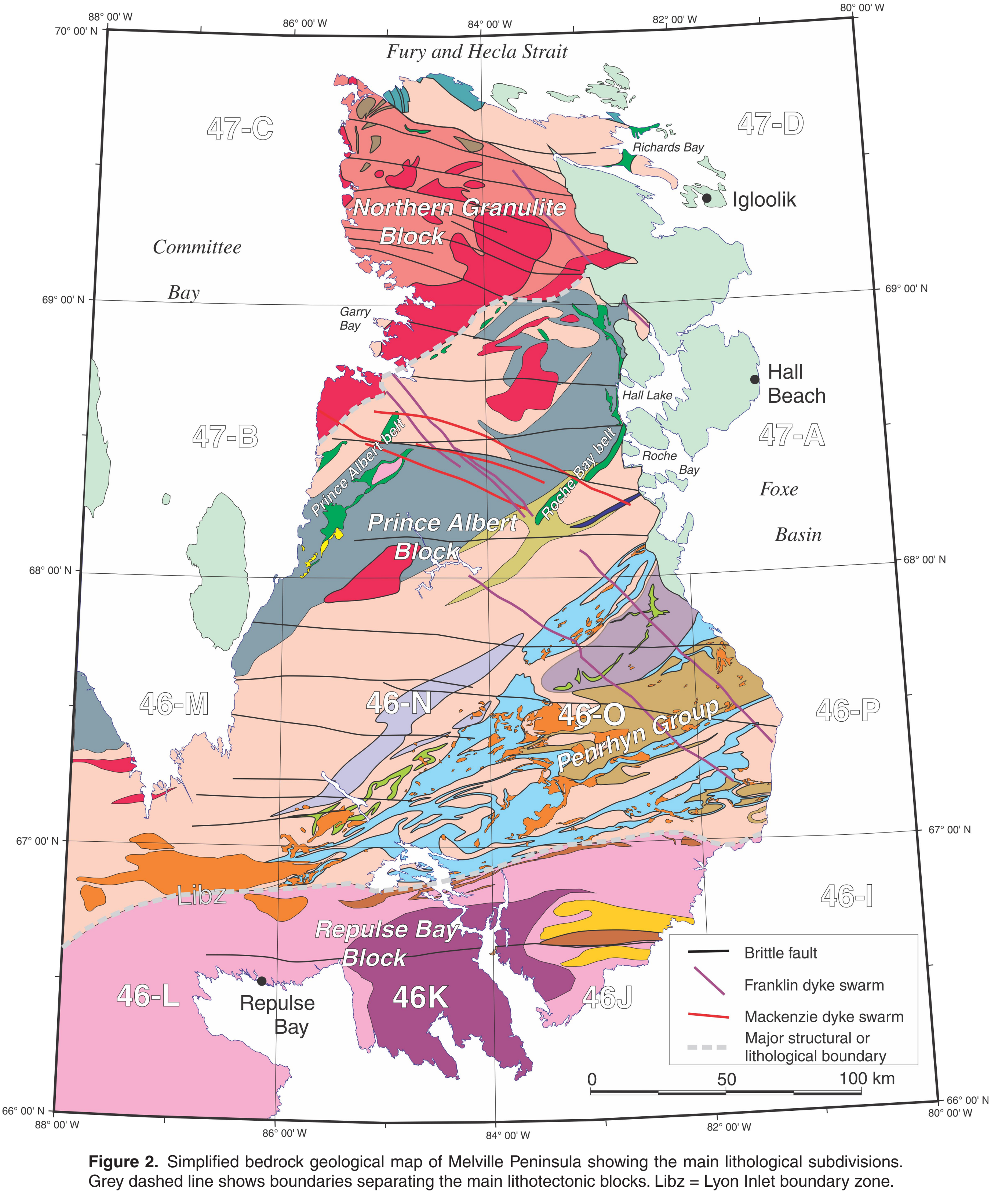

Figure 2. Simplified bedrock geological map of Melville Peninsula showing the main lithological subdivisions. Grey dashed line shows boundaries separating the main lithotectonic blocks. Libz = Lyon Inlet boundary zone.

LEGEND

Phanerozoic cover

Fury and Hecla group (Meso-Proterozoic)

Syncollisional intrusions, pegmatite

Metaconglomerate, redbed sandstone, marl, crossbedded arkosic arenite and minor quartz arenite (Folster Lake Formation).

Repulse Bay supracrustal cover

Ferrugenous pelite and psammopelite, marble

Penrhyn Group (Paleoproterozoic)

Upper — Metasiltstone, psammopelite, minor metapelite, local turbidite, greywacke

Lower — Quartzite, marble, calc-silicate gneiss, metapelite, sulphidic metapelite

Early Paleoproterozoic intrusive rocks

Bimodal leucogabbro-anorthosite and granite plutonic suite, massive to weakly foliated

Diorite, quartz-diorite and minor granite, weakly to moderately foliated

Repulse Bay Block (Archean)

Charnockite and other orthopyroxene-bearing plutonic rocks locally with lower crustal xenoliths

Mainly felsic migmatitic orthogneiss with tectonically dismembered metagabbro dykes

Intermediate to felsic orthogneiss, migmatitic

Rae Craton

Late Archean (ca. 2.60 Ga) felsic intrusions, leucogranite

Late Archean felsic to intermediate intrusions (Hall Lake suite)

Predominantly charnockite and mangerite gneiss and retrograde metamorphic equivalents

Paragneiss, undivided

Felsic to intermediate plutons, orthogneiss and migmatite, undivided.

Undivided supracrustal rocks including felsic, mafic and ultramafic metavolcanic rocks, metapelite, oxide-facies banded iron-formation, ferrugenous psammite.

Ultramafic rock including pyroxenite and serpentinite flows and/or sills

Archean supracrustal rocks, mainly siliciclastic with minor mafic to felsic volcanic rocks

Archean supracrustal rocks including komatiite, basalt, rhyolite, dacite, andesite, banded iron-formation and siliciclastic metasedimentary rocks

Figure 2. (Legend)

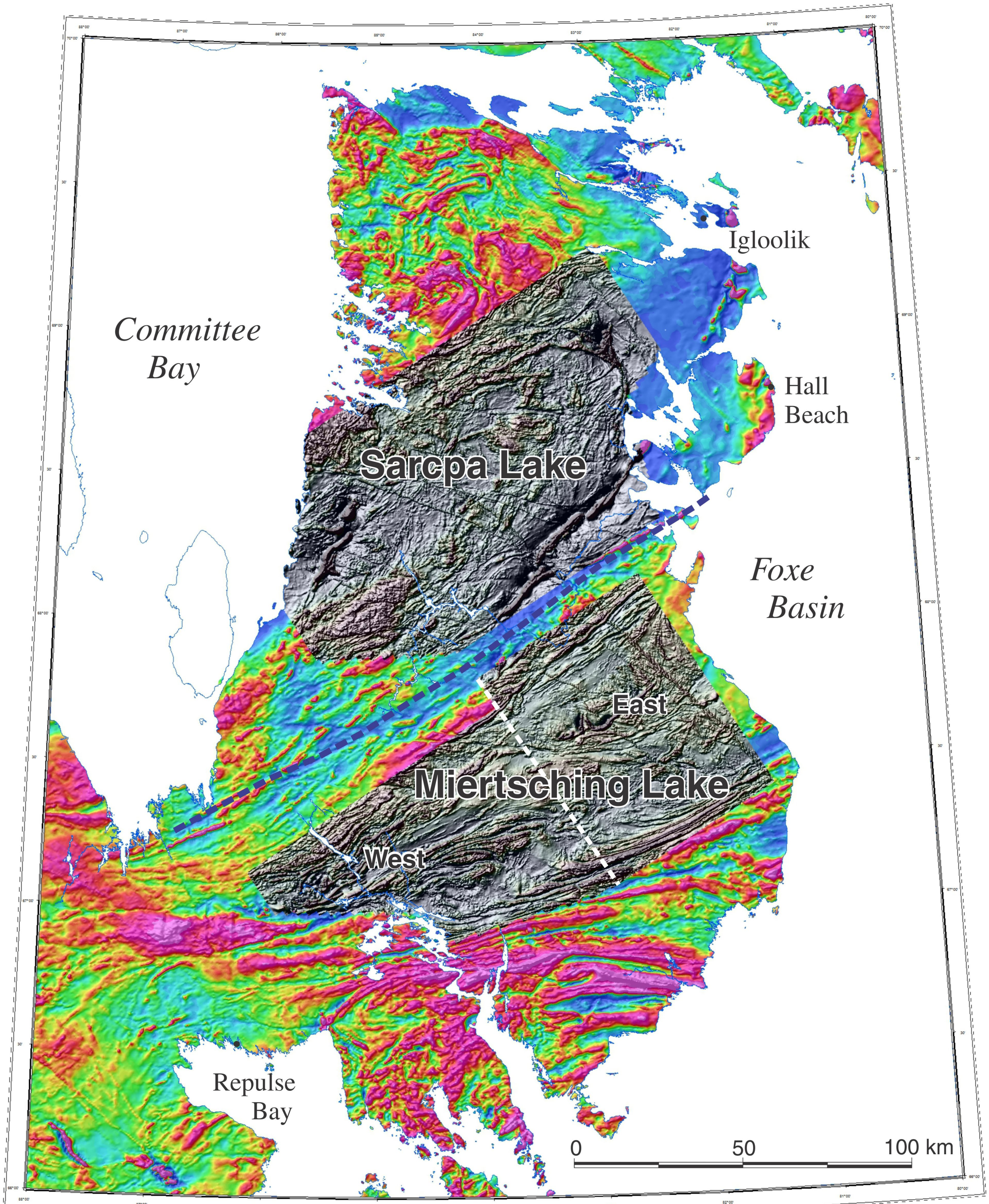

Figure 3. a) Map of Melville Peninsula with total-field aeromagnetic images from three new high-resolution surveys (Sarcpa Lake, West Miertching, East Mertching), shown in shaded relief. Line spacing: 400 m, flight height: 150 m. The regional aeromagnetic image in background is from analogue acquisition from the 1970s. The boundary separating the 'northern structural zone' from the 'southern structural zone' is shown (blue dashed line, *see* text for explanation).

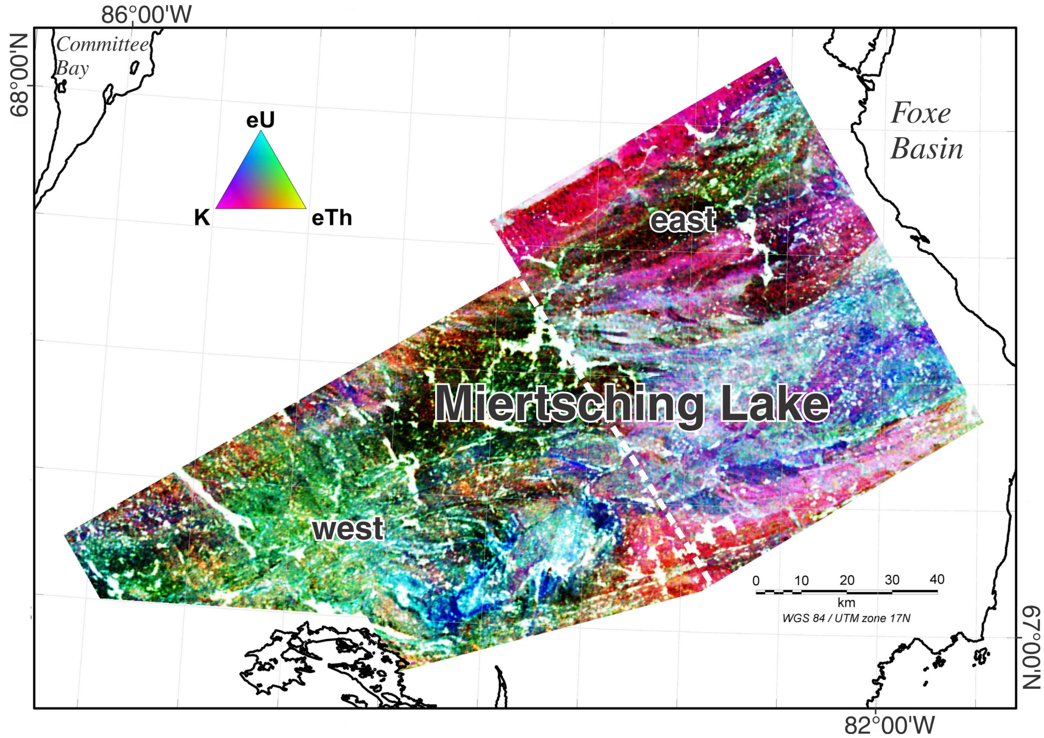

Figure 3. (cont.) b) High-resolution (*see* Fig. 3a) airborne radiometric map, Miertsching Lake survey, with ternary U-K-Th plot shown.

plutonic rocks with minor supracrustal screens; the Prince Albert Block, which consists of upper-greenschist to middle-amphibolite facies Archean supracrustal rocks as well as plutonic rocks and orthogneiss; variably deformed and metamorphosed metasedimentary rocks of the Paleoproterozoic Penrhyn Group, which overlay and are in stratigraphic and/or thrust contact with the Prince Albert Block; and a predominantly gneissic domain composed of variably strained, high metamorphic grade orthogneiss intruded by charnokite and overlain by sparse belts of presumed Paleoproterozoic cover rocks, informally named the Repulse Bay Block (Fig. 2). On the western side of the peninsula near the shore of Committee Bay, Archean rocks are unconformably overlain by the Paleoproterozoic clastic sedimentary sequence of the Folster Lake Formation (Frish, 1982). In the north along Fury and Hecla Strait, Archean crust is unconformably overlain by Mesoproterozoic fluvial to shallow-marine sequences of the Fury and Hecla Group, now block-faulted and forming south-dipping cuestas (Chandler, 1988; Long and Turner, 2012). The boundary between the Prince Albert and Repulse Bay blocks (herein referred to as the Lyon Inlet boundary zone) consists of a steeply dipping zone of moderate to intense transposition which appears, from the regional aeromagnetic map pattern and kinematic indicators, to have accommodated dextral transpressional shear. A number of brittle faults transect the peninsula (*see* Fig. 5a). They trend 90° to 110° and form deeply incised troughs. Some of these faults are overlain by Phanerozoic platform sedimentary rocks of the Foxe Basin, whereas others appear to displace the latter, suggesting a complex fault history both predating and postdating the Ordovician and Silurian.

ARCHEAN SUPRACRUSTAL ROCKS

Two main strands of Archean supracrustal rocks occur in map areas 47-A and 47-B, outlining a regional curvilinear structural trend visible on satellite imagery and aeromagnetic maps. The two strands are referred to herein as the Prince Albert and Roche Bay greenstone belts. Archean greenstone occurring on the western side of the peninsula in the Prince Albert Hills form the type locality for the Prince Albert Group as defined by Heywood (1967). Based on reconnaissance work, Heywood included the Committee Bay belt as well as other greenstone strands occurring in the northeastern Rae Craton within the Prince Albert Group; however, U-Pb zircon analysis on a rhyolite from that locality yielded an age of ca. 2.97 Ga (Wodicka et al., 2011), confirming the presence of volcanic rocks older than the mainly ca. 2.73–2.70 Ga volcanic ages reported from the Woodburn Group and Committee Bay belt (Skulski et al., 2003). These data demonstrate that the Prince Albert greenstone belt is about 240 million years older than the Woodburn Group and Committee Bay belt, precluding any direct correlations. The present authors henceforth refer to the strand of supracrustal rocks that occurs in the Prince Albert Hills (Prince Albert greenstone belt) as the type locality of the

Prince Albert Group and consider it distinct from the above-mentioned Committee Bay and Woodburn greenstone belts. The other large strand, occurring on the eastern side of Melville Peninsula is herein referred to as the Roche Bay greenstone belt. Between the Prince Albert and Roche Bay belts are numerous small occurrences of supracrustal rocks, either engulfed as rafts in plutonic rocks, or as tectonically dismembered units suggesting a potential structural continuity with the Roche Bay and/or Prince Albert belts. Distinct strands of Archean supracrustal rocks occur further south in basement windows beneath the Penrhyn Group. A separate strand of supracrustal rocks that occurs in northeast Melville Peninsula in the Richards Bay area and nearby islands and referred to herein informally as the Bouverie Island greenstone belt, has been described in detail by Schau (1993). There is currently insufficient data to determine with certainty whether the Prince Albert, Roche Bay, and the Bouverie Island belts formed a single supracrustal entity prior to the emplacement of voluminous Archean plutonic suites, or if they evolved separately. Preliminary Nd isotopic data does, however, point to a common ancestry with mantle extraction ages of approximately 3.2–2.8 Ga for the Prince Albert and Roche Bay belts (L. Nadeau, preliminary data, 2011). Until further studies suggest otherwise, the present authors are taking a conservative approach and describing them as separate belts. One feature they do have in common is the presence of substantial volumes of magnetite- and hematite-bearing Algoma-type banded iron-formation, suggesting a possible association with the Mary River Group in northern Baffin Island.

Prince Albert greenstone belt

The Prince Albert greenstone belt occurs on the western side of the peninsula and strikes parallel to the Roche Bay belt. Parts of it were mapped in detail by Frisch and Goulet (1975), and Frisch and Jenner (1975), and are described in a GSC Bulletin published by Frisch (1982). Two recent 1:50 000 scale bedrock geology maps covering the southwest and northeast parts of the belt have been published in the course of this project (Machado et al., 2011, 2012). The belt is continuously exposed along a strike length of about 60 km and has a maximum width of 12 km. These rocks are generally highly strained and show evidence of tight to isoclinal folding with steeply plunging axes. Low-strain domains in the belt preserve numerous primary volcanic or sedimentary features such as pillow lavas (Fig. 4a), spinifex texture (Fig. 4b), and graded bedding in clastic sedimentary rocks, hence locally providing criteria from which stratigraphic order can be established. The stratigraphic base consists of thick basaltic sequences (flows and sills) with rare ultramafic interflows, komatiite flows and sills, and thin felsic volcanic intervals including quartz- and feldspar-phyric rhyolite. This lower sequence is locally overlain by a clastic and chemical metasedimentary succession that includes oxide-facies banded iron-formation (Fig. 4c), silicate-facies iron-formation, metaturbidite, and mafic wacke (Fig. 4d). The metasedimentary package locally contains white to light grey actinolite- and/or biotite-bearing layers that are interpreted as felsic to intermediate composition volcanic or volcaniclastic strata. Oxide-facies banded iron-formation appears to cap this metasedimentary succession, above which unconformably lies a polymictic conglomerate (Fig. 4e) that includes quartz-pebble, banded iron-formation, siltstone, garnetite, and fine-grained felsic to mafic clasts of possible volcanic origin. The conglomerate grades upward into mixed felsic and intermediate composition rock that resemble felsic tuff breccia, which is in turn overlain by a thick sequence of felsic to intermediate composition rocks of possible volcanic origin. Supracrustal rocks of the Prince Albert Group are intruded by kilometre-sized bodies and sills of peridotitic, gabbroic, or more felsic composition such as quartz-feldspar porphyry and feldspar-phyric tonalite and diorite, some which may represent subvolcanic intrusions (Fig. 4f). A mineralized komatiitic peridotite body was described in Houlé et al. (2010) and hosts significant mineralization that grades up to 16% nickel.

Roche Bay greenstone belt

The Roche Bay greenstone belt is well exposed in map area 47-A and southeast of 47-B where it outlines a slightly arcuate anomaly pattern on aeromagnetic maps. There is little in terms of previous publications on the stratigraphy of that belt, except for an early mineral assessment file report (Norman H. Ursel Associates, unpub. report, 1969). The belt consists of two strands. The main one on the northwestern side is formed predominantly of silicate- and oxide-facies banded iron-formation (BIF) (Fig. 5a), siliciclastic rocks including quartzite, psammite (Fig. 5b), metaturbidite, volcanic rocks including komatiite, basalt (Fig. 5c), rhyolite, and volcaniclastic rocks. The supracrustal package comprises elongated, strike-parallel sheets of ultramafic rock, gabbro, quartz-feldspar porphyry, plagioclase-phyric diorite, and tonalite that, for the most part, likely represent subvolcanic intrusions. Approximately south of 68°15′N, metasedimentary rocks are more prominent than metavolcanic rocks, and the latter are mainly represented by thin basaltic flows, that locally exhibit pillow structures. In the northern extension of the Roche Bay belt west and northwest of Hall Lake, the supracrustal sequence described above is dominated by basaltic flows and overlain by a polymictic conglomerate unit composed mainly of fine-grained felsic to intermediate metavolcanic and siliciclastic clasts (Fig. 5d). That unit grades upward into a thick sequence of volcanic rock–derived sediments of bulk felsic to intermediate composition (Fig. 5e). An isolated screen of supracrustal rocks west of the clastic assemblage contains mafic and ultramafic flows, silicate- and oxide-facies banded iron-formation and minor psammite and quartzite.

A second extensive strand of supracrustal rocks that splays from the main belt and strikes about 070° azimuth occurs south-southwest of Roche Bay. That strand is dominated by one or more

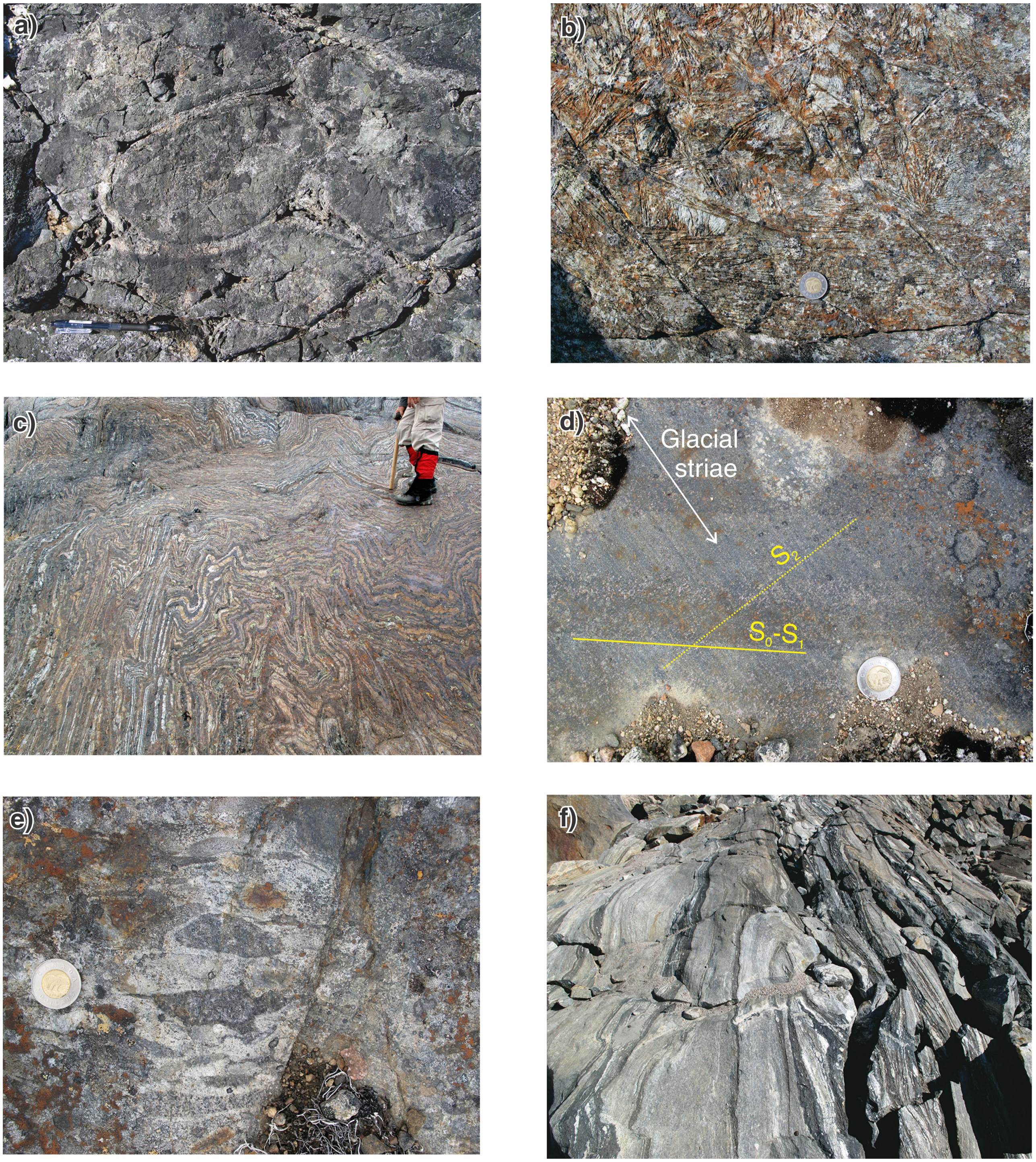

Figure 4. Outcrop photographs from the Prince Albert greenstone belt in the Prince Albert Hills area showing **a)** Archean pillow basalt with well preserved selvage and keel, in this case indication younging toward the west (photograph looking west); pencil is 14 cm long; 2013-286; **b)** spinifex texture in komatiite lava flow; coin is 28 mm wide; 2013-267; **c)** intensely folded oxide-facies banded iron-formation; hammer is 38 cm long; 2013-278; **d)** coarse compositional layering (S_0-S_1) in mafic wacke, stratigraphically below the banded iron-formation shown in Figure 4c above; S_2 cleavage is shown, as well as glacial striae; coin is 28 mm wide; 2013-272; **e)** polymictic conglomerate; coin is 28 mm wide; 2013-266; and **f)** highly strained, mixed tonalite-diorite subvolcanic intrusion in unit PAgb mafic volcanic rocks, forming banded gneiss; bottom of photograph is 1.5 m wide; 2013-283. All photographs by D. Corrigan.

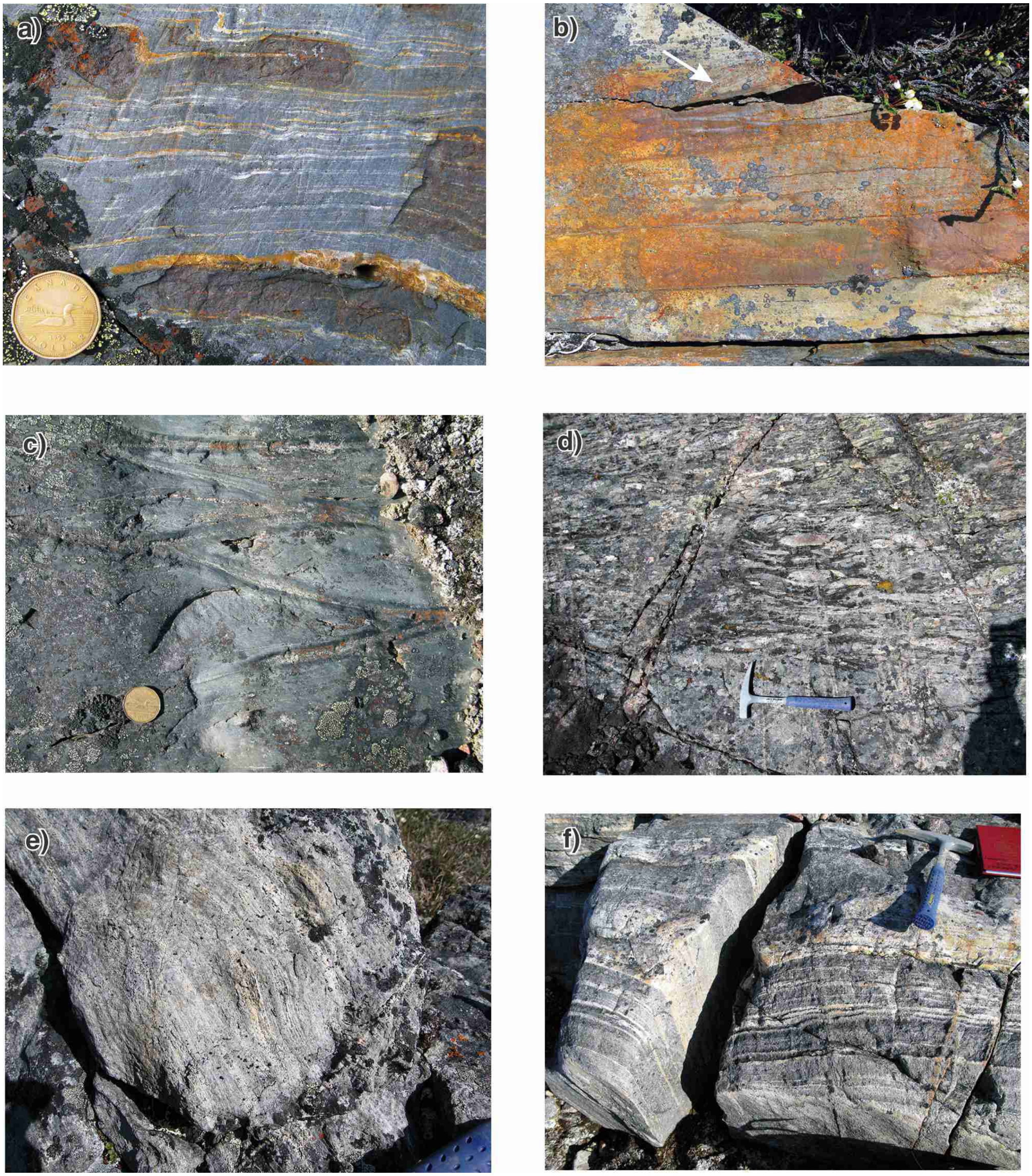

Figure 5. Outcrop photographs from the Roche Bay greenstone belt showing: **a)** magnetite-rich banded iron-formation from the northern extent of the belt, northwest of Hall Lake; coin is 26 mm wide; 2013-268; **b)** ferruginous psammite with small-scale crossbeds (visible in layer in top part of photograph, *see* arrow) in the southwestern part of the belt; bottom of photograph is 0.5 m across; 2013-284; **c)** slightly flattened pillow structures in basalt, southwest Roche Bay belt near location of Figure 5b; coin is 26 mm wide; 2013-273; **d)** polymictic conglomerate consisting mainly of fine-grained metavolcanic and metasedimentary clasts, Roche Bay belt on western shore of Hall Lake; hammer is 38 cm long; 2013-287; **e)** layered metavolcanic (or volcaniclastic) rock of felsic to intermediate composition adjacent to (and to the east of) polymictic conglomerate shown in Figure 5d. Stratigraphic top direction unknown; bottom of photograph is 40 cm across; 2013-280; **f)** ca. 2.77 Ga, highly strained, banded tonalitic orthogneiss flanking the Roche Bay greenstone belt supracrustal to the southeast, inland from western shore of Roche Bay; hammer is 38 cm long; 2013-271. All photographs by D. Corrigan.

continuous, decametres thick ultramafic sills that intrude subparallel to a supracrustal sequence that includes mafic volcanic rocks, oxide-facies banded iron-formation and rare, thin quartzite beds. The ultramafic sills are completely recrystallized and metamorphosed to talc-tremolite-serpentine schist.

Supracrustal rocks of the Roche Bay belt are intruded by at least two suites of felsic to intermediate plutonic rocks. An early suite of multiply injected intrusions, dated at ca. 2.76 Ga (Wodicka et al., 2011) has been transposed into parallelism with the main regional structural trend, to the extent that it appears quite gneissic and has been interpreted in earlier reports as basement gneiss (Fig. 5f). The intrusions are dominantly of tonalitic composition, but also include dioritic, granitic, and aplitic phases. For the most part the different phases are medium-grained, nonmigmatitic, and are thoroughly recrystallized. The second suite consists of voluminous, locally K-feldspar megacrystic granitic to granodioritic plutons and batholiths that crosscut the fabric in the supracrustal rocks and themselves bear a weak foliation parallel to the main regional structural trend. Preliminary U-Pb zircon ages for this later suite range between ca. 2.73 Ga and 2.69 Ga (Wodicka et al., 2011).

For the most part, strain in the Roche Bay belt is sufficiently high to locally obliterate original sedimentary and volcanic structures, including stratigraphic top indicators, hindering along-belt correlations and the establishment of a depositional history. Where top indicators are found, structural complications such as faults and the presence of tight to isoclinal folds make it difficult to establish overall younging directions. Northwest of Hall Lake, thick mafic volcanic sequences including abundant pillow structures suggest younging toward the northeast. The sequence contains at least two distinct layers of oxide-facies banded iron-formation and rare layers of quartz-pebble conglomerate and felsic volcanic rocks less than a few metres thick. West of that occurrence, another isolated supracrustal package approximately 1 km by 5 km consists of a thick banded iron-formation and metapelite overlain by a polymictic conglomerate that includes numerous platy clasts of quartzite, likely derived from chert horizons in the Algoma-type banded iron-formation. Structurally above that is a schistose, muscovite-rich metasedimentary unit containing andalusite porphyroblasts, itself overlain by volcanic to volcaniclastic rocks of felsic to intermediate composition. The last assemblage is referred to as the "Tuktu" banded iron-formation occurrence by Advanced Exploration Inc. (2012).

PLUTONIC ROCKS

A large proportion of Melville Peninsula is underlain by a domain of mixed rocks that cannot be separated into units at the scale of the present mapping; these rocks include orthogneiss, migmatite, and plutonic rocks of predominantly felsic to intermediate composition, with minor mafic to ultramafic plugs. The orthogneiss and migmatite (Fig. 6a) appear to form the oldest plutonic units, and are intruded by more compositionally homogeneous plutons (Fig. 6b, 6c). An imprecise minimum U-Pb zircon age of ca. 2953 Ma obtained on a foliated granodiorite (Frisch, 1982) suggests that plutonic rocks perhaps as old as the volcanic rocks may occur in the region.

The largest volume of plutonic rock is represented by weakly to moderately foliated granitic, granodioritic, and tonalitic intrusions that are relatively homogeneous except for the presence of rare rafts or enclaves of amphibolite and diorite. Dated intrusions have yielded preliminary U-Pb zircon ages of about 2.73 Ga to 2.70 Ga and ca. 2.60 Ga (Wodicka et al., 2011). These younger suites crosscut tight to isoclinal folds developed in the Archean supracrustal rocks, suggesting that the main deformation is Archean. It is permissible and actually quite likely that the weaker penetrative fabric parallel to the regional structural grain observed in the above plutons is Paleoproterozoic.

Of potential economic interest are a number of mafic to ultramafic intrusions scattered throughout the map area. These include the "BIL gabbro" (B.M. Tiger, unpub. assessment report, 1973), which hosts disseminated sulphide minerals including chalcopyrite and pentlandite. That particular intrusion was explored for base metals by Borealis Ltd. in the 1970s. It forms a spectacular rusty hilltop visible from several kilometres away at UTM co-ordinates 418100E, 7642082W, UTM zone 17W (Fig. 6d). In the northern portion of NTS map area 47-B, numerous small intrusions and plugs of ultramafic rock produce a dotted magnetic-high pattern on aeromagnetic maps. One such intrusion comprises a voluminous coarse-grained orthopyroxenite associated with layered metagabbro. Fractures within the orthopyroxenite host large plates of molybdenite (Fig. 6e). A rock sample including molybdenite and located at 584634E, 7610304W, UTM zone 16N yielded assay values of 1783 ppm Mo, 4 ppm Au, 24 ppb Pt, 51 ppb Pd, 778 ppm Bi, and 1233 ppm V.

DYKE SWARMS

At least four major mafic dyke swarms occur on Melville Peninsula. An older set of amphibolite dykes up to 100 m wide and oriented north to about 020° azimuth cuts across most of the rock units observed in 47-A and -B, including the ca. 2.70 Ga plutons. This set of dykes, perhaps originally gabbroic in composition, has relic chilled margins and coarser grained interiors, but are completely amphibolitized, containing metamorphic amphibole prophyroblasts and mostly recrystallized plagioclase. Some of these dykes contain a weak northeast-trending foliation parallel to the main regional trend. The peninsula hosts undeformed, Proterozoic mafic dykes of the ca. 1270 Ma Mackenzie and ca. 723 Ma Franklin swarms (Fahrig and Jones, 1969; Fahrig et al., 1971; LeCheminant and Heaman, 1989; Heaman et al., 1992). Although less common, the area also hosts a set of east-trending dykes potentially associated with the ca. 2.19 Ga

Figure 6. Outcrop photographs of plutonic rocks in NTS map area 47-A and -B showing **a)** typical migmatitic orthogneiss forming potentially oldest plutonic component, intruded by younger Archean granite dykes and veins; hammer is 38 cm long; 2013-275; **b)** typical outcrop exposure of ca. 2.7 Ga to 2.6 Ga granitic to granodioritic plutons showing relatively weak fabric and exfoliation structures (shallow-dipping set of fractures); bottom of photograph is 2 m across; 2013-285; **c)** ca. 2.60 Ga tonalite northwest of the Prince Albert greenstone belt showing weak east-striking either late Archean or Paleoproterozoic foliation; bottom of photograph is 0.5 m across; 2013-279; **d)** aerial view of ca. 2.7 Ga 'BIL gabbro' pluton, with disseminated Fe-Cu-Ni sulphides forming spectacular gossan; pluton is about 300 m in diameter; width of field at bottom of photograph is approximately 200 m across; 2013-282; **e)** molybdenite (silver colour) on fracture surface in orthopyroxenite; rest of outcrop surface is covered in lichen; coin is 26 mm wide; 2013-277; **f)** altered feldspar phenocrysts in amphibolite dyke, possibly part of the MacQuoid Proterozoic dyke swarm; coin is 26 mm wide; 2013-276. All photographs by D. Corrigan.

MacQuoid swarm (Tella et al., 1997) based on their orientation and presence of characteristic, whitish glomeroporphyritic pseudomorphs of clinozoisite and sericite after plagioclase (Fig. 6f). These dykes are cut by the 1270 Ma Mackenzie dykes and bear a static metamorphic overprint comprising greenschist–lower amphibolite transition facies paragenesis. Rare, unmetamorphosed, pyroxene- and plagioclase-phyric diabase dykes with aphanitic matrix oriented about 025° azimuth occur in the Prince Albert Hills and are likely Phanerozoic based on their apparent shallow level of emplacement.

STRUCTURE AND METAMORPHISM

From a regional structural perspective, Melville Peninsula can essentially be separated into a northern domain, where Archean structures and fabrics dominate, and a southern zone, with pronounced Paleoproterozoic structural and thermal overprint (e.g. Schau, 1975; Schau et al., 1993); however, Archean fabrics do occur locally in basement structural windows in the southern structural domain and Paleoproterozoic fabrics extend in the 'northern structural domain', although to a lesser extent. The boundary between the two domains, although diffuse, lies approximately alongside and to the south of the Roche Bay greenstone belt (dashed line in Fig. 3a), and could be interpreted as the northernmost extent of penetrative, thick-skinned Trans-Hudson Orogeny material (ca. 1.83–1.80 Ga) basement reactivation (Henderson, 1983). South of this boundary, transposition foliations are generally moderately to shallowly southeast dipping (Fig. 7a), with shallow-plunging, orogen-parallel main fold axes. In the 'northern structural domain', Archean rocks typically preserve Archean moderately to steeply dipping fabrics and have steeply plunging fold axes. Strong transposition of lithological units into parallelism with the strike of the Penrhyn fold belt can be observed at least 30 km forelandward in basement rocks, north of the leading edge of the Penrhyn fold nappe. North of that zone of intense transposition, strain is more variable in style and orientation, and discriminating fabrics as being either Archean or Paleoproterozoic becomes more arduous since both generations appear to more or less parallel in orientation of bulk transposition.

Deformation in the Prince Albert and Roche Bay belts is dominated by the presence of tight to isoclinal folds with steeply plunging hinges (Fig. 7b). Two sets of folds are observed with the dominant, regional F_2 folds overprinting an earlier cleavage (S_2) formed during F_1 folding (Fig. 7b, c). The F_2 axial planes are subparallel to the main foliation in ca. 2.75 Ga granitoid rocks and these structures are truncated by ca. 2.60 Ga intrusions, suggesting that the main Archean deformation event may have occurred during that time interval.

One unexpected observation was the relatively high strain and metamorphic overprint documented in the Proterozoic Folster Lake Formation, which was previously interpreted by as being relatively undeformed, except for the occurrence of large-amplitude, upright open folds, and metamorphosed to a maximum grade of subgreenschist facies (Schau et al., 1993). The intensity of deformation can be best observed in marl layers near the base of the succession, which shows a definite bedding-cleavage relationship defined by muscovite and the synkinematic growth of zoned allanite-epidote porphyroblasts, suggesting at least uppermost greenschist- to lower amphibolite-facies metamorphism. Further upsection in the dominantly arkosic strata, the effect of Paleoproterozoic overprint is less obvious due to the more refractory phases present, except perhaps by the presence of ductilely sheared quartz veins (Fig. 7d). Metamorphic fabrics in the Folster Lake Formation include both a bedding-parallel mica foliation (S_0/S_1) and an S_2 axial-planar foliation. The S_0/S_1 fabric defines an open to closed upright syncline with a steep axial plane trending approximately 040°. Basement rocks beneath the Folster Lake Formation are altered to chlorite and sericite and form a metamorphosed regolith a few metres thick (Frisch, 1982).

The metamorphic grade in the Prince Albert and Roche Bay greenstone belts is moderate, having reached a maximum of lower- to middle-amphibolite facies. Cordierite-andalusite and staurolite-garnet schist units are commonly observed in protoliths of pelitic composition. Biotite and muscovite form the stable phases in metapelite, but late retrogression to chlorite, perhaps an effect of Paleoproterozoic overprint, is also observed. In intermediate volcanic rocks, hornblende, actinolite, biotite, and plagioclase, with or without garnet, forms the main stable metamorphic assemblage. Frisch (1982) estimated the peak metamorphic conditions in these belts to have been below 600°C and 3 kbar. Metamorphic conditions in the southern structural domain reached lower amphibolite to granulite facies and are the result of protracted terrane accretion and collision between ca. 1.87 Ga and 1.80 Ga, along the northern margin of the composite Trans-Hudson Orogeny (Henderson, 1983; St-Onge et al., 2006; Gagné et al., 2009).

ECONOMIC GEOLOGY

The abundant and locally thick banded iron-formation occurrences on Melville Peninsula were the most significant mineral discovery of Operation Wager in the 1960s (Heywood, 1967). Accordingly, the recently acquired Sarcpa Lake aeromagnetic survey measured an impressive maximum intensity of 124 000 nT at 176 m flight altitude above ground, centred at 85°14′00"W; 68°25′ 04"N over the Prince Albert greenstone belt. Mineral exploration for iron ore is presently active within the Roche Bay and Prince Albert belts. Iron ore occurs as magnetite- and locally hematite-bearing Algoma-type banded iron-formation, with locally rich, metres wide bands attaining up to 90% magnetite. Other

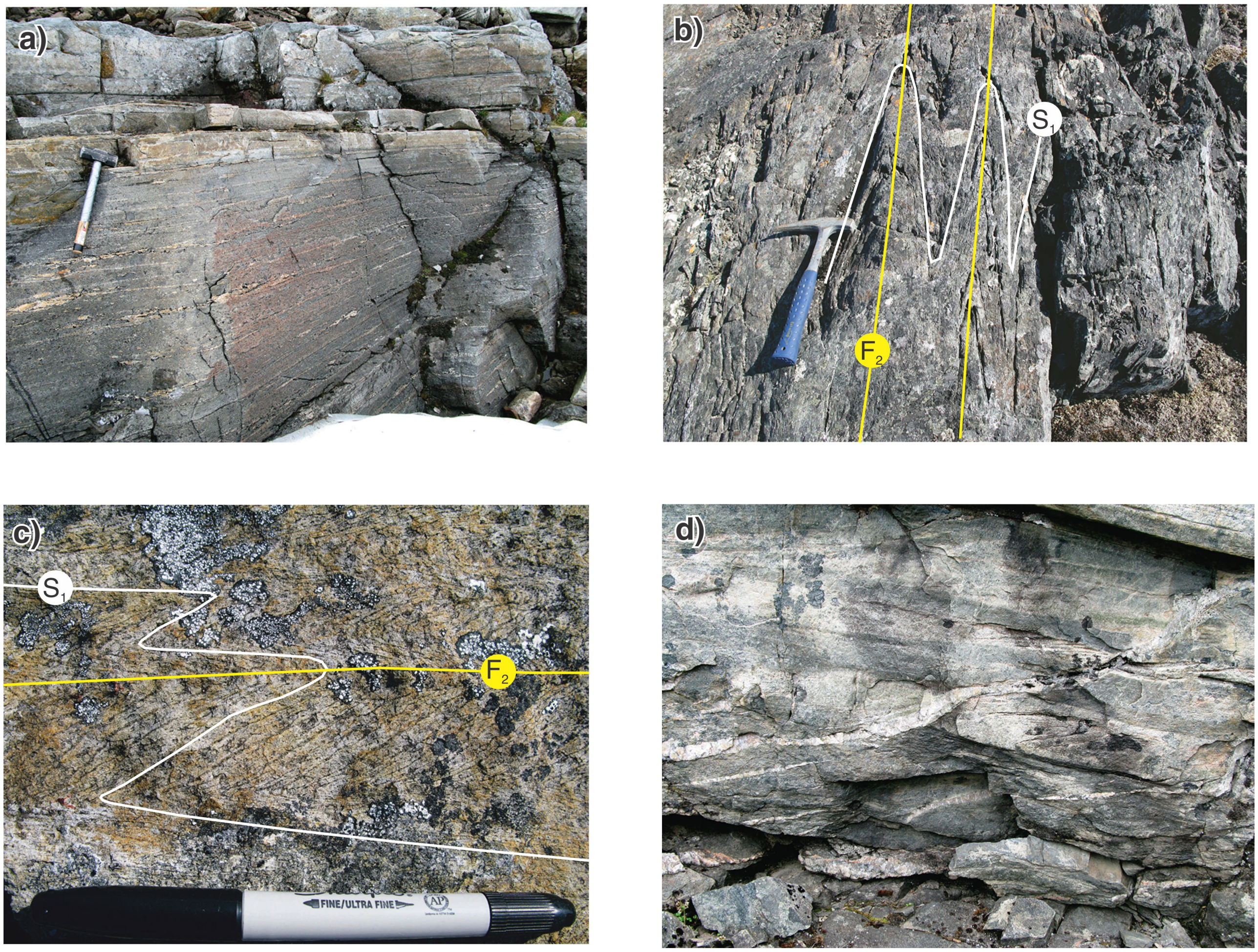

Figure 7. Outcrop photographs showing **a)** tectonized contact between siliciclastic base of Paleoproterozoic Penrhyn Group quartzite and psammite (top) and Archean basement (grey foliated tonalite with transposed granite veins); hammer head is perched on contact; hammer is 50 cm long; 2013-281; **b)** tightly folded mafic volcanic rocks of the Prince Albert greenstone belt showing an earlier fold axial-planar cleavage (S_2) refolded by tight to isoclinal, steeply plunging folds (F_2 axial plane shown); hammer is 38 cm long; 2013-270; **c)** S_1 pressure-solution cleavage formed in ca. 2.97 Ga Prince Albert greenstone belt rhyolite folded by F_2 folds; marker is 13 cm long; 2013-274; **d)** ductilely deformed quartz vein in shallow-dipping Paleoproterozoic Folster Lake Formation, showing local top-to-the-southwest shear (view looking southeast on steep outcrop face); bottom of photograph is 2 m across; 2013-269. All photographs by D. Corrigan.

than iron ore, Melville Peninsula has occasionally been the focus of a number of predominantly base-metal exploration programs since the 1970s. Diamond exploration in the late 1990s led to the discovery of three kimberlite fields, two on the mainland and one on Wales Island in Committee Bay. The two diamondiferous kimberlite fields on Melville Peninsula, Aviat and Quigaliq, are currently being explored by Stornoway Diamond Corporation.

One of the priorities of the project was to identify areas with high potential for mineral exploration. To help achieve this goal, archived lake sediment and stream samples were reanalyzed (Day et al., 2009), and a large number of new analyses were obtained on till samples (Dredge, 2009). An additional set of geochemical data was acquired from till and mudboil samples collected in order to more accurately define some of the metal enrichment zones identified in earlier analyses (Tremblay et al., 2010; Tremblay and Paulen, 2012). Among some of the most notable discoveries based on either geochemical surveys or new bedrock mapping are: 1) massive to semimassive Ni-Cu±PGE mineralization in metaperidotite in the Prince Albert belt and in isolated ca. 2.70 Ga gabbro (Houlé et al., 2010); 2) high Ag (up to 86 g/tonne)+Zn-Cu-Pb±Au in an Archean volcanogenic massive-sulphide–type environment; 3) strong Ni-Cr anomalies in till down-ice from ultramafic sills in the Roche Bay belt (Tremblay et al., 2010); 4) high gold grain counts in mudboil analyses coincident with arsenopyrite in gossans over part of the Roche Bay belt (Tremblay et al., 2010); and 5) large molybdenite crystals carrying 4 g/tonne Au in fractures within orthopyroxenite intrusions north of the Prince Albert belt.

In the authors' opinion, in addition to iron, the Ni-Cu±PGE and Ag-rich volcanogenic massive-sulphide–type showings in the Prince Albert belt form the most attractive new prospects on the western side of the peninsula. The gold grain–arsenopyrite association, as well as high Ni-Cr anomalies in till within the main branch of the Roche Bay belt form significant new discoveries on the eastern side of the peninsula. Numerous small, variably metamorphosed and deformed ultramafic plugs, some quite rusty, occur in the southeastern quadrant of NTS map area 47-B/16, in the area where Dredge (1995) reported the highest regional Ni anomaly in till (7420 ppm Ni, 782 ppm Co, 177 ppm Cr, 70 ppm Tl). Apart from the gold grains in till and arsenopyrite anomaly mentioned above, little is known about the gold prospectivity in the region.

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