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2018

Permanent link: https://doi.org/10.4095/306622

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Recommended citation
Berman, R.G., Davis, W.J., Sanborn-Barrie, M., Whalen, J.B., Taylor, B.E., McMartin, I., McCurdy, M.W., Mitchell, R.K., Ma, S., Coyle, M., Roberts, B., and Craven, J.A., 2018. Report of activities for the GEM-2 Chantrey-Thelon activity: Thelon tectonic zone project, Nunavut; Geological Survey of Canada, Open File 8372, 22 p. https://doi.org/10.4095/306622

Publications in this series have not been edited; they are released as submitted by the author.

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Forward

The Geo-mapping for Energy and Minerals (GEM) program is laying the foundation for sustainable economic development in the North. This program provides modern public geoscience that will provide the foundation for long-term decision making related to responsible land-use and 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 2017, research scientists from the GEM program successfully carried out 27 research activities, 26 of which will produce an activity report and 12 of which included fieldwork. Each activity included aspects of 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 partners as the program advances.

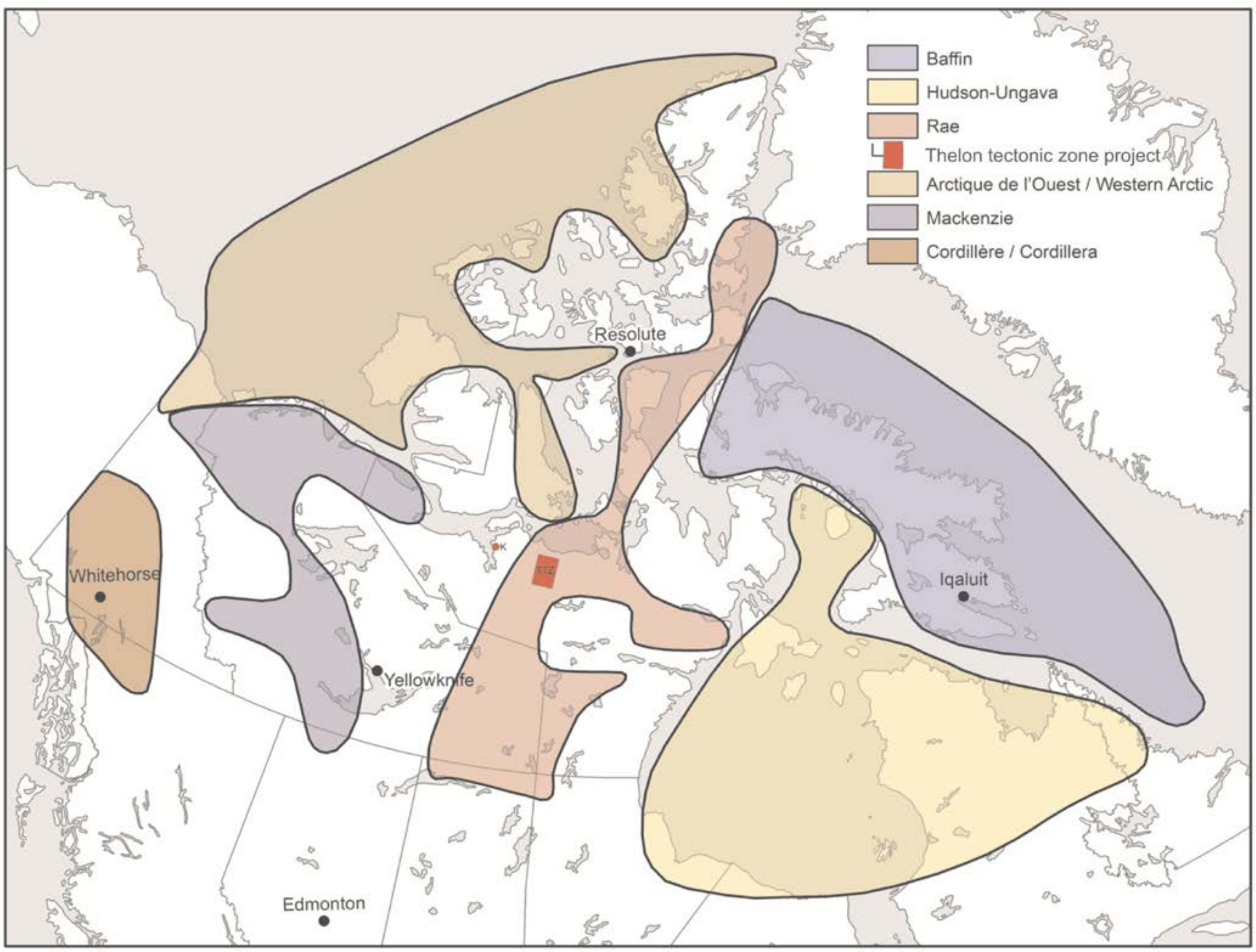

Figure 1. Location map showing the Thelon tectonic zone (Ttz) and Kilohigok basin (K) study areas within the GEM-2 Rae region of interest (pink).

Introduction

Following a 550 km-long reconnaissance-scale geological transect across the western Rae craton and Thelon tectonic zone (Berman et al., 2015a), the Chantrey – Thelon project was initiated to better understand the geological evolution and mineral potential of the Montresor belt, Elu basin, and the central Thelon tectonic zone (Ttz). Investigations of the Montressor region led to a new bedrock map of the belt (Percival et al., 2016), reconciled lithological and metamorphic contrasts to reflect early thrust and late extensional faulting (Tschirhart et al., 2015; Percival and Tschirhart, 2017; Percival et al., 2017), and highlighted the belt's IOCG-type mineral potential (Percival et al., 2015). Fieldwork in the Elu basin and northeast margin of the adjacent Kilohigok basin (K in Figure 1) has upgraded understanding of the evolution of Paleoproterozoic sedimentation (Ielpi et al., 2016) and revealed potential for unconformity-related uranium mineralization (Ielpi and Rainbird, 2015). This report describes 2017 activities in the final year of the Ttz project stemming from fieldwork in 2014 and 2016 (Berman et al., 2015b, 2016; McMartin and Berman, 2015; McCurdy et al., 2016; McCurdy and McMartin, 2017).

The Ttz comprises a series of pronounced, N- to NNE-striking magnetic highs and thin, intervening lows that extend >500 km from the MacDonald fault to north of Queen Maud Gulf (Fig. 2). The extension of these magnetic anomalies south of the MacDonald fault into the Taltson magmatic zone has long been considered to reflect continuity of the Taltson-Thelon orogenic system (Hoffman, 1988). The Ttz has been postulated to represent a ca. 2.0 Ga continental arc built on the western flank of the Rae craton and subsequently intensely deformed during ca. 1.97 Ga collision with, and subsequent indentation by, the Slave craton (Hoffman, 1988; Culshaw et al., 1991). Alternative models propose that the Ttz formed in an intracontinental setting either after crustal thinning (Thompson et al., 1989), or within an interior mountain belt far removed from an active plate boundary (Chacko et al., 2000; Schultz et al., 2007). A primary goal of the bedrock component of this project is distinguishing between, and refining these tectonic models in order to derive a comprehensive understanding of the evolution, architecture and economic potential of this major feature of the Canadian Shield.

The Ttz is extensively covered by Quaternary sediments of variable thickness. These include thick till deposits, often streamlined within the terminal zone of the Dubawnt Lake Ice Stream (DLIS), a series of eskers terminating at coalescing outwash plains and terraces, and minor till moraines which are part of the MacAlpine Moraine System (McMartin and Berman, 2015; indicated in Fig. 3). The till composition over the DLIS reflects a distal provenance: rich in exotic Dubawnt Thelon sandstone debris, relatively clay-rich, SiO_2-rich, and depleted in most trace and major elements (except SiO_2) with respect to till outside the ice stream footprint (McMartin, 2017). Beyond the ice stream, till composition reflects a local provenance and glacial dispersal from Ttz rocks. The main objectives of the surficial geology component of the Ttz project are to provide a Quaternary geological framework required for interpreting the transport history of surficial sediments and to collect targeted till samples for mineral potential evaluation and provenance studies. Surficial studies complement stream sediment studies (McCurdy et al., 2013; 2016; McCurdy and McMartin, 2017) aimed at locating areas with elevated mineral potential.

Methods

Activities during this wrap-up year involve completion of bedrock geochronological studies aimed at establishing the range of plutonic rock crystallization ages, follow-up Sm-Nd isotopic studies to better define crustal domains, completion of metamorphic studies as part of two student theses (M.Sc., Ma; Ph.D., Mitchell), release of multidisciplinary data and interpretations as open file reports and journal papers, and completion of two new 1:250,000 scale bedrock maps. In addition, a high-resolution aeromagnetic survey was flown over the northern part of the study region (NTS map sheet 76I; Figure 3) in March 2017 (Coyle, 2017a, b).

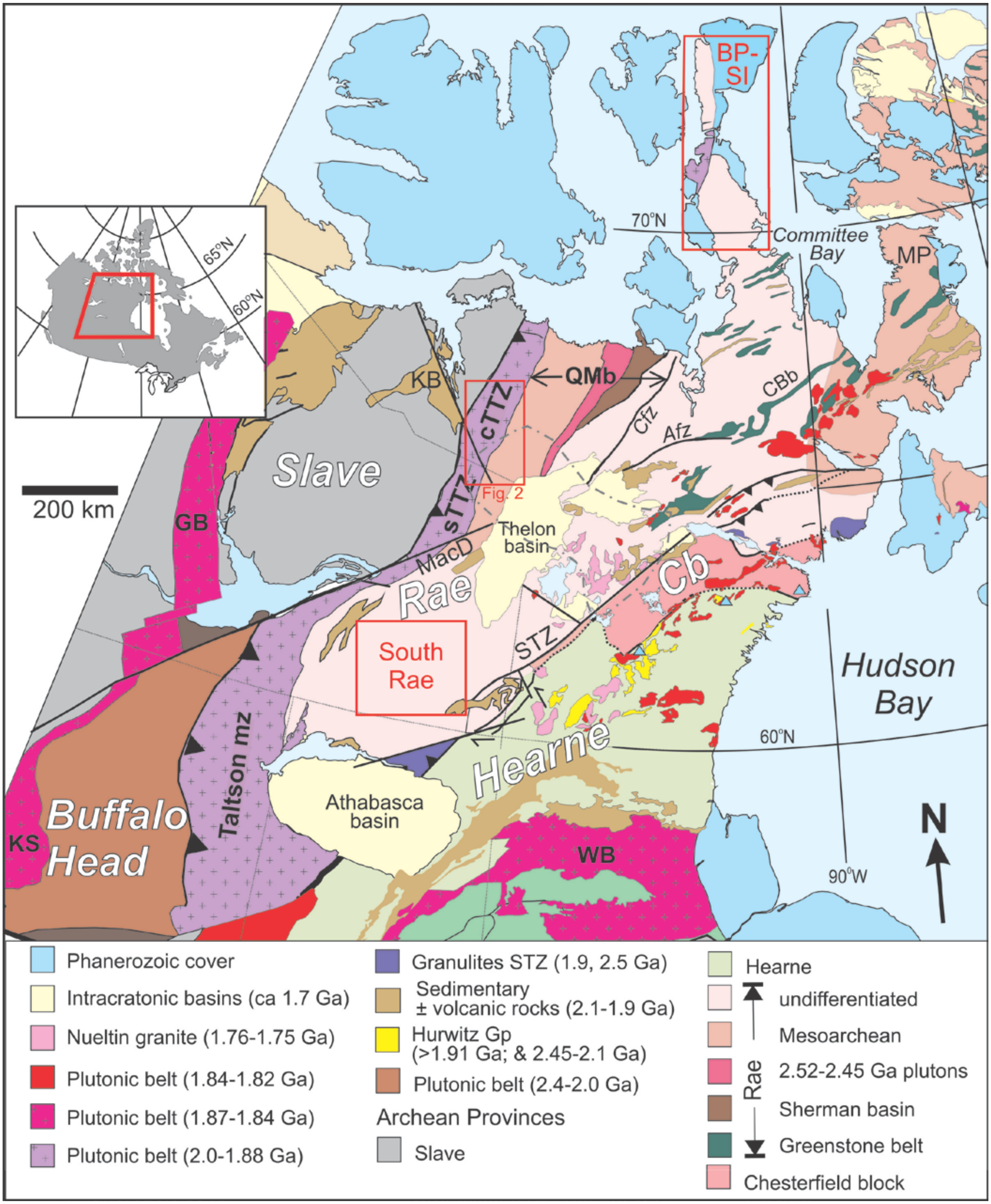

Figure 2. Geological map of northern Canada showing major tectono-magmatic elements and the location of three field-based GEM-2 activities (red boxes) focussed along western Rae craton, including the Thelon tectonic zone project. Abbreviations: Afz=Amer fault zone; BP-SI=Boothia Peninsula-Somerset Island; Cb=Chesterfield block; CBb=Committee Bay belt; Cfz=Chantrey fault zone; KS = Kitsuan magnetic high; MP=Melville Peninsula; mz=magmatic zone; QMb=Queen Maud block; Stz=Snowbird tectonic zone; tz=tectonic zone, WB= Wathaman batolith. Grey dash-dot curve shows position of Dubawnt Lake Ice Sheet.

Results

Aeromagnetic survey:

A 13,210 line km, high-resolution (400 m line spacing) aeromagnetic survey was flown west of the Queen Maud Migratory Bird Sanctuary between March 10-28, 2017 in NTS map sheet 76I (Fig. 3). These data highlight the extent of ca. 2.0-1.9 Ga plutonic suites reflected by high amplitude anomalies corresponding to the Western, Central and Eastern plutonic belts (p.b.), and the regional extent of a linear corridor of peraluminous leucogranite reflected by a quiet magnetic zone of low amplitude that transects the Queen Maud Migratory Sanctuary. A subtle, but key feature of the survey is the lineament within the magnetic high that mainly corresponds to Paleoproterozoic, variably orthopyroxene-bearing quartz diorite to monzogranite of the Western plutonic belt. Geological and isotopic constraints indicate that this curvilinear magnetic low (indicated by arrows in Fig. 3) marks the boundary between the Western plutonic belt and magnetite-bearing plutonic rocks of the Overby Lake domain, a distinct crustal domain within the eastern Slave craton. The survey also shows the north-closing hinge of a tight synform within the Western plutonic belt that is not apparent in the adjacent supracrustal-bearing Ellice River domain.

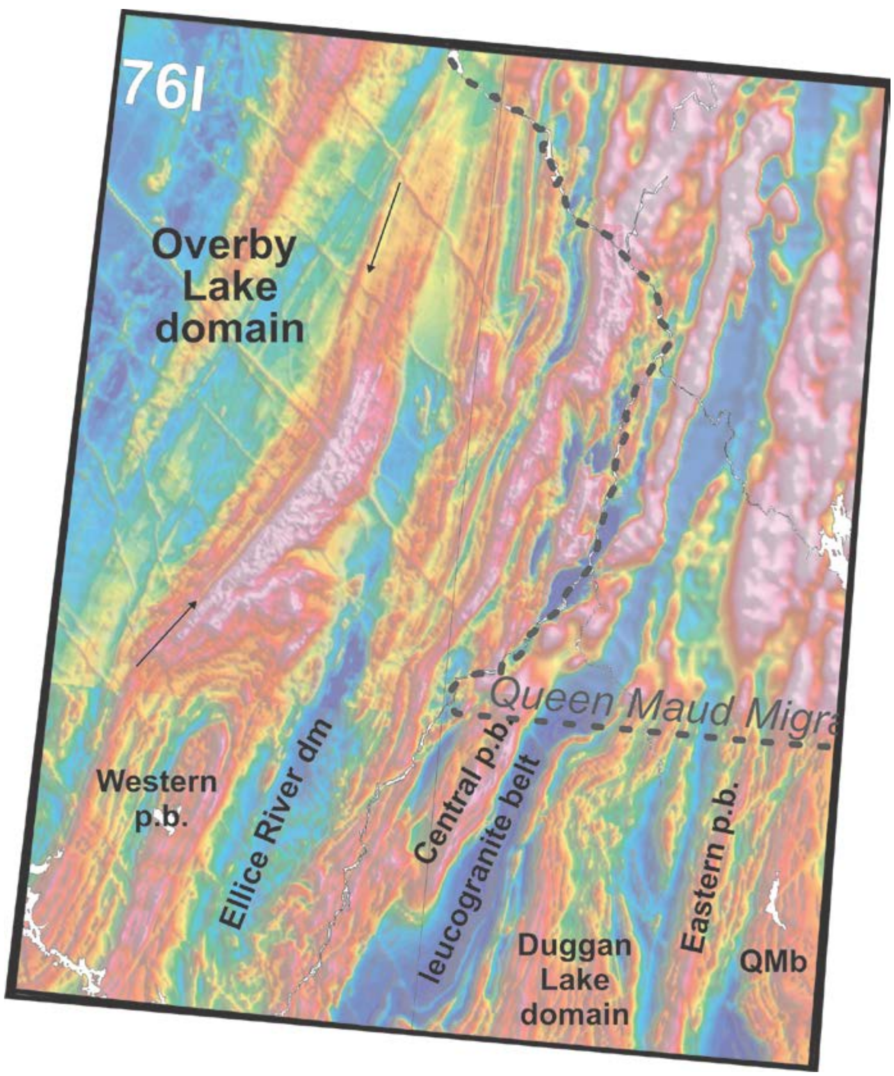

Figure 3. Total field high-resolution aeromagnetic map of NTS map sheet 76I (Coyle, 2017a,b); arrows point to the thin, curvilinear relative magnetic low that marks the interface between Neoarchean magnetite-bearing plutonic rocks of the eastern Slave craton (Overby Lake domain) and Paleoproterozoic, orthopyroxene-magnetite plutonic rocks of the Ttz. Abbreviations: dm=domain; p.b.=plutonic belt; QMb=Queen Maud block.

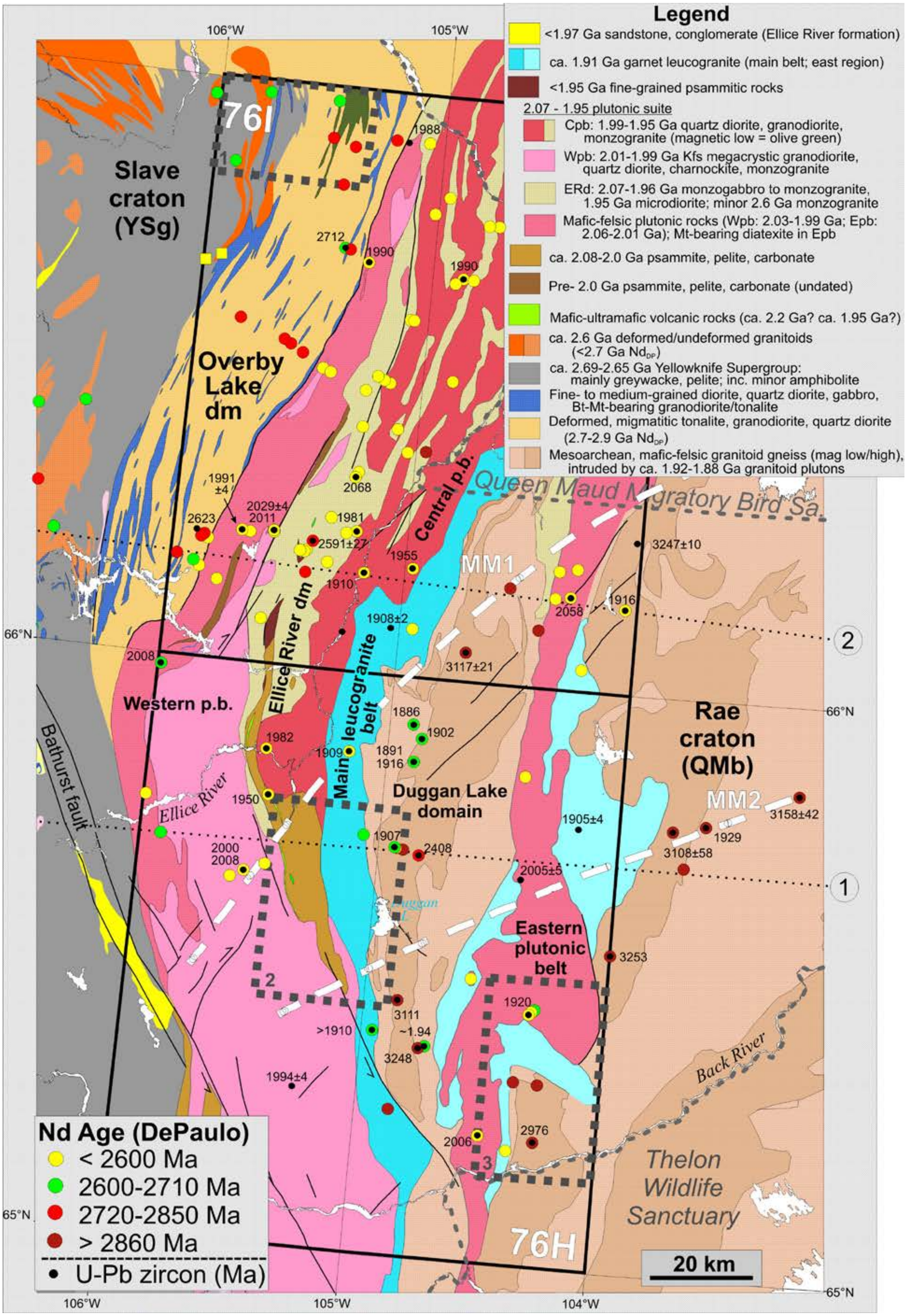
Legend
<1.97 Ga sandstone, conglomerate (Ellice River formation)
ca. 1.91 Ga garnet leucogranite (main belt; east region)
<1.95 Ga fine-grained psammitic rocks
2.07 - 1.95 plutonic suite
Cpb: 1.99-1.95 Ga quartz diorite, granodiorite, monzogranite (magnetic low = olive green)
Wpb: 2.01-1.99 Ga Kfs megacrystic granodiorite, quartz diorite, charnockite, monzogranite
ERd: 2.07-1.96 Ga monzogabbro to monzogranite, 1.95 Ga microdiorite; minor 2.6 Ga monzogranite
Mafic-felsic plutonic rocks (Wpb: 2.03-1.99 Ga; Epb: 2.06-2.01 Ga); Mt-bearing diatexite in Epb
ca. 2.08-2.0 Ga psammite, pelite, carbonate
Pre- 2.0 Ga psammite, pelite, carbonate (undated)
Mafic-ultramafic volcanic rocks (ca. 2.2 Ga? ca. 1.95 Ga?)
ca. 2.6 Ga deformed/undeformed granitoids (<2.7 Ga Nd_DP)
ca. 2.69-2.65 Ga Yellowknife Supergroup: mainly greywacke, pelite; inc. minor amphibolite
Fine- to medium-grained diorite, quartz diorite, gabbro, Bt-Mt-bearing granodiorite/tonalite
Deformed, migmatitic tonalite, granodiorite, quartz diorite (2.7-2.9 Ga Nd_DP)
Mesoarchean, mafic-felsic granitoid gneiss (mag low/high), intruded by ca. 1.92-1.88 Ga granitoid plutons
Nd Age (DePaulo)
< 2600 Ma
2600-2710 Ma
2720-2850 Ma
> 2860 Ma
U-Pb zircon (Ma)
Slave craton (YSg)
Overby Lake dm
Ellice River dm
Central p.b.
Western p.b.
Main leucogranite belt
Duggan Lake domain
Eastern plutonic belt
Rae craton (QMb)
Queen Maud Migratory Bird Sa.
Bathurst fault
Ellice River
Back River
Thelon Wildlife Sanctuary
76I
76H
MM1
MM2
20 km
106°W
105°W
104°W
66°N
65°N

Figure 4 (opposite page). Simplified geologic map of the central Ttz (NTS map sheets 76H and 76I), based on interpretation of aeromagnetic data integrated with previous work (Thompson, 1986; Frith, 1982), 2014 & 2016 fieldwork, and preliminary geochronological, isotopic and geochemical data. Sm-Nd model ages are shown with coloured circles (plutonic rocks) and squares (amphibolites). Smaller black circles denote locations of zircon crystallization ages (Frith and van Breemen, 1990; van Breemen et al., 1987; Davis et al., 2013, 2014; W.J. Davis unpublished ages are shown without errors). Abbreviations: dm = domain; p.b. = plutonic belt; Cpb = Central p.b.; Epb = eastern p.b.; ERd = Ellice River domain; Wpb = Western p.b.; GL = Goose Lake camp; QMb = Queen Maud block; YSg = Yellowknife Supergroup. Circled numbers along right margin denote MT transects shown in Fig. 7 (see below). Dashed white lines show two moraines of the MacAlpine Moraine System (MM1, MM2). Grey dotted boxes numbered 1-3 are areas discussed under “Economic Potential”.

Bedrock Geology and Geochronology

Delineation of geological map units in the central Ttz is challenging due to the high strain state and attenuation of lithologies, the similarity of plutonic rock compositions (quartz diorite – granodiorite – monzogranite) and metamorphic grade (upper amphibolite) of Archean and Paleoproterozoic granitoid rocks, combined with the scarcity of supracrustal rocks other than Yellowknife Supergroup rocks of the Slave craton that are restricted to the NW corner of NTS-76I (Fig. 4). In addition, extremely heavy lichen cover permits few opportunities to trace units and observe contact relationships, even in areas where bedrock is exposed. For these reasons, the new geological map for NTS sheets 76H and 76I relies heavily on interpretation of high-resolution aeromagnetic data integrated with targeted bedrock mapping, geochronology, geochemistry, Sm-Nd isotopic data, and a digital compilation (Buller et al., in prep) of the archival collection of the GSC’s 1983-1985 Tinney Hills – Overby Lake project (Thompson, 1986).

The bedrock geological map consists of eight, primarily metaplutonic domains (Fig. 4) which provide a first-order control on economic potential in the region. Three linear, high-amplitude anomalies represent ca. 2.0 Ga, commonly orthopyroxene-bearing plutonic rock belts, of which the 1.99-1.96 Ga central belt may be slightly younger than the dominantly 2.0-1.99 Ga western and eastern belts. Older plutonic components with ages between 2.06 – 2.02 Ga are identified in the western and eastern belts. A strong ca. 2.02 Ga peak in the detrital zircon population of a metapsammite in the Ellice River domain (Davis et al., in prep.) suggests ca. 2.02 Ga plutonic rocks could have been a significant component of these belts, and could further distinguish the Ttz from the 1.99-1.94 Ga Taltson magmatic zone, with which it has long been correlated (Hoffman, 1988). Preliminary age data suggest that the low amplitude magnetic feature corresponding to the Ellice River domain (Fig. 4) represents 2.07 – 2.0 Ga granodiorite to monzogranitic plutonic rocks whose oxygen isotope signatures indicate greater interaction with sedimentary rocks than plutonic rocks corresponding to adjacent magnetic highs (Taylor et al., 2017). In the southern Ellice River domain, two sequences of Paleoproterozoic sedimentary rocks have been defined: one younger than 1.95 Ga and containing detrital zircons of the main ca. 2.0-1.98 Ga “Thelon” plutonic phases; and an older “pre-Thelon” sequence deposited between 2.08 and 2.0 Ga (Davis et al., in prep.). Sm-Nd model ages indicate that mafic volcanic rocks of the Ellice River domain, a probable source of base-metal geochemical anomalies (see below), are Paleoproterozoic in age; geochemical characteristics suggest they may have formed in a back-arc setting contemporaneous with Ttz plutonic rocks (Whalen et al., 2018).

Zircon geochronology and Sm-Nd isotopic data establish that Mesoarchean crust of the Queen Maud block extends further west than previously recognized (Hoffman and Hall, 1993) to include the 400 km^2 Duggan Lake domain (Fig. 4). West of the Mesoarchean Duggan Lake domain, a ~400 km-long garnet-bearing leucogranite belt is peraluminous and has δ^{18}O greater than 9 (Taylor et al., 2017), consistent with formation by inversion and melting of a sedimentary basin that marks the west flank of the Rae craton.

Six metamorphic events are recorded by zircon geochronology in plutonic rocks and monazite geochronology in metasedimentary rocks (Davis et al. 2014; Mitchell et al., 2017). From oldest to youngest, these include:

- ca. 2580 Ma, recognized only in Yellowknife Supergroup supracrustal rocks of the Slave craton
- ca. 2350 Ma, recognized only in the Duggan Lake and QMb of the Rae craton; its absence in the eastern Slave craton offers no support for a model of ca. 2.4 - 2.35 Ga Slave-Rae collision proposed by some workers (Schultz et al., 2007; Tersmette, 2012)
- ca. 2000 Ma, recognized in the Western and Eastern plutonic belts, points to a regional contact metamorphism associated with charnockitic plutonism (van Breemen et al., 1987)
- ca. 1950 Ma upper amphibolite-facies metamorphism, recognized locally in the Eastern plutonic belt, Duggan Lake domain, and eastern Slave craton; this timing is consistent with 1.97 Ga Slave-Rae collision (Grotzinger and McCormick, 1988)
- ca. 1920-1890 Ma, recognized in all domains including QMb, and associated with upper amphibolite-facies metamorphism and leucogranite formation; this event is interpreted to reflect peak metamorphism associated with continued tectonic thickening
- ca. 1820 Ma, recognized at several locations within Slave craton and Ttz, and associated with lower amphibolite-facies metamorphism in < 2.08 Ga supracrustal rocks of the southern Ellice River domain; this event appears to reflect renewed convergence across the Ttz due to far-field effects of the Hudsonian orogeny

Geochronology of Kilohigok basin

Detrital zircons were analysed from nine samples collected from the Goulburn Supergroup in the Bathurst Inlet area (K in Figure 1). The analyses document dominantly Slave sources in samples of the Kimerot platform (Kenyon formation) and lower parts of the Bear Creek Group (Hackett and Rifle Formations). Increasing proportions of zircon with Thelon (2.0-1.98 Ga), Queen Maud granitoid suite (ca. 2.5 Ga) and Arrowsmith orogen (ca. 2.3 Ga) ages occur in the Beechey and Burnside formations, consistent with their formation in a foredeep developed during ca. 1.97 Ga collision of the Slave and Rae cratons (Grotzinger and McCormick, 1988). Samples of the Brownsound and Amagok formations include post-1.9 Ga zircon consistent with deposition during a renewed episode of convergence (Grotzinger and McCormick, 1988).

<u>Bedrock geochemistry</u>

Whole rock major and trace element geochemistry for 193 bedrock samples provides the first comprehensive geochemical dataset for the Ttz (Whalen et al., 2018). Highlights of these data include:

1) Indications of a convergent margin tectonic setting for the ca. 2.02-1.98 Ga Thelon plutonic suite, reflected by tectonic discrimination diagrams pointing to continental arc and slab-failure magmatism (Fig. 5); the significant proportion of mafic rocks in the Ttz suite also supports this setting rather than an interior mountain belt setting (cf. Schultz et al., 2007)

2) Mafic volcanic rocks of the Ellice River belt have arc (one sample) and back-arc (4 samples) signatures which suggest they may be contemporaneous with ca. 2.0 – 1.96 Ga plutonism

3) 1.90-1.88 Ga high-Zr plutons form a distinct textural (post-tectonic) and "within plate" geochemical group marking the end of the Thelon orogenic event

4) Rae basement plutonic rocks have distinctive low-K compositions, which do not extend into the Taltson magmatic zone (Tmz) basement (Goff et al., 1986)

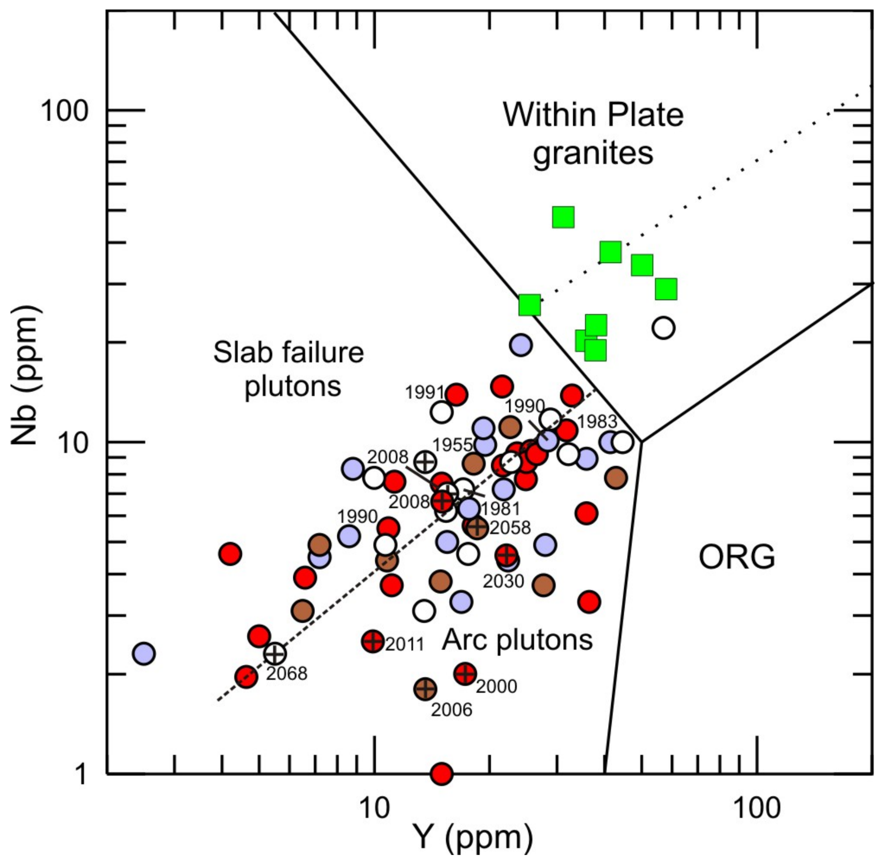

Figure 5. Tectonic discriminant diagrams for the ca. 2.06-1.98 Ga plutonic suite and 1.90-1.88 Ga high-Zr plutonic rocks; Symbols: red, white, blue, brown circles are Western, Ellice River, Central, and Eastern plutonic belts, respectively; circles containing crosses represent > 2.0 Ga samples (ages given in Ma) which mostly plot in "arc" field; green squares are 1.90-1.88 Ga, post-tectonic, high-Zr rocks

5) Late (i.e., ca. 1.9 Ga) Tmz (Goff et al., 1986; Chacko et al., 2000) and Ttz plutonic suites are similar geochemically; however, early Ttz plutonic rocks are significantly more mafic and have arc-like signatures not present in most early Tmz plutons, suggesting the Tmz is not directly correlative with the Ttz (as recently proposed by Ashton et al. (2014)

<u>Sm-Nd isotopes</u>

Sm-Nd isotopic data were collected to provide insight into crust formation ages and mantle source reservoirs for the various plutonic suites, and to help delineate map units and crustal domains (Fig. 4). Major conclusions drawn from these data include:

1) The newly recognized Overby Lake domain of the eastern Slave craton is characterized by older Sm-Nd model ages (and lighter oxygen isotopes) compared to Slave craton basement further west (Fig. 6); the latter also hosts Yellowknife Supergroup supracrustal rocks that are absent in the Overby Lake domain

2) With few exceptions, ca. 2.06-1.98 Ga Ttz plutonic rocks show evolved Nd isotopic compositions (ε_{Nd} = -3 to -2) without significant variations from east to west (Fig. 6), in contrast to pronounced variations in Nd isotopic compositions of basement across the region (ε_{Nd} = -18 to -7; Fig. 6); this suggests that Ttz plutonic rocks intruded Mesoarchean “ Queen Maud-like” crust of the western Rae craton and were subsequently tectonically juxtaposed with Slave-Overby Lake crust

3) ca. 1.9 Ga plutonic rocks have more evolved signatures (ε_{Nd} = -5 to -6; Fig. 6) consistent with greater interaction with, and/or derivation (via partial melting) from, western Rae crust and/or its cover;

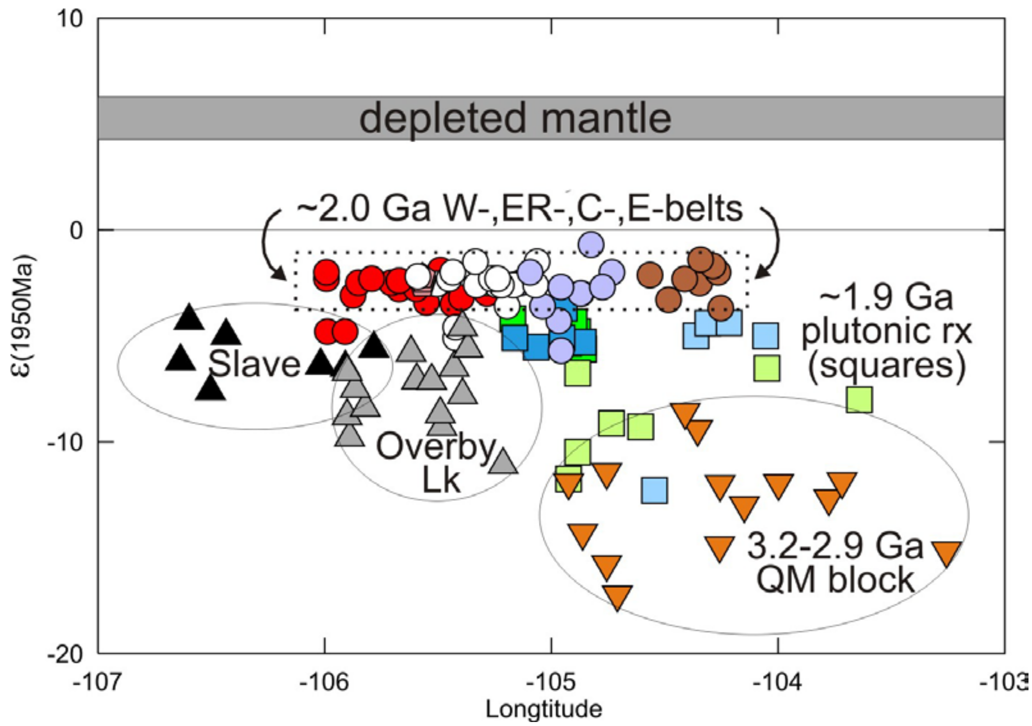

Figure 6. ε_{Nd} variation with latitude. Symbols as in Figure 5. Note that consistency of ε for most ca. 2.06-1.98 Ga plutonic rocks (circles) is in marked contrast to strong E-W variation in ε_{Nd} for ‘basement’ rocks (triangles)

<u>Magnetotelluric transects:</u>

Three dimensional inversion of magnetotelluric data collected across two east-west transects (Fig. 4; Roberts et al., 2015) suggest a Rae over Slave geometry (Fig. 7), however the overall crustal structure is complex, consistent with its polyorogenic history. The non-conductive upper 10 km is interpreted to reflect widespread plutonic rocks mapped at the surface and formed during convergence at ca. 2.0 Ga and crustal melting at ca. 1.9 Ga. Below this level, strongly conductive crust occurs in Rae craton, but it is more muted and deeper in Overby Lake domain (OL) and absent beneath the Yellowknife Supergroup hosted part of the Slave craton. The high conductivity regions of the Rae are speculated to have formed via plutonic/metamorphic processes associated with the ca. 2.4 - 2.35 Ga Arrowsmith orogeny.

A thin, high conductivity region at highest crustal levels (C1 in the southern section, Fig. 7) coincides with supracrustal rocks of the Ellice River domain, and may reflect sulphide enrichment as reflected by overlying surficial metal-rich geochemical anomalies (area 2 in Fig. 4; see Fig. 11a below).

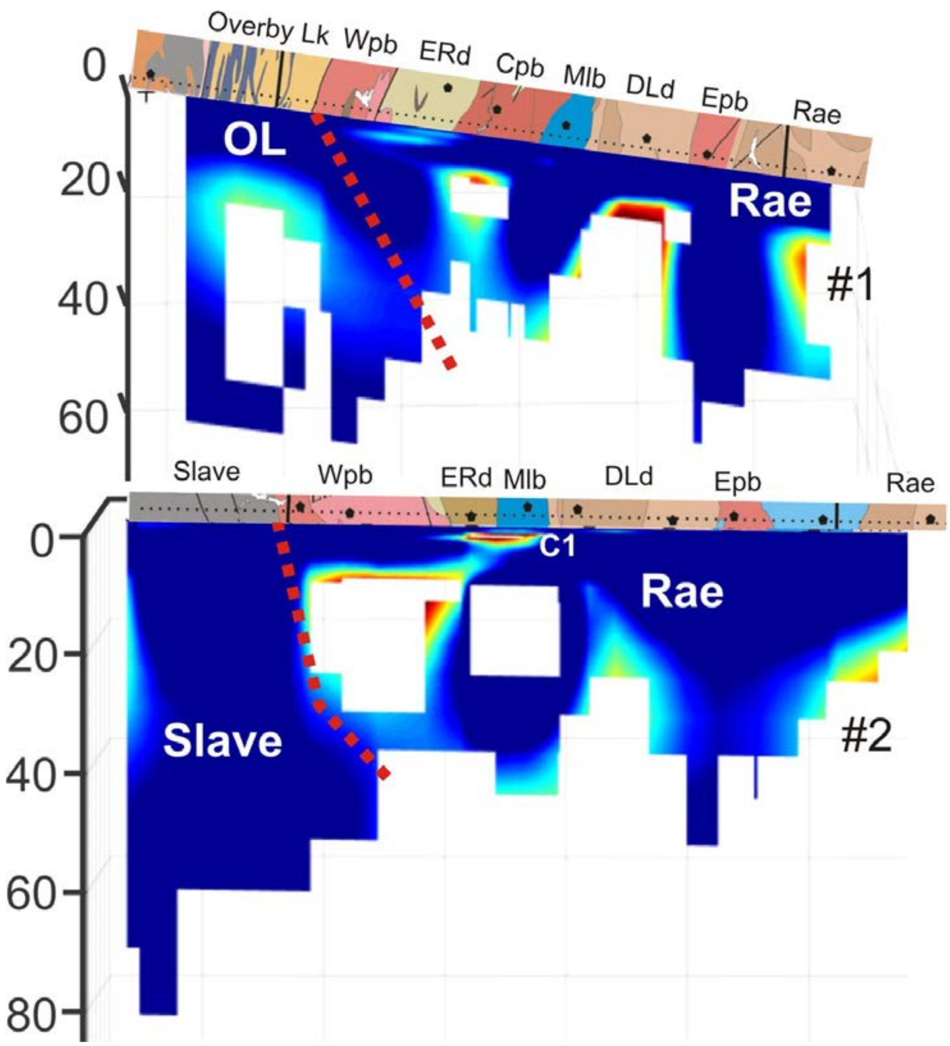

Figure 7. Magnetotelluric model of two transects (indicated in Fig. 4) across NTS 76H (bottom) and 76I (top). White areas are regions without reliable constraints. Top strips show geological domains from Figure 4. Note that Overby Lake domain (OL) does not appear to extend as far south as transect 2 (Fig. 4). Abbreviations: Cpb = Central plutonic belt, DLd = Duggan Lake domain (Rae crust), Epb = Eastern plutonic belt, ERd = Ellice River domain, Mlb = main leucogranite belt, Wpb = Western plutonic belt

<u>Oxygen isotopes</u>

Whole-rock oxygen isotope analyses were collected for 96 granitoid rocks that are representative of the main crustal domains (Fig. 4). The primary conclusions drawn from these data are:

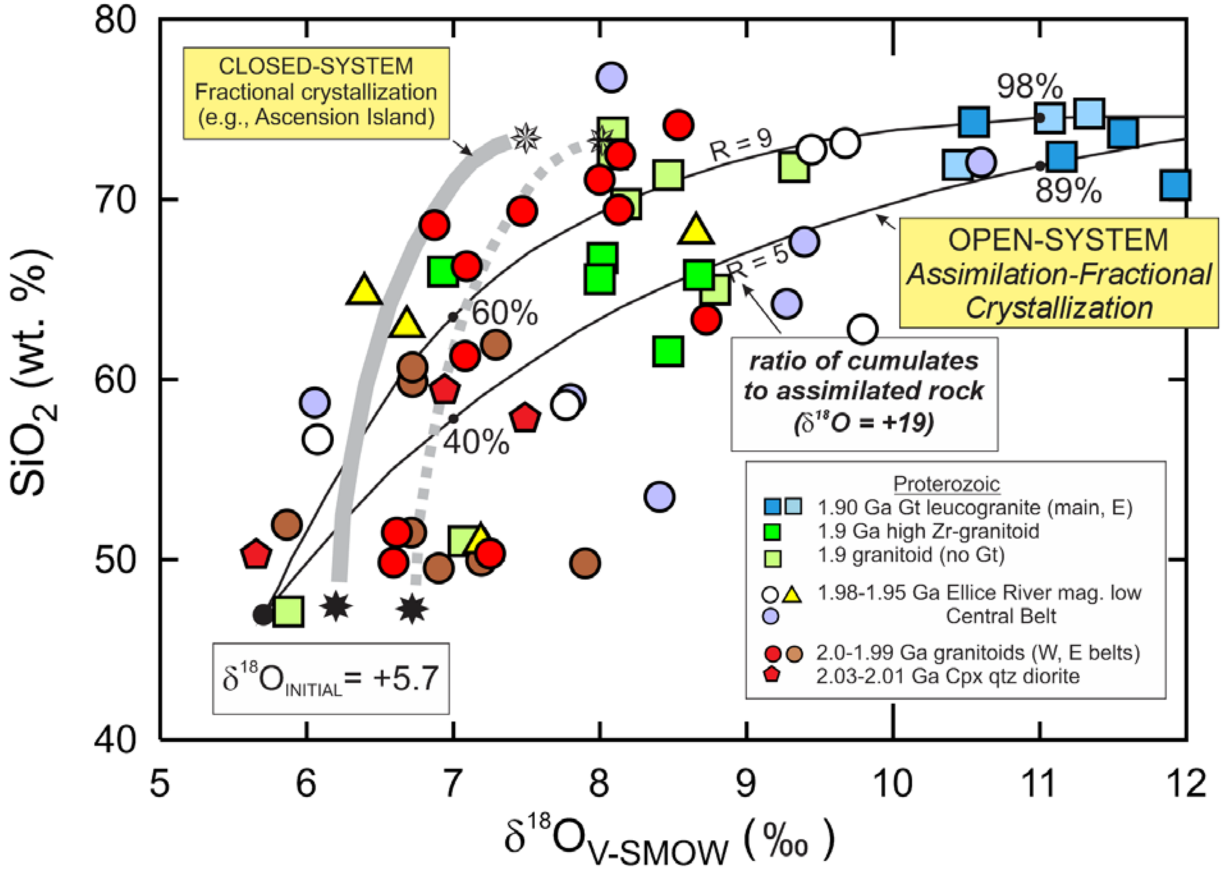

Figure 8. Plot of wt. % SiO_2 vs $\delta^{18}O$ for Proterozoic igneous rocks of the Thelon Tectonic Zone; samples are grouped by age. Model oxygen isotope evolution curves are shown for both open and closed systems. WPB rocks (red circles; dotted grey curve) plot as if related by closed-system fractional crystallization (compare to thick, grey curve for Ascension island suite) of mantle derived magma. The open-system, AFC processes are general in nature, and describe contamination by a sediment (e.g., shale) with $\delta^{18}O$ = 19.

1) Low $\delta^{18}O$ values ($\delta^{18}O$ = ~ 6) approaching mantle values of least fractionated ca. 2.0 Ga plutonic rocks (Figs. 8, 9a) support generation in a convergent margin tectonic setting, consistent with trace element geochemical signatures of arc (± slab failure) plutonic rocks (see Fig. 5 and related text)

2) Peraluminous leucogranites form a distinct, heavy $\delta^{18}O$ group ($\delta^{18}O$ ~10-12) consistent with their generation by melting of sediments and/or sedimentary rocks during ca. 1.9 Ga orogenesis

3) Samples of the Western and Eastern plutonic belts generally have $\delta^{18}O < 8$ and approximate (dotted grey curve in Fig. 8) predicted trends for closed system fractionation (solid grey curve in Fig. 8), whereas the trend towards heavier $\delta^{18}O$ of the Central plutonic belt ($\delta^{18}O$ up to 10.5) and Ellice River plutonic rocks ($\delta^{18}O$ up to ~9.8) reveal the influence of assimilation of a sedimentary component in their evolution (Fig. 8)

4) The light $\delta^{18}O$ of early Ttz plutonic rocks (Fig. 9a) contrasts with early granitoids of the Taltson magmatic zone (De et al., 2000; Fig. 9b), a difference that further strengthens geochronological and geochemical indications that the Tmz is not directly correlative with the Ttz

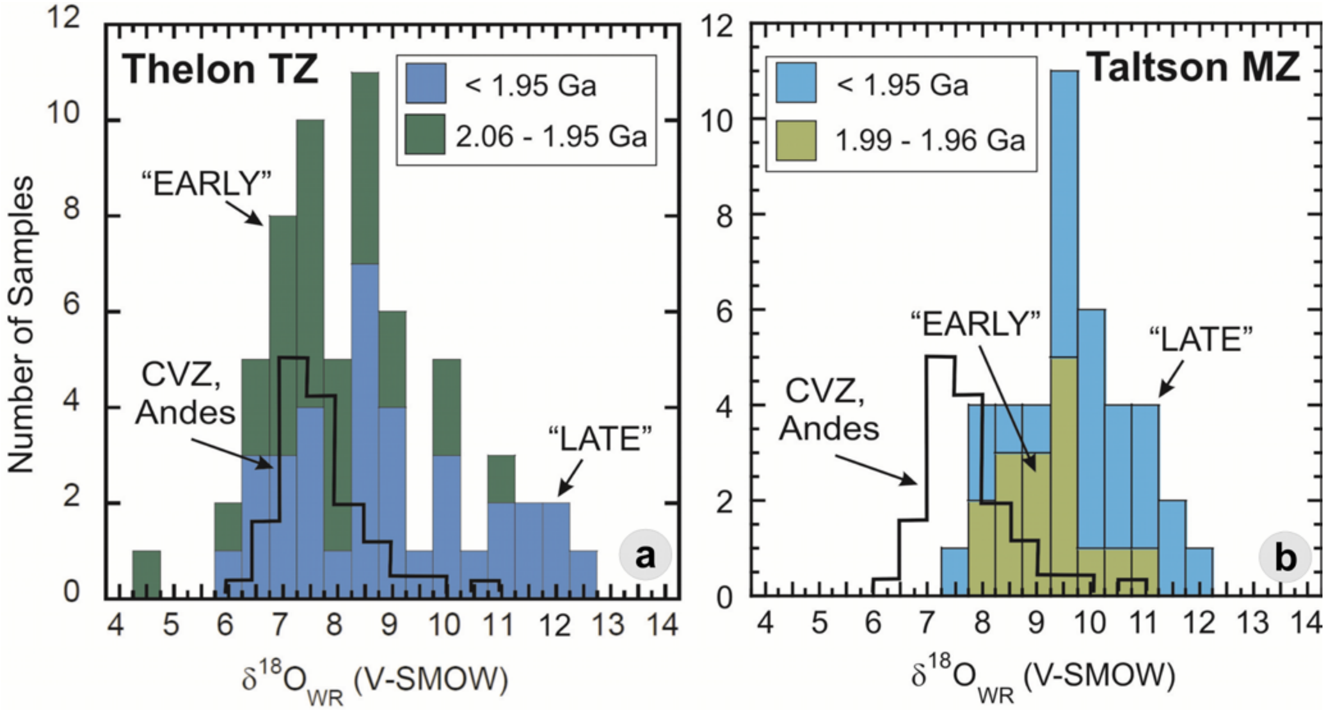

Figure 9. Two histogram plots of $\delta^{18}O_{WR}$ for 'early' and 'late' suites of granitoids in the Ttz and Tmz (De et al., 2000) indicate a marked contrast between these two areas. Whereas, all granitoid rocks younger than 1.95 Ga reflect rather 'heavy' isotopic compositions, data from the Ttz represent a much broader variation. More strikingly, granitoid rocks older than 1.95 Ga in the Ttz are characterized by a greater range and lower values of $\delta^{18}O_{WR}$, reflecting greater mantle affinity than revealed in the Tmz.

Economic Potential:

Geochemically anomalous areas identified in 2012 and 2014 sampling surveys were resampled in 2016 (McCurdy et al., 2013; McCurdy et al., 2016; McMartin and Berman, 2015). The following highlights and maps integrate the results over the 3 field seasons in 3 primary areas of elevated economic potential (Fig. 4). A more complete interpretation is presented in McCurdy and McMartin (2017).

Base and precious metals – area 1

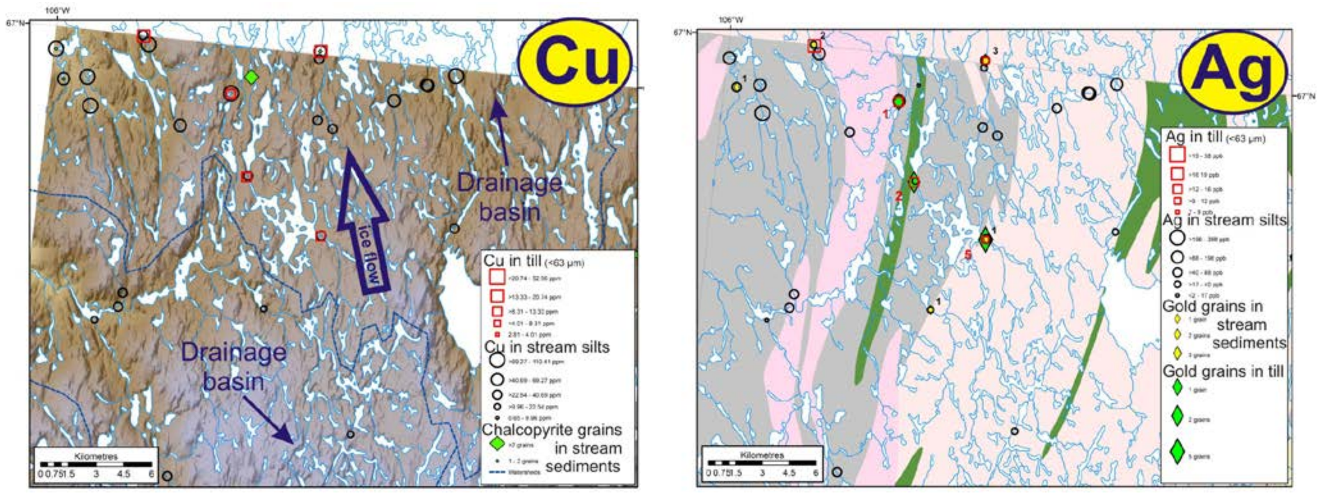

Figure 10: Northwestern NTS 76I showing anomalous metal contents in stream and till samples. a) Cu (in ppm; aqua regia) and chalcopyrite grains superimposed on the digital elevation model; b) Ag (in ppm; aqua regia) and gold grains superimposed on bedrock geology map (modified from Fig. 4)

Elevated Cu and other base metals (Pb, Ni, Zn) in streams and tills collected in 2016 (McCurdy and McMartin, 2017) support data from stream silts analyzed in 2014. Collectively, these data suggest base-metal potential in the northwest part of NTS 76-I over rocks of the eastern part of the Slave craton (Fig. 10, left). Chalcopyrite grains occur in multiple stream samples. Follow-up sampling in 2016 confirmed anomalous Ag in stream silts within north-flowing streams sampled in 2014. Multiple gold grains in both stream and till samples indicate a potential source or sources within metasedimentary rocks and/or metavolcanic rocks of the eastern Slave craton.

Base metals – area 2

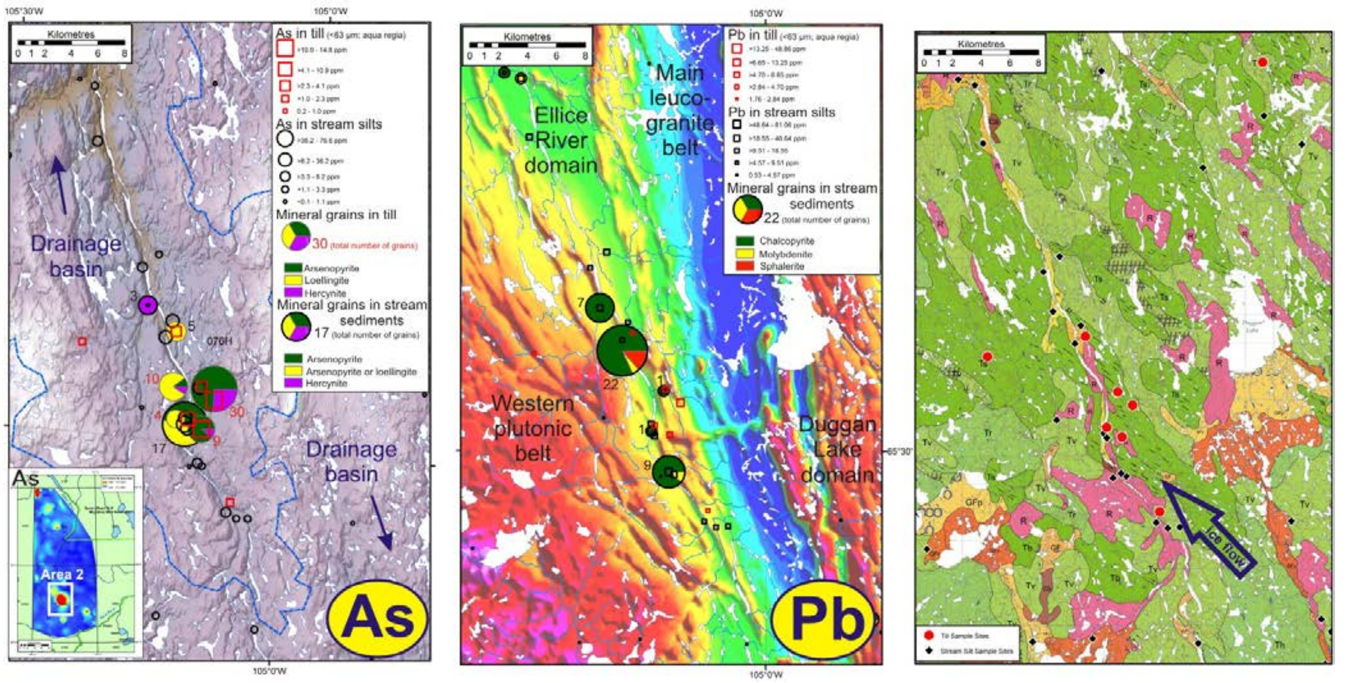

Figure 11: Duggan Lake area with elevated metal contents from stream sediments and till. a) As contents (ppm; aqua regia) and arsenopyrite, loellingite and hercynite grain counts superimposed on the digital elevation model. Inset shows As in stream silts over the entire project area; b), Pb contents (ppm) and selected sulphide grain counts superimposed on total field aeromagnetic map, note that Cu and Zn show similar distributions; c) location of samples superimposed on surficial geology (St-Onge & Kerr, 2013). Surficial legend: Tv = till veneer; Ts=streamlined till; Tb=thick till; Tr=ribbed till; R=bedrock

Resampling in 2016 up-ice and up-stream of the strong base metal and sulphide anomaly in area 2 (Fig. 11a, inset) indicates separate signatures from two distinct sources: 1) a strong As±Bi-arsenopyrite-loellingite-hercynite±scheelite anomaly (Fig. 11a) sourced in a magnetic high on the east side of the Ellice River domain that corresponds to mixed migmatites and sheared felsic granitoids, potentially indicative of a contact metamorphic deposit; 2) a Cu-Pb-Zn-Ag±Mo±W-chalcopyrite-sphalerite-molybdenite anomaly (Fig. 11b) that may be associated with Paleoproterozoic mafic volcanic rocks of the Ellice River domain.

Gold – area 3

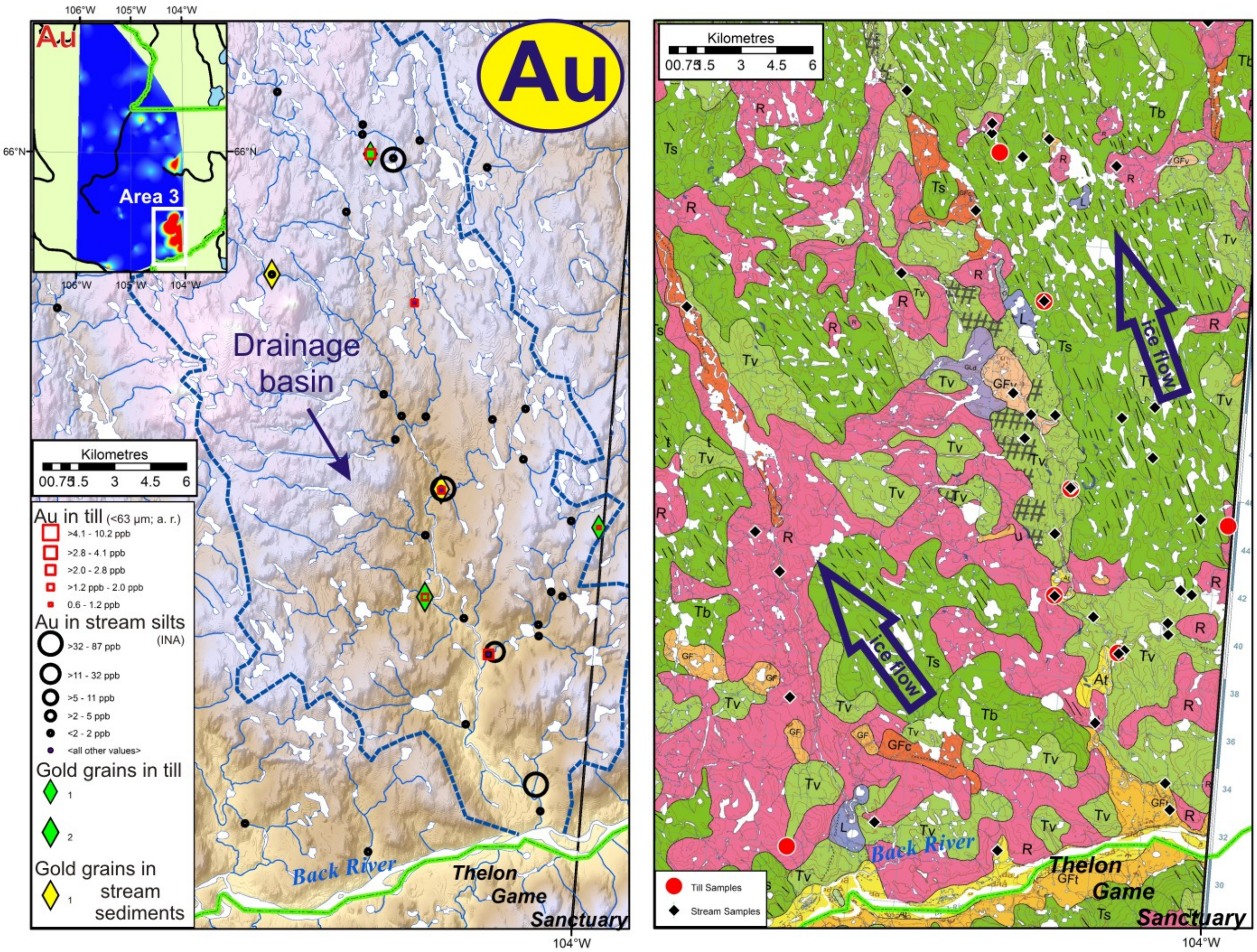

Figure 12: Southeastern NTS 76H (area 3 in Fig. 4) showing gold in stream sediments and till. a) Au (ppb) and Au grains superimposed on digital elevation model. Inset shows gold in stream silts over entire project area; b) location map of samples relative to underlying surficial geology (St-Onge & Kerr, 2013); Tv=till veneer, Ts=streamlined till, Tb=thick till, R=bedrock

Follow-up results support data from stream sediments in 2012 (Fig. 12a, inset) suggesting a Au source within a drainage basin flowing south into the Back River. The distribution of Au in stream sediments decreases downstream, but glacial transport is in the opposite direction and all gold grains are reshaped, reflecting a complex transport history. Field work indicates that this anomaly is sourced in a region with high-grade dioritic rocks and iron formation.

Conclusions

This GEM-2 project is providing greatly improved understanding of the evolution, architecture and economic potential of the central Ttz. Primary conclusions include:

1. Plutonism in the Ttz initiated earlier (2.07 – 2.03 Ga) than previously established, and ~80 Myr earlier than plutonic activity documented in Taltson magmatic zone, with which the Ttz has long been correlated.

2. The geochemistry of 2.07 – 1.96 Ga plutonic rocks is indicative of a convergent margin setting, with both arc and slab-failure magmatism indicated; these interpretations argue against the model that Ttz formed in an intracontinental setting.

3. Nd-Sm isotopic data strongly suggest that all Ttz plutonic belts interacted with very similar evolved crust, for which the ca. 3.2 – 2.9 Ga western Rae (QMb) is the most suitable candidate.

4. 3-D models of magnetotelluric transects are consistent with the present architecture of the Ttz reflecting west-vergent thrusting of the Rae craton over the Slave craton, consistent with our interpretation of Nd-Sm isotopic variations summarized above.

5. The most widespread metamorphism (upper amphibolite-facies) occurred at ca. 1.92 - 1.89 Ga, during which a 400 km-long leucogranite belt formed from inversion and melting of a sedimentary basin marking the west flank of the Rae craton.

6. Plutonic rock crystallization ages and/or Nd-Sm isotopic data demonstrate: (a) the 400^2 km Duggan Lake domain comprises ca. 3.2 – 2.9 Ga crust akin to the Queen Maud block; (b) the Overby Lake domain is an isotopically and lithologically distinct domain in the eastern Slave craton.

7. The eastern boundary of the Overby Lake domain is established to lie within a highly strained, magnetic high where Archean magnetite-bearing Overby Lake granitoid rocks are in contact with Paleoproterozoic magnetite-orthopyroxene granitoids of the Ttz.

8. Differences in crystallization ages, major and trace element geochemistry, and oxygen isotope data demonstrate that the Ttz is not a simple correlative of the Taltson magmatic zone, as has long been considered; thus, tectonic models developed for the Tmz are not directly applicable to the Ttz.

9. Quaternary studies indicate an early regional ice movement towards the north followed by a shift to the northwest and west-northwest during deglaciation, as the ice front receded progressively to major ice recessional positions marked by the MacAlpine Moraine System (MMS); major changes in till clast content, texture and geochemical composition within and outside the Dubawnt Lake ice stream footprint coincide with an ice-front position at the southern segment of the MMS.

10. Till and stream sediment data reveal three primary areas of elevated economic potential: (a) base and precious metals in the eastern Slave craton, northwest 76I; (b) base metals associated with Paleoproterozoic supracrustal rocks of Ellice River domain; (c) gold associated with dioritic rocks and/or iron formation within southeastern 76H.

Acknowledgments

We thank Jacques Pinard for sample preparation, Pat Hunt for SEM assistance, and Katherine Venance for acquiring microprobe data. S. Pehrsson provided a constructive review of this contribution to the GEM-2 Rae activity.

References

Berman, R.G., Nadeau, L., Percival, J.A., Harris, J.R., Girard, E., Whalen, J.A., Davis, W.J., Kellett, D., Jefferson, C.W., Camacho, A., and Bethune, K., 2015a. Geo-Mapping Frontiers' Chantrey project: bedrock geology and multidisciplinary supporting data of a 550 kilometre transect across the Thelon tectonic zone, Queen Maud block, and adjacent Rae craton; Geological Survey of Canada, Open File 7698.

Berman, R.G., Nadeau, L., McMartin, I., McCurdy, M., Craven, J., Girard, E., Sanborn-Barrie, M., Carr, S., Pehrsson, S., Whalen, J., Davis, W.J., Roberts, B., and Grenier, A., 2015b. Report of activities for the Geology and Mineral Potential of the Chantrey-Thelon Area: GEM-2 Thelon tectonic zone project; Geological Survey of Canada, Open File 7693, 14p, doi:10.4095/295644.

Berman, R.G., Sanborn-Barrie, M., Nadeau, L., Brouillette, P., Camacho, A., Davis, W.J., McCurdy, M.W., McMartin, I., Weller, O.M., Chadwick, T., Liikane, D.A., and Ma, S., 2016. Report of activities for the geology and mineral potential of the Chantrey-Thelon area: GEM-2 Rae project; GSC Open File, v. 8129, p. 12p., doi:10.4095/299386.

Blake, W. Jr., 1963. Notes on the glacial geology, northeastern District of Mackenzie; Geological Surveyof Canada, Paper 63-28, 12 p.

Card, C.D., Bethune, K.M., Davis, W.J., Rayner, N. and Ashton, K.E., 2014. The case for a distinct Taltson orogeny: Evidence from northwest Saskatchewan, Canada. Precambrian Research, v. 255, p. 245-265.

Chacko, T., De, S.K., Creaser, R.A., and Muehlenbachs, K., 2000. Tectonic setting of the Taltson magmatic zone at 1.9-2.0 Ga: A granitoid-based perspective; Canadian Journal of Earth Sciences, v. 37, p. 1597-1609.

Coyle, M., 2017a. Residual total magnetic field, aeromagnetic survey of the Overby-Duggan area, part of NTS 076-I south, Nunavut; GSC Open File, v. 8281, p. 1 sheet.

Coyle, M., 2017b. Residual total magnetic field, aeromagnetic survey of the Overby-Duggan area, part of NTS 076-I north, Nunavut; GSC Open File, v. 8282, p. 1 sheet.

Craven, J.A., Roberts, B., Berman, R.G., and Roots, E., 2015. Preliminary results of a Magnetotelluric survey in the Chantrey-Thelon area; GEM-2 Thelon tectonic zone project; Geological Survey of Canada, Open File 7931, 29pp. doi:10.4095/297426.

Culshaw, N., 1991. Post-collisional oblique convergence along the Thelon tectonic zone, north of the Bathurst Fault, NWT, Canada; Journal of Structural Geology, v. 13, p. 501-516.

Davis, W., Berman, R.G., and MacKinnon, A., 2013. U-Pb Geochronology of Archival Rock Samples from the Queen Maud Block, Thelon Tectonic Zone and Rae Province, Kitikmeot Region, Nunavut, Canada; Geological Survey of Canada, Open File, v. 7409, p. 42p, doi:10.4095/292663.

Davis, W.J., Berman, R.G., Nadeau, L., and Percival, J.A., 2014. U-Pb Zircon Geochronology of a Transect Across the Thelon Tectonic Zone, Queen Maud Region, and Adjacent Rae Craton, Kitikmeot Region, Nunavut, Canada. Geological Survey of Canada, Open File 7652, 38 pp doi:10.4095/295177

Davis, W., Sanborn-Barrie, M., Berman, R.G., and Pehrsson, S., in prep. U-Pb Geochronology of Paleoproterozoic supracrustal belt, Thelon tectonic zone, Nunavut; Canadian Journal of Earth Sciences.

De, S.K., Chacko, T., Creaser, R.A., Muehlenbachs, K., 2000. Geochemical and Nd–Pb–O isotope systematics of granites from the Taltson magmatic zone, NE Alberta: implications for Early Proterozoic tectonics in western Laurentia; Precambrian Research, v. 102, p. 221–249.

Frith, R.A., 1982. Geology, Beechey Lake-Duggan Lake, District of Mackenzie; Geological Survey of Canada, Open File, v. 851 (1:125,000).

Frith, R.A., and van Breemen, O., 1990. U-Pb zircon age from the Himag plutonic suite, Thelon Tectonic Zone, Churchill Structural Province, Northwest Territories; Geological Survey of Canada, Paper, v. 89-2, p. 49-54.

Goff, S.P., Godfrey, J.D., and Holland, J.G., 1986. Petrology and Geochemistry of the Canadian Shield of Northeastern Alberta; Alberta Research Council, Edmonton Bulletin 51, 60 p.

Grotzinger, J. P. and McCormick, D.S., 1988. Flexure of the early Proterozoic lithosphere and the evolution of Kilohigok Basin (1.9 Ga), northwest Canadian Shield, in, New Perspectives in Basin Analysis, K. Kleinspehn and C. Paola (eds.), Springer-Verlag, New York, p. 405-430.

Hildebrand, R. and J. Whalen (2017). The Tectonic Setting and Origin of Cretaceous Batholiths within the North American Cordillera: The Case for Slab Failure Magmatism and Its Significance for Crustal Growth. GSA Special Paper 532: 1-113.

Hoffman, P.F., 1988. United plates of America, the birth of a craton: Early Proterozoic assembly and growth of Laurentia; Annual Reviews of Earth and Planetary Science, v. 16, p. 543– 603.

Hoffman, P., and Hall, L., 1993. Geology, Slave craton and environs, District of Mackenzie, Northwest Territories, Geological Survey of Canada, Open File, Volume 2559 (scale = 1:1000000).

Ielpi, A. and Rainbird, R.H., 2015. Geological framework of the 1.9–1.6 Ga Elu Basin, western Nunavut: representative sedimentology, gamma-ray spectrometry and lithogeochemistry; Canada-Nunavut Geoscience Office, Summary of Activities 2014, p. 89-96.

Ielpi, A. and Rainbird, R.H., 2016. Reappraisal of Precambrian sheet-braided rivers: evidence for 1.9 Ga deep-channelled drainage. Sedimentology, v. 63, p. 1550-1581.

McCurdy, M.W., Berman, R.G., Kerr, D.E., and Vaive, J.E., 2013. Geochemical, Mineralogical and Kimberlite Indicator Mineral Data for Silts, Heavy Mineral Concentrates and Waters, Duggan Lake Area, Nunavut (NTS 76H and 76I South); Geological Survey of Canada, Open File 7471.

McMartin, I., and Berman, R.G., 2015. Till composition across the MacAlpine Moraine System: results from the GEM-2 Thelon tectonic zone project, Nunavut (NTS 76H and 76I); gscof, v. 7910, p. 21 pages, doi:10.4095/296833.

McCurdy, M.W., Berman, R.G., McMartin, I., and Grenier, A., 2016. Geochemical and Mineralogical Data for Stream Silts, Stream Waters and Heavy Mineral Concentrates, Ellice River Area, Nunavut (Parts of NTS 76-H and NTS 76-I); Geological Survey of Canada, Open File 7887.

McCurdy, M., and Mcmartin, I., 2017. Geochemical and Mineralogical Data for Stream Sediment and Proximal Till Sites, Ellice River Area, Nunavut (Parts of NTS 76-H and NTS 76-I); GSC Open File, v. 8302, p. 26, https://doi.org/10.4095/306211.

McMartin, I. and Berman, R.G., 2015. Till composition across the MacAlpine Moraine System: results from the GEM-2 Thelon tectonic zone project, Nunavut (NTS 76-H and NTS 76-I); Geological Survey of Canada, Open File 7910.

Mitchell, R., Berman, R.G., Davis, W.J., and Carr, S.D., 2017. Paleoproterozoic metamorphism of the Thelon Tectonic Zone and margins of the Slave and Rae Archean cratons - insights into the nature and timing of the Slave-Rae Collision; GAC Prog. with Abstr., 40, p. 265.

Percival, J.A., Davis, W.J., and Hamilton, M.A., 2017. U-Pb zircon geochronology and depositional history of the Montresor Group, Rae Province, Nunavut, Canada; Canadian Journal of Earth Sciences, v. 54, p. 512-528.

Percival, J.A., Tschirhart, V., Davis, W.J., Berman, R.G and Ford, A., 2016-YES. Geology, Montresor River area, Nunavut, parts of NTS 66-H and NTS 66-I; Geological Survey of Canada, Canadian Geoscience Map 231.

Percival, J.A. and Tschirhart, V., 2017. Trans-Hudsonian far-field deformation effects in the Rae foreland: an integrated geological-3D magnetic model. Tectonophysics, 699, 82-92.

Roberts, B., Craven, J.A., Berman, R.G., and Roots, E., 2015. Preliminary results of a Magnetotelluric survey in the Chantrey-Thelon area; GEM-2 Thelon tectonic zone project; gscof, v. 7931, p. 29 p., doi:10.4095/292237.

Schultz, M.E.J., Chacko, T., Heaman, L.M., Sandeman, H.A., Simonetti, A., and Creaser, R.A., 2007. Queen Maud block: A newly recognized Paleoproterozoic (2.4-2.5 Ga) terrane in northwest Laurentia; Geology, v. 35, p. 707-710.

St-Onge, D. A. and D. E. Kerr (2013). Reconnaissance surficial geology, Duggan Lake, Nunavut, NTS 76-H. Canadian Geoscience Map 113 (1 sheet).

Taylor, B., Berman, R.G., Whalen, J.B., and Davis, W.J., 2017. Thelon Tectonic Zone: Crustal origins, tectonic setting, and implications for the Thelon-Taltson orogenic belt -- An oxygen isotope perspective; GAC Prog. with Abstr., 40, p. 372.

Tersmette, D., 2012. Geology, geochronology, thermobarometry, and tectonic evolution of the Queen Maud block, Churchill craton, Nunavut, Canada [M.Sc. thesis]; Edmonton, Alberta, University of Alberta, 161 p.

Thompson, P., 1986. Geology, Tinney Hills-Overby Lake (West Half), District of Mackenzie, Northwest Territories; Geological Survey of Canada, Open File 1316 (1:125,000).

Thompson, P.H., 1989. An empirical model for metamorphic evolution of the Archaean Slave Province and adjacent Thelon tectonic zone, north-western Canadian Shield; *in* Daly, J.S., Cliff, R.A., and Yardley, B.W.D. eds.), Evolution of metamorphic belts, Geological Society Special Publication, v. 43, p. 245-263.

Tschirhart, V., Percival, J.A. and Jefferson, C.W., 2015. Geophysical models of the Montresor metasedimentary belt and its environs, central Nunavut, Canada. Canadian Journal of Earth Sciences, v. 52, 833-845.

Van Breemen, O., Thompson , P.H., Hunt, P.A., and Culshaw, N., 1987. U - Pb zircon and monazite geochronology from the northern Thelon Tectonic Zone, District of Mackenzie; Geological Survey of Canada Paper, v. 87-2, p. 81-93.

Whalen, J. B., et al. (2018). Bedrock geochemistry of the central Thelon tectonic zone. Geol. Surv. Canada Open File 8234: 27p.