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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 provides 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 in Canada's North.

During the summer 2015, GEM program has successfully carried out 17 research activities that include geological, geochemical and geophysical surveying. These activities have been 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.

Introduction

Public perception of abundant northern resources awaiting exploitation contrasts with industry's low rate of exploration success in the southern Rae Province of NWT and Nunavut. Based on the number of known mineral occurrences, one could conclude that the region is under-endowed relative to other Shield terranes of comparable geology. However, several factors have contributed to the low level of exploration activity and success: coarse and antiquated geological coverage; difficult access; widespread surficial deposits that hinder observations of bedrock; and unsettled land claims that increase exploration risk relative to other regions. In feedback meetings, Industry advised that GEM data provides a necessary catalyst for exploration in *terra incognita* and it strongly supports the concept of completing the map of the North by mapping the most remote regions. Under the Geomapping Frontiers project of GEM 1 the least known and explored part of the South Rae Province was targeted for data mining (Harris et al., 2013; Pehrsson et al., 2013, Davis et al., 2015), new geophysical (Kiss and Coyle, 2012) and geochemical data acquisition (McCurdy et al., 2015), and field reconnaissance (Pehrsson et al., 2014). That exercise demonstrated that the region has unrecognized mineral potential and dramatically more complex geology than had previously been appreciated.

Following the 360 km-long reconnaissance-scale geological transect in 2012 (Pehrsson et al., 2015; Davis et al., 2015), the South Rae project of GEM 2 (Fig 1) was initiated to address a number of scientific questions relevant to the mineral exploration industry in a region broadly referred to as the South Rae craton. The area of study (Fig. 1) has not seen field investigation since the GSC's helicopter reconnaissance of 1955-1958. The main goal of the present activity is to advance geologic understanding and attract mineral exploration to this underexplored, frontier region of Northwest Territories by addressing the following questions:

1. What is the orogenic architecture of the Rae Province and the nature, extent and temporal evolution of its Neoarchean crust and how do they determine the distribution of its mineral resources?

2. What is the nature, composition and distribution of the Quaternary sediments and how can they be used for drift prospecting in this region?

3. What geochemical anomalies can be identified in lake sediments and surface waters, till, and bedrock, and how can they impact exploration initiatives in the region?

Planned research over the project lifetime (2015-2018) will tackle the aforementioned questions with the following approaches:

a) high-resolution aeromagnetic and radiometric surveys of the McCann-Beaverhill-Carey lake areas (NTS 65L, 75G, I);

b) remote predictive mapping (RPM) incorporating geophysical and archival sample information;

c) bedrock mapping and targeted metallogenic assessments combining a variety of scales and approaches depending on exposure and access along multiple transects, with focus on potential terrane boundaries;

d) assays, geochemistry, geochronology and sediment and/or rock property data on all field samples to broaden the framework geoscience knowledge to a critical mass for development of modern geologic models and correlations with better known regions to the north and south.

e) lake and till sediment survey over key transect areas to aid in regional map unit interpretation and understanding regional metallogenic potential;

f) thermobarometric and pressure-temperature-time studies to assess the architecture and tectonic evolution of the Rae craton

g) metallgoenic studies of existing known mineral deposits in the map area, including the Thye Lake Ni-Cu-PGE situated in southeast Northwest Territories (75A) and the Hoidas Rare Element deposit of Northern Saskatchewan.

g) surficial geological mapping of landforms and sediments based on interpretation of imagery (air-photos, Landsat etc.) and field-based observations to provide a regional Quaternary geological framework;

h) elucidation of ice-flow history and cumulative glacial transport and dispersal patterns through mapping and interpretation of ice-flow indicators and till compositional data.

A synthesis of new information and correlation of bedrock and surficial features with those of Saskatchewan to the south, and other areas of the Rae project to the north, will conclude the project.

A reconnaissance 6 day helicopter-based field visit to the southern Rae Province, NWT was completed during the summer of 2014 (Campbell and Eagles, 2014) and formed the basis for orientation of the 2015 field activities.

While the general region of interest for the surficial and bedrock study is defined by 60 to 62˚ latitude and 104 to 110˚ longitude (covering 7 NTS map sheets, 65E, 75 A to C, and 75F to H), the field component of the project will focus on 5 map sheets (65E, 75A, B, G and H) where little to no field-based bedrock or surficial geological maps are available.

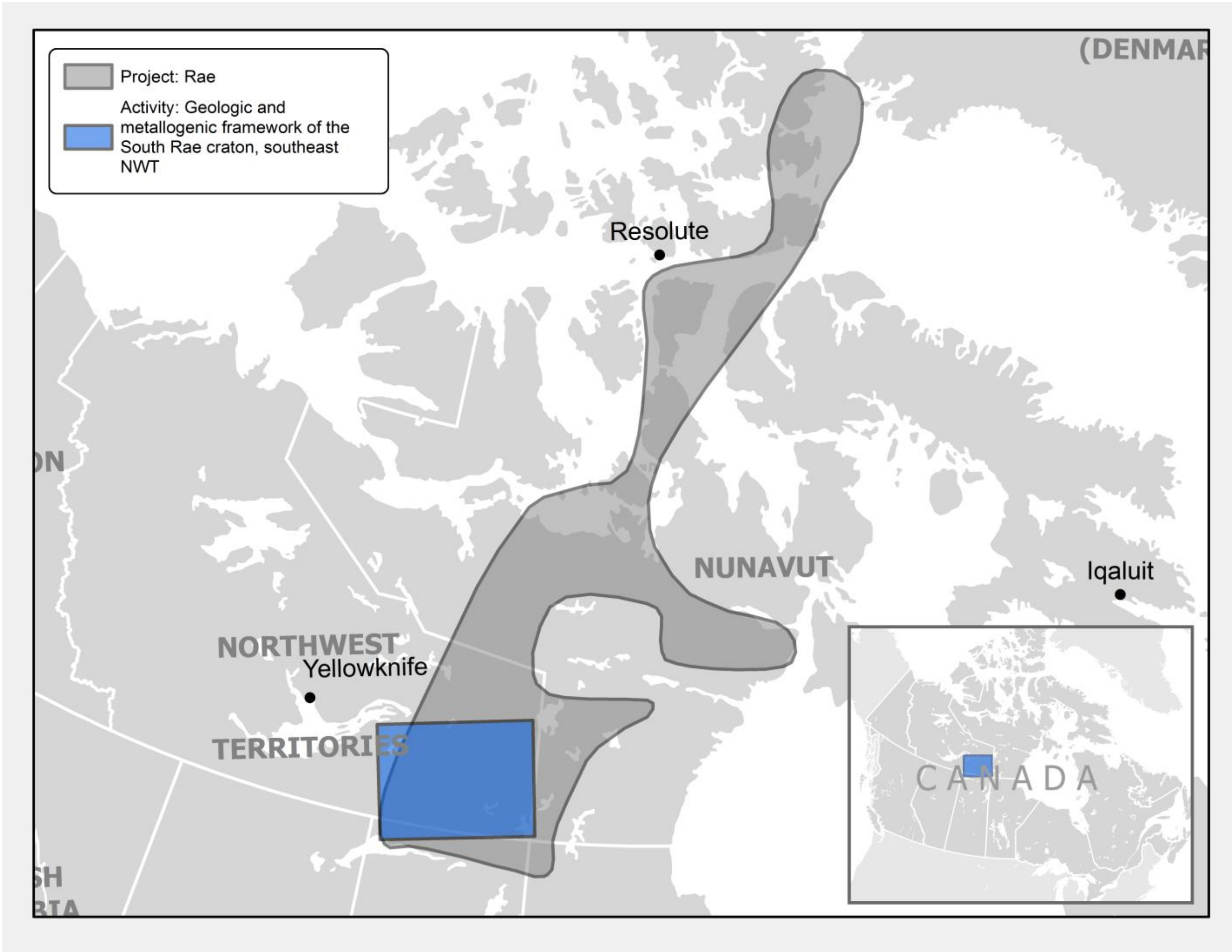

Figure 1. Location of the GEM 2 South Rae Activity (blue box) of the Rae project.

Methodology

Fieldwork between June 30 and August 4, 2015 was based from a low-impact tent camp (Fig. 2) situated on a peninsula in central Wignes Lake, NWT in the southern part of NTS map sheet 75A (Fig. 3). The field camp was set up by staging fuel and camp gear on Twin Otter flights from Stoney Rapids, Saskatchewan. A Bell 206L3 helicopter provided air support for bedrock and surficial studies over the entire 35 day period. In addition, a Bell 206B helicopter was used for 28 days to support a stream sediment geochemical survey and bedrock mapping. Regional surficial and bedrock observations and sampling (Fig. 2) were accomplished by a team of 7 senior geologists/geochemists of the GSC and Northwest Territories Geological Survey, 4 university researchers (students and supervisors) and 3 junior geological assistants supported by a GIS specialist, 1 geophysicist, 2 helicopter pilots, 1 engineer, a cook and a camp manager.

Fig. 2: Wignes Lake tent camp, southeastern
Northwest Territories, base for 2015 field activities

Results

Bedrock geology:

Bedrock mapping in 2015 was focussed in NTS map sheets 75A and B. In total, bedrock data were collected from more than 400 sites (Fig. 4). Highlights of this work include:

a) Recognition of the lithologic and structural continuity of four major subdomains from northern Saskatchewan into southern Northwest Territories. These roughly NNE-striking, crustal domains have distinct aeromagnetic characteristics (Fig. 4) and include (from west to east):

1) a metaplutonic and metasedimentary granulite-facies domain dominated by granodiorite and orthopyroxene-garnet diatexite (Fig. 5) of unknown age. This feature lies immediately along strike of the Ena domain of Northern Saskatchewan and has a similarly characteristic high aeromagnetic signature associated with granulite facies metaplutonic rocks.
2) the metaplutonic and metasedimentary granulite-facies McCann domain dominated by supracrustal, migmatitic and metaplutonic rocks including metapsammite, metapelite, iron-

formation (Fig. 6) and lesser intermediate volcanic rocks. This domain has an overall low aeromagnetic signature related to its more felsic bulk composition and abundance of migmatitic metasedimentary rocks.

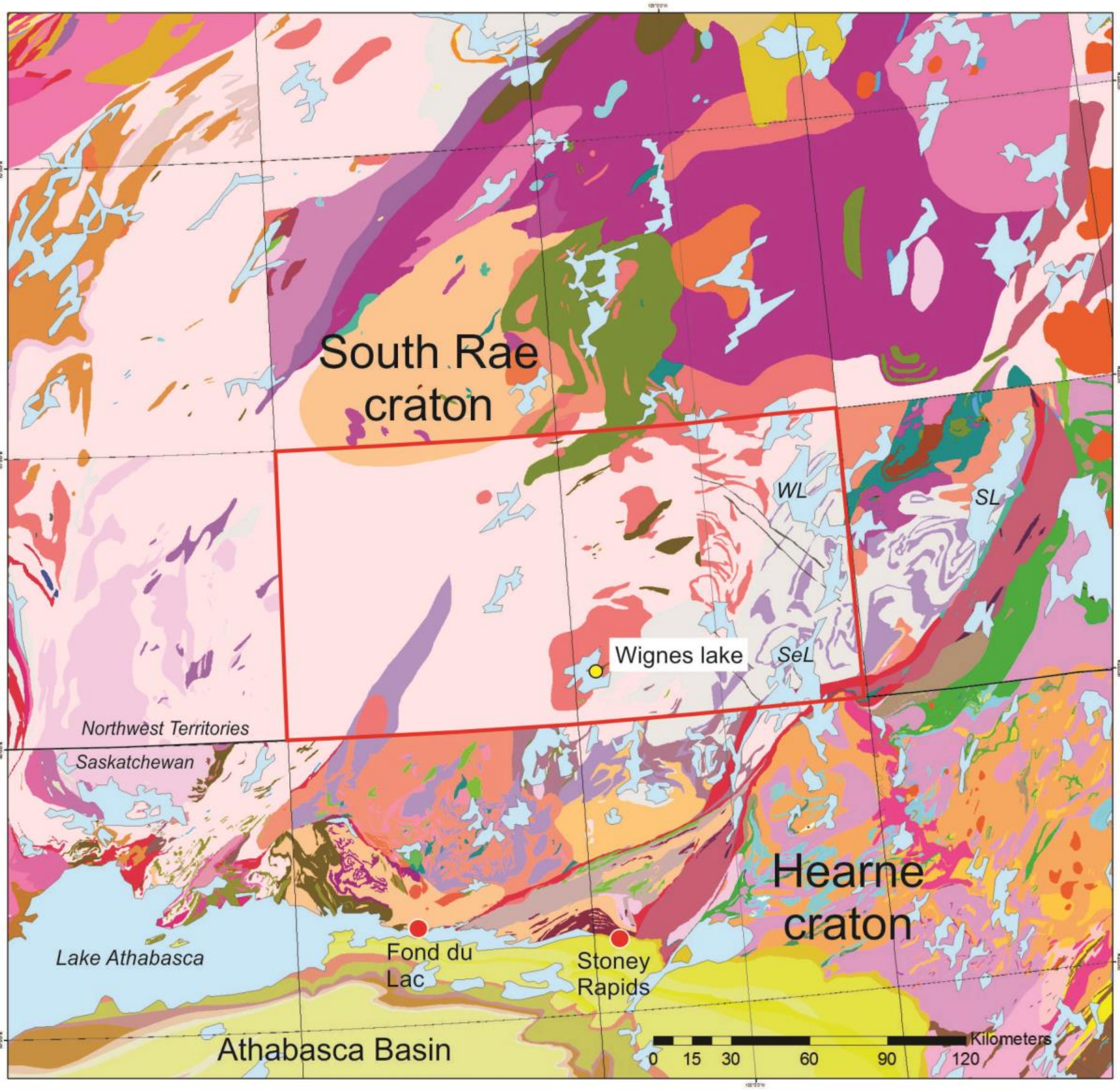

Figure 3: Bedrock compilation geology map (Pehrsson et al., 2013) of project area (parts of NTS 75A, B, G, H), showing location of 2015 base camp and study area.

3) the metaplutonic Firedrake domain dominated by monzogranite to tonalite orthogneisses (Fig. 7a), migmatitic granodiorite to monzogranite (Fig. 7b) and lesser diorite, quartz diorite and gabbro. A few localities of metapelite and semi-pelite were also noted. This domain has a convoluted high/low banded aeromagnetic pattern that outlines large, crustal-scale internal

folds and broad regions of muted moderate total field aeromagnetic intensity apparently characteristic of the migmatitic granodiorite suite.

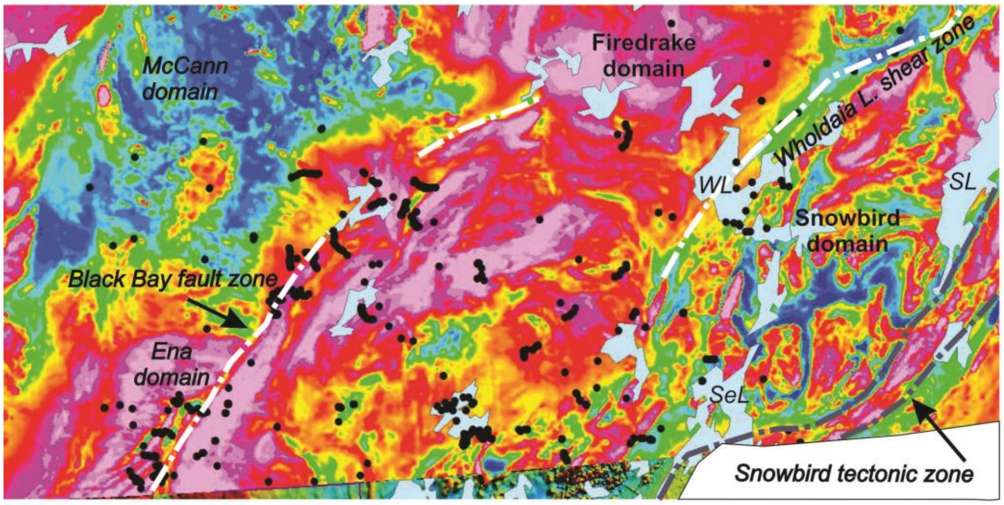

Fig 4: Aeromagnetic map of the study area (75A and B) and parts of adjacent map sheets (65D, E; 75 G, H). 2015 bedrock geology stations are shown as black dots. Fault zones delimiting the boundaries of interpreted crustal domains are shown in white dash. Abbreviations: SL: Snowbird Lake; SeL: Selwyn lake; WL-Wholdaia lake

4) the composite Snowbird domain, comprising middle- to upper-amphibolite facies metasedimentary and mafic metavolcanic/intrusive rocks. This domain is characterized by distinct, arcuate, aeromagnetic lows outlining complex fold patterns, within a moderate-intensity aero magnetic background (Fig. 8).

Fig 5: Migmatitic diatexite of the Ena domain. Coarser-grained garnet-orthopyroxene-rich layers alternate with finer-grained orthopyroxene-rich layers. Brunton for scale is 17 cm.

Fig 6: Metasedimentary migmatite of the McCann domain. Restite layers of garnet-amphibole-orthopyroxene silicate-facies banded iron formation (centre) and ortho-pyroxene-biotite-sillimanite metapsammite are engulfed in nebulitic orthopyroxene-garnet leucosome. Note the blue coloration of quartz-rich reaction rims on the central restite, typical of McCann domain rocks Brunton for scale is 17 cm.

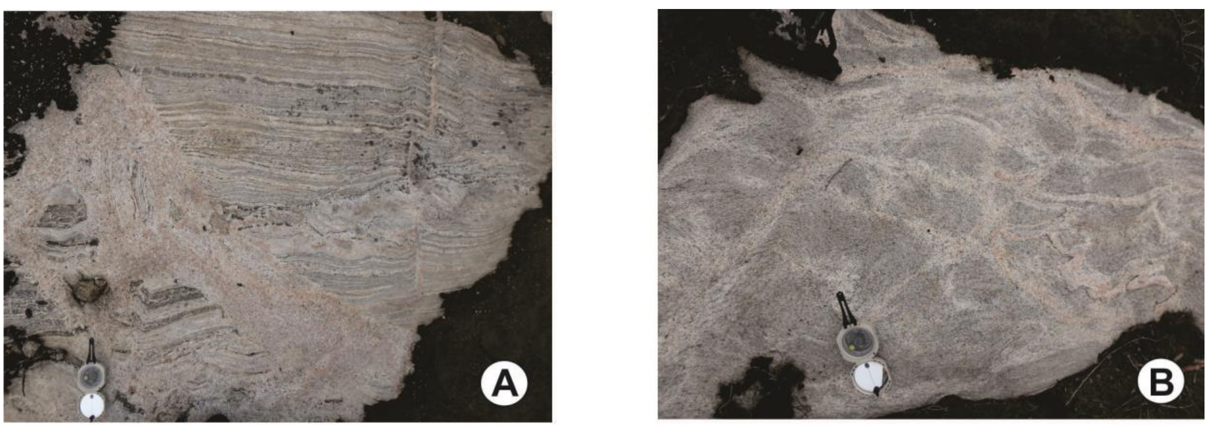

Fig 7: Dominant lithologies of the Firedrake domain. A) Banded hbl +/- grt +/- cpx tonalitic orthogneisses showing compositional layering to more mafic-rich dioritic layers and rectilinear nature of layering. B) Nebulitic, recrystallized bt+/- hbl granodioritic with in-situ irregular granodiorite to monzogranitic melt pods and veins. Unit in B typical occurs as sheets and mappable layers engulfing unit A, particularly in the Wignes Lake area. Brunton compass for scale is 17 cm.

b) Collection of 313 bedrock samples to fully characterize geochemical, mineral assemblage and metallogenic differences between the domains and constrain the tectonic setting and tectonothermal evolution of the plutonic, volcanic and sedimentary rocks of the area

c) Collection of 20 samples for geochronology aimed at unravelling key age relationships and placing timing constraints on the geologic evolution

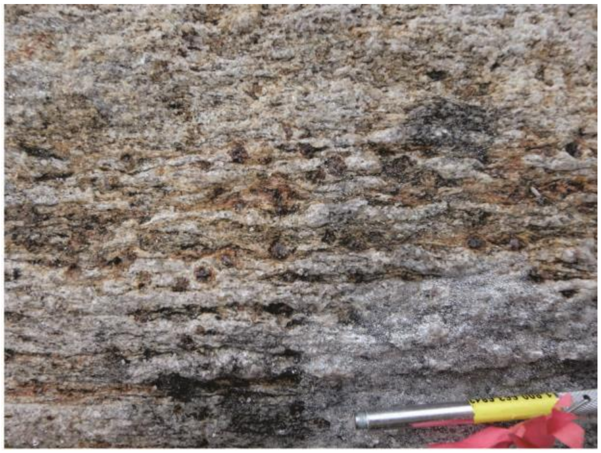

Fig 8: Garnet-sillimanite-biotite metapelite of the Snowbird domain. Magnet pen for scale is 12 cm.

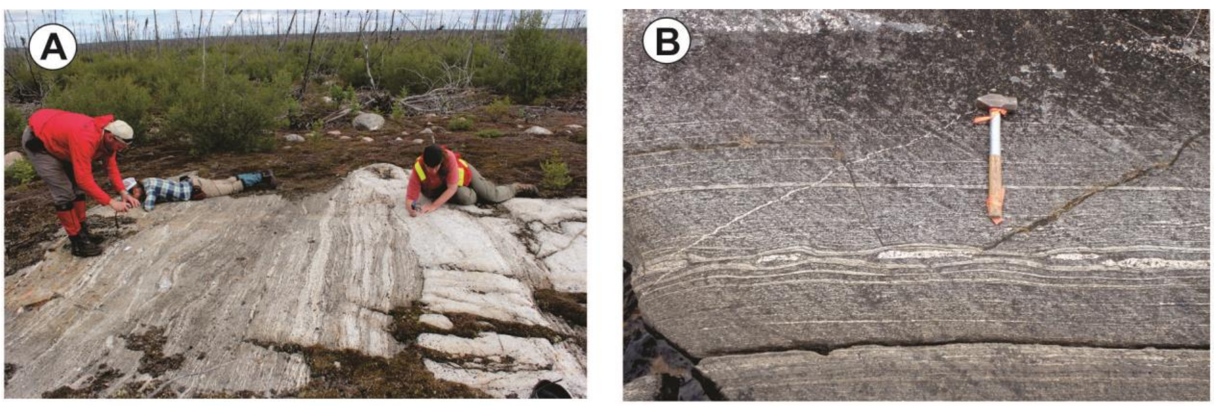

Fig 9: Typical units of the Wholdaia Lake shear zone. a) Blastomylonite with disaggregated leucocratic veins and dykes in blastomylonite. C/S texture, intrafolial folds, back-rotated boudins and shear band structure observed in this vicinity. b) Tectonite developed in hornblende+/-clinopyroxene quartz diorite. Strongly transposed tonalite vienlets display back-rotatted boudin structure. Plagioclase phenocrysts of the origiinal protolith now carry a 20:1 aspect ratio and form augen or delta-porphyroclasts. Hammer for scale is 30 cm.

d) Identification of a number of previously unknown, kinematically complex, high-strain zones which provide insight into the structural evolution of the region. The major Wholdaia Lake ductile fault zone (Fig. 4) separates the Firedrake and Snowbird domains between Wholdaia Lake and the Nunavut border. It is associated with a distinct, straight aeromagnetic low and may extend southward to the Saskatchewan border (Fig. 9a, b). The Black Bay fault zone was identified within the southern part of 75B and includes both high grade ductile and lower grade brittle-ductile deformation components (Fig. 10).

e) Discovery of seven new uranium- rare earth? mineral showings in two general areas with samples collected for assay (Fig. 11, 12).

Fig 10: Ductile deformation style within the Black Bay fault zone, Northwest Territories. Layers of less foliated monzogranite Aappear to have been injected into tonalitic-granodioritic orthogenesis of the Firedrake wallrocks. Note the penetrative, banded nature of the foliation in the latter and strong foliation in the injected monzogranite. Hammer for scale is 40 cm long.

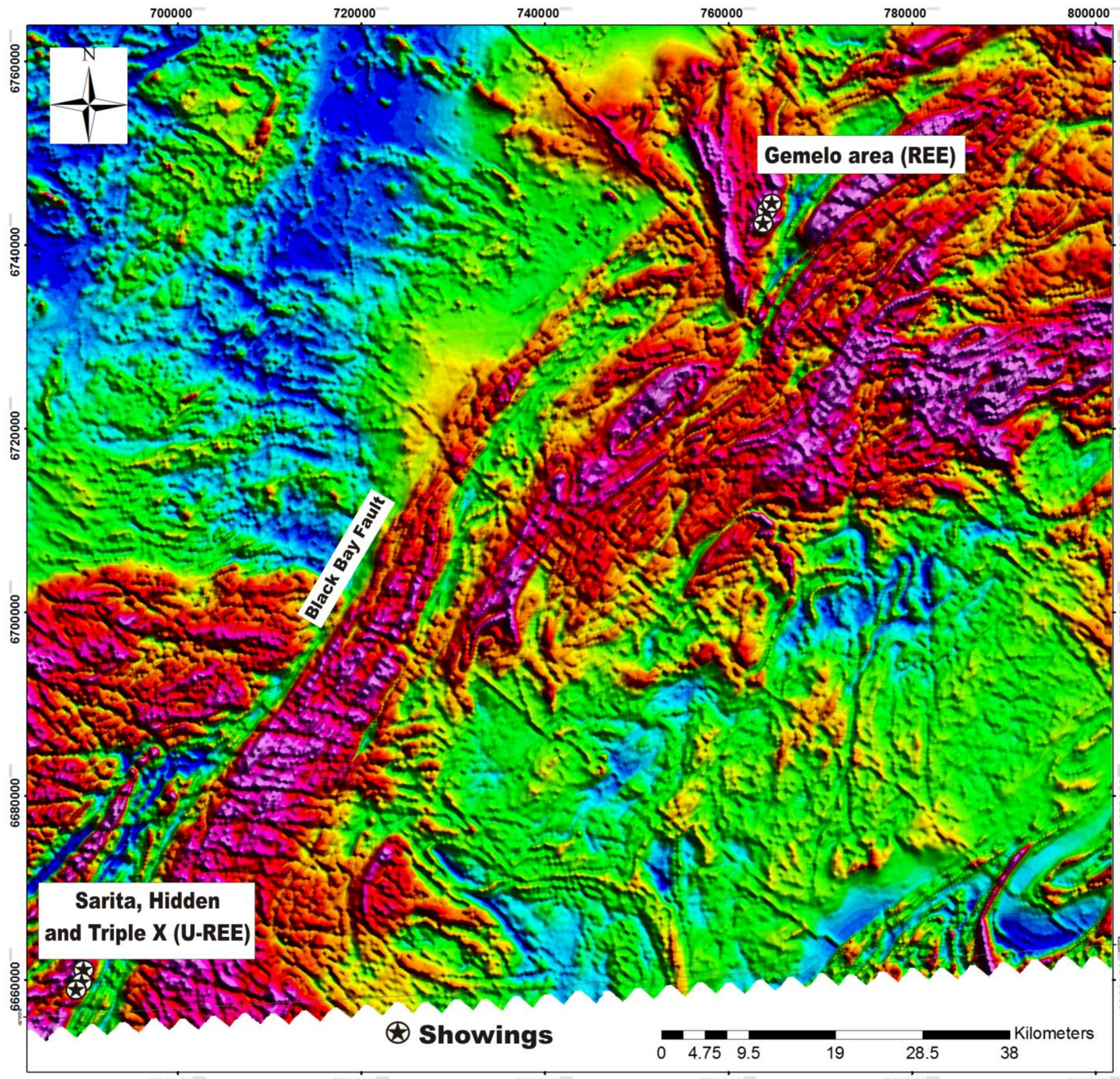

Figure 11. Location of new mineral showings in South Rae plotted against aeromagnetic regional total field data.

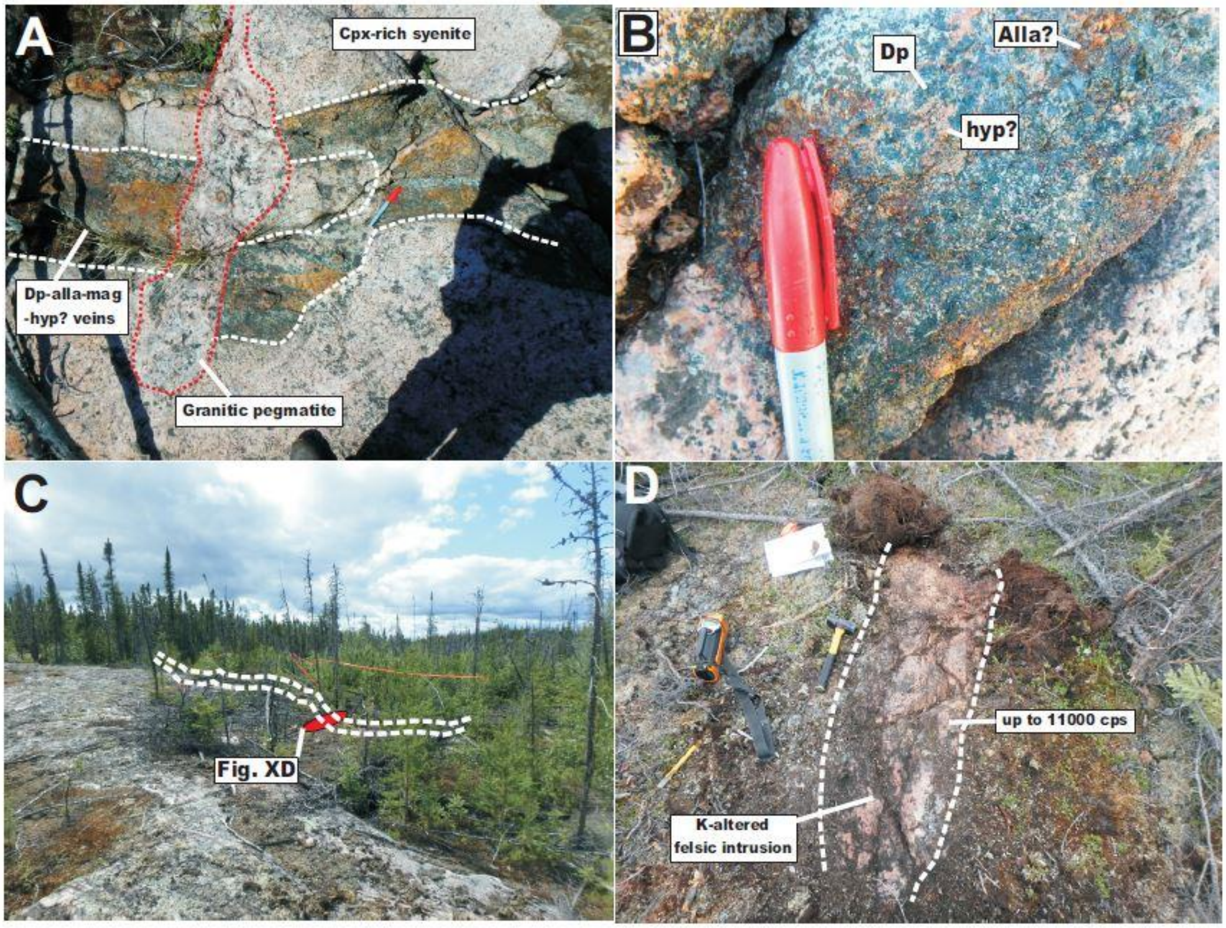

Figure 12: Photos of selected features of new mineral showings:

A) Gemelo area. Diopside (dp)-allanite(alla)-magnetite (mag)-hyalophane (hyp?) veins similar to those recognized at the Hoidas deposit crosscut a syenitic intrusion. A younger granitic pegmatite cuts the veins.
B) Magnification of the vein in A, the “rusty brown” mineral is interpreted as weathered allanite.
C) Trace of the Sarita showing. The showing extends for ~14 m with a variable width of 0.30-0.8 m, roughly trending to the SW-NE. An extension of this structure (~16 m x 0.3-0.7 m) has been found a 100 m SE from this location.
D) Red inset shown in C. The anomalous rocks (up to 11000 cps) were mostly covered by soil , and they exhibit intense K-feldspar alteration, which gives them a “salmon” red color.

Surficial geology:

Building on 2014 reconnaissance field activities (Campbell and Eagles, 2014), this summer’s fieldwork focused on surficial geological mapping at 1:100 000 scale and a reconnaissance-scale till sampling survey along selected transects covering NTS map sheets 75A and B. The objectives were to fill in a major gap in Quaternary geological framework including map coverage, document glacial transport characteristics, determine regional surficial till compositions, and gather data concerning the glacial and post-glacial histories of this area.

Ground and/or remote observations were recorded at ~ 245 sites (157 ground observations) (Fig. 13). Ninety-four till samples were taken from 88 sites for compositional (textural, geochemical and lithological) and indicator mineral analyses. Multiple small scale erosional ice -flow indicators (e.g. striations, grooves, roche moutonnée) were measured at 55 locations. To help establish a minimum age for ice-free conditions in this area, 2 beach sand samples and 1 basal peat sample were collected for respective optically stimulated luminescence (OSL) and radiocarbon 14C dating. Rock and till samples were collected from the vicinity of the Hoidas Lake REE deposit in Saskatchewan (Fig. 13) to characterize its geochemical and mineralogical signature in till. The objective is to provide guidance for future prospecting along the Black Bay fault for similar U-REE mineralization.

Preliminary mapping of streamlined landforms (Fig. 14a) and measurement of small-scale erosional features reveal at least 4 phases of ice flow and 3 main regional flow sets within the study area. The main l ice flow during deglaciation across the breadth of the area splayed (diverged) from nearly westward across the northern part of both 75A and B to southwestward in the southern part of 75B. Much less conspicuous, hence not previously mapped, is evidence of two older ice flow events. Ice appears to have flowed generally toward the southwest at some early (pre or early-deglacial) time across the entire map area. This regional SW flow is prominent in the southeast part of 75A where there is no evidence of the younger westward flow. The oldest regional flow (which may predate late the Wisconsin stage identified at several locations throughout the 2015 map area, is to the south. Rare SSE/ NWW flow indicators were noted but the relative age is unknown. Relative ages of ice flow are based on observed crosscutting relationships between both landforms and the striations records (Fig. 14b).

Distinctive pebble to boulder size erratics, such as Dubawnt Supergroup units (Fig. 14c) (eg. Barrensland and Baker Lake groups sandstones, Wharton group - Pitz Lake volcanics, red siltstones) were found in variable concentrations throughout the area. These erratics are derived from sources located at greater than 200 km to the north-northeast and suggest long transport distances. Their

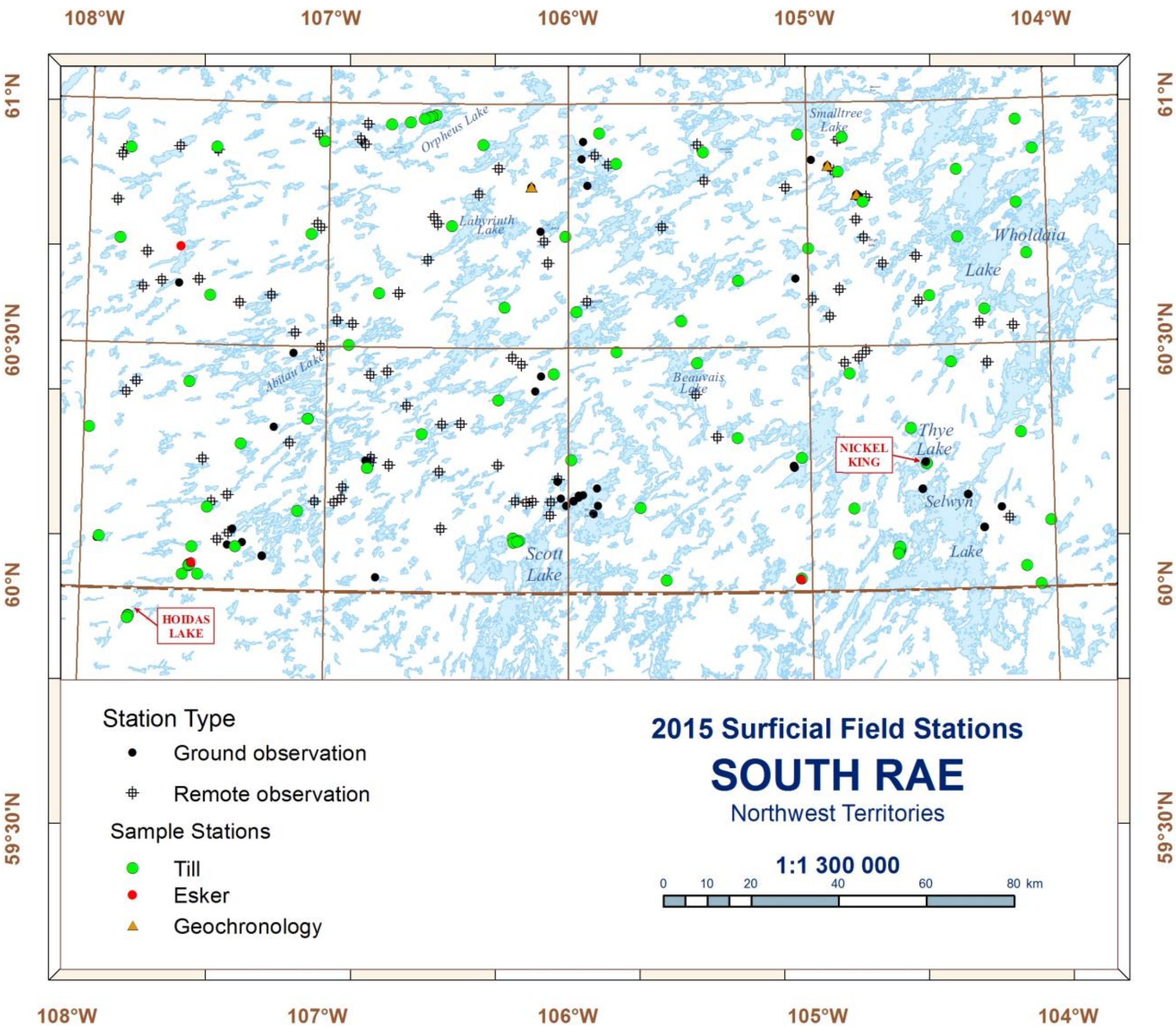

Figure 13: Location of 2015 surficial field stations (ground and remote) and samples.

presence in the study area suggests sustained transport and dispersal of glacial debris by the old southward flow.

Within the map area, bedrock exposure varies from 1 to 40 percent. The thickness of the drift varies from a thin discontinuous cover interspersed with bedrock, to thick blankets which mask the underlying bedrock. The dominant surficial material is till of varying composition, thickness and genesis. The till occurs as thin veneer, streamlined and ridged moraine, and as hummocky terrain. Where the till is thick it is predominantly streamlined (Fig. 14a). Based on rock types, depositional environment and thickness, the till composition is variable from silty sand to bouldery sand to matrix rich sandy diamictons.

Numerous parallel subglacial meltwater corridors trend WSW- SW across the map area (>200km). The corridors are typically 2-4 km wide and spaced 5-15 km apart with most being 5-10 km apart. Their lengths vary from 20km tributaries to > 200 km (extend out of the map area). There are two types of signature landform/deposits assemblages of the corridors: 1) eskers, parallel trains of either ice-contact glaciofluvial (hummocks and ridges) deposits or terraced glaciofluvial deposits, and 2) trains of hummocky till, boulder lags with small discontinuous eskers and related deposits. Much of the hummocky till is interpreted as a product of subglacial meltwater erosion and forms a contiguous landform assemblage with the esker complexes. In several places , streamlined landform remnants are present in association with the eroded till hummocks which supports this genetic interpretation of the till hummocks. Where the remnants occur, hummock development was arrested before meltwater erosion completely obliterated previously formed drumlins. Note that Aylsworth and Shilts (1989) mapped most occurrences of what are here called hummocky till and ice-contact ridges within these corridors as ribbed (Rogen) moraine. However, these hummocky till trains lack organized ridge systems and the ice-contact ridges within the corridor do not match the characteristic criteria of ribbed moraine (Hättestrand, 1997, Moller, 2006, 2010). We recognize only a few ridges in the Selwyn, Wholdaia and Scott lakes areas as more likely Rogen moraines. In the Scott –Wignes lakes area, short south-trending eskers and meltwater channels ending in subaqueous fans indicate late deglacial localized shift in meltwater drainage south into an ice marginal lake.

New mapping indicates glacial lakes were more extensive in this area than previously thought (Prest et al. 1968). Beaches, littoral and nearshore sands, trimlines, reworked till and glaciofluvial sediments indicate the presence of large, relatively stable, proglacial lake(s) inundating as high as 430 m asl within the Dubawnt drainage basin in northern and eastern part of NTS 75A (Fig. 14d). The many terraced and/or scarped slopes noted in NTS 75B map area may represent paleo-shorelines of short-lived ice marginal lakes present along the receding ice margin when it was west of the Dubawnt and Thelon drainage basins. Alternatively some or all of these scarps could be a product of meltwater erosion.

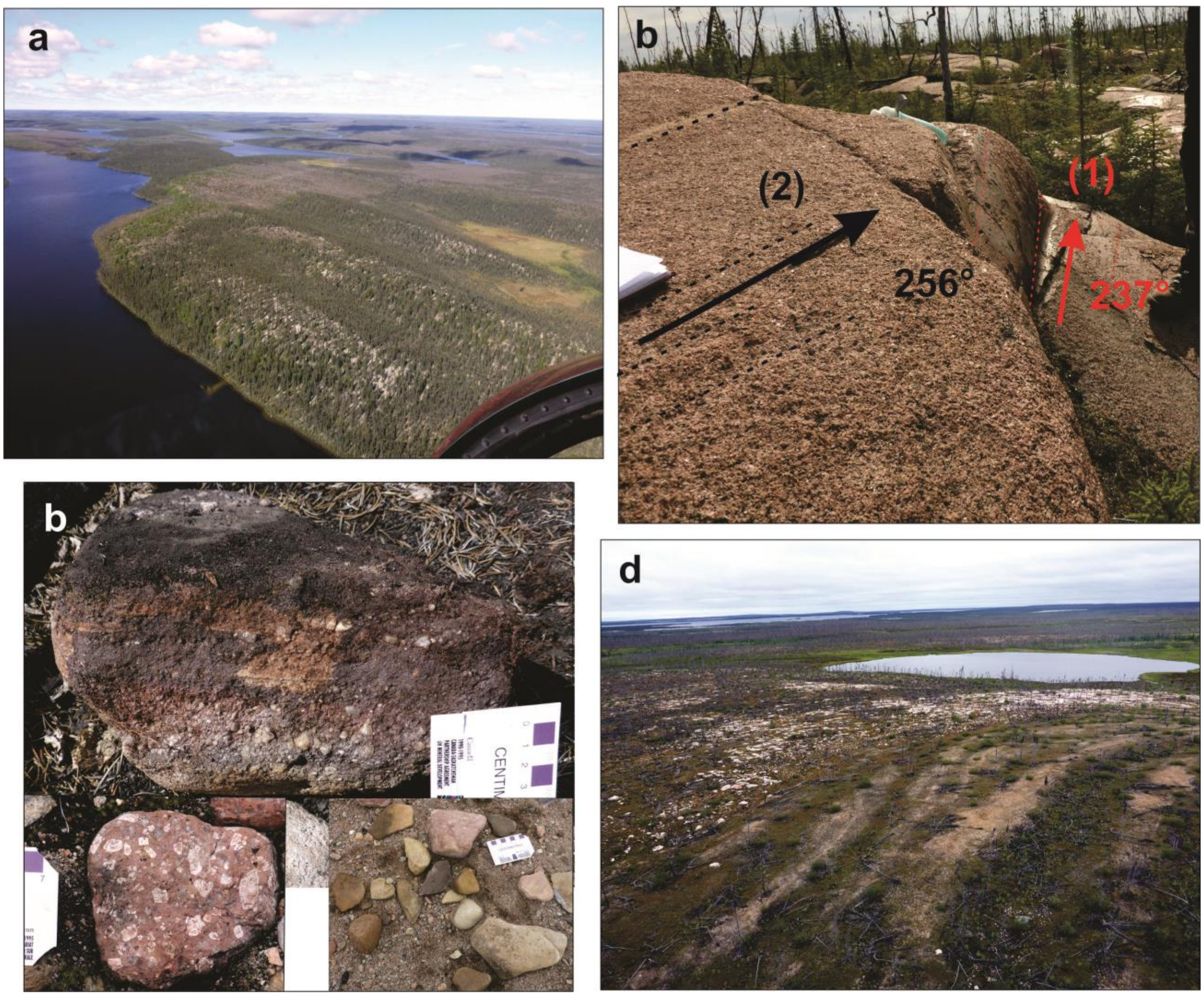

Figure 14: Surficial geology: a) Streamlined landforms comprised of till indicate prominent (W-SW). Ice flow is from right to left; b) relative position of striations and grooves on outcrop indicate relative age relationship between the southwest (1; protected lee) and westward (2; on top) ice flow; c) Erratic boulders and clasts from 3 different sites: Dubawnt Supergroup pebbly sandstone, Pitz Lake volcanic (bottom left) and a variety of sandstones, siltstones and Pitz lake volcanics (bottom right); and d) a series of beaches at ~ 410m asl above bedrock exposed by wave erosion, southeast of Smalltree Lake.

<u>Lake sediment geochemistry:</u>

Lake sediment and surface water samples were collected at 407 sites within priority areas of National Topographic System (NTS) 75-B (Abitau Lake) to characterize surrounding rocks and identify geochemical anomalies. Over a period of 11 working days two sample crews working with a Bell 206B Jet Ranger on floats collected an average of 37 sites per day, ranging from 9 sites on the first day to 49 sites on two subsequent days. At each site 6 variables in surface waters, including pH, temperature, conductivity, and dissolved oxygen, were measured and recorded.

Sediment samples were partially dried in camp before packing and shipment to Ottawa for further drying and preparation for analysis at a commercial laboratory. Surface water samples were filtered in camp to provide an aliquot for acidification with HNO3 (nitric acid) and a filtered, non-acidified sample. Water samples were shipped air freight to Ottawa for analysis in GSC laboratories.

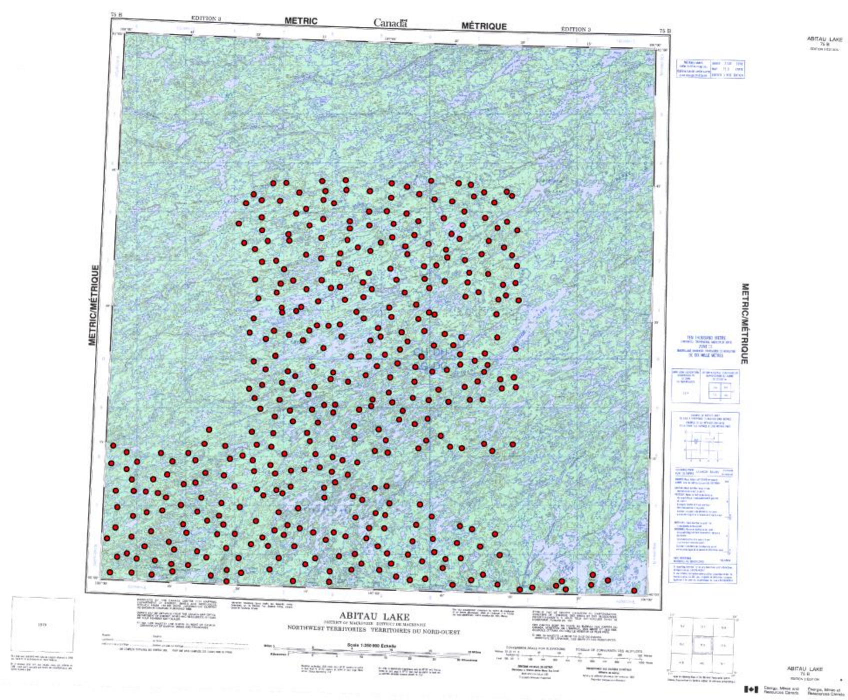

Fig. 15: Site locations of centre-lake sediment and surface water samples collected within the boundaries of NTS 75-B (Abitau Lake).

Concentrations of 65 elements in lake sediment samples are being determined at a commercial laboratory using a modified aqua regia "partial" digestion. Concentrations of trace and major elements in acidified and un-acidified lake surface waters are being determined at GSC laboratories in Ottawa. Results will be released in a GSC open file.

Future work

- Geochemical, Nd isotopic and geochronological analyses of bedrock samples will help characterize the age and origin of the proposed crustal domains and their geological components.

- Structural and tectonometamorphic studies will aid in evaluating the tectonic evolution of the area and its role in the evolution and assembly of the Canadian shield.

- Gossan analyses and targeted studies of new occurrences and the Thye Lake nickel deposit will aid in understanding the area's regional metallogenic potential.

- Bedrock mapping, targeted research and/or lake sediment studies will continue in the 75G, H map sheets in 2016 and 65D in 2017.

- Preliminary reports will be released in each of the 2016 and 2017 field seasons. Final bedrock maps, open files and reports for the area will be released in 2018

- Till compositional analyses will help identify potential targets and define cumulative glacial transport and dispersal patterns to guide economic mineral exploration in the area.

- Continued field-based regional scale mapping and targeted till sampling in NTS map-sheets 75G and H will support construction of the Quaternary geological model for this region.

- Surficial maps for all investigated NTS sheets will be released as GEM 2 publications

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