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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 2015 field season, the GEM program successfully carried out 14 research 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.

Project Summary

The GEM2 Southern Core Zone activity is undertaking surficial and bedrock mapping and related geochemical and mineralogical studies in northern Quebec and Labrador (McClenaghan et al., 2014, 2015). These activities are aligned with the objectives and goals of GEM to increase economic prosperity of northern communities and Canada through stable, long-term investment in northern mineral exploration and development. Bedrock mapping and mineral resource exploration in northern Quebec and Labrador is challenging because bedrock is largely covered by unconsolidated surficial sediments deposited by a complex sequence of glacial events influenced by a migrating ice divide. Significant parts of northern Quebec and Labrador have no surficial geology maps, and little geochemical or indicator mineral data from the glacial sediment (till). This lack of surficial geological information results in poorly understood till thickness, glacial history, and dispersal mechanisms and patterns, which collectively hinder mineral exploration using till prospecting methods.

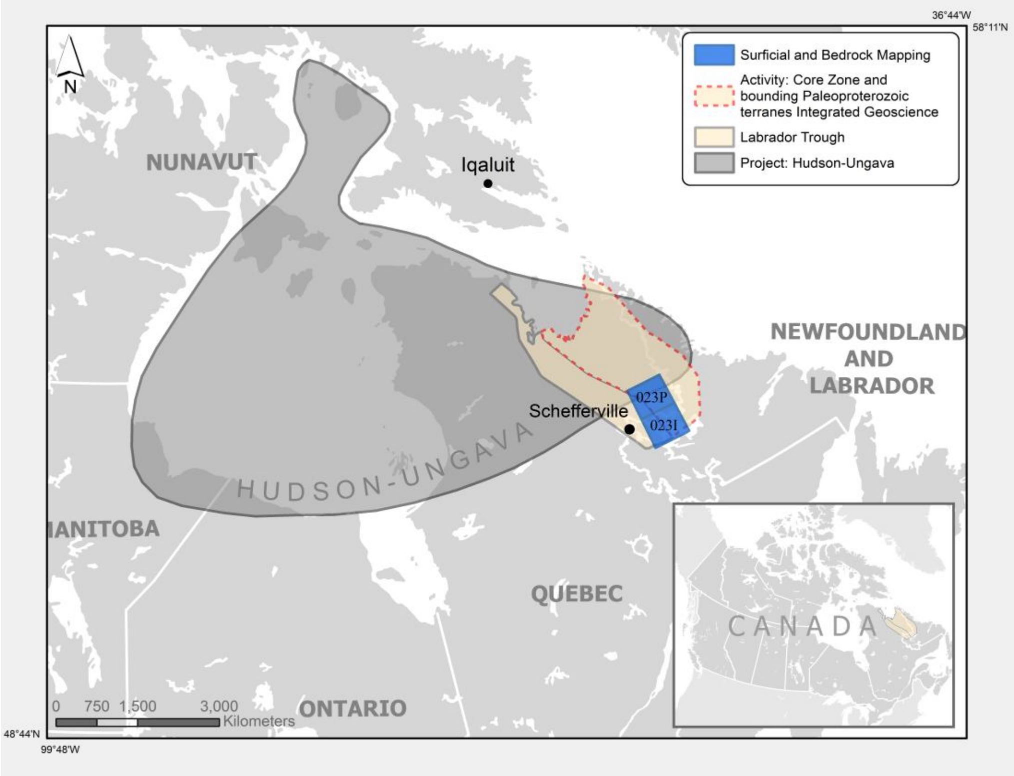

Figure 1. Location of the Southern Core Zone surficial and bedrock mapping activity (NTS 23P, 23I), part of the GEM Hudson-Ungava project

In order to address this challenge, new surficial mapping, indicator mineral, and geochemical surveys in association with new bedrock mapping are taking place across NTS sheets 23P and 23I (Fig. 1), to generate new regional geoscience data and knowledge that will be used to increase natural resource exploration successes and reduce risks to the mineral exploration sector. The poorly understood bedrock geology and mineral potential of the southern Core Zone will be addressed by 3 main activities: 1) regional surficial mapping and till geochemical/mineralogical sampling; 2) compilation of lake sediment geochemical data across both Quebec and Labrador, to generate a set of coherent geochemical maps for the region; and 3) detailed bedrock mapping and geochronology in targeted areas.

Introduction

A re-evaluation of the prospectivity of the southern Core Zone, an under-explored, till-covered region that straddles the Quebec – Labrador boundary east of the Schefferville iron-ore district (Fig. 1,2), is being carried out through integrated surficial studies and bedrock mapping. This report focuses on the bedrock mapping component undertaken from July 30 - August 12, 2015 in this region. Bedrock mapping is directly supporting surficial activities through identification of the sources of diagnostic lithologies occurring within till, so that dispersal directions and distances can be quantified. In addition, bedrock studies are focused on establishing the time at which major rock units were formed and deformed, with the goal of developing a calibrated chronology for the region that can be used to test long-held stratigraphic correlations and refine tectonic models.

New data for the region will highlight areas of increased mineral prospectivity, allow a more tractable link between metal contents in till and source rocks, and provide a more robust tectonostratigraphic and magmatic context within which to undertake mineral exploration activities.

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. 2). The Core Zone represents a complex medial hinterland between the Archean Superior and North Atlantic cratons, consisting 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 (Dunphy and Skulski 1996; James et al. 1996) and Kuujjuaq suite (Perrault and Hynes 1990). It is characterized by well-delineated NNW-striking lithotectonic trends, except where cut by posttectonic Mesoproterozoic plutons in the east-southeast (Fig. 2). The Core Zone is transected by two regionally extensive high strain zones: the dextral lac Tudor and dextral rivière George shear zones (Fig. 2, 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. Originally recognized to record rifting of Superior craton and development of an ocean basin (Dimroth 1978; Wardle and Bailey 1981), Paleoproterozoic iron-bearing metasedimentary rocks and lesser volcanic rocks were designated the Labrador Trough (Harrison, 1952 and references therein) to reflect their accumulation in a broad, elongate geosyncline, or trough. With the suggestion that the upper part of the volcano-sedimentary sequence may represent foredeep deposits formed in advance of thrust nappes (Hoffman 1987), the belt was renamed the New Québec Orogen (Hoffman 1988, 1990, Wardle et al. 1990; Fig. 2).

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) inferred to represent an accretionary complex marking a suture between the Core Zone and North Atlantic craton (Van Kranendonk and Ermanovics 1990; Rivers et al. 1996).

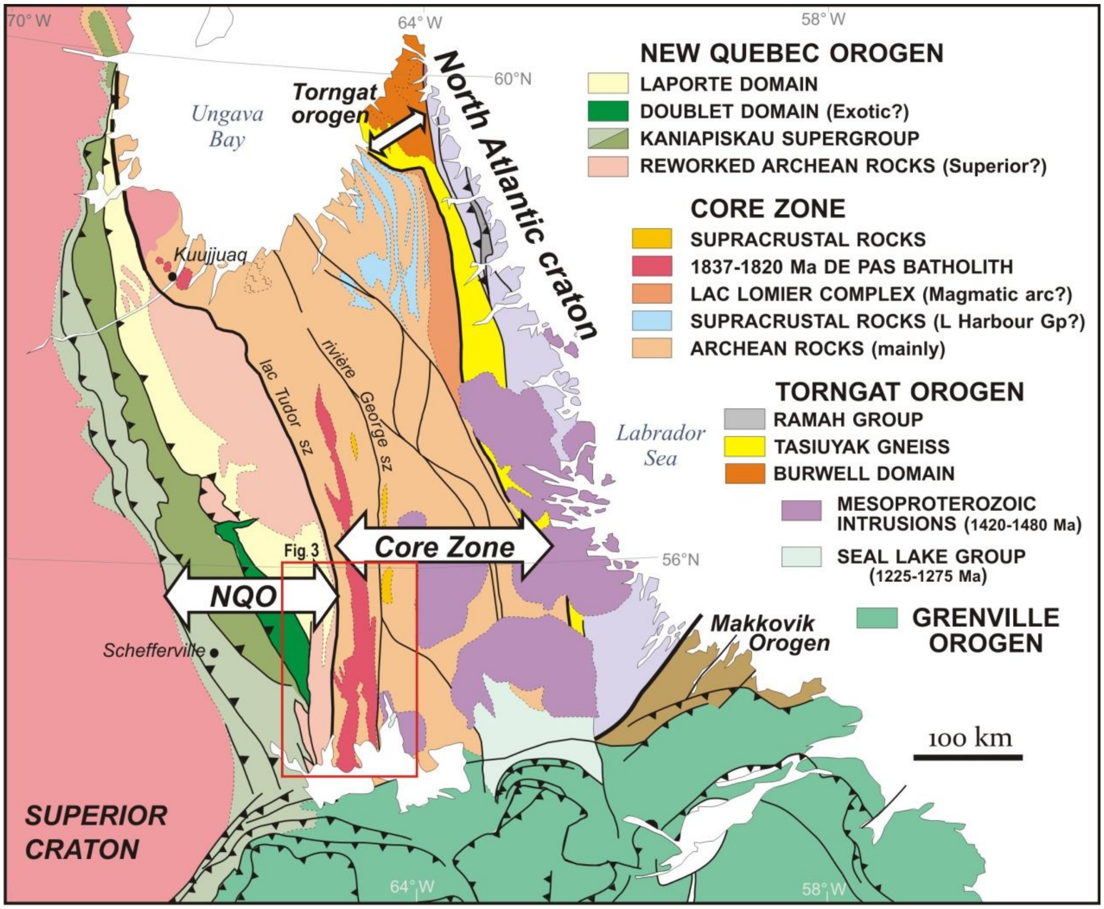

Figure 2. Major tectonostratigraphic components of the Core Zone and its bounding orogenic belts, the New Québec Orogen (NQO) to the west, Torngat Orogen to the east, and Makkovik Orogen to the southeast. Also shown as unsubdivided are the Archean Superior and North Atlantic cratons, and ca. 1.1 Ga Grenville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

Methodology

The study area comprises two 1:250 000 NTS sheets, 23P and 23I (Fig. 3), transected by the Quebec–Labrador provincial boundary, and is broadly divided into three domains: (1) the western supracrustal-dominated New Québec Orogen, which includes the Kaniapiskau Supergroup (Labrador Trough), Doublet zone and Laporte domains; (2) the western Core Zone dominated by Archean plutonic basement rocks cut by the ca. 1.84-1.82 Ga De Pas batholith; and (3) the central Core Zone, an eastern supracrustal-plutonic domain (Ntshuku-Atshakash-Zeni, Mistinibi-Raude) cut by ca. 1.48-1.42 Ga post-orogenic plutons. In order to extend bedrock mapping coverage acquired in 2014 (Fig. 3; McClenaghan et al. 2014) and gain further insight into unresolved stratigraphic and structural relationships (Sanborn-Barrie, in press), five areas were prioritized for bedrock mapping in 2015. In addition, identification and sampling of key units for U-Pb analysis was undertaken across the map area, to acquire quantitative age constraints and understanding of provenance for key units within the southern Core Zone. These data will be further integrated with data to the north (Corrigan et al., 2015*a*,*b*) to improve models of basin development, crustal growth, and tectonic evolution, to provide a more robust context for assessing the mineral potential of the Core Zone and its bounding orogens.

2015 Targeted Mapping

Mapping priorities for 2015 (red ellipses in Fig. 3) focussed on the Laporte domain in the northwest, the Lobstick supracrustal sequence in the south, the lac Zeni complex in the east-central part of the map area, the north-trending Atshakash-Ntshuku-Hutte Savage supracrustal corridor in the north, and the Mistinibi-Raude migmatite domain in the northeast.

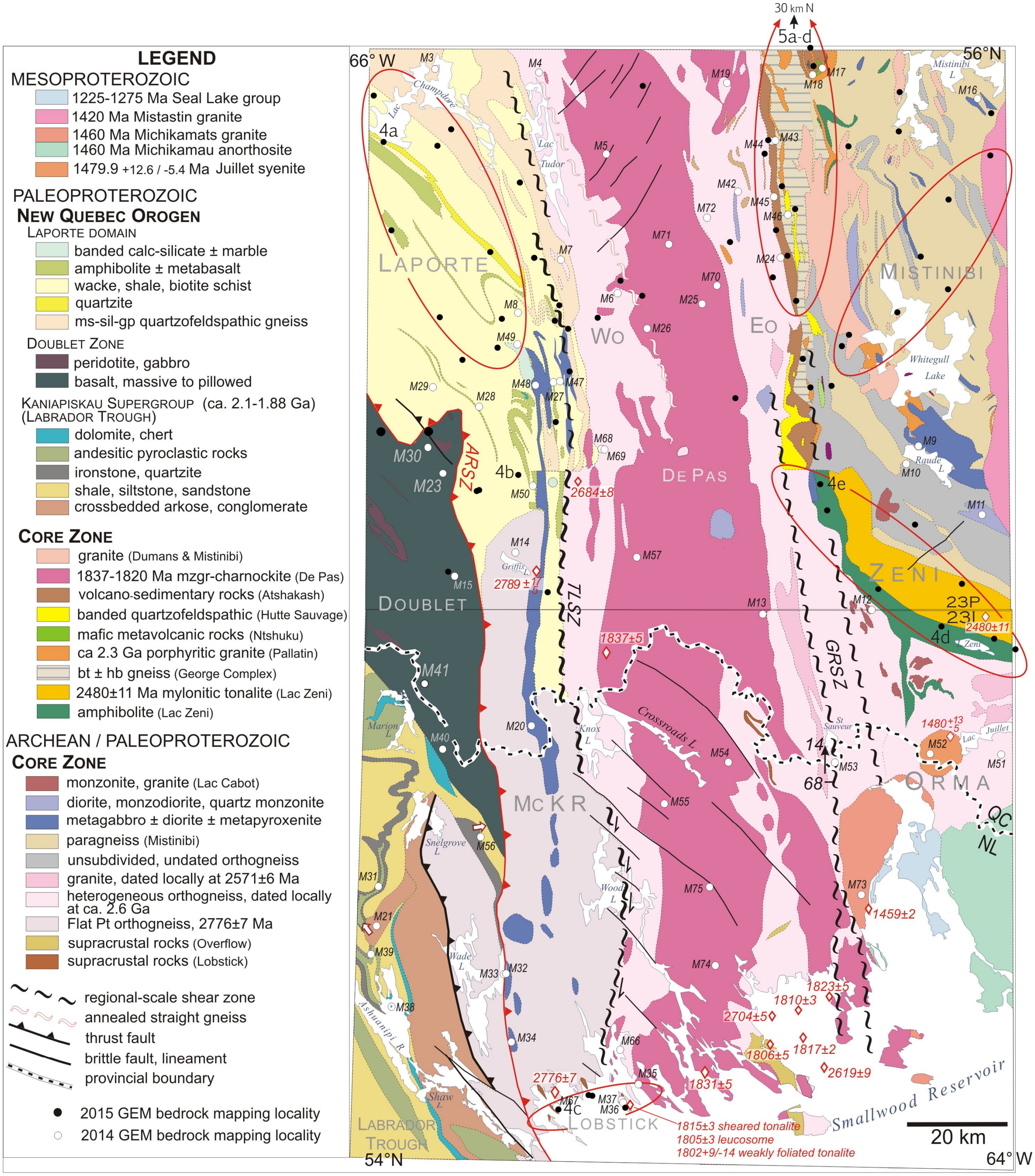

Figure 3. Bedrock geology of the southern Core Zone, NTS 23P and 23I from Wardle et al. (1997) and Ministère de l'Énergie et des Ressources naturelles (2010) showing areas where 2015 mapping was targeted (red ellipses), 2015 mapping localities (solid black circles), 2014 mapping localities (open white 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), David et al. (2011) and David et al. (2012). Alphanumerics indicate location of photographs in Fig. 4 and 5. Abbreviations: McK R = McKenzie River domain, Wo = western orthogneiss, Eo = Eastern orthogneiss, *TLSZ* = Tudor Lake (lac Tudor) shear zone, *GRSZ* = George River (rivière George) shear zone.

1) Laporte domain

The northwest part of the map area comprises the Laporte domain (Fig. 2, 3), where clastic metasedimentary rocks, amphibolite and felsic plutonic rocks are exposed. The tectonostratigraphic position and affinity of the Laporte domain has long been debated and remains unresolved. Early stratigraphic and structural interpretations considered these rocks as Archean basement (Harrison 1952), and/or assigned them to an eastern allochthonous belt (Dimroth et al., 1970), noting that the domain included amphibolite-facies rocks equivalent to the Core Zone, as well as tectonic slices (nappes) of Archean basement. Other mappers (e.g. Baragar 1967; Moorhead and Hynes 1990; Poirier et al. 1990; Clark and Wares 2005) interpreted rocks of the Laporte domain to be correlative, at least in part, with 1.88-1.87 Ga Cycle 2 rocks of the Kaniaspiskau Supergroup. More specifically, Girard (1995) defined a succession of metapelites ± metaquartzite, calc-silicate, sulphide iron formation and amphibolite (Deborah Lake Formation) which he interpreted to intercalate with, and overlie ca. 1885 Ma metabasaltic rocks (Doublet/Willbob Formation). Wardle and Bailey (1981) interpreted the Laporte domain to be transitional with a >1000 m thick turbidite sequence (Menihek Formation), interpreted as a foredeep flysch (Hoffman 1987), both locally conformably overlain by ca. 1885 Ma mafic volcanic rocks (Doublet/Willbob Fm). Others speculated that the Laporte domain could include remnants of an accretionary complex (Van der Leeden et al. 1990; Wardle and Van Kranendonk 1996).

Fourteen localities within the Laporte domain were mapped and sampled in 2015 to assess its lithological character and architecture. The western half of the domain is largely comprised of fine sand- to silt size clastic rocks, typically represented by biotite±muscovite lithic wacke with lesser interstratified feldspathic arenite. In contrast, a prominent ridge of white-weathering, massive, poorly bedded, well-sorted quartz arenite, 150-280 m wide (Fig. 4*a*), extends more than 30 km from the south shore of lac Champdoré southeast to the Tudor Lake shear zone (Fig. 3). Amphibolite units purported to occur throughout the western Laporte domain (Fig. 3) were not observed. In contrast to the western half, the eastern Laporte domain exposes muscovite ±graphite ±sillimanite leucogranitic rocks as well as immature, granite-derived grit conglomerate and feldspathic wacke (Fig. 4*b*). The immature, poorly sorted clastic rocks may mark an unconformity on granitoid rocks (basement?). An increase in metamorphic grade occurs across the Laporte domain from greenschist facies in the west, to upper amphibolite facies in the east.

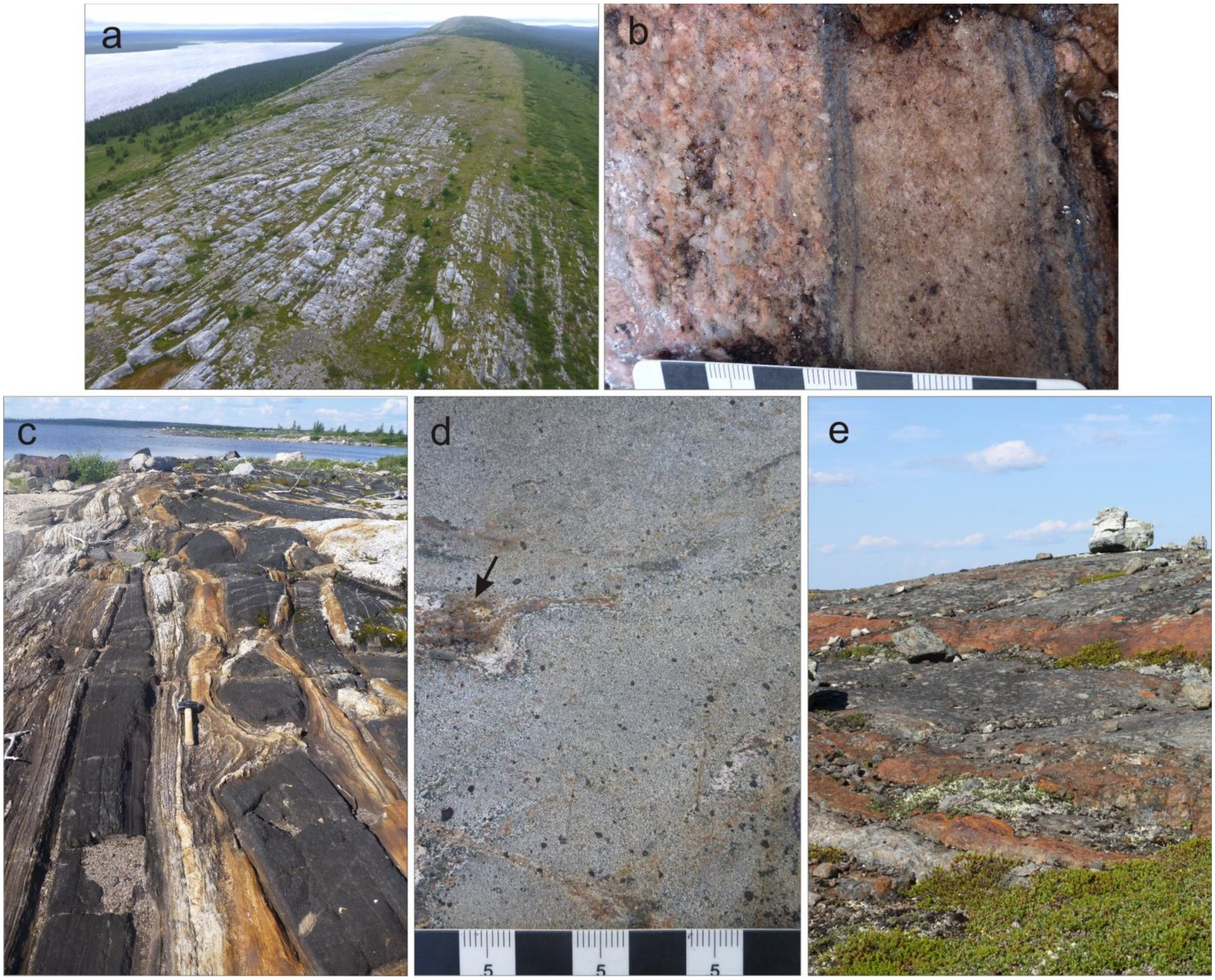

Figure 4 Lithological units in prioritized areas mapped in 2015, with locations indicated by alphanumerics in Fig. 3. *a*) quartz arenite ridge extending southeast of lac Champdoré, Laporte domain, northwest map area; *b*) granite-derived grit conglomerate interbedded with arkose and heavy mineral bands, southeast Laporte domain; *c*) paragneiss cut by boudinaged ultramafic sills, Lobstick group, Smallwood Reservoir; *d*) detail showing homogeneous, fine-grained texture of andesite cut by coarse-grained granite (arrow), eastern lac Zeni complex; *e*) andesitic sequence with gossanous layering and associated biotite– amphibole±garnet alteration, northwest lac Zeni complex.

2) *Lobstick Supracrustal sequence*

Supracrustal rocks associated with the western orthogneiss complex (Wo in Fig. 3) are rare and relatively poorly exposed, with the exception of wave-washed exposures on the shores of small islands in the Smallwood Reservoir. Here, lithologically diverse supracrustal rocks were informally designated the Lobstick group (James et al. 1993), given their exposure on the former Lobstick Lake, which was incorporated into the reservoir in the late 1960's. It is not yet established whether the Lobstick group is an Archean assemblage cut by the ca. 2776 Ma McKenzie River domain orthogneiss (Fig. 3), or part of a younger, possibly Proterozoic, supracrustal sequence that is tectonically imbricated with the orthogneiss. Difficulty establishing this is due to the lack of precise U-Pb age determinations, and the high-strain state of these units, such that contacts between supracrustal and plutonic rocks are tectonic and coplanar.

Four localities of the Lobstick supracrustal sequence and associated intrusive rocks were mapped in 2015 on island exposures within northern Smallwood Reservoir. These exposures were dominated by biotite-garnet ± sillimanite paragneiss cut by ultramafic to mafic sills (Fig. 4*c*), orthogneiss and lesser clinopyroxene calc-silicate ± marble. Several gossanous zones were sampled for assay.

3) Lac Zeni complex

The lac Zeni complex refers to an arcuate panel of rocks in the east-central map area (Fig. 3). Originally designated the lac Zeni volcano-sedimentary complex by Danis (1991) and Taner (1992), it was renamed the lac Zeni Complex by Hammouche (2011) in recognition of a significant component of intrusive rocks including orthogneiss. The complex is reported to comprise amphibolite derived from both mafic plutonic and volcanic rocks, mylonitic rocks derived from amphibolite and orthogneiss, and lesser paragneiss and iron formation (Hammouche et al. 2012). A U-Pb age of 2480 ± 11 Ma (David et al., 2009) was obtained from mylonitic leucotonalite interlayered with mylonitic amphibolite and granite 5.5 km NNE of lac Zeni (Fig.3). The arcuate shape of the complex relative to the north-striking George River shear zone (GRSZ in Fig. 3), suggested that the lac Zeni complex was influenced by localized shear strain, and that least-strained rocks may be preferentially preserved in its eastern part. Examination of the lac Zeni complex was a priority in 2015 given the reported presence of volcanic rocks with associated Cu±Au mineralization. In addition, understanding the character of the lac Zeni complex will allow a basis for comparison to supracrustal rocks occurring within the GRSZ to the north.

Seven localities within the arcuate lac Zeni complex were examined in 2015 (Fig. 3). Texturally homogeneous, fine- to very fine-grained rocks of mafic (colour index (CI)=55) to andesitic (CI=25; Fig. 4*d*) composition are widespread throughout the 'amphibolite' unit (Fig. 3), consistent with a volcanic origin. Locally, the volcanic rocks are characterized by biotitic patches with amphibole±garnet-rich veins and associated gossanous layers (Fig. 4*e*). These localities may record alteration by hydrothermal fluids that precipitated base metals, prior to regional deformation and metamorphism.

4) Ntshuku – Hutte Sauvage

A collage of greenschist- to upper-amphibolite facies supracrustal rocks are exposed in a north-trending corridor in the northern part of the map area (Fig. 3). These supracrustal rocks were designated distinct assemblages 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 (Atshakash, Ntshuku), some 2 km wide and up to 100 km along tectonic strike. This corridor was interpreted to reflect a restricted (starved) intra-arc volcano-sedimentary basin (Van der Leeden et al. 1990), unconformably overlain by a cratonic-rift assemblage designated the Hutte Sauvage group (Girard 1992), best exposed north of the map area. Previous examination of the Ntshuku assemblage in 2014 could not verify the presence of volcanic rocks. Rather, the 'assemblage' appeared to be dominated by highly strained porphyritic intrusive rocks (porphyroclastic mylonites) leading to speculation that a Z-shaped bend occurred in the George River shear zone at this locality (Sanborn-Barrie, in press).

Twelve localities along the supracrustal collage were mapped in 2015 to assess lithology, identify samples for U-Pb dating, consider tectonic setting and, collectively, provide a more robust foundation on which to base correlations across the southern Core Zone. In general, rocks within this corridor are very highly strained, consistent with localized deformation within the GRSZ. Supracrustal rocks are dominated by brown weathering phylonitic semipelite ± pelite, locally cut by coarse-grained to pegmatitic granite. The southern part of the corridor exposes highly strained mafic metavolcanic rock with several one-metre wide panels of banded rocks of intermediate composition, possibly equivalent to those of the lac Zeni complex.

Three exposures of the Hutte Sauvage assemblage, located north of the map area, were visited in 2015 to allow comparison with clastic sequences within the map area. Conglomerate containing well-rounded cobble- to pebble-size clasts of massive to foliated granitic rocks, set in a fine sand-size, recessively weathered, dolomitic matrix (Fig. 5*a,b*) is interpreted by Girard

(1992) as the basal member of the Hutte Sauvage group. Poorly sorted feldspathic wacke with grit-size quartz (Fig. 5*c*), interpreted as the middle member, is overlain by light grey-weathering quartz arenite with local cross stratification (Fig. 5*d*) indicating younging to east. The east-facing quartz arenite is interpreted as the upper member of the group and the youngest clastic rock in the region (Girard 1992).

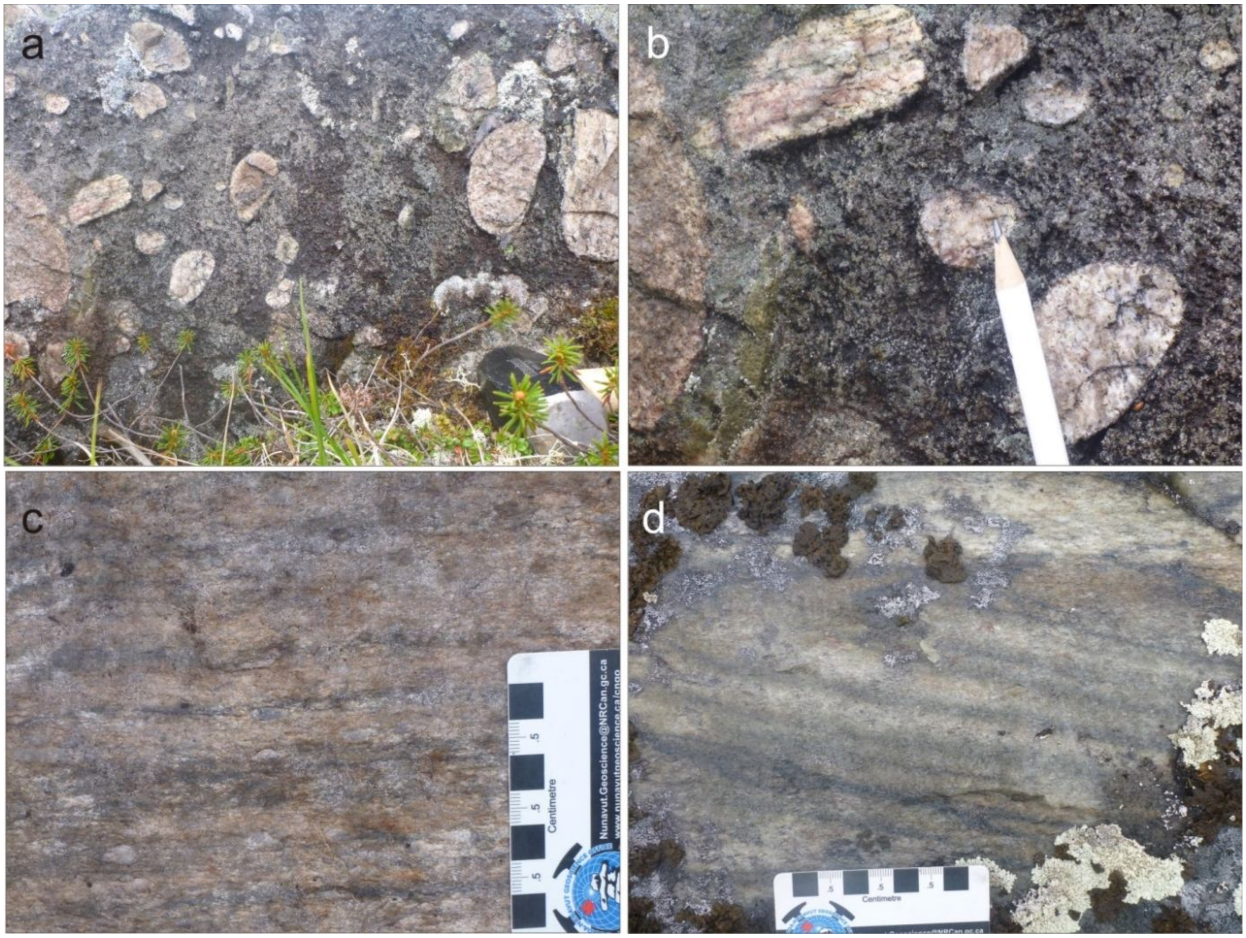

Figure 5. Representative exposures of the Hutte Sauvage group, located 29 km north of the map area. *a*) conglomerate with well-rounded pebble-size granitic clasts, some displaying internal fabrics of variable intensity, set in dark grey, dolomitic matrix; *b*) detail of conglomerate in *a*) showing internal weak foliation in granite clast parallel to pencil, at a high angle to strong foliation in adjacent granitic clast, both set in recessively weathered, pitted, dolomitic matrix; *c*) poorly sorted feldspathic arenite, interstratified with conglomerate; *d*) quartz arenite with local cross stratification, upper Hutte Sauvage group.

5) Mistinibi-Raude

The northeast part of the map area, designated 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.

Nine localities within the Mistinibi-Raude domain were mapped in 2015. Moderately to strongly deformed tonalitic orthogneiss is a dominant lithology in this region. Garnet porphyroblastic leuocogranite with biotitic schlieren and lesser semipelite were also observed.

Sampling for Geochronology

Although there has been a long history of bedrock mapping, compilations, exploration activities and mining in this region, beginning with A.P. Low's remarkable trek in 1893-1895 (Low, 1896), the southern Core Zone lacks quantitative data on the age of many of its key map units as well as their provenance. As part of this GEM2 activity, sixteen units were identified and sampled during 2015, with the aim of significantly improving understanding of the timing of sedimentation, volcanism and plutonism across the region, and strengthening the geological context in which exploration for base- precious metals and rare earth elements can continue. U-Pb analysis of these samples over the coming year will:

- establish maximum depositional ages for key stratigraphic horizons,
- date volcanism in regions of associated base-metal mineralization,
- distinguish Archean versus Paleoproterozoic heritage,
- elucidate the ages of exhumed source rocks.

Future works/next steps

With all the planned objectives of the 2015 field season successfully accomplished, planning and prioritization of laboratory work for the Fall/Winter 2015-2016 is underway. Analytical activities will include thin section petrological evaluations, U-Pb, geochronology and assay. The acquisition of new geochronological data will establish the age of key plutonic and volcano-sedimentary rock packages and allow historical correlations to be assessed, strengthened and revised. Careful field observations integrated with laboratory studies such as geochronology, petrology and assay are critical in effectively testing tectonic models which, in turn, places constraints on potential mineralization environments. By developing and testing tectonic models, this work contributes to reducing exploration risk in Canada's north.

Acknowledgments

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