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Refining lithological and structural understanding of the southern Core Zone, northern Quebec and Labrador in support of mineral resource assessment

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M. Sanborn-Barrie

Foreword

The Geo-mapping for Energy and Minerals (GEM) program is laying the foundation for sustainable economic development in the North. The Program is providing modern public geoscience that will set the stage for long-term decision making related to investment in responsible resource development. Geoscience knowledge produced by GEM supports evidence-based exploration for new energy and mineral resources, and enables northern communities to make informed decisions about their land, economy and society. Building upon the success of its first five-years, GEM has been renewed until 2020 to continue producing new, publically available, regional-scale geoscience knowledge of Canada's North.

During the 2014, GEM's renewed research program was launched with 14 field activities that included geological, geochemical and geophysical surveying. These activities were undertaken in collaboration with provincial and territorial governments, northerners and their institutions, academia and the private sector. GEM will continue to work with these key collaborators as the program advances.

Abstract

Integrated mapping of the southern New Québec Orogen - Core Zone as part of the second phase of Geomapping for Energy and Minerals (GEM-2) is providing insight into the collisional orogen between the Superior and North Atlantic cratons by investigating the composition, age and architecture of intervening crust at a scale that will bridge knowledge of Archean and Paleoproterozoic tectonomagmatic evolution across the Quebec - Labrador border. In 2014, bedrock mapping of seventy-five localities investigated clastic and carbonate rocks of the Kaniapiscau Supergroup (eastern Labrador Trough), mafic metavolcanic rocks of the Doublet Zone, granitoid basement and unconformably overlying metasedimentary rocks of the Laporte domain, orthogneissic basement and the cross-cutting 1837-1820 Ma De Pas Batholith, and a collage of supracrustal rocks and associated gabbroic plutons that attain upper amphibolite to granulite facies (migmatitic Mistinibi domain) east of the De Pas batholith. 2014 observations were assessed in light of previous understanding of this region and a number of questions or knowledge gaps were identified which formed the basis for supporting laboratory analysis and targetted mapping in 2015. Bedrock findings are being integrated with surficial mapping, till analysis and glacial dispersion studies, collectively contributing knowledge for increased exploration effectiveness across this part of Quebec and Labrador.

Introduction

The Core Zone is a composite Precambrian lithotectonic terrane that forms the easternmost part of the Canadian Shield in western Labrador and southeastern Quebec. Long considered as the southeastern extension of the Rae Province (Hoffman 1988, 1990*a*) and designated the southeastern Churchill Province (Van Kranendonk et al., 1993; James et al. 1996), the Core Zone comprises Archean rocks, Paleoproterozoic supracrustal rocks and variable age plutons extensively reworked during ca. 1.8-1.9 Ga collision of the Superior and North Atlantic (or Nain) cratons (Fig. 1, 2). Given the relatively poorly known nature of this lithotectonic terrane, combined with significant glacial cover across its southern region (Klassen 1999), an integrated study of its bedrock geology and glacial history was undertaken in 2014 as part of the GEM-2 Hudson-Ungava project (McClenaghan et al. 2014; Corrigan et al. 2015). Improved understanding of the age, provenance and tectonometamorphic history of the southern Core Zone, and formulation of new glacial dispersal models are anticipated outcomes of this project to support increased exploration effectiveness in Quebec and Labrador.

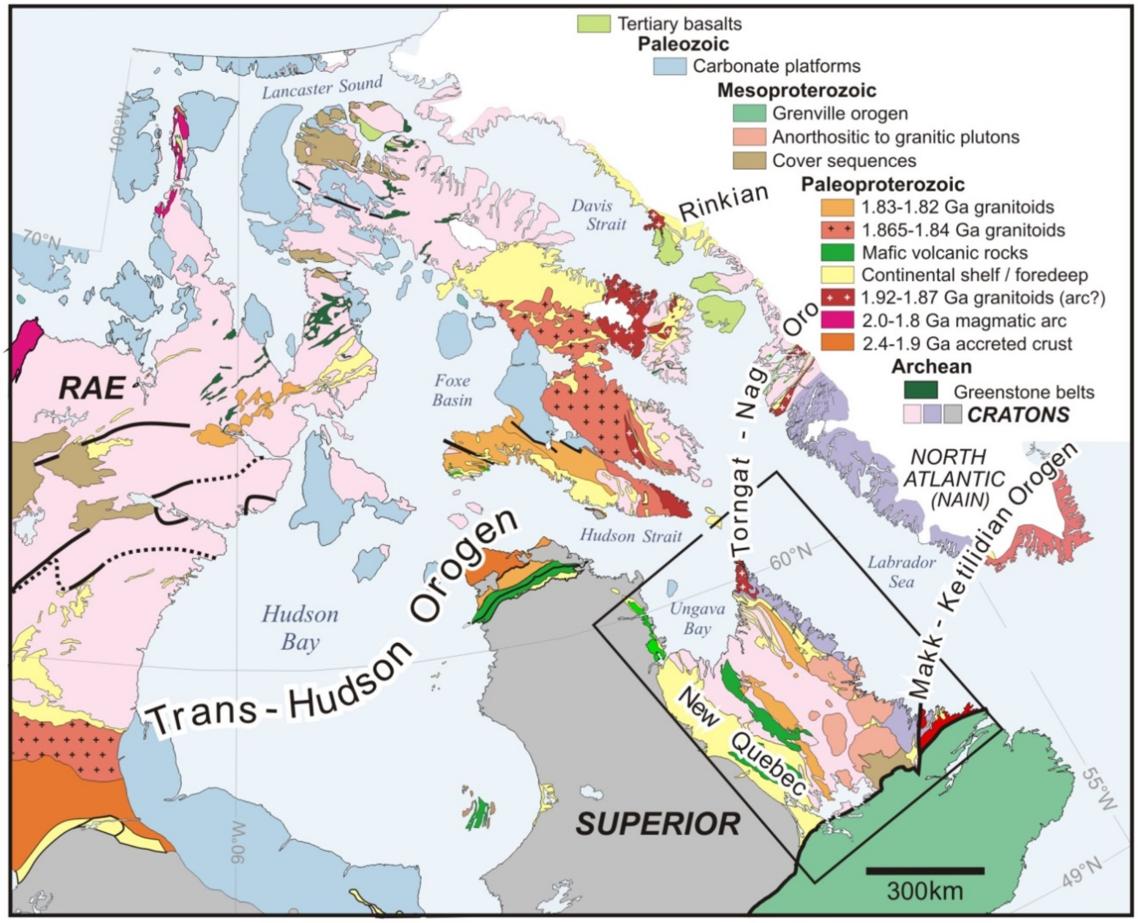

Figure 1. Regional tectonic setting of eastern Laurentia showing the Core Zone in the context of Paleo-proterozoic orogens including the ca. 1.83 Ga Trans-Hudson, ca. 1.91-1.85 Ga Torngat-Nagssugtoqidian and ca. 1.9-1.85 Makkovikian-Ketilidian orogens

This report presents lithological and structural observations across the southern Core Zone (inset box labelled Fig. 4 in Figs. 2, 3) acquired during 2014 mapping. Given that mineral exploration strategies are predicated on tectonic environment, bedrock mapping was undertaken to determine the nature and heritage of crust exposed between the Archean Superior and North Atlantic cratons. Specifically, whether the medial “core zone” shows affinity to the Archean Rae craton, as long postulated (Hoffman 1988), whether it might represent cryptic Meta-Incognita terrane, presently inferred to underlie parts of southern Baffin Island (St-Onge et al. 2000), or whether it constitutes a distinct crustal block. Similarly, the age and setting of various lithotectonic components (i.e., Laporte, Doublet, Ntshuku, Atshakash, and Zeni volcano-sedimentary complexes; Fig. 4) will establish constraints on the evolution and architecture of the eastern New Québec Orogen and Core Zone and a better context for assessing mineral prospectivity. The character and timing of major penetrative deformation across the southern core zone will be assessed in light of current tectonic models that invoke collision in the north (Kuujjuaq) at ca. 1840-1829 Ma (Machado 1990), some 25 m.y. prior to that proposed in the south (Smallwood Reservoir) at ca. 1805±3 Ma (James and Dunning 2000). And finally, the role of the 1837-1820 Ma De Pas Batholith, similar in age and composition to the 1840-1833 Ma Kuujjuaq (lac Stuart and Elbow Island) plutons and 1835-1830 Ma Narsajuaq suite will be considered in the overall context of collision with Superior craton to the west and North Atlantic craton to the east.

Regional Geological Setting

The 300 km wide Core Zone extends from Ungava Bay in the north to southern Labrador, where it is truncated by units and structures related to the ca. 1.1 Ga Grenville Orogen (Fig. 1, 2). It is a complex medial hinterland of reworked Archean crust (Van der Leeden et al. 1990; Wardle et al. 1990; Nunn et al. 1990; James et al. 1996; Isnard et al. 1998), supracrustal rocks of ca. 2.32 Ga (Girard 1990) and <1.95 Ga (Scott and Gauthier 1996) age, and voluminous plutonic rocks of the 1.84-1.82 Ga De Pas Batholith

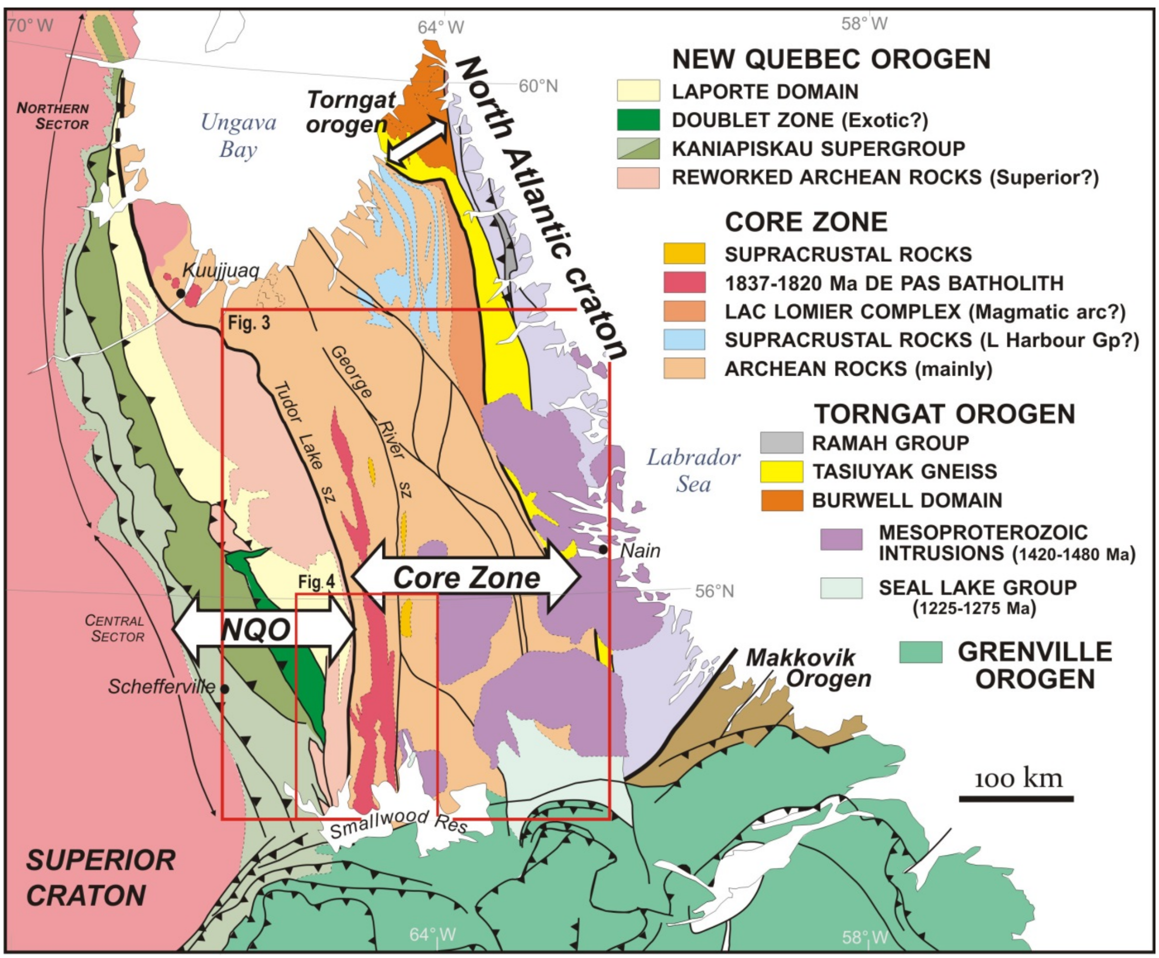

Figure 2. Major tectonostratigraphic components of the Core Zone and its bounding orogenic belts, the New Québec Orogen (NQO) to the west, Torngat Orogen to the east, and Makkovik orogen to the southeast. Also shown as unsubdivided are the Archean Superior and North Atlantic (or Nain) cratons, and ca. 1.1 Ga Grenville Orogen.

(Dunphy and Skulski 1996; James et al. 1996) and Kuujjuaq suite (Perrault and Hynes 1990). The Core Zone is generally characterized by strong NNW-striking aeromagnetic anomalies (Fig. 3), except where voluminous Mesoproterozoic plutons (yellow outlines in Fig. 3) have attenuated or overprinted well-delineated NNW trends. High-amplitude positive magnetic expressions, 20-30 km wide and >200 km long, are diagnostic of both the 1.84-1.82 Ga De Pas batholith (**DP** in Fig. 3) and the lac Lomier complex (Ermanovics and Van Kranendonk 1990; **LL** in Fig. 3). Curvature of magnetic anomalies is consistent with a component of localized dextral shearing across the western margin of the Core Zone along the Tudor Lake (lac Tudor) shear zone (**TLsz** in Fig. 3) and dextral shearing internal to the Core Zone along the George River (rivière George) shear zone (**GRsz** in Fig. 3).

To the west, the Core Zone is flanked by a west-vergent, fold and thrust belt developed in 2.1-1.86 Ga sedimentary and volcanic cover rocks (Kaniapiskau Supergroup) and involving Superior craton basement. The Kaniapiskau Supergroup has long been recognized as recording cratonic rifting and incipient development of an ocean basin (Dimroth 1978; Wardle and Bailey 1981) and, historically, was designated the "Labrador Trough", to reflect accumulation in an elongate basin, or trough (Harrison 1952). With the suggestion that the upper part of the sequence may represent foredeep deposits formed in advance of thrust nappes (Hoffman 1987), this fold and thrust belt was renamed the New Québec Orogen (Hoffman 1988, Wardle et al., 1990).

To the east, the Core Zone is flanked by a doubly-vergent, fan-shaped wedge (Torngat Orogen) developed primarily in juvenile (<1.94 Ga) Paleoproterozoic metasedimentary rocks (Tasiuyak gneiss). The Tasiuyak paragneiss is inferred to represent an accretionary complex demarcating a suture between the Core Zone and North Atlantic craton (Van Kranendonk and Ermanovics 1990; Rivers et al. 1993; Van Kranendonk 1996).

Methodology

The study area comprises two 1:250 000 National Topographic System (NTS) sheets, 23P and 23I transected by the Quebec–Labrador provincial boundary (Fig. 4). It exposes three main lithotectonic entities: 1) the New Québec Orogen including the Kaniapiskau Supergroup, Doublet zone and Laporte domain; 2) the western Core Zone including Archean basement and De Pas Batholith; and 3) the central Core Zone a composite supracrustal-plutonic domain (Ntshuku-Atshakash-Zeni, Mistinibi) with its post-orogenic plutons. The character of these three domains and their internal lithotectonic elements are described below.

Bedrock information related to lithology, mineral assemblages, metamorphic grade, structural style and relative deformational history was acquired at 75 localities (Fig. 4) where surficial mapping and till sample collection were also undertaken over the course of 2 weeks in July 2014. This approach allowed an overview of southern Core Zone bedrock and surficial geology in a logistically efficient manner in a short period of time. A number of outstanding questions, or knowledge gaps, that became apparent based on the existing framework mapping (Wardle et al. 1997; Ministère de l'Energie et des Ressources naturelles 2010), newly acquired observations and data, and collected samples, conclude this report.

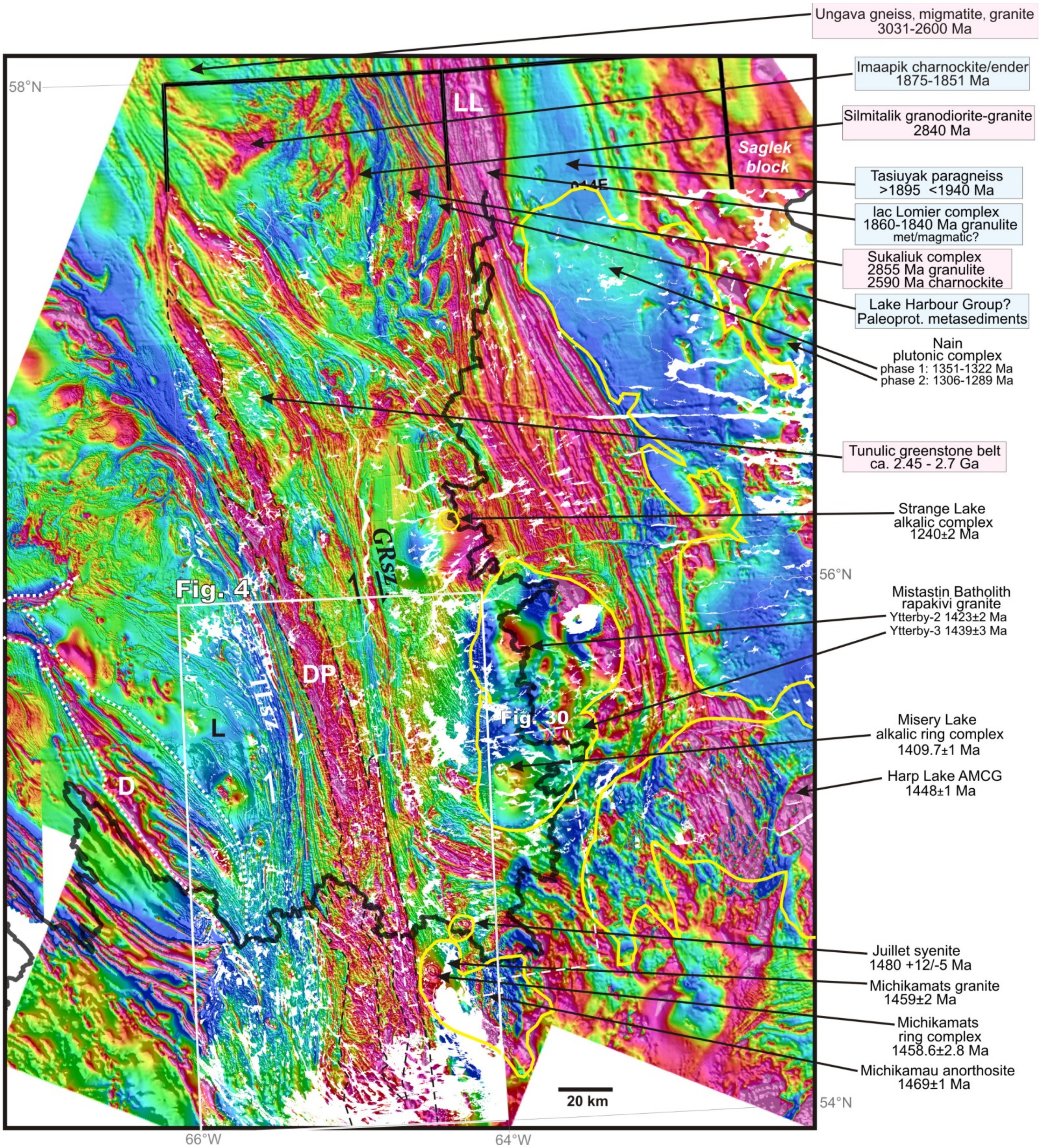

Figure 3. Regional aeromagnetic data for the central and southern Core Zone and bounding orogens (Dumont et al. 2010). Age information for various suites is shown in pink (Archean), blue (Paleoproterozoic) and uncoloured (Mesoproterozoic) boxes to right (see Figure 4, 5 and text for age determination references). Abbreviations: D-Doublet Zone; DP-De Pas Batholith; GRsz-George River shear zone; L-Laporte Domain; LL-lac Lomier Complex; TLsz-Tudor Lake shear zone.

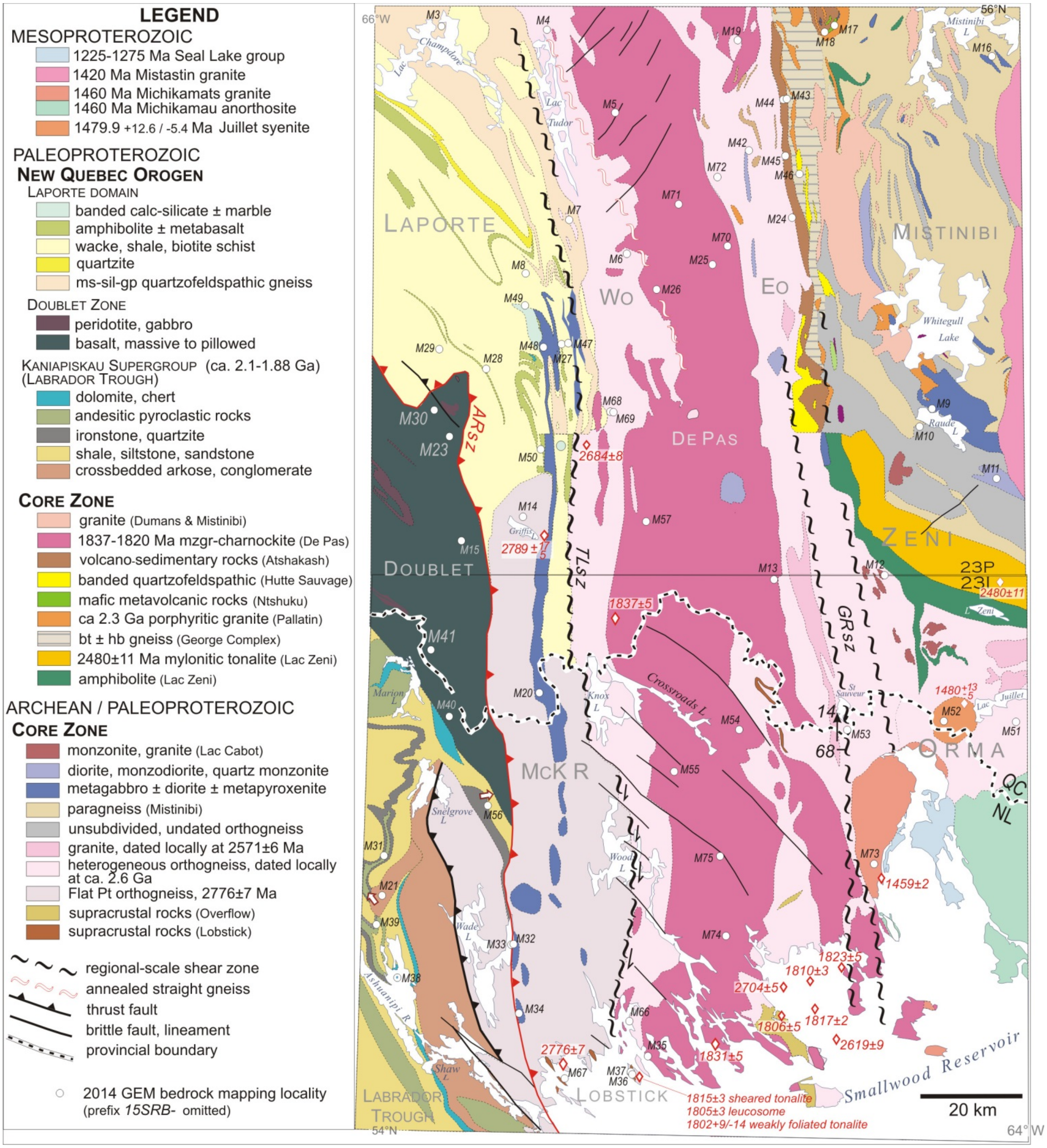

Figure 4. Bedrock geology of the eastern New Québec Orogen and southwestern Core Zone (NTS 23P, 23I) from Wardle et al. (1997) and Ministère de l'Énergie et des Ressources naturelles (2010) showing 2014 GEM2 mapping localities (open white circles), regional structures, and currently available U-Pb zircon ages (open red diamond symbols with age and error in Ma) compiled from James et al. (1996), James & Dunning (2000), David & Dion (2010) and David et el. (2011, 2012). 2014 GEM2 station locations and corresponding samples all have a prefix of 14SRB- which has been omitted here for simplicity. Abbreviations: ARsz-Ashuanipi River shear zone; GRsz-George River shear zone; McK R-McKenzie River domain; TLsz-Tudor Lake shear zone.

Geology of the New Québec Orogen

Kaniapiskau Supergroup

The Kaniapiskau Supergroup extends for >1000 km from east of Ungava Bay through Québec and Labrador to within 300 km of the St Lawrence River. It reflects a linear basin along the eastern margin of Superior continent into which clastic and chemical metasedimentary rocks and lesser volcanic rocks were deposited as several shallowing-upward siliciclastic-carbonate ± iron formation sequences and their transition to a deeper water basinal environments (Dimroth et al. 1970; Wardle and Bailey 1981). The most complete stratigraphic record is preserved in its central sector[1] (Fig. 2), where two principal sedimentary cycles (Fig. 5) are exposed. The lower cycle initiated during rifting prior to 2.169 Ga (Rohon et al. 1993) and records deposition of a thick (1500-3000m) continental clastic sequence (Seward Group), followed by shallow marine transgression, subbasin development and shelf collapse (Le Fer Formation siltstone-shale), re-establishment of the shelf (Denault Formation dolostone and stromatolitic dolomite) and 2nd-stage subbasin development (Dolly Formation siltstone-shale and slump-induced Fleming chert breccia). Cycle 2 stratigraphy reflects renewed transgression following a long (>175 – 260 my) period of relative tectonic quiesence (Rohon et al., 1085; Clark and Wares 2005). The second cycle commenced with deposition of the Wishart Formation quartzite (50-300 m) followed by the black ferruginous Ruth Formation shale, the economically significant Sokoman iron formation (120-240 m) and associated subaerial 1880 Ma Nimish Formation alkaline volcanic rocks. Deposition of the >1000 m thick turbiditic Menihek Formation (Fig. 5) marked the second major transgression and collapse of the shallow-shelf environment that characterized much of the underlying Cycle 2 units. Cycle 2 disconformably overlies Cycle I and oversteps it, becoming younger to the west (Findlay et al., 1995), such that basal quartzite of the Wishart Formation typically rests unconformably on basement rocks of the Superior margin (Ashuanipi Complex). These stratigraphic relationships are well established along the length of the orogen and are consistent with either a westward prograding foredeep (Hoffman 1987) or a subsiding and widening basin.

The Sokoman Formation and correlative iron-formations occur throughout the length of the New Québec Orogen and constitute one of the most extensive iron formations in the world. In the Schefferville area, the Sokoman Formation is a typical cherty, Superior-type iron-formation, containing peloids, ooliths and commonly displaying thin and irregular bedding, local cross bedding and intraformational conglomerates (Stubbins et al. 1961; Zajac 1974). It is stratigraphically divisible into three regionally extensive members: a lower, 10-30 m thick, silicate–carbonate (siderite)-shale member, a middle 90-150 m thick member of mainly cherty hematite iron-formation containing 30–70% iron oxides, and an upper, 25–60 m thick, silicate–carbonate member (Stubbins et al. 1961; Chauvel and Dimroth 1974).

[1]Exposure of such an extensive stratigraphic section of the Labrador Trough near Knob Lake, Schefferville, led Harrison (1952) to refer to these rocks as the Knob Lake Group, but he noted that such parochial terminology might be abandoned in consideration of the more regional context, as recently recommended by Clark and Wares 2005.

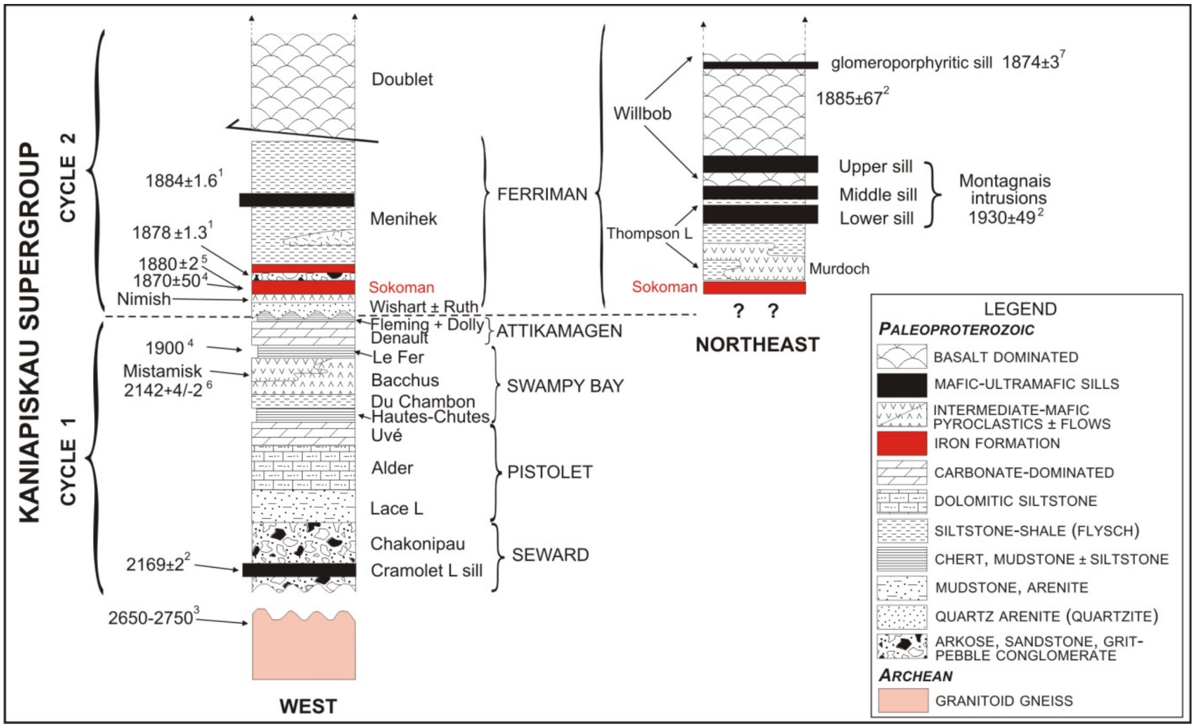

Figure 5. Lithostratigraphy of the south-central Labrador Trough (modified from Rohon et al., 1993) showing available radiometric data. [1]Findlay et al. (1995) zircon U-Pb on quartz-syenite cobble (1877.8±1.3 Ma) from conglomerate intercalated with Nimish and Sokoman formations; plagioclase-glomeroporphyritic sill (1884±1.6 Ma) that cuts middle Menihek turbidite; [2]Rohon et al. (1993) zircon U-Pb on granophyre (2169±2 Ma), whole rock Pb-Pb on tholeiite (1885±67), whole rock Pb-Pb on gabbro and ultramafic cumulates (1930±49 Ma); [3]Machado et al. (1989) zircon U-Pb on granodiorite 2721±3 Ma; [4]Fryer (1972) whole rock Rb-Sr on slate (1855 ±75 Ma, 1900 Ma, and 1870 ±50 Ma); [5]Chevé and Machado (1988) zircon U-Pb on carbonatite dyke, Castignon complex (1880±2 Ma), considered contemporaneous with the Sokoman Fm; [6]T E Krogh and B Dressler (unpub. data cited in Clarke 1984, and Machado et al. 1989) zircon U-Pb on rhyolite (2142+4/-2 Ma); [7]Machado et al. (1997) zircon U-Pb on glomeroporphyritic gabbro (1874±3 Ma) cutting Hellancourt tholeiitic basalt.

2014 Observations

A section through uppermost Cycle 1 and lower Cycle 2 metasedimentary rocks of the Kaniapiskau Supergroup was examined in the immediate vicinity of Schefferville. Here, yellow-brown weathering Denault Formation dolomite, brown-weathering Dolly Formation shale, grey flinty chert breccia of the Fleming Formation, grey-weathering Wishart Formation quartzite, and red-weathering Ruth shale and iron-rich Sokoman formation are easily accessed by road. Within the study area (23P-23I), metasedimentary rocks interpreted as Cycle 1 (localities M21, M38 M56; Fig. 4) and volcanic rocks attributed to Cycle 2 (localities M31, M39; Fig. 4) were examined.

Cross-bedded quartz arenite – *Chakonipau/Snelgrove formation, Lower Seward Group?*

Pink-grey weathering quartz arenite at locality M21 (Fig. 4) exhibits well-developed cross stratification (S_0 222/52°NW) at a 10-15 cm scale (Fig. 6*a*), indicative of younging to the NW at this locality. These rocks are generally poorly sorted and poorly graded, with medium- to coarse-sand size cross-bedded horizons interstratified with rare massive coarse sand to grit size beds (Fig. 6*b*). The unit contains more than 90% quartz as 2 mm – 0.5 mm, round to subangular granules, ~4% very fine (20-80 μm) muscovite that fringes most quartz grains (Fig. 6*c,d*), and no observable feldspars. Cross bedding is highlighted by dull grey bands, average 3-5 mm wide, dominated by specular hematite (0.2-0.5 mm) with 3-5% titanite and trace zircon.

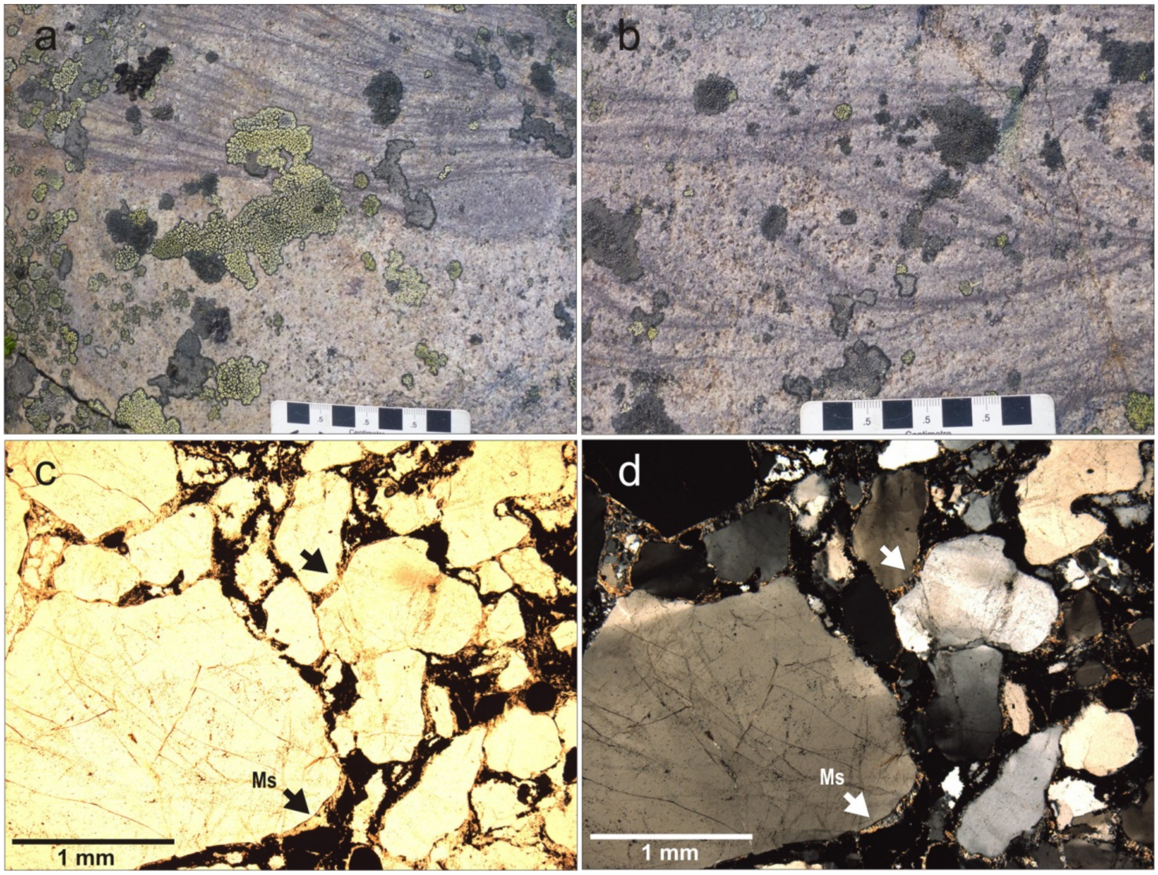

Figure 6. Pink-weathering quartzose arenite (locality M21) of the eastern Labrador Trough. *a*) rare massive bed, 20 cm wide, composed of unsorted coarse sand to grit, interstratified with crossbedded arenite; *b*) well-preserved cross stratification defined by dull grey specular hematite-rich bands; *c*) plane-polarized photomicrograph showing quartz-rich nature of arenite, interstitial specular hematite (opaque) and muscovite fringe on quartz (Ms); *d*) same thin-section view in cross-polarized light.

These rocks were attributed to the lower Seward Group (Chakonipau Formation of Dimroth 1968; Snelgrove Lake Formation of Wardle 1982) and considered to have formed as sand and gravel bars proximal to and sourced from an Archean basement high (Snelgrove Arch). However, their quartz-rich character is inconsistent with the typically “arkosic” Seward strata, which is also reported to contain clasts derived from adjacent basement rocks. The prominence of cross laminations defined primarily by specular hematite, raises the possibility this unit is derived from iron-bearing Cycle 2 strata (e.g., Sokoman formation) and younger than previously interpreted. The unit shows similarities to crossbedded, muscovite-bearing, specularite-laminated and hematite-stained meta-arkose of the Hutte Savage group (Van der Leeden et al., 1990; Girard 1992), exposed east of the De Pas Batholith (and just north of the map area). U-Pb detrital zircon dating is planned to constrain the maximum depositional age of this unit and determine the age(s) of its source rocks. Northwest of Schefferville, deposition of Cycle 1 is interpreted to have commenced prior to 2169±2 Ma, the age of a 0.15 m wide granophyric albitic granite vein cutting equigranular amphibole gabbro, in that the granophyre is interpreted as a late-stage differentiation product of the potassium-poor tholeiitic Cramolet Lake amphibole gabbro sill which, in turn, cuts the basal, rift-related sediments of the Seward Group (Rohon et al. 1993). Felsic volcanic rocks of the Mistamisk Formation towards the top of Cycle 1 have an age of 2142 +4/-2 Ma (Chevé and Machado 1988), providing a minimum age of deposition for the Seward Subgroup.

__Arenaceous Dolomite, Ashuanipi River__ *(Denault Formation, Attikamagen Group)*

Arenaceous dolomite is well exposed on a small island in the Ashuanipi River (locality M38, Fig. 4) where thin to medium bedded rocks (Fig. 7*a*) are south-striking with a moderate dip to the west (S_0=198/53°W). Very fine grading and associated colour changes (Fig. 7b) indicate younging to the west, consistent with that for cross-bedded quartz arenite at locality M21, 16 km to the north (*described above*). These well-bedded, fine siliceous carbonate rocks are transected by a strong spaced cleavage and fracture cleavage (S_1) oriented 345/73°NE, that is axial planar to rare S-folds at this exposure. In thin section, a cryptocrystalline dolomitic groundmass supports 3-14% evenly dispersed clear, 20 μm quartz grains.

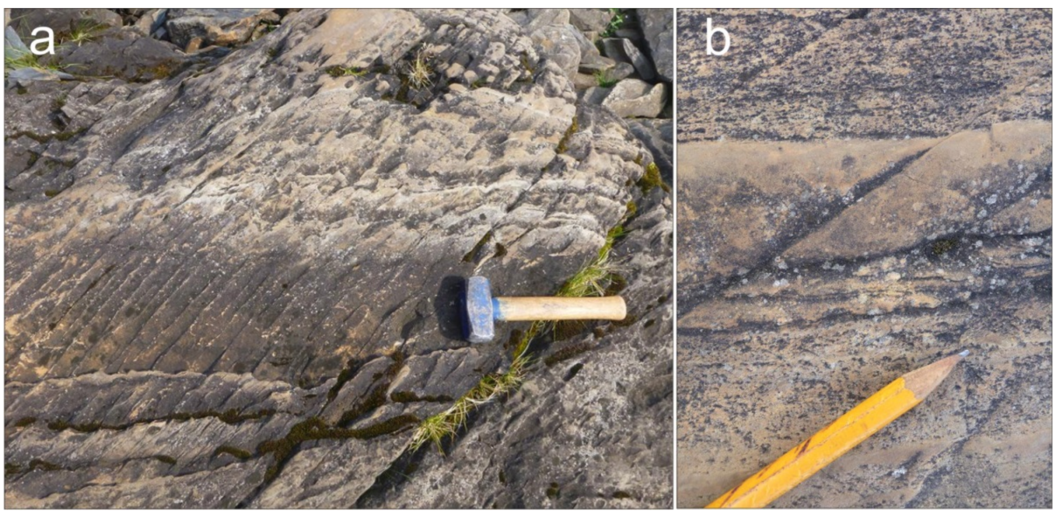

Figure 7. Arenaceous dolomite exposed on the Ashuanipi River (locality M38), western facies of the Denault Formation

This dolomitic unit is part of a coherent carbonate unit, ~500 m wide, that extends some 60 km along strike from Seward Lake in the north, across the Ashuanipi River (locality M38), to Blanchet Lake in the south (Fig. 4). This unit appears to be the southern extension of a dolomitic unit exposed north of Marion Lake (Fig. 4) which has been interpreted as homotaxial (same stratigraphic position but not necessarily same age) as the Denault Formation (Donaldson 1963, 1966) and, collectively, formed during re-establishment of a shallow-water carbonate shelf environment at a late stage of Cycle 1.

__Quartz arenite, Quartzite Lake__ *(Seward Group? Wishart Formation? upper Menihek Formation?)*

One of the most easterly exposures of strata designated as part of the Kaniapiskau Supergroup (Wardle 1982) is represented by a 70 m thick section of white-weathering quartz arenite (locality M56 in Fig. 4) exposed ~300 m east of Quartzite Lake (Fig. 8). These rocks are part of a ca. 28 km long, NNW-striking unit that can be traced to the eastern arm of Wade Lake (Fig. 4). The quartz arenite is composed of ~97% quartz with ~2% very fine (10-20 μm) blades of colourless to very pale green prismatic mica which locally cast an emerald green bloom on weathered surfaces. In thin section, pale green mica occurs as interconnected minute blades decorating quartz grain boundaries. Orange-brown heavy minerals bands seen in outcrop (Fig. 8*b*) contain mainly anhedral sphene and trace amounts of subhedral, internally zoned, 30-60 μm zircon.

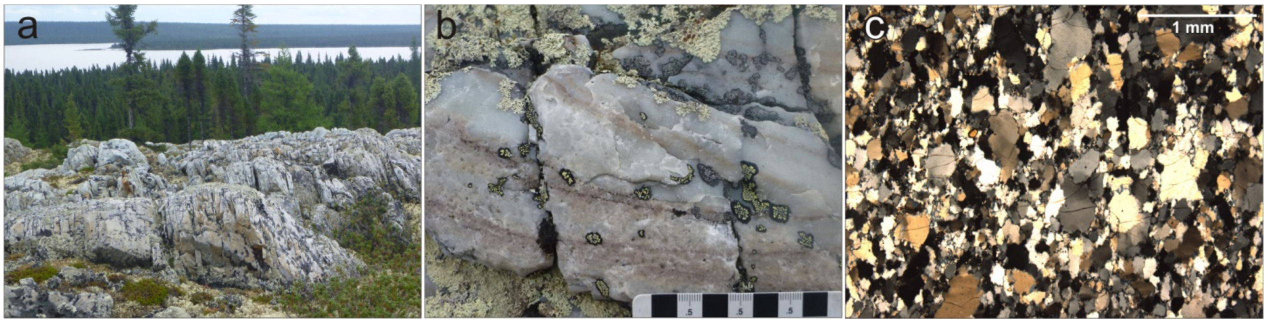

Figure 8. Quartz arenite, southeastern New Québec Orogen. *a*) view to WSW of white-weathering quartz arenite exhibiting steeply dipping spaced cleavage (S_1=065/67°SE), Quartzite Lake in background; *b*) detail of cherty texture of quartz arenite with locally developed crossbeds; *c*) microphotograph in cross-polarized light (5x magnification) showing sutured nature of quartz-rich matrix.

According to Wardle (1982), quartz arenite exposed east of Quartzite Lake conformably overlies clastic rocks at locality M21 (*described above*) and is part of the Seward Group (basal Cycle I). However, in the depositional evolution of the Kaniapiskau Supergroup, orthoquartzite also forms the basal transgressive sequence (Wishart Formation) of Cycle 2, disconformably overlying Cycle 1. Wishart orthoquartzite is interpreted to have been deposited prior to ca. 1877 Ma, the age interpreted for overlying volcanic rocks of the Nimish Formation (*discussed below*; Figure 5). In this setting, orthoquartzite is considered to have formed as sand bar complexes offshore of a fault-controlled, basement culmination (Wardle and Bailey 1981). This basement culmination, formerly designated the Snelgrove Arch, and described below as part of the western orthogneiss, is one of several basement highs thought to mark the break between shallow-water shelf deposition in the west, and basinal or basin-slope deposition to the east. Alternatively, quartz arenite at Quartzite Lake was assigned as an "*atypical facies*" of the upper Menihek Formation, a 1000 – 1500 m thick transgressive sequence at the top of Cycle 2 (Fig. 5). Although the Menihek Formation typically comprises grey, rhythmically bedded, tubiditic siltstones and shales (Harrison et al., 1972) in the west, and black shale-siltstone-greywacke turbidites in the east, Wardle and Bailey (1981) postulated that localized clean, crossbedded sands may have accumulated in a shallow-water environment proximal to the Snelgrove basement high. The age and provenance of this quartz arenite unit will be investigated through U-Pb zircon dating in order to derive quantitative constraints to support or refute these various interpretations.

Intermediate pyroclastic tuff *(Nimish Formation, Ferriman Group)*

Pale green to buff weathering pyroclastic volcanic rocks are exposed in the southwest part of the map area (locality M31, M39; Figure 4). These exposures are dominated by poorly bedded, polylithic pyroclastic breccias (Fig. 9, 10). They have been assigned to the Nimish Formation (Wardle 1982), a dominantly basaltic volcanic suite of subalkaline to alkaline affinity (Evans 1978) with local trachyte, trachyandesite, comendite and rhyolite. Although dominated by vesicular, largely subaerial, mafic lavas interbedded with basaltic conglomerates, volumetrically minor rhyolite and dacite (i.e., locality M31, M39) are interpreted as felsic centres to the complex. Nimish volcanic rocks are interpreted to occur both at the stratigraphic base (Evans 1978) and stratigraphic top of the Sokoman Formation (Wardle 1979), such that the entire interval of ironstone deposition may have been punctuated by subalkaline to alkaline magmatism. The 1877.8 ± 1.3 Ma (MSWD=1.2) age of the Nimish volcanic sequence is based upon an U-Pb age of a quartz-syenite cobble from associated conglomeratic rocks, based on the assumption that the syenitic cobble represents an intrusive equivalent of the more felsic volcanic component. This assumption is based upon petrographic and geochemical similarities between the extrusive and intrusive rocks (Findlay et al., 1995). A more direct age of Nimish Formation volcanic rocks will be sought through U-Pb dating of a plagioclase-phyric rhyodacite tuff breccia (Fig. 10) with associated base-metal mineralization sampled near Galena Lake (locality M39, Fig. 4).

Figure 9. Poorly bedded, polylithic dacite pyroclastic tuff breccia (locality M31).


Figure 10. Plagioclase-phyric dacite pyroclastic breccia, Galena Lake (locality M39).

Doublet Zone

The west-central study area exposes a wedge-shaped metabasalt-dominated block (Fig. 4) which contrasts with intermediate pyroclastic rocks (Nimish Formation) of the Kaniapiskau Supergroup. The Doublet Zone exposes mainly massive flows of mafic composition, with rare pillowed flows, collectively cut by peridotitic to gabbroic sills of the ca. 2.16-1.88 Ga Montagnais suite. Five localities within the Doublet Zone (M15, 23, 30, 40, 41) were mapped and sampled to compare with basaltic rocks of the Baby or Howse domains (Skulski et al. 1993), and with intermediate pyroclastic rocks (Fig. 9, 10) that are part of the continental margin succession and more closely linked to Superior craton.

Locality M15 exposes massive fine-grained flows (Fig. 11*a*) and at least one 10 m thick, steeply W-dipping pillowed horizon (S_0 = 170/85°W) with well-formed pillows indicative of younging toward the east. Accordingly, these strata are steeply overturned. In contrast, fine-grained chloritic metabasalt at locality M23 (Fig. 4) was notable for its strongly developed, flat-lying (2-25° dip to the SSE), east-striking (060-100°) foliation. Throughout the outcrop, equally strong flattening (S) and extensional (L) strain yields an LS fabric with a consistent southeast-plunging mineral lineation (2-9° to the 120°). This fabric may be an expression of a regional-scale fault (Ashuanipi River shear zone-Gill Lake fault), interpreted to

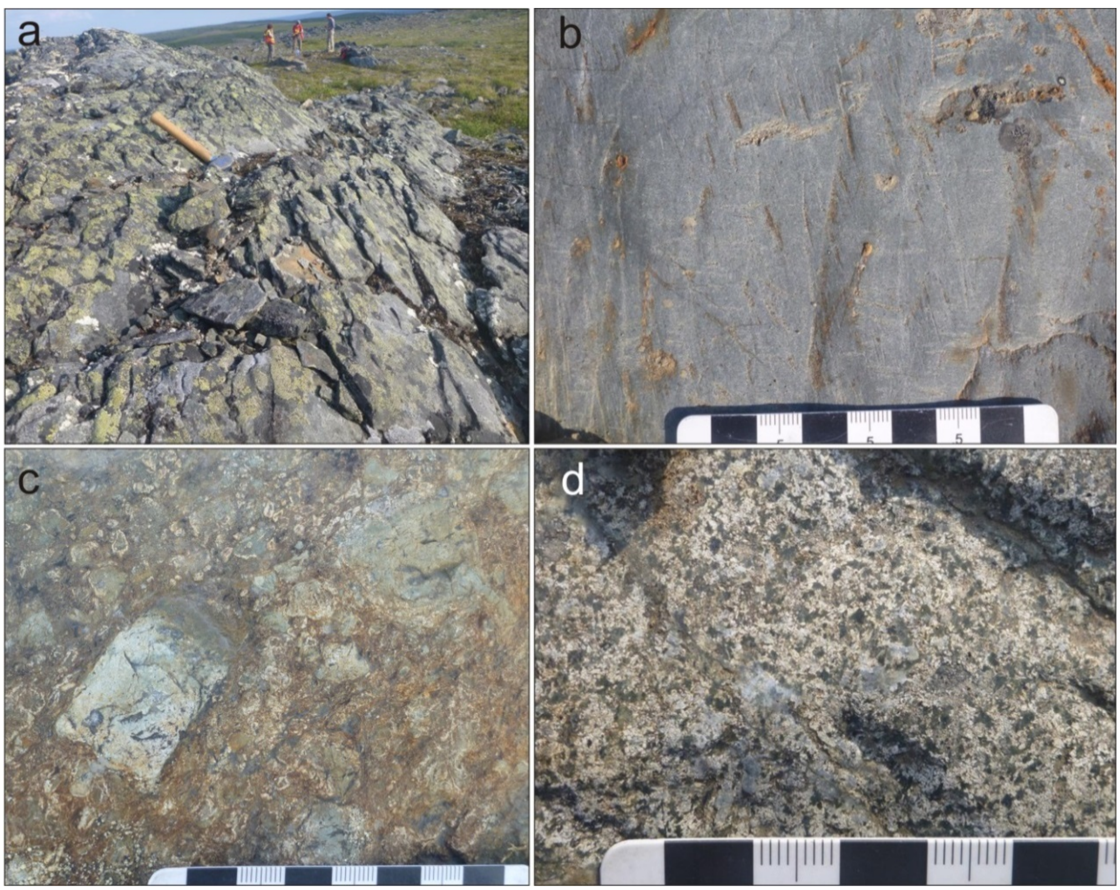

Figure 11 Mafic rocks of the Doublet Zone. *a*) oblique view to south of foliated (178/45°W), fine-grained metabasalt at locality M30; *b*) detail of the aphanitic texture of a glacially striated massive flow at locality M15; *c*) fragmental texture in otherwise typically massive metabasalt at locality M41, consistent with explosive interaction with seawater (hyaloclastite); d) medium- to coarse-grained patch of clinopyroxene gabbroic anorthosite, locally developed in gabbro, locality M40.

form the eastern boundary of the Doublet Zone (Frarey 1967; Findlay et al. 1995; Fig. 4, 12). One km northwest, metabasaltic rocks at locality M30 (Fig. 11*b*) possess a moderately developed west-dipping foliation (178/45°W) with a down-dip mineral lineation (43° plunge to W (298°). Locality M41 exposes mafic rocks of variable texture, where aphanitic to fine-grained rocks with local hyaloclastite texture (Fig. 11*c*) are consistent with a flow origin, while equigranular medium-grained rocks, of similar composition to the flows, represent either coarse-grained internal sections of flows or gabbroic sills. At locality M40, a ridge of medium- to coarse-grained gabbro and gabbroic anorthosite (Fig. 11*d*) represent one of numerous tholeiitic, mafic-ultramafic sills classified under the general name Montagnais sills, which are contemporaneous and comagmatic with their associated volcanic rocks (Baragar 1967; Dimroth 1978; Rohon et al. 1993; Skulski et al. 1993; Findlay et al. 1995).

The affinity of the Doublet Zone is uncertain. Wardle and Bailey (1981) suggest it locally conformably overlies the Kaniapiskau Supergroup which they believe is transitional with the Laporte domain (*described below*). Other workers report contacts between the Doublet Zone and the eastern basinal facies of the Kaniapiskau Supergroup as strictly tectonic, expressed by the Walsh Lake fault (Frarey 1967) and Gill Lake fault, respectively (Fig. 12). These faults obscure a clear connection to the

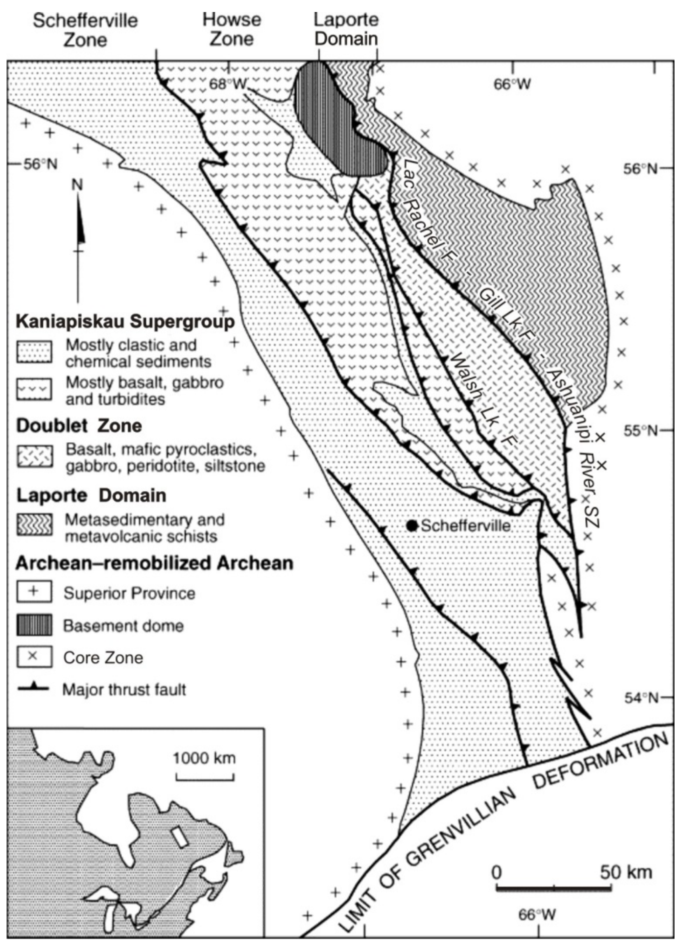

Figure 12. Lithotectonic subdivision of the central New Québec Orogen (modified from Findlay et al., 1995). Abbreviations: F-fault; Lk-lake; SZ-shear zone.

Superior craton, and do not rule out that the Doublet Zone is an exotic, allochthonous domain (Hoffman 1990a,*b*, Wardle et al. 2002), or transitional crust formed at the boundary between extended Superior continental crust and Paleoproterozoic oceanic crust (James and Dunning 2000).

Laporte Domain

The northwest part of the map area exposes the Laporte domain (Fig. 2, 4, 12), where clastic metasedimentary rocks, amphibolite and felsic plutonic rocks are expressed by a relatively uniform, low-intensity magnetic signature (**L** in Fig. 3). The tectonostratigraphic position and affinity of the Laporte domain remains unresolved. Early stratigraphic and structural interpretations considered the Laporte as Archean basement (Harrison 1952) or as an allochthon (Hoffman 1990a), essentially the westernmost hinterland of the New Québec Orogen, noting that it included amphibolite-facies rocks equivalent to the Core Zone, as well as tectonic slices (nappes) of Archean basement (Dimroth et al. 1970; Hoffman). Since then, many workers (e.g., Fahrig 1951; Baragar 1967; Moorhead and Hynes 1986; Poirier et al. 1990; Clark and Wares 2005) have considered the Laporte domain to be correlative, at least in part, with 1.88-1.87 Ga Cycle 2 rocks of the Kaniaspiskau Supergroup (Fig. 5). For instance, Girard (1995) defined a succession of metapelites with some metaquartzite, calc-silicate, sulphide iron formation and amphibolite (Deborah Lake Formation) which he interpreted to intercalate with, and overlie metabasaltic rocks correlated with the ca. 1885 Ma Willbob Formation (Rohon et al., 1993). Wardle and Bailey (1981) interpreted the Menihek Formation to be transitional with the Laporte domain, both locally conformably overlain by mafic volcanic rocks of the Doublet/Willbob formations. Alternatively, others speculate the Laporte domain may include remnants of an accretionary complex (Van der Leeden et al. 1990; Wardle and Van Kranendonk 1996).

Seven localities within the Laporte domain (Fig. 4) were mapped and sampled for this study to further investigate its provenance, age and tectonic setting. Grey-weathering biotite wacke (Fig. 13) in the southwest Laporte domain (localities M29, M28, M50, Fig. 4) is strongly foliated, with compositional and subtle grain size variations reflecting medium- to thin-bedded strata, parallel to foliation. These fine sand- to silt-size rocks are micaceous, with 12-30% biotite and 5-20% muscovite, in addition to 40-60% quartz and generally less than 10% plagioclase. K-feldspar is absent. In addition, locality M29 contains 2% subhedral to anhedral garnet (0.25 mm) and 3% chlorite occurring as radial porphyroblasts, 500-800 μm, that overgrow the 100μm biotite+muscovite+plag+quartz matrix. Locality M50 is also garnet bearing, with 2-4% subhedral to anhedral garnet that commonly contains a well-developed internal fabric oblique to that in the matrix. Presence of a fabric internal to garnet is consistent with deformation prior to and/or during metamorphism at this locality. That metamorphism outlasted strain is evidenced by truncation of matrix biotite by garnet. Biotite wacke of the Deborah Lake Formation generally displays a strong foliation (S_1) parallell to bedding (S_0) which is SE-striking and SW-dipping at locality M29 (S_0+S_1= 135/62°SW), but which steepens and becomes ENE-dipping (S_0+S_1=330/72°NE, locality M28) and more northerly striking (354/66°E, locality M50) in proximity to the Tudor Lake shear zone.

Figure 13. Strongly foliated biotite wacke, Deborah Lake, Laporte domain. Locality M28.

The eastern Laporte domain (localities M8, M48, M27, M47) exposes white-weathering, leucocratic quartzofeldspathic rocks with muscovite as a key constituent. As noted by Van der Leeden et al. (1990) and Girard (1995), these rocks are characterized by the presence of trace amounts of graphite, specular hematite and associated iron oxide, resulting in rosey-red streaks throughout. In contrast to the interpretation of Girard (1995) these rocks, in large part, are suspected to be plutonic, with only a relatively small proportion of muscovitic psammite present (Fig. 14). Locality M8, previously interpreted as arkosic metasedimentary rocks, exposes strongly lineated leuco-monzogranite (Fig. 15*a,b*) whose primary plutonic texture is masked on horizontal exposures by strong shallow extensional strain, but recognizable on lower strain vertical exposures to comprise 50% quartz, 30% K-feldspar as 1-3 mm porphyroclasts (and 100 μm subgrains), 10% plagioclase and 3% muscovite (<0.5 mm). Subtle textural distinction between rocks of plutonic or sedimentary origin in this region, may be due to partial digestion of metasedimentary enclaves within S-type leucogranite, and/or may indicate that metasedimentary rocks of the eastern Laporte domain are derived from leucogranitic rocks that they unconformably overlie.

Figure 14. Peraluminous granite with muscovitic schlieren, Laporte domain (locality M27).

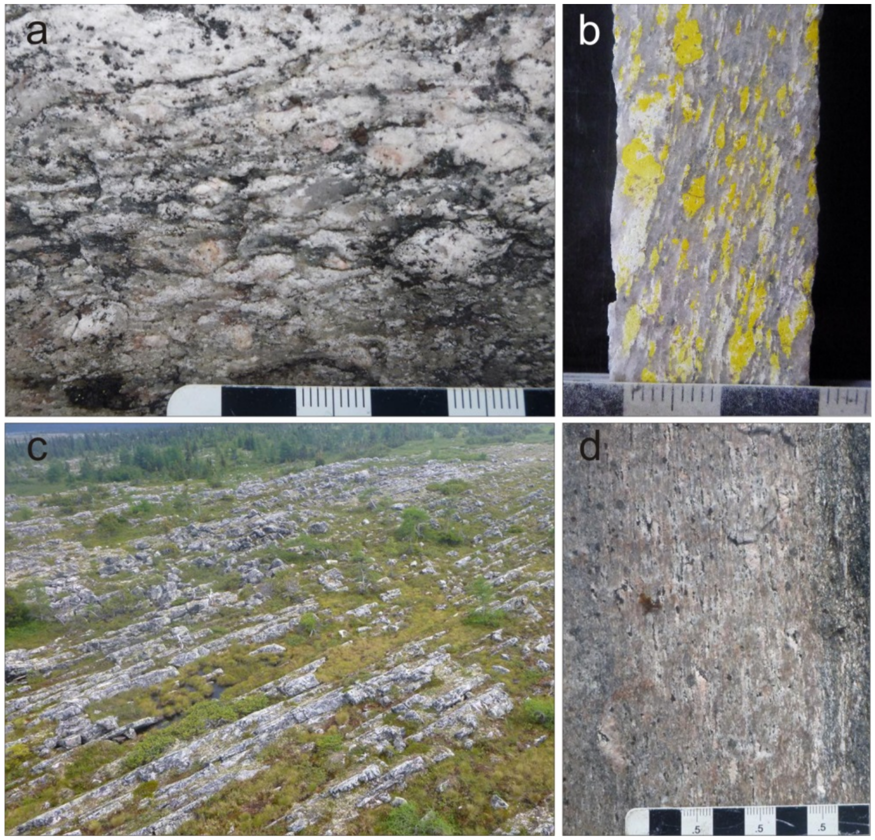

Figure 15. White-weathering muscovite leucogranite, eastern Laporte domain. *a*) horizontal exposure of strongly lineated muscovite leucogranite at locality M8; *b*) slab of sample M8 perpendicular to extension showing 25% K-feldspar (stained yellow) as 3-5 mm porphyroclasts and 1 mm subgrains in a quartz-rich (grey), plagioclase-bearing (white) groundmass; *c*) oblique view of strongly foliated and jointed character of muscovite leucogranite at locality M47; *d*) detail showing equigranular, medium-grained texture of leucogranite, locality M47.

Geology of the western Core Zone

Western orthogneiss complex

Metaplutonic rocks west of the De Pas Batholith have historically been subdivided into two main components: an orthogneiss complex of uncertain affinity exposed along the length of De Pas Batholith, and a fault-bounded wedge of metaplutonic rocks in the southwest, south of Snelgrove Lake (Fig. 4), purported to be reworked Archean Superior craton. The western orthogneiss complex, also referred to as the western zone (James and Mahoney 1994), and western gneiss zone (Wardle et al., 1990; van der Leeden 1990; James et al., 1993) has been further subdivided into the McKenzie River domain west of the lac Tudor shear zone, and the Crossroads Domain, east of the lac Tudor shear zone (James et al. 1996). Metaplutonic rocks of the McKenzie River domain are dated at two localities. In the southern map area, an age of 2776±7 Ma was obtained from tonalite gneiss exposed on the northwest shore of Smallwood Reservoir (James et al. 1996) while a similar age of 2789 +17/-5 Ma was obtained for tonalite gneiss at Griffis Lake (David et al. 2011) in the central map area (Fig. 4). Within the Crossroads domain, granitic rocks (Saint-Sauveur) exposed 20 km NNE of Griffis Lake yielded an age of 2684±8 Ma (David and Dion 2010), some 100 m.y. younger than the McKenzie River orthogneiss. The fault-bounded wedge of metaplutonic rocks referred to as the Snelgrove Arch (Wardle and Bailey 1981) has not been dated.

Eight exposures of the western orthogneiss complex (M4, M6, M7, M36, M37, M66, M68, M69 in Fig. 4) were examined to investigate the character, age, affinity and tectonometamorphic history of metaplutonic rocks into which the De Pas Batholith was emplaced. Outstanding questions related to these rocks include whether they differ in age, composition, and/or isotopic character from rocks purported to represent reworked Superior crust; and whether a component of the western orthogneiss complex is Paleoproterozoic in age, possibly representative of an older (subduction-generated?) phase of the De Pas Batholith.

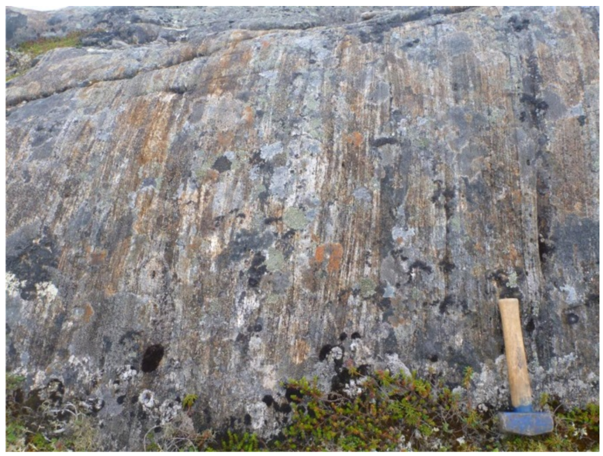

Figure 16. Straight recrystallized orthogneiss, with flattening (L<S) gneissosity oriented 337/86°NE, with steep lineation plunging 74° to the SE (130); locality M4, northern map area.

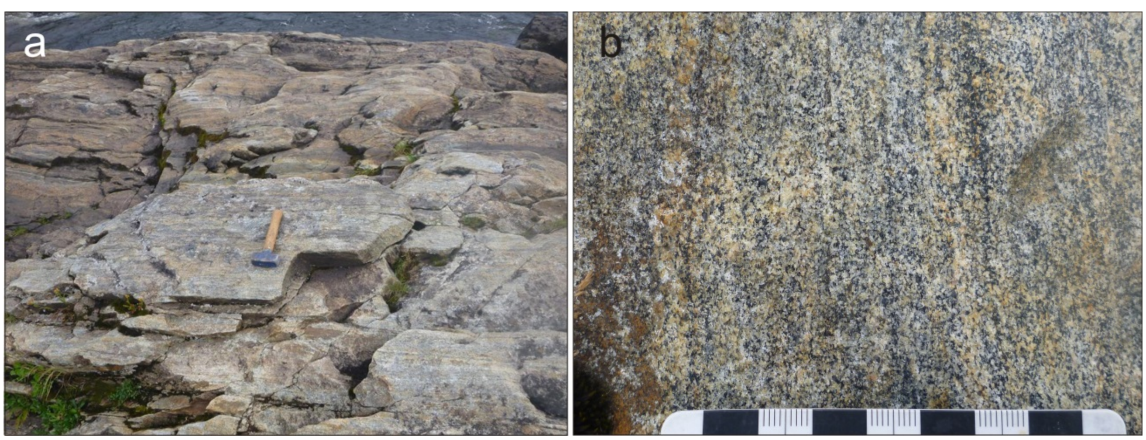

Figure 17. Foliated to gneissic hb+opx-mt±cpx±bt diorite of the western orthogneiss complex, Crossroads Domain, locality M69, central map area. *a*) view to East of steeply east-dipping flattening (L<S) foliation oriented 355/75°E (perpendicular to hammer), with mineral lineation plunging 68° to the northeast (045); *b*) detail of a) showing slightly gneissic flattening foliation on horizontal.

Figure 18. Enclaves of western orthogneiss ("Crossroads" domain) proximal to De Pas batholith, southern map area, locality M66. *a*) view to north of inclusions of strongly recrystallized coarse-grained monzogranite orthogneiss enclosed in weakly foliated opx-cpx-bt-mt quartz monzonite (De Pas) cut by pegmatite vein. Note consistent moderate eastward (to right) dip of gneissosity in orthogneiss; *b*) coherent, east-dipping panel of monzogranite orthogneiss; *c*) strongly foliated to gneissic mafic granulite inclusions with internal 005/65°E foliation, within weakly foliated De Pas monzogranite.

Supracrustal rocks associated with the western orthogneiss complex are rare and relatively poorly exposed. A 1 m wide panel of buff-weathering paragneiss at locality M14, immediately north of Griffis Lake (Fig. 4) contains 15% biotite and 6-10% garnet in addition to quartz and feldspar. Well-exposed supracrustal rocks associated with the western orthogneiss occur along the shores of small islands in northwest Smallwood Reservoir (Fig. 4). Here, lithologically diverse supracrustal rocks were informally designated the Lobstick group (James et al. 1993), given their exposure on the former Lobstick Lake, incorporated into the Smallwood Reservoir in the late 1960's. The Lobstick group includes semipelite, iron-rich metasedimentary rocks, and mafic metavolcanic rocks at locality M67 (Fig. 19), the latter displaying a very strong, straight tectonic compositional layering oriented 158/85°W (Fig. 19*c*). Amphibolite-facies metamorphism is indicated by 15-30% garnet in addition to 15-40% biotite in quartzo-feldspathic metasedimentary rocks, and 8% garnet in addition to 75%

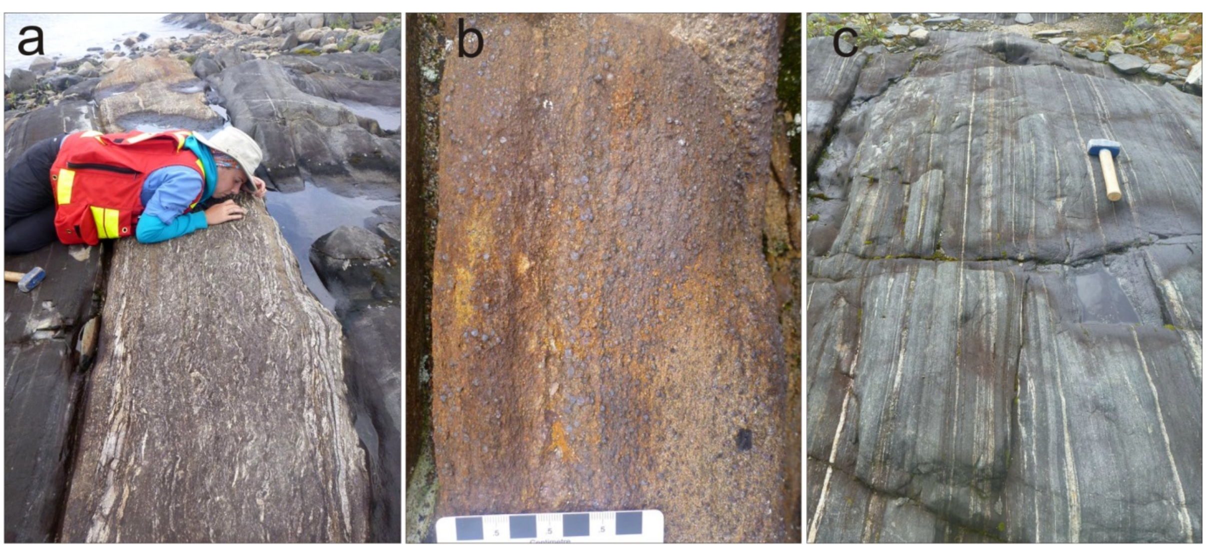

Figure 19. Supracrustal rocks of the Lobstick group at locality M67, northwest Smallwood Reservoir. *a*) semi-pelite; *b*) gossanous, iron-rich, garnet-bearing metasedimentary rocks; *c*) tectonized metabasalt with straight compositional shear foliation at 158/85°WSW.

hornblende in metavolcanic rocks. Strongly tectonized and recrystallized diopsidic layers, suspected to be calc-silicate horizons (Fig. 20) and minor marble are interlayered with orthogneiss and quartz-rich rocks of uncertain affinity 10 km east (localities M36, M37; Fig. 4).

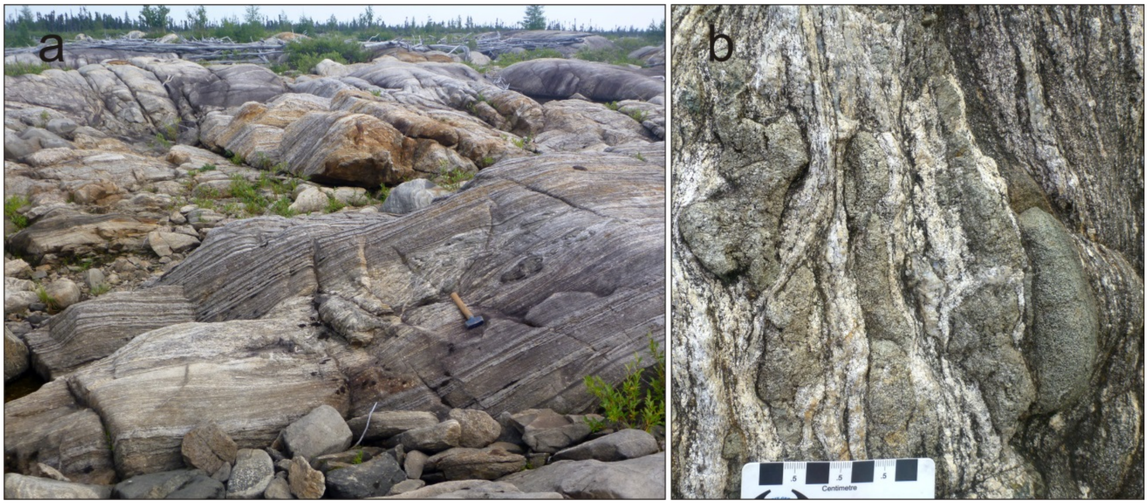

Figure 20. Calc-silicate±pelite of the Lobstick group, locality M37, northern Smallwood Reservoir. *a*) panel of calc-silicate enveloped by strongly tectonized granulite-facies quartz-rich rocks of uncertain affinity and orthogneiss; b) detail of calc-silicate boudin transected by network of coarse-grained leuco-charnockite veins.

It is not yet established whether the Lobstick group is an Archean assemblage cut by the ca. 2776 Ma McKenzie River domain orthogneiss prior to deformation, or part of a younger, possibly Proterozoic sequence that is tectonically imbricated with the orthogneiss. Difficulty establishing this arises by lack of precise U-Pb age determinations, and the high strain displayed by all units such that contacts between supracrustal and plutonic rocks are structural and coplanar.

The region interpreted to be underlain by a fault-bound wedge of reworked Superior craton (Snelgrove Arch; Wardle et al. 1997) is a poorly exposed, drift and tree-covered area. Three (helicopter-accessible) localities were investigated in 2014 (localities M32, M33 and M34; Fig. 4) but these topographically high exposures are all composed of massive to weakly foliated medium- to coarse-grained mafic ± ultramafic plutonic rocks, suspected to be part of the Montagnais mafic plutonic suite. In general they are composed of 60-80% hb±cpx±mt, although gossanous melanogabbro at locality M33 contains up to 40% magnetite. They generally record a low degree of strain, with rare narrow zones of high strain localized within a variolitic horizon at locality M34, indicating localized strain outlasted mafic magmatism. No felsic plutonic rocks belonging to the Snelgrove Arch were observed.

De Pas Batholith

The De Pas is a highly elongate felsic batholith that strikes northerly for over 300 km, with an average width of approximately 40 km. It is dominated by K-feldspar porphyritic monzogranite-granodiorite-syenogranite ± quartz monzonite with lesser charnockite, enderbite and isotropic granite-granodiorite±syenite. The southern part of the De Pas Batholith has been dated at several localities, with U-Pb zircon ages of 1837.3±4.5 Ma, 1831±5 Ma and 1823±5 Ma (David et al. 2011; James et al.

1996) (Fig. 4). The batholith displays a notable change in mineralogy from orthopyroxene-bearing assemblages in its western half, to hornblende-biotite assemblages in the east. Although hornblende-biotite granodiorite-monzogranite in the east is more evolved and slightly younger than the orthopyroxene-bearing phases in the west, both are co-magmatic "I-type" granitoids of calc-alkaline character (Van der Leeden et al. 1990). Van der Leeden et al. (1990) interpreted the batholith as having a volcanic arc affinity based upon the Pearce geochemical classification scheme (Pearce et al. 1984). This scheme may not, however, effectively discriminate volcanic arc from post-collisional granites (Pitcher 1983; Förster et al 1997), the latter setting supported by the narrow range of composition and SiO_2 content of De Pas rocks, the dominance of biotite over hornblende as a mafic component, and the high Zr and light rare-earth element (LREE) contents of many of the De Pas samples (Kerr et al., 1994). The west to east transition from granulite- to amphibolite facies across the pluton, led Dunphy and Skulski (1996) to suggest the De Pas Batholith exposes a tilted crustal section, with a deeper structural level reflected by orthopyroxene-bearing assemblages in the west. They linked crustal tilting to shortening related to collision of Superior craton, in support of pre-collisional arc-related emplacement of the De Pas Batholith. However, as previously mentioned, interpretation of the De Pas Batholith as a subduction-generated arc is inconsistent with the predominance of granitic (potassium rich) rocks with high Zr and LREE chemistry, aspects more typical of syn- to post-collisional crustal suites than to subduction-generated suites (Roberts and Clemens 1993).

Advances in understanding the tectonic setting of the De Pas batholith and its emplacement relative to collision of Superior craton are being addressed in this study through petrographic examination focused on the relative timing of deformation and metamorphism across this part of the Core Zone. In addition, mafic phases potentially reflecting an earlier subduction-generated phase of De Pas are being investigated by U-Pb dating of dioritic to quartz dioritic rocks marginal to the K-feldspar porphyritic monzogranite that dominates the batholith. Presently it is unknown whether these dioritic rocks are Archean or Paleoproterozoic in age and, hence, whether they represent part of the De Pas suite, and evidence of a broader compositional spectrum extending into the tonalite-trondjemite-granodiorite (TTG) field, as might be anticipated if the De Pas formed in a continental magmatic arc setting.

The topographically high and relatively well-exposed ca. 1837-1820 Ma De Pas Batholith was examined at numerous localities (M5, M13, M25, M26, M35, M54, M55, M70, M71, M74, M75; Fig. 4). Most of these localities expose weakly foliated, medium-grained, K-feldspar porphyritic biotite-hornblende monzogranite - quartz monzonite. In the western margin of the batholith, fresh 1-2 mm grains of orthopyroxene make up 10% of mafic constituents, in addition to ~10% hornblende+magnetite at locality M26 and 6% in addition to 15% hb+mt+bt at locality M75. Also in the west, ~4% thoroughly retrogressed orthopyroxene, 0.25-1 mm, occurs with hornblende ± biotite and moderately altered plagioclase (localities M35, M55; Fig. 4), possibly linked to fault-facilitated fluid flow. The prograde reaction hornblende+biotite going to orthopyroxene is in evidence at centrally located station M71.

The De Pas Batholith typically displays a low-moderate intensity foliation defined by aligned mafic minerals and elongate quartz (Fig. 21). Rarely, K-feldspar is aligned or elongated (Fig. 21*d*). Thoughout the batholith, foliation strikes consistently NW to N (325-358°) and dips moderately to steeply (60-78°) east. Exceptions are at M54 where subtly aligned laths of K-feldspar are oriented 310/65°NNE, and at M75 where foliation dips steeply west (188/73°W).

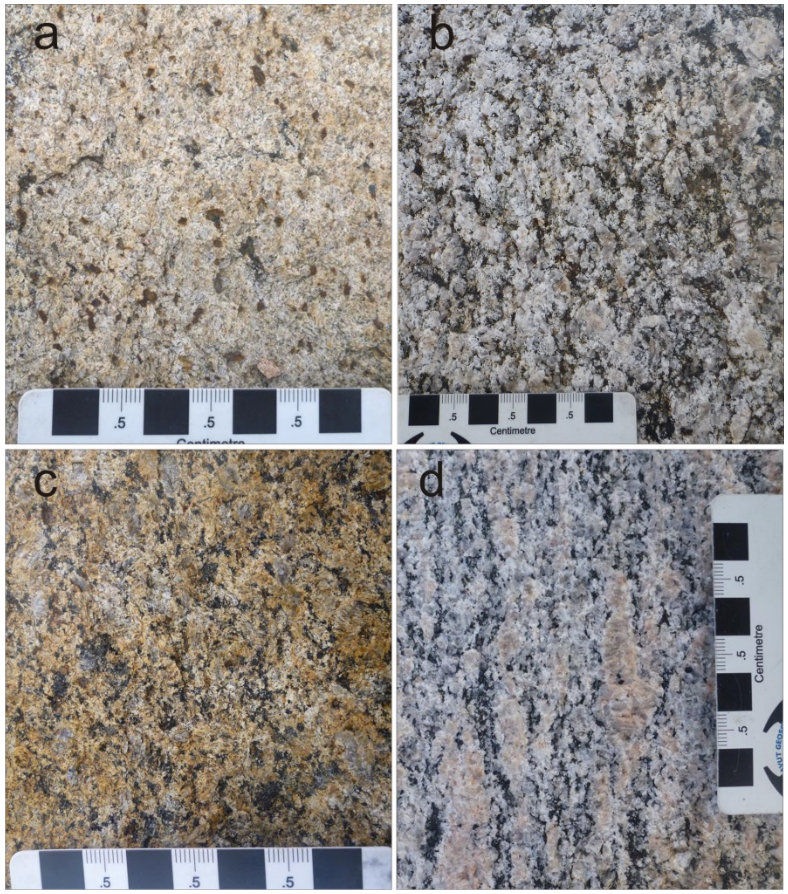

Figure 21. Representative exposures of the De Pas batholith. *a*) weakly foliated medium-grained charnockite, northwestern margin, locality M5; *b*) northeastern margin, locality M70 *c*) south-central batholith, locality M74; *d*) moderate foliation in K-feldspar porphyritic biotite granite, eastern margin, locality M13.

Dioritic rocks (localities M57, M68, M69, M19; Fig. 4) of unknown age and affinity occur west and east of K-feldspar porphyritic granite of the De Pas Batholith, and their relationship to the batholith will be tested through isotopic methods. These dioritic phases similarly reflect the granulite- to amphibolite-facies transition that typifies known De Pas rocks, whereby moderately foliated to gneissic (348/65°ENE) hornblende-orthopyroxene-magnetite±-clinopyroxene±biotite diorite is exposed in the west (Fig 22*a;* localities M68,69 and M57, Fig. 4), while weakly foliated (020/75°E) hornblende-biotite quartz diorite is exposed in the east (Fig. 22*c*; locality M19, Fig. 4). Internal to the De Pas Batholith, highly strained and isoclinally folded xenoliths (Fig. 22*b*) indicate that a high degree of strain preceeded emplacement of the charnockitic/monzogranite phase of the batholith, in contrast to the generally weak to moderate strain displayed throughout the batholith (Fig. 21), highlighting the low degree of post-emplacement strain.

Figure 22. Dioritic rocks proximal to De Pas batholith of uncertain affinity. *a*) foliated opx-cpx-mt quartz monzodiorite at locality M57 with single moderate straight foliation oriented 348/65°E; b) highly strained, isoclinally folded straight diorite gneiss xenoliths cut by weakly foliated opx-bearing monzogranite at locality M26; *c*) weakly foliated (020/75°E) hb-bearing quartz diorite at locality M19.

Eastern orthogneiss complex

Orthogneissic rocks exposed east, and along the length, of the De Pas Batholith were designated part of the Crossroads domain (James et al. 1996; Valley 2010) between the Tudor Lake and George River shear zones. Three localities of the eastern orthogneiss were examined (M72, M42, M53; Fig. 4).

Orthogneiss at M72 (Fig. 23*a*) is oriented 185/55°W. Migmatitic orthogneiss at M42 has gneissosity oriented 348/54°E which is openly buckled and locally transected by a second-generation foliation (S_2) oriented 002/60°E. The orthogneiss contains massive to weakly foliated mafic xenoliths. Locality M53 exposes porphyroclastic mylonite (Fig. 23*b,c*) that coincides with the GRsz (Fig. 4). This mylonitized granodiorite, whose age will provide a maximum timing constraint on shearing within the GRsz, is cut by weakly foliated syenogranite dykes whose age will provide a minimum constraint on shearing.

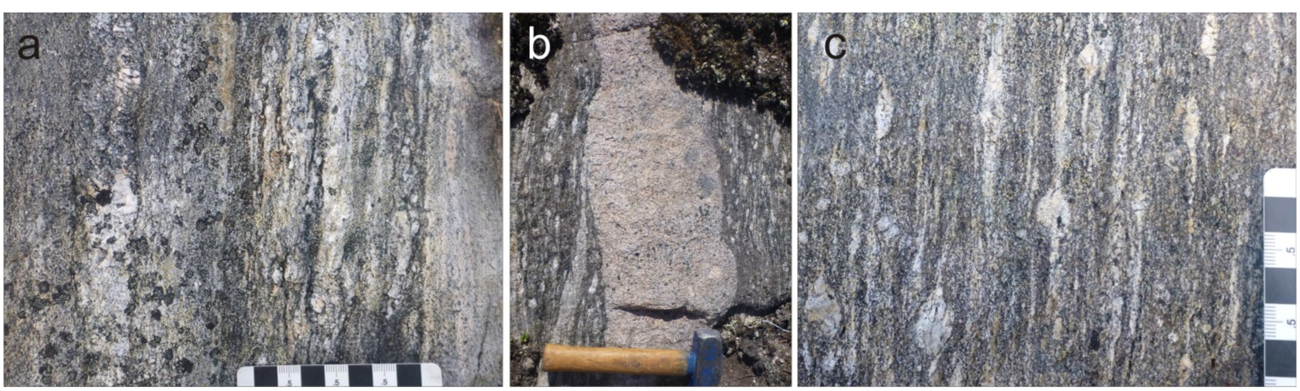

Figure 23. Orthogneiss east of De Pas batholith *a*) injection orthogneiss, (locality M72), comprised of fine-grained grey diorite cut by variable abundance of mzgr-qzmz veins, some of which may be apophyses of De Pas. Gneissic foliation (S_2) at 185/55°W is axial planar to F_1 folds; *b*) feldspar porphyroclastic granodiorite mylonite cut by less strained syenogranite (M53); c) detail of feldspar-porphyroclastic granodiorite mylonite of *b*).

Geology of the central Core Zone

A collage of greenschist- to upper-amphibolite facies supracrustal rocks of the central Core Zone are exposed in the northeastern map area. These supracrustal rocks have been designated as distinct assemblages (Ntshuku, Atshakash, Zeni) by previous mappers (Girard 1990; Van der Leeden et al. 1990) who described a corridor of interbedded graphitic schists, cherty quartz arenite, schistose metatuff and metabasalt, some 2 km wide and up to 100 km long parallel to tectonic strike. They are interpreted to reflect a restricted (starved) intra-arc volcano-sedimentary basin (Van der Leeden et al. 1990), unconformably overlain by a cratonic-rift assemblage (molasse?) designated the Hutte Sauvage group (Girard 1992). Seven localities along this supracrustal collage were mapped in 2014 to assess lithology, identify samples for U-Pb dating, consider tectonic setting and, collectively, provide a more robust foundation on which to base correlations within the Core Zone.

The Ntshuku assemblage is described as comprising mainly metavolcaniclastic and metabasaltic rocks (Girard 1990; Van der Leeden et al. 1990; Ministère de l'Énergie et des Ressources naturelles 2010: NTS 23P15 lac Pallatin), that are considered to be extrusive equivalents to the ca. 2.3 Ga Pallatin Intrusive Suite (Girard 1990). Two localities of the Ntshuku assemblage, formerly identified as mafic metavolcanic rocks (unit $pP_{\mathbf{nts10}}$ on 23P15 compilation map, MERN 2010) on northwest Pallatin Lake were examined (localities M17, M18; Fig. 4). Locality M17 exposes equigranular, medium-to coarse-grained gabbro (Fig. 24*a*) with lesser clinopyroxenite and gabbroic anorthosite. These mafic plutonic rocks are massive to weakly foliated, with rare primary igneous layering (Fig. 24*b*), and are cut by discrete shear zones, average 7 cm wide (Fig. 24*c*). A feldspar porphyroclastic texture internal to some shear zones suggests strain may have been localized, in part, by granitoid veins. No volcanic rocks or their metamorphic equivalents were observed at locality M17.

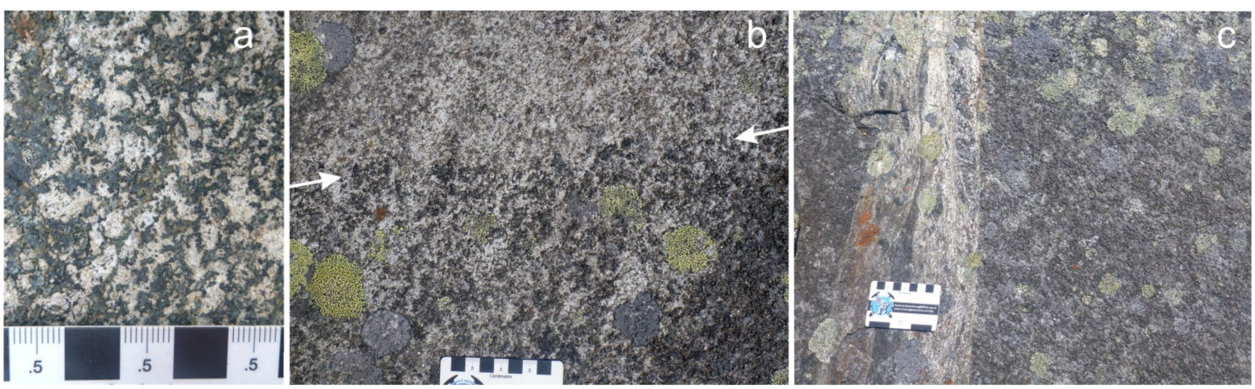

Figure 24. Gabbro-gabbroic anorthosite, Ntshuku assemblage (locality M17, Fig. 4). *a*) massive coarse-grained texture, typical of exposure; *b*) rare primary compositional layering with white arrows indicating interface between gabbroic anorthosite (upper) and gabbroic (lower) horizons; *c*) light-weathering, discrete 7 cm wide shear zones transecting coarse-grained massive gabbro.

Along the northeastern edge of the map area (locality M18, Fig. 4), mylonitic rocks exhibiting polyphase deformation are widespread. Porphyroclastic rocks (Fig. 25*a*,*c*) provide evidence of the original coarse-grained plutonic protolith for some of the units, in contrast to fine-grained mylonitic rocks (Fig. 25*b*,*c,d*) of uncertain, possibly supracrustal origin. At least two phases of deformation are indicated by mylonitic layers with pinch and swell structures (extensional strain) that have been subsequently folded (contractional strain). Given the structural and lithologic complexity of rocks assigned to the Ntshuku assemblage, this region will be revisited in 2015 to further investigate the significance of the mylonites, their kinematics, and the protolith of the rocks affected by strain in this part of the Core Zone.

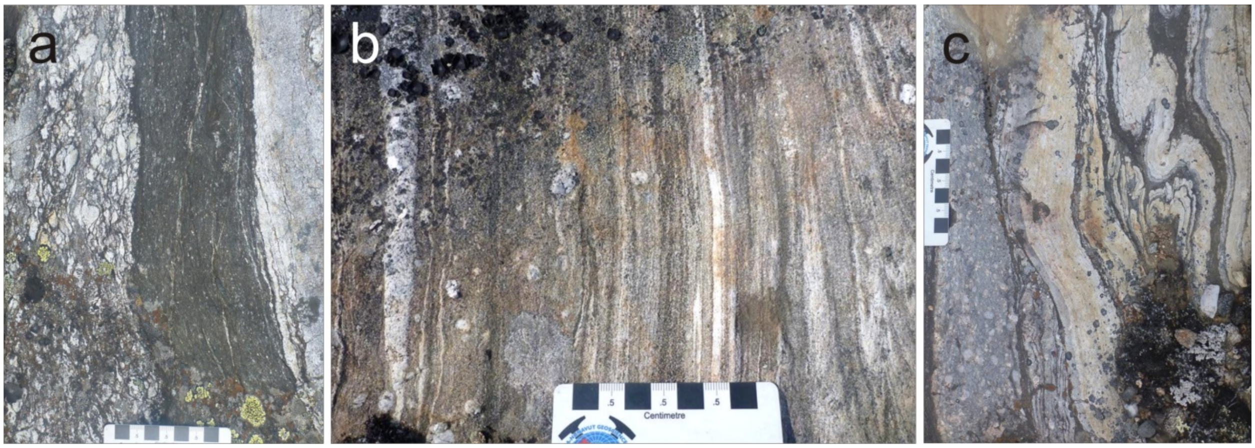

Figure 25. Highly strained Ntshuku assemblage (MERQ 2010) with porphyroclastic units of plutonic origin interlayered with fine-grained units of potential supracrustal origin (locality M18, Fig. 4). *a*) compositional and textural heterogeneity diagnostic of this exposure; *b*) porphyroclastic mylonite of possible supracrustal origin; *c*) parasitic S-folds of highly strained light and dark weathering rocks of uncertain origin, interlayered with K-feldspar porphyroclastic granodiorite. Note parasitic fold hinges of previously boudinaged light weathering unit of uncertain origin.

Atshakash assemblage

Four localities along the north-striking Atshakash assemblage (localities M24, M43, M44, M45, Fig. 4) were examined in 2014 to assess its character, age and affinity. Supracrustal rocks at all localities displayed strong to intense planar tectonic fabrics, consistent with deformation within the north-striking, near-vertical George River shear zone (Fig. 4). From north to south, salient observations of the Atshakash assemblage are as follows. Mafic rocks with a colour index (CI) of 60-65 and an average grainsize of 0.2 mm, exposed at M43, are compositionally and texturally consistent with a mafic volcanic origin. No evidence of primary volcanic textures were noted, suggesting these originated as massive metavolcanic flow(s). A minor component of andesitic rocks (colour index ~25 (biotite+hornblende) at locality M43, provides a target for U-Pb dating. These metavolcanic rocks display an intense foliation (008/90°E), parallel to the N-striking tectonostratigraphy east of the De Pas Batholith (Fig. 4). Locality M44 (Fig. 4), 200 m to the west, exposes strongly foliated metagabbro with CI=60 has a recrystallized equigranular texture (~3 mm), and is less strained than the adjacent metavolcanic rocks. Rhyolite reported at this locality (Ministère de l'Énergie et des Ressources naturelles, 2010: NTS 23P10 lac Mortrel) was not observed. Metasedimentary rocks at locality M45 (Fig. 4) include light, buff weathering quartz psammite (Fig. 26*b*) consisting of a quartz-rich (~75%) recrystallized groundmass (50-100 μm) with 20% isolated, evenly dispersed, aligned mica (biotite>chlorite>muscovite; avg 50 μm long) and 2% isolated grains of feldspar (20 μm), with rare 1-2 mm porphyroblasts of biotite. Rare elliptical garnet porphyroblasts, up to 1 cm, contain a strong internal fabric parallel to foliation which wraps them, indicating strain preceeded and outlasted metamorphism. Interlayered rust-brown weathering semipelite (Fig. 26*c*) is composed of 40% biotite + 5% muscovite in a quartz-rich matrix. In thin section, the quartz-rich groundmass is highly sutured (i.e., not annealed) indicative of strain outlasting metamorphism, and micas occur as well-formed shear bands.

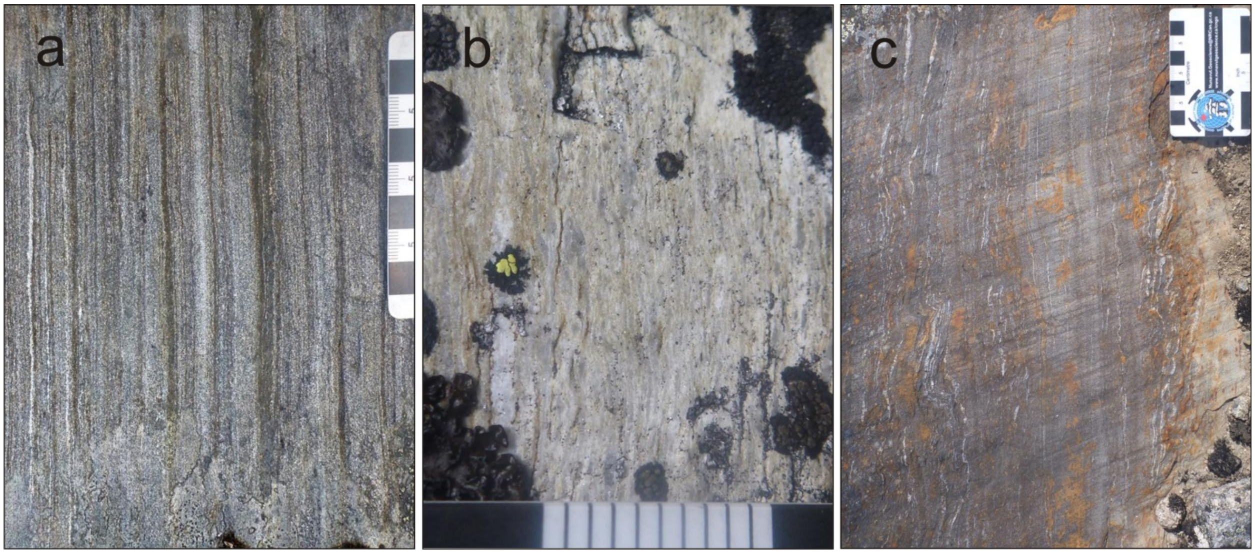

Figure 26. Supracrustal rocks of the Atshakash sequence. *a*) tectonized meta-andesite, 10 km south of M24; *b*) light buff-weathering quartz psammite cut by 1-2 mm quartz veins, locality M45; *c*) rusty-weathering bt-ms semipelite with well-developed glacial striations, locality M45.

Some 10 km to the south (locality M24, Fig. 4), talcose schist (Fig. 27*a*) composed of ~70% altered feldspar with 20% pale green biotite, 10% blue-green amphibole and 3% sphene possibly representing sheared and altered supracrustal rocks, is in contact with orthogneiss (Fig. 27*b*). Here, schistosity oriented 345/63°ENE is axial planar to tight folds in adjacent tonalite (Fig. 27).

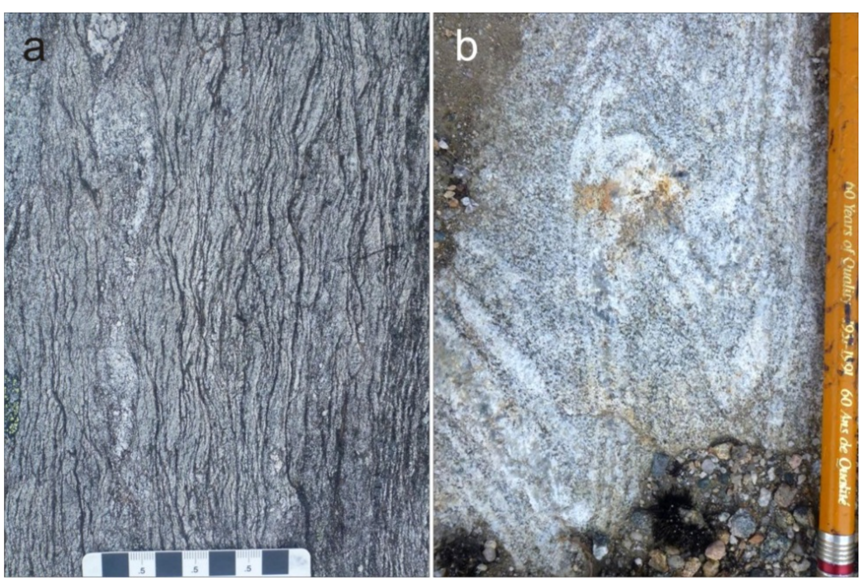

Figure 27. Deformed rocks at locality M24, east of De Pas Batholith. *a*) talcose schist of likely supracrustal origin with strong 345/63°ENE S_2 foliation; *b*) tonalite gneiss with gneissosity (S_1) folded tightly, pencil parallel to F_2 axial planes oriented 345/65°ENE.

Mistinibi-Raude migmatite domain

The northeast part of the map area, referred to as the Mistinibi-Raude domain (Van der Leeden et al. 1990) is distinguished by its high-grade, migmatitic character. Dominated by paragneiss, this domain also includes pre- late- and post-tectonic granitoids, diorite, and mafic-ultramafic plutonic rocks. None of the units have been dated, nor has the time of main penetrative tectonometamorphism been established. Inhomogeneous diatexite at locality M16 (Fig. 28*a*) comprises 20% pelitic-semipelitic layers enveloped by ~50% leucocratic veins and patches of quartzofeldspathic material (melt). Pelitic rocks are granulite facies with 10% orthopyroxene (1-2 mm), 4% biotite (0.25-0.5 mm), 5% garnet (average 3 mm up to 8 mm) which is typically anhedral irregular and very heavily included. Mafic layers and enclaves, 3-15 cm wide, are fine-grained, equigranular, non-magnetic, with a colour index of ~80 (Fig. 28*b*) consisting of 30% biotite, 25% hornblende, 15% clinopyroxene and 10% orthopyroxene with 8% plagioclase and 1% magnetite. These likely originated as mafic dykes and/or sills that cut the metasedimentary domain prior to the main tectonometamorphism.

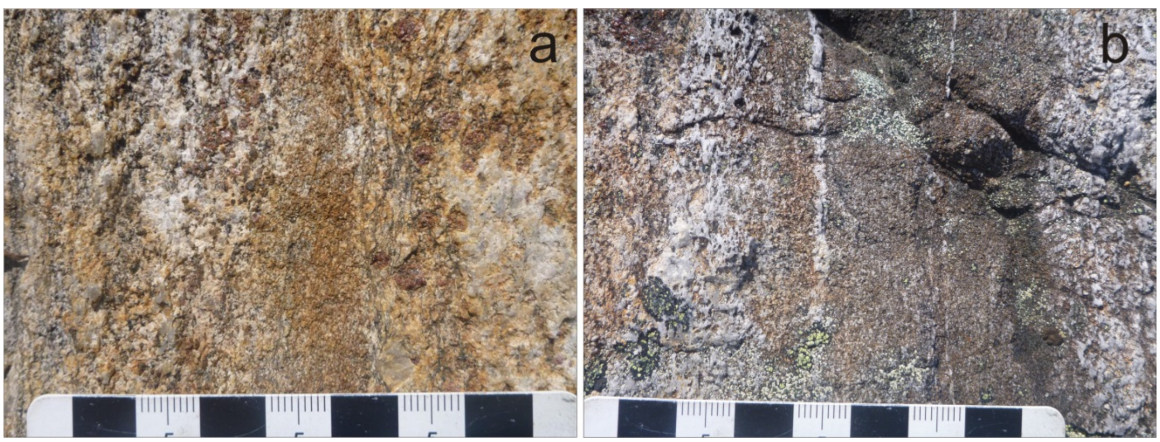

Figure 28 Mistinibi migmatite domain, Locality M16. *a*) inhomogeneous diatexite; *b*) 6 cm wide fine-grained mafic layer cut by leucocratic veins.

In the southern part of the domain, the Lac Raude gabbroic complex is dominated by hornblende-pyroxene gabbro, with lesser diorite ± quartz diorite and minor metapyroxenite. The Raude gabbro (locality M9, Fig. 4) is texturally variable with both medium-grained, equigranular (Fig. 29*a)* and plagioclase-porphyritic (Fig. 29*b*) phases. The gabbro has a colour index of ~50, consisting of 10% clinopyroxene, 15% hornblende and 10% biotite, and is strongly to moderately magnetic. Plagioclase phenocrysts, average 1-2 cm in length, define a moderately developed foliation oriented 325/72°E.

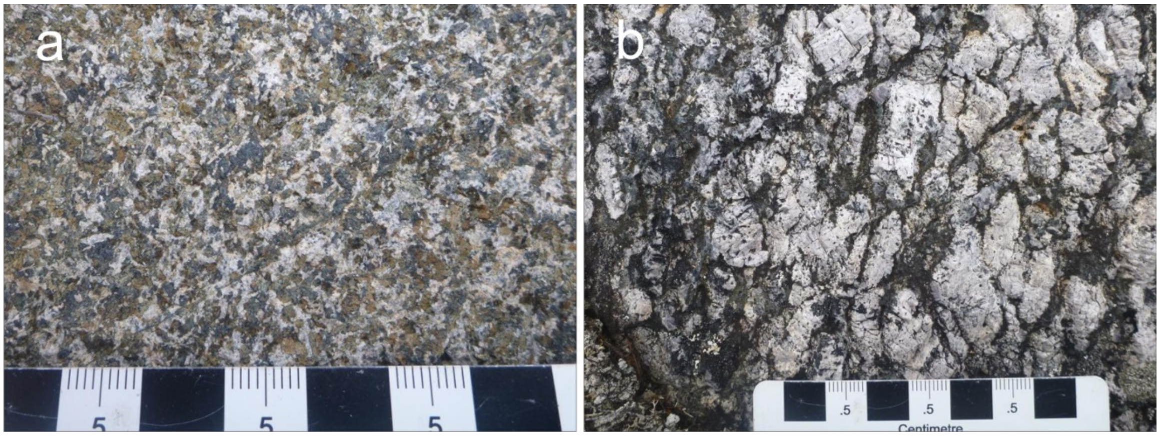

Figure 29. lac Raude gabbroic complex, locality M9. *a*) equigranular medium-grained hb-cpx-bt gabbro; *b*) plagioclase por-phyritic gabbro with moderate 325/72°E foliation defined by aligned phenocrysts.

Post-tectonic Mesoproterozoic plutons

Post-tectonic Mesoproterozoic plutons are exposed along the eastern margin of the map area. They include granite, syenite and anorthosite that are relatively well dated (U-Pb), in contrast to other units of the southern Core Zone. The oldest dated phase of the Mesoproterozoic suite is the circular Juillet syenite (locality M52, Fig. 4; Fig. 30), with an age of 1479.7+12.6/-5.4 Ma (David et al., 2012). Successive, voluminous plutonism in the southeast is represented by the 1469±1 Ma Michikamau anorthosite (Kerr and McNicoll 2010), 1459±2 Ma Michikamats granite (James et al., 1994), and the Michikamats syenite ring-complex unit (Figs. 3, 4, 30) dated at 1458.6±2.8 Ma (Kerr and Hamilton 2014). Although 20 my younger, the Michikamats ring complex is comparable in size, shape and composition to the Juillet syenite, and consists of syenite with iron-rich ferrosyenite reflected by concentric rings in its magnetic expression (Fig. 30). The northeastern edge of the map area exposes the west margin of the voluminous, 5000 km^2 Mistastin Batholith. The batholith is dominated by pyroxene ± olivine granite and monzonite dated at 1439±3 Ma, which is cut by biotite-hornblende granite dated 1423±2 Ma (Kerr and Hamilton 2014). Syenitic-granitic phases of both the ca. 1459 Michikamats and ca. 1440-1423 Ma Mistastin complexes are REE-enriched (Kerr and Hamilton 2014).

Younger still, are the 1409.7±1 Ma Misery Lake (David et al. 2012) and 1240±2 Ma Strange Lake (Miller et al 1997) complexes, which host potentially important rare earth element (REE)-Zr-Nb deposits, and occur just north (Strange Lake) and east (Misery Lake) of the map area (Fig. 3).

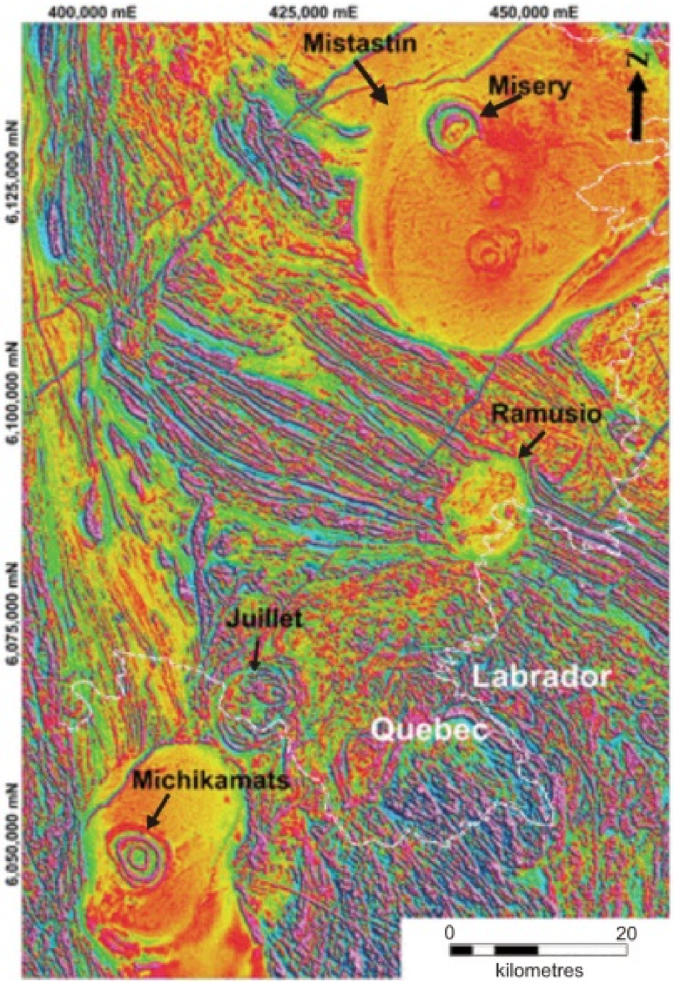

Figure 30. Magnetic gradient map of the southern Core Zone (Dumont et al., 2010) reflecting at least five concentric Mesoproterozoic intrusions, the ca. 1480 Ma Juillet, 1459 Ma Michikamats and 1410 Ma Misery syenites and the ca. 1482 Ramusio and 1439-1423 Ma Mistasin granites. From Petrella et al., 2014.

Regional-scale shear zones

The Tudor Lake and George River shear zones extend regionally along the length of the Core Zone (Fig. 2). Mainly expressed as topographic lineaments, these poorly exposed structures were examined at only a small number of localities. Observations in 2014 concur with previous interpretations of dextral strike-slip movement on the Tudor Lake shear zone with a mappable change in extensional fabric from steep in the northwest (i.e., locality M29) to increasingly shallow at localities M8 and M50 where the Tudor Lake shear zone strikes 355°, dips 66° and displays a strong shallow north-plunging extensional lineation. East of the De Pas Batholith, the George River shear zone extends some 200 km with an apparent width from 6 km to 20 km wide. Very strong flattening strain and both dextral and sinistral vorticity is recorded by rocks within this structure, which appears to be localized within supracrustal rocks of the Zeni, Atshakash and Ntshuku assemblages. Samples were collected for U-Pb analysis that aim to better constrain the time of shearing along the George River shear zone.

Assessment of Gaps

Bedrock mapping conducted in 2014 in concert with an extensive review of literature for the New Québec Orogen (including Labrador Trough) and southern Core Zone, has highlighted a number of outstanding questions in regard to lithotectonic correlations, age and affinity of key units, and tectonic evolution of this area. These include:

- the depositional age and provenance of easternmost clastic rocks attributed to the Kaniapiskau Supergroup, to test the long-held prediction that cross-bedded arenite is part of the ca. 2.16 Ga lower Seward Group, and determine whether quartz arenite at Quartzite Lake is part of ca. 2.1 Ga Cycle 1 or ca. 1.88 Ga Cycle 2 strata;
- the architecture, age and provenance of the Laporte domain;
- whether the Lobstick supracrustal sequence is part of an Archean basement complex cut ca. 2776 Ma plutonic rocks of the McKenzie domain, western orthogneiss complex, or whether it is a tectonically imbricated Paleoproterozoic sequence, possibly correlative with the Laporte domain;
- whether there exists an older, more mafic and potentially subduction-generated arc phase of the De Pas Batholith, or whether this weakly to moderately foliated granite-dominated batholith records syn- to late-collisional crustal melting;
- the depositional age, provenance and tectomometamorphic history of the northern supracrustal sequences (Mistinibi-Atshakash);
- whether rocks designated by previous workers as Ntshuku assemblage represent a distinct lithological assemblage or whether they are a structural panel (i.e., folded mylonites of the George River shear zone);

Insight into these aspects of the New Quebec Orogen and southern Core Zone will be gained through follow-up bedrock mapping, analytical work (geochronology, geochemistry), petrography and structural analysis.

Conclusions

In conclusion, new GEM integrated lithological and structural mapping together with targetted sampling of key units for geochemical and geochronological analysis, is elucidating the character and tectonometamorphic evolution of the New Quebec Orogen and southern Core Zone. This knowledge will be used to strengthen the foundation on which interpretations of heritage, affinity and mineral prospectivity of this under-explored region are based.

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