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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)

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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)

INTRODUCTION

A regional stream sediment, heavy mineral and water geochemical survey was carried out around the Ellice River, southeast of Bathurst Inlet, in the central part of the Kitikmeot administrative region of Nunavut in 2014 (Fig. 1) adjoining an area where a similar survey was completed in 2012 (McCurdy et al., 2013). This report consists of field observations and analytical data from 92 sites for 65 elements in stream silts by a partial method of analysis (aqua regia digestion), 35 elements in stream silts by a near-total method (Instrumental Neutron Activation) and 62 elements in waters. Mineralogical data derived from 36 heavy mineral concentrate samples are included with this report. Analytical results and field observations form part of a national geochemical database (Adcock et al., 2013) used for resource assessment, mineral exploration, geological mapping, and environmental studies. Sample collection, preparation procedures and analytical methods are specified and carefully monitored to ensure consistent and reliable results regardless of the area, the year of collection or the analytical laboratory undertaking the analyses (McCurdy et al., 2014).

Funds for the collection and analysis of stream silts, heavy mineral concentrates and waters were made available under the Geo-mapping for Energy and Minerals (GEM) Program at Natural Resources Canada (NRCan). GEM is delivered at the federal level by NRCan and the Polar Continental Shelf Project (PCSP).

The 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.

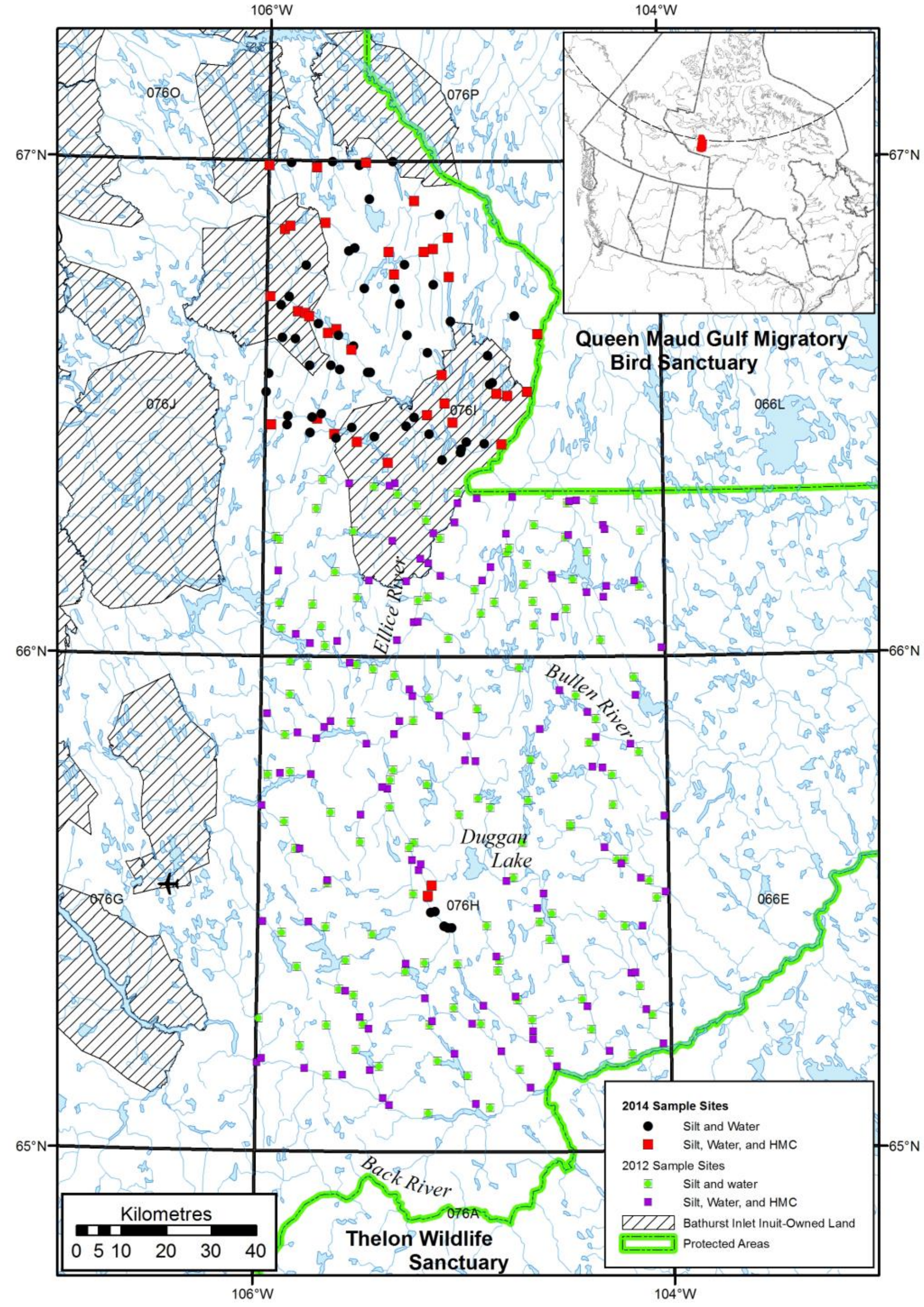

Figure 1 Stream silts, heavy mineral concentrates and water sampling sites in 2012 (McCurdy et al., 2013) and 2014, Duggan Lake – Ellice River area, Nunavut. Sabina Gold and Silver Corporation's Goose Lake Camp (airplane silhouette) is located west of Duggan Lake in NTS map sheet 76G.

REGIONAL SETTING

Location and Physiography

The survey falls within the Garry Lake Lowland ecoregion that extends across dominantly granitic Archean and Paleoproterozoic rocks, forming a broad, level to gently sloping plain that reaches about 300 m above sea level (asl). The mean annual temperature is approximately -10.5°C with a summer mean of 5.5°C and a winter mean of -26.5°C. The mean annual precipitation ranges from 200-275 mm. This ecoregion is classified as having a low arctic climate. The characteristic vegetation is shrub tundra. Dwarf birch, willow, and alder grow on warm, dry sites; poorly drained sites are dominated by willow, sedge, and moss. The lowland is composed of Turbic and Static cryosols developed on discontinuous, thin, sandy moraine with Organic Cryosolic soils on level high-centre peat polygons. Permafrost is continuous with low ice content throughout the ecoregion. This ecoregion provides summer range for caribou and breeding habitat for snow and Canada goose, and other waterfowl. Moose, red and arctic fox, snowshoe hare, arctic ground squirrel, masked shrew, lemming, wolf, lynx, weasel, snowy owl, shorebirds, and other raptors can be observed. Land uses include fishing, trapping, and hunting (Ecoregions Working Group, 1989).

Bedrock geology

The geochemical survey spans the boundary between the eastern Slave craton and the Thelon tectonic zone (TTZ) on the western flank of the Rae craton (Fig. 2). The TTZ comprises a series of pronounced, north- to NNE-striking magnetic anomalies that extend ~500 km from the MacDonald fault to Queen Maud Gulf (Hoffman, 1988). The TTZ has been postulated to represent a continental arc built on the western flank of Rae craton and subsequently intensely deformed during collision with, and indentation of the Slave craton (Hoffman, 1988). Alternative models propose that the TTZ formed in an intracontinental setting either after crustal thinning (Thompson et al., 1986) or within an interior mountain belt far removed from an active plate boundary (Chacko et al., 2000; Schultz et al., 2007).

The eastern Slave craton is dominated by metasedimentary and metavolcanic rocks of the Yellowknife Supergroup intruded by 2.61 – 2.58 Ga granitoids (Frith, 1982; Thompson et al., 1986). Metamorphic grade increased eastward from lower- to upper-amphibolite facies during both Neoarchean and Paleoproterozoic (Thelon orogeny) events. This gradient culminates northeast of the Bathurst fault in 76-I (Fig. 2; region between S2 and S3), where the proportion of supracrustal rocks decreases as deeper crustal levels expose migmatitic granitoid gneisses interspersed with thin metavolcanic belts and screens (Thompson et al., 1986).

The western Rae craton consists largely of Mesoarchean upper amphibolite to granulite facies granitoid rocks of the Queen Maud block (Fig. 2). The easternmost of three belts of ca. 2.01-1.99 Ga plutonic rocks (Davis et al., 2013; Berman et al., 2015c) separates a Mesoarchean crustal domain (Duggan Lake domain; Fig. 2) that appears to have been part of the Queen Maud block at least until ca. 2.3 Ga (Berman et al., 2015c). In several places, plutonic rocks in the eastern plutonic belt are associated with magnetite-bearing diatexites (Berman et al., 2015a, b) which may be the source rocks of a significant Au anomaly in stream sediments (McCurdy et al., 2013).

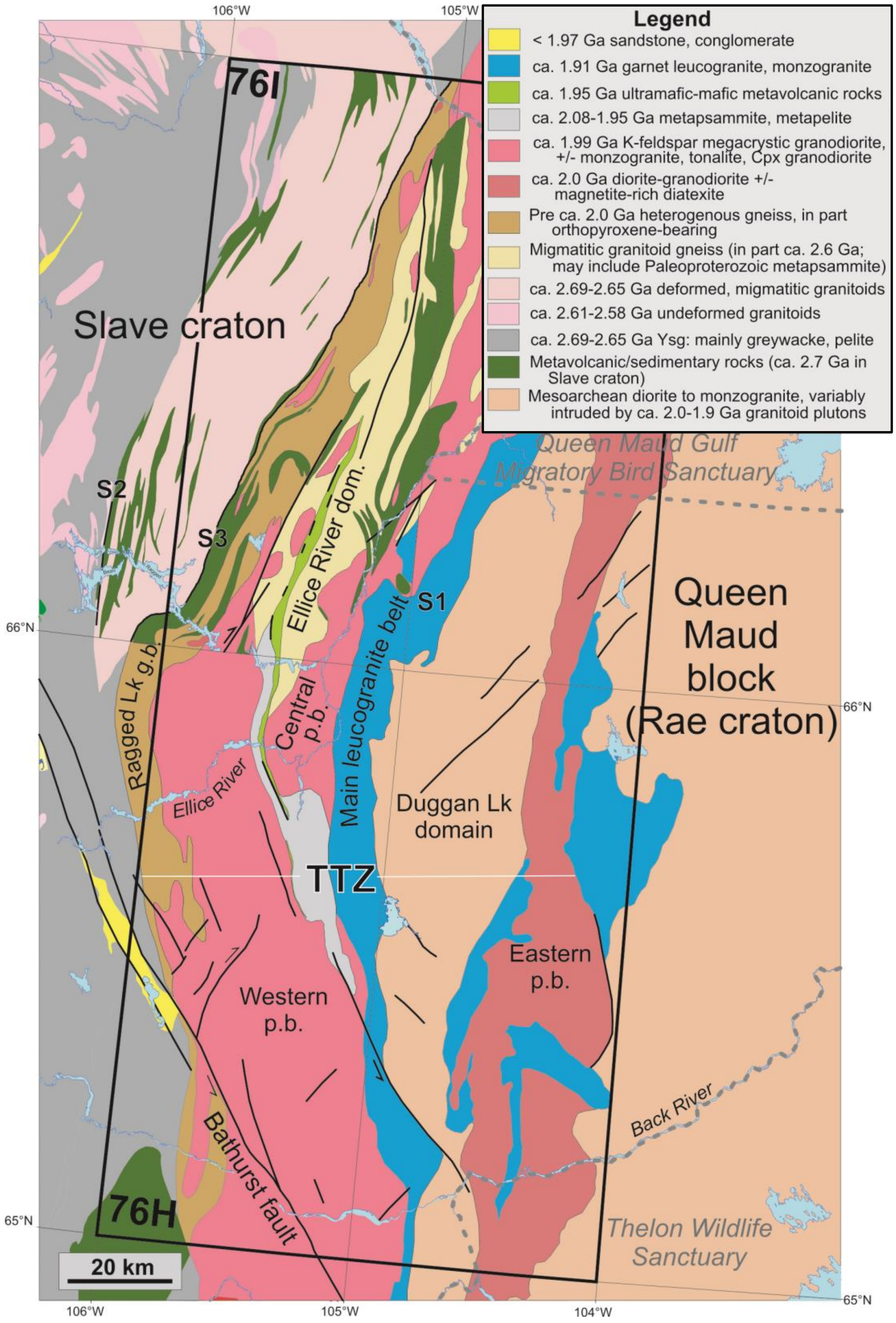

Figure 2 Simplified bedrock compilation map of the study area (NTS 76-H and 76-I), incorporating modifications of Frith (1982) and Thompson et al. (1986). Dashed grey lines are sanctuary boundaries. S1-S3 are alternative suture locations; Ysg = Yellowknife Supergroup; p.b. = plutonic belt; g.b. = gneiss belt; dom = domain.

The extent of Rae and Slave craton within the TTZ has not been well established. The pronounced, >100 km long magnetic low on the west side of the Duggan Lake domain (Fig. 2) largely comprises variably strained garnet leucogranite that potentially formed from melting of Rae margin sediments (Berman et al., 2015b). This would put the edge of the Rae craton (S1, Fig. 2) ~ 60 km east of the boundary based on the distribution of Yellowknife Group supracrustal rocks (S2, Fig. 2; Thompson, 1992) and ~ 40 km east of a Slave-Rae suture (Culshaw, 1991; Hoffman and Hall, 1993) corresponding to the western limit of recognized Paleoproterozoic plutonic rocks (S3; Thompson et al., 1986; Fig. 2). The upper amphibolite to granulite facies region between alternate suture locations S1 and S3 is marked by the ca. 2.01-1.99 Ga western and central plutonic belts that are intrusive into high-grade gneisses at least as old as 2.03 Ga (Davis et al., 2014; Berman et al., 2015c). The pedigree of the crustal domain (Ellice River domain; Fig. 2) between these two belts is presently unknown, but a ca. 2.59 Ga age of monzogranite gneiss (Davis et al., 2014) suggests affinity with the Slave craton. The Ellice River domain hosts a 1.95 Ga ultramafic to mafic metavolcanic belt (Davis, unpublished data; Berman et al., 2015b) which is spatially associated with pronounced geochemical anomalies (e.g. Ag, Pb, Cu, Zn, Ni, U; McCurdy et al., 2013), and interstratified with well foliated Paleoproterozoic psammitic rocks at anomalously low metamorphic grade (lower amphibolite facies) compared to surrounding rocks.

Timing constraints on the structural evolution of the region are not precisely established. In the eastern Slave craton Neoarchean NW-striking, high-strain foliations are rotated into concordance with the north to north-northeast strike of steeply dipping foliations and high-strain zones within the TTZ. Northwest-vergent thrusting of granulite-facies gneiss onto the Slave craton (S2, Fig. 2) is considered to have accompanied thin-skinned shortening of Goulbourn Group rocks in the eastern Slave craton (Culshaw, 1991). Subsequent transpression was associated with southeast-vergent thrusting and dominantly dextral kinematics, except for ductile deformation in the vicinity of the Bathurst fault (Culshaw, 1991). Brittle deformation on this fault accommodated southward extrusion of crustal blocks during indentation of the Slave craton.

Quaternary geology

The study area is covered by variable thicknesses of Quaternary deposits. McMartin and Berman (2015) provide an overview of the Quaternary geology of the study area, which is summarized below. During the last Wisconsin glaciation, the study area was affected by Keewatin Sector Ice of the Laurentide Ice Sheet (e.g. Dyke and Prest, 1987). Consistent striae, glacially-moulded bedrock surfaces and streamlined landforms indicate regional ice flow towards the north to northwest into Queen Maud Gulf and Bathurst Inlet and require that a major outflow center existed southeast of the study area, presumably associated to various positions of the Keewatin Ice Divide (KID). The KID was active and dynamic throughout the last glaciation until final deglaciation and had a major influence on the sediment distribution, landform patterns and glacial dispersal trains of mainland Nunavut west of Hudson Bay (e.g. Aylsworth and Shilts, 1989; McMartin and Henderson, 2004). During deglaciation, ice flow shifted to the northwest as recorded by cross-cutting fine striae and sub-parallel streamlined landforms, and, as the ice front receded progressively to major ice recessional positions marked by the MacAlpine Moraine System (MMS; Fig. 3), the flow shifted further to the west-northwest. Concurrent marine inundation in the lowlands occurred during deglaciation and extended to the upper reaches of Ellice River between 205 m and 210 m asl (Fig. 3).

Reconnaissance-scale mapping largely based on air photo interpretation (Dredge and Kerr, 2013; St-Onge and Kerr, 2103), as well as recent GEM field observations (McMartin et al., 2013; McMartin and Berman, 2015) reveal distinct glacial landscapes on either side of Ellice River, as well as below and above the post-glacial marine limit (Fig. 3). East of Ellice River, much of the lowland areas below the post-glacial marine limit are covered by till veneers interspersed by areas of bedrock outcrops, and silty marine deposits forming extensive plains between drumlins. Above the post-glacial marine limit, widespread till veneer and streamlined till blankets are more common. In the southeast part of NTS 76-I map sheet, eskers lead up to a continuous series of morainic deposits that form the most northern splay of the MacAlpine Moraine System. Broad areas of coalescing glaciofluvial fans and outwash plains of sand and gravel deposits are aligned in front (north) of the morainic ridges (Fig. 4a). The area west of the river is dominated by glacially scoured bedrock containing shallow glacially scoured lake basins (Fig. 4b) and areas of thin till in lowlands (Fig. 4c). The Duggan Lake map sheet (NTS 76-H) to the south is dominantly covered by thick till deposits, often streamlined or hummocky. Northwestward trending subglacial meltwater corridors containing eskers (Fig. 4d), modified till, boulder lags, and local zones of scoured bedrock cross the entire area.

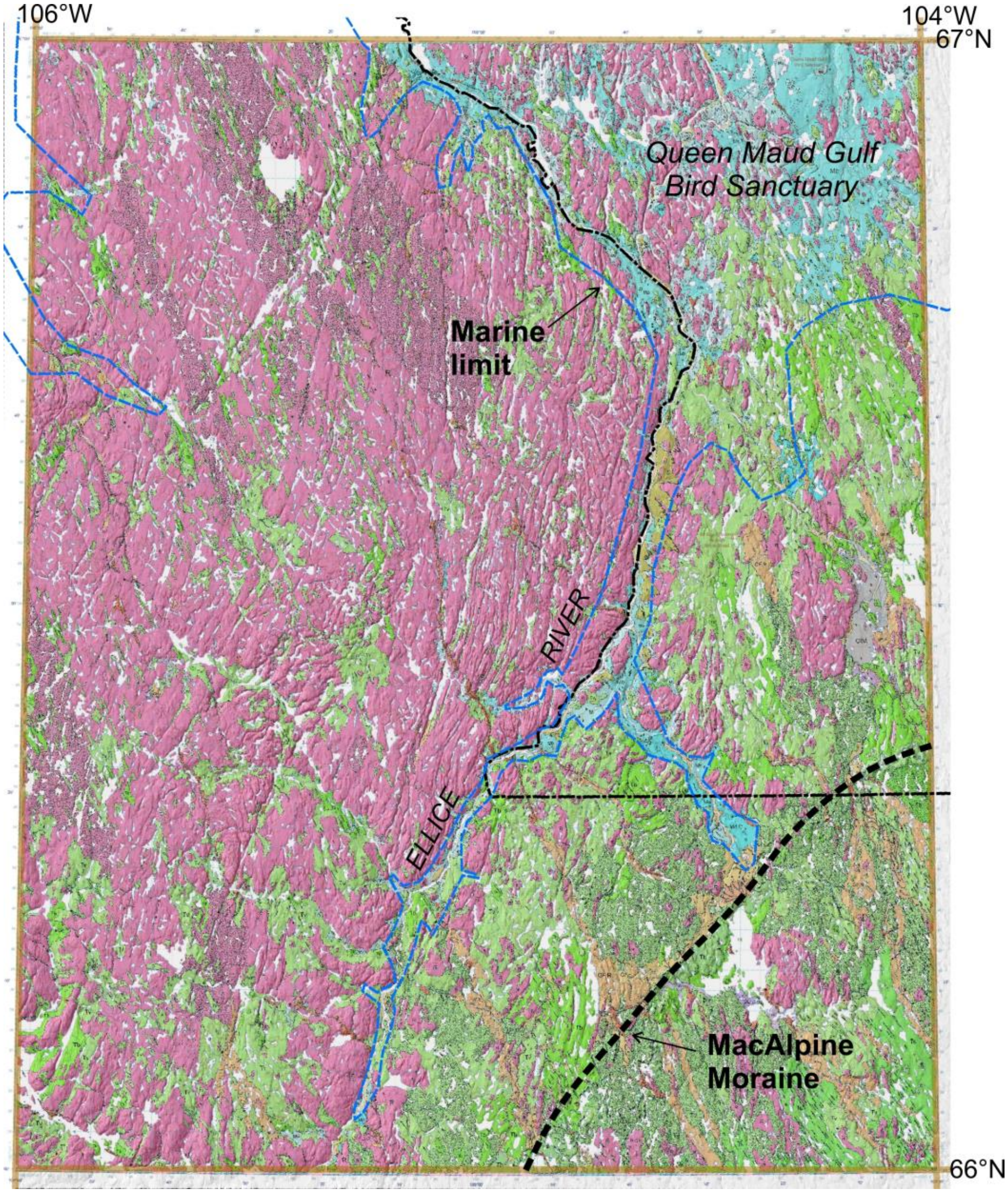

Figure 3 Surficial geology map of the Overby map sheet area (Dredge and Kerr, 2013) over digital elevation model. Pink colors represent bedrock, green = till, orange = glaciofluvial deposits, blue = marine deposits and grey = organic deposits. Complete legend is given in Dredge and Kerr (2013). Location of marine limit and MacAlpine Moraine is modified from Prest et al. (1968)

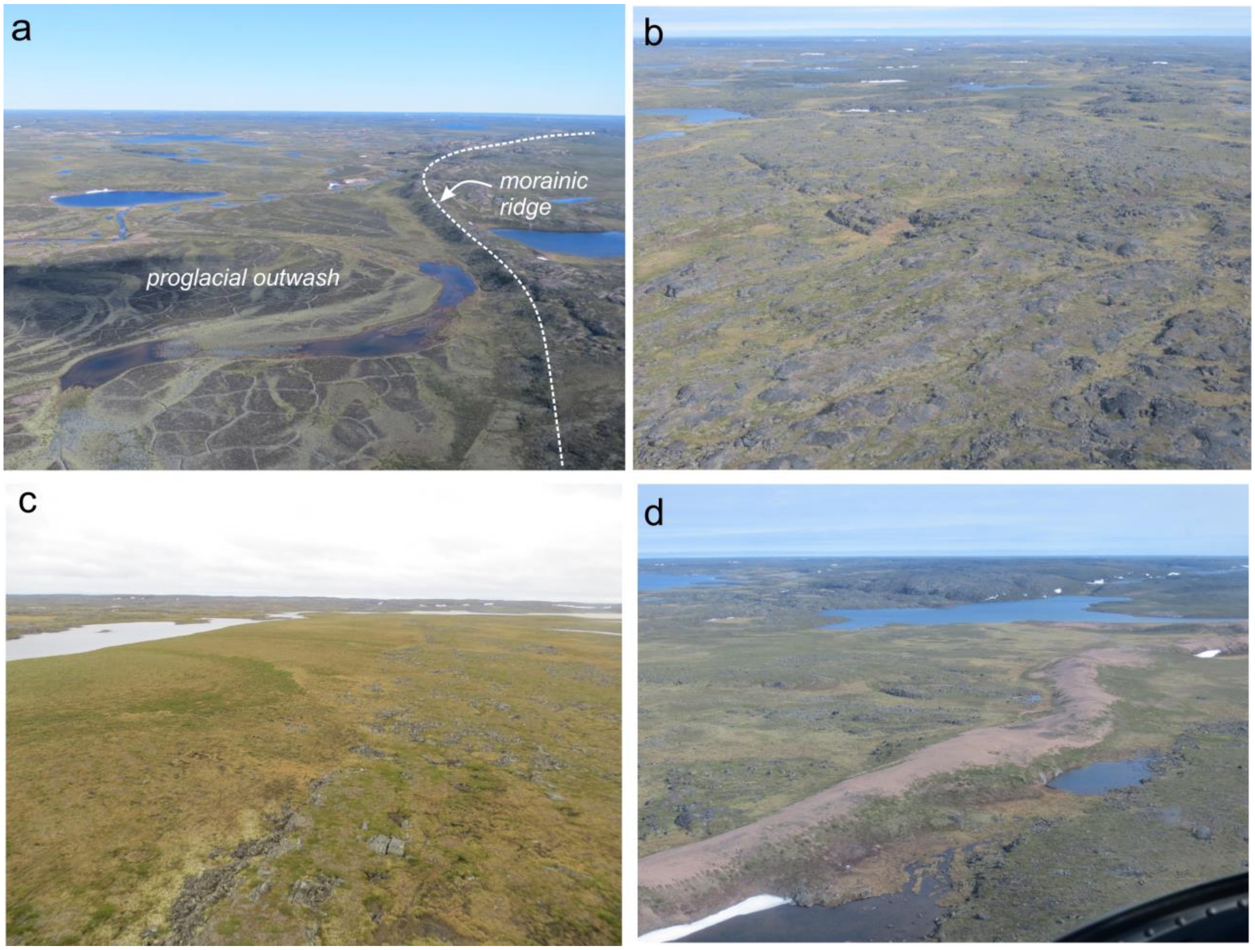

Figure 4 Photographs of a) Proglacial outwash plain of sand and gravel deposits in front of a major morainic ridge, part of the MacAlpine Moraine System; b) glacially-scoured bedrock outcrops overlain by thin bouldery till west of Ellice River; c) grassy thin till in low areas west of Ellice River; d) esker ridge bordered by scoured thin till and boulder-covered bedrock in the southwest part of the NTS 76-I map area.

SAMPLE COLLECTION

Stream Sediments (Silts)

At each site, a synthetic cloth bag (18 cm x 32 cm) was two-thirds filled with silt or fine sand collected from the active stream channel (Fig. 5). The silt sample was collected after the water sample(s) and before the bulk sediment sample. Commonly, the sampler collected silt by hand from various points in the active channel while moving upstream, over a distance of 5 to 15 m. If the stream channel was found to consist mainly of clay, coarse material or organic sediment from which suitable sample material is scarce or absent, moss mat from the stream channel, which commonly contains trapped silt, may have been added to the sample. A pair of silt samples, at a site picked at the discretion of the sampler (generally based on ease of collection) and assigned sequential sample numbers, was collected at one site within each sequence of 20 samples. The first sample of the pair is referred to as the ‘First Field Duplicate) in the appendices and the second is referred to as the ‘Second Field Duplicate’. Routine (non-duplicate) field samples are referred to as ‘Routine’ samples in the appendices. Field observations were digitally recorded on a tablet using a standard form developed jointly by the GSC and the Northwest Territories Geological Survey.

Figure 5 Pre-labelled synthetic cloth bags and high-density polyethylene (HDPE) bottles (inset) are used to collect samples of stream silts and stream waters. A bulk sample, for the recovery of heavy minerals, is collected by wet-sieving coarse-grained stream sediment using a US Sieve Series 12-mesh (1.68 mm) sieve in a plastic pail lined with a polyethylene sample bag. The gold pan is used for adding water for wet sieving, not for heavy mineral concentrate panning. A sample composed of granules and pebbles, for pebble counts, is collected at bulk sample sites by sieving >12 mesh material through a US Sieve Series 2-mesh (10 mm) sieve and collecting the <10 mm material in a labelled synthetic cloth bag (not shown). (Photos: Noble Exploration Services).

Stream Waters

At each site the 6 variables listed in Table 1 were measured in stream waters using a YSI ('Yellow Springs Instrument Company') Professional Plus handheld multi-parameter meter.

	Range	Accuracy	Resolution	Units (Recorded)
Dissolved Oxygen (%)	0-500%	0 to 200% (±2% of reading or 2% air saturation, whichever is greater)	1% or 0.1% air saturation	%
Temperature	-5 to 70°C	±0.2°C	0.1°C	°C
Conductivity	0 to 200 mS/cm	±0.5% of reading or 0.001 mS/cm, whichever is greater	0 to 500 µS/cm=0.001; 501 to 5000 µS/cm=0.01	µS
pH	0 to 14 units	±0.2 units	0.01 units	pH units
Oxidation-Reduction Potential (ORP)	-1999 to +1999 mV	±20 mV in redox standards	0.1 mV	mV
Air Pressure	375 to 825 mmHg	±1.5 mmHg from 0 to 50°C	0.1 mmHg	kPa

Table 1 Specifications for YSI Professional Plus hand-held multi-parameter meter (for parameters measured in-situ).

Waters were sampled in mid-channel, from flowing water where possible. Three water samples were collected at each site. After rinsing two 60-ml HDPE bottles with filtered stream water, water was collected for a filtered, acidified sample ('FA' in appendices) and a filtered, un-acidified sample ('FU' in appendices) by drawing stream water into a 60 ml plastic syringe and filtering into each HDPE bottle (Fig. 5, inset) through a 0.45 µm disposable filter unit. A third unfiltered sample was collected for an unfiltered, acidified sample ('UA' in appendices). In addition to single sets of three samples from 'Routine' sites, at sites picked by the sample crew for duplicate silt samples, two sets of water samples were collected; 'First' and 'Second' field duplicate.

Heavy Mineral Concentrates

Ideal sites for the collection of bulk stream sediments for the recovery of heavy minerals fraction are located at the upstream ends of mid-channel boulder bars and behind mid-stream boulders (Prior et al., 2009). Material was collected by shovel from one (preferred) or more holes dug in the stream bed (commonly to depths of a few 10's of centimetres. A 22.7 litre (5-gallon) plastic pail was lined with a heavy-duty (4-Mil) polyethylene bag measuring 46x61 cm (18x24 inches). Material was wet-sieved into the pail through a U.S. Sieve Series 12-mesh (1.68 mm) stainless steel sieve until a sample weight of 10-15 kg was attained. The bag lining the pail, labelled with the sample number, was taped shut with black plastic (electrical) tape and placed into a second bag, also labelled with the sample number, and taped.

SAMPLE PREPARATION

Stream Sediments (Silts)

The synthetic cloth bags containing the silt samples were placed into plastic bags, taped with electrical tape and shipped directly to the GSC laboratories in Ottawa, where they were unpacked and air-dried at temperatures below 40ºC. After drying, samples were disaggregated and sieved through a minus 80-mesh (177 µm) screen (Girard et al, 2004). An aliquot sample of a Certified Reference Material (CRM) and an analytical duplicate sample were inserted into each block of twenty samples. An analytical duplicate sample is a split from a Routine Sample or a Field Duplicate after the samples have been prepared for analysis but before analysis, and analyzed using the same methods as the routine samples.

Stream Waters

Water samples were kept cool and away from light until shipment to GSC laboratories in Ottawa. Upon arriving at the laboratory, samples were acidified with 0.5 ml 8M HNO_3. Samples to monitor quality assurance (acid and sample blanks) were prepared and added to each batch of samples in the field. Certified reference standards were inserted into each block of 20 water samples in the lab. Analytical duplicate water samples were included in the sample suite.

Heavy Mineral Concentrates

Samples were processed at Overburden Drilling Management Limited, Ottawa, Ontario. Before processing, a 500-g split for a character sample was collected from each sample and archived. The bulk sediment samples were then progressively reduced by a range of laboratory procedures to concentrate heavy minerals. Initially a low-grade shaking table concentrate was prepared from each of the samples. Gold grains, sulphides and other mineral grains were recovered at this stage by panning and were counted: gold grains were measured and classified as to degree of wear (reflecting distance of transport). The concentrate from tabling was separated in methylene iodide diluted with acetone to S.G. 3.2 to recover heavy minerals including Cr-diopside and olivine. Magnetite was removed after the heavy liquid separation and the remaining concentrate cleaned with oxalic acid to remove limonite stains. The dried concentrate was sieved into several size fractions, (<0.25 mm, 0.25 to <0.5 mm, 0.5 mm to <1.0 mm, = 1.0 mm to 2.0 mm). The <0.25 mm fraction was archived and the 0.25 to 0.50 mm fraction was sorted with a Carpco® drum magnetic separator into strongly (0.6 amp), moderately (0.8 amp), weakly (1.0 amp) and non-paramagnetic (>1.0 amp) fractions. A flow sheet outlining the processing procedures can be seen in Figure 6.

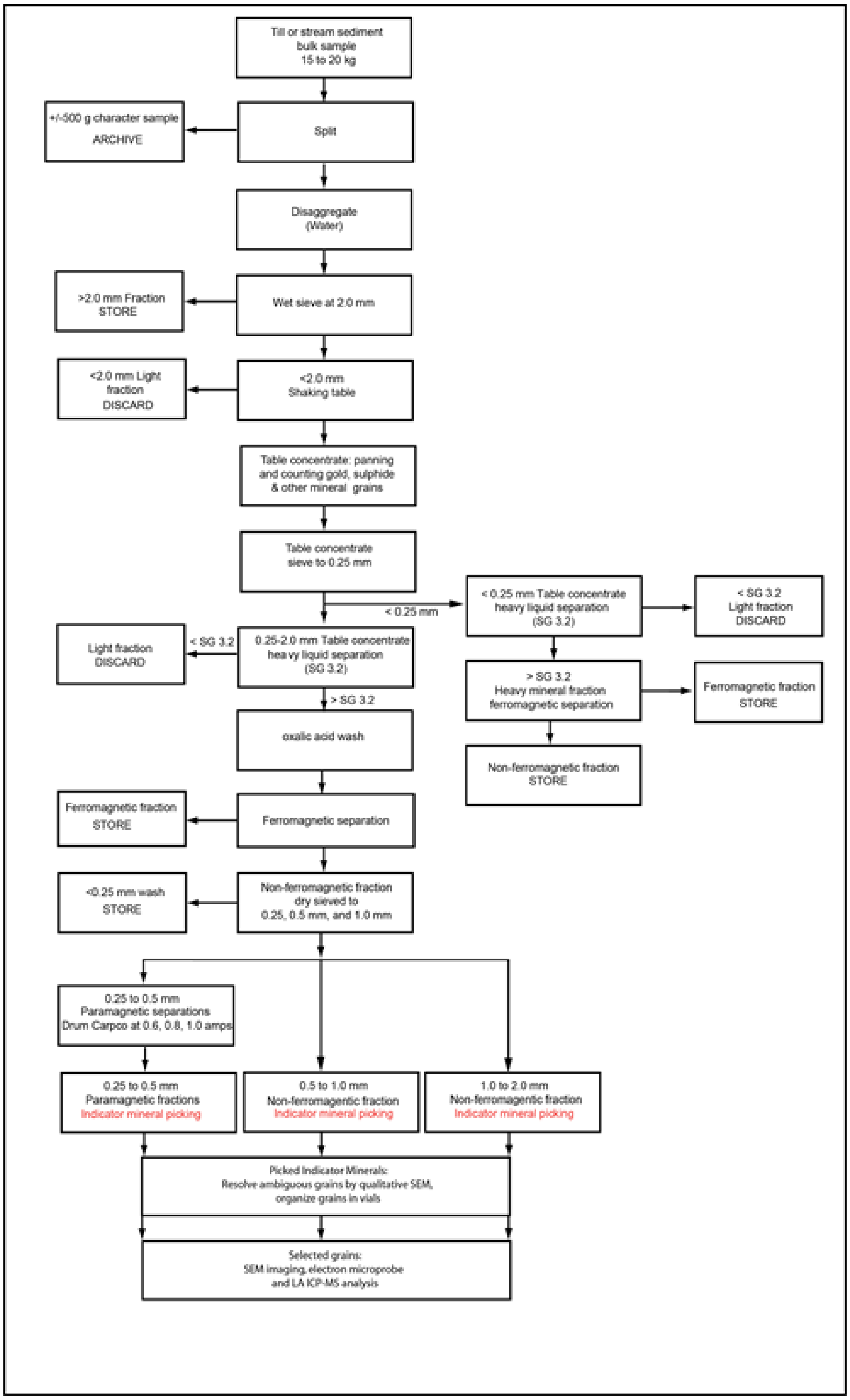

Figure 6 Flow sheet for procedures used at Overburden Drilling Management used to process bulk stream sediment samples for heavy mineral identification

ANALYTICAL PROCEDURES

Stream Sediments (Silts)

Instrumental Neutron Activation Analysis (INAA)

Samples were analysed at Maxxam Analytics, Mississauga, Ontario. Weighed and encapsulated samples were packaged for irradiation along with certified reference materials, field and analytical duplicates. Samples and quality control insertions were irradiated together with neutron flux monitors in a two-megawatt pool type reactor. After a seven-day decay period, samples were measured with a high-resolution germanium detector. Typical counting times were 500 seconds. Elements determined by INA analysis are listed below in Table 2.

Variable	Detection Limit	Units of Measurement	Variable	Detection Limit	Units of Measurement
Ag	2	ppm[1]	**Ni**	10	ppm
As	0.5	ppm	**Rb**	5	ppm
Au	2	ppb[2]	**Sb**	0.1	ppm
Ba	50	ppm	**Sc**	0.2	ppm
Br	0.5	ppm	**Se**	5	ppm
Cd	5	ppm	**Sm**	0.1	ppm
Ce	5	ppm	**Sn**	100	ppm
Co	5	ppm	**Ta**	0.5	ppm
Cr	20	ppm	**Tb**	0.5	ppm
Cs	0.5	ppm	**Te**	10	ppm
Eu	1	ppm	**Th**	0.2	ppm
Fe	0.2	pct[3]	**Ti**	500	ppm
Hf	1	ppm	**U**	0.2	ppm
Ir	50	ppb	**W**	1	ppm
La	2	ppm	**Weight**	0.01	g[4]
Lu	0.2	ppm	**Yb**	2	ppm
Mo	1	ppm	**Zn**	100	ppm
Na	0.02	pct	**Zr**	200	ppm

[1] parts per million
[2] parts per billion
[3] percent
[4] grams

Table 2 Elements determined by INA analysis of stream silt samples.

Inductively Coupled Plasma Mass Spectrometry (ICP-MS) and Other Analyses

Samples were analysed at Bureau Veritas Commodities Canada Limited, Vancouver, using a proprietary ‘AQ250 – Ultratrace by ICP Mass Spec.’ package with the optional extended packages for rare earth elements (+REE) and precious metals Pt and Pd (+PGM). For the determination of 65 elements listed in Table 3, a 0.5 gram sample was leached with a modified aqua regia solution ($HCl:HNO_3$, 1:1). The sample solution was analysed by inductively coupled plasma emission spectroscopy.

Loss-on-ignition was determined at Bureau Veritas using a one-gram sample. Each sample, in a Leco® crucible, was placed into a 100° C muffle furnace and brought up to 500° C for one hour. The oven was then cooled to 100º C and the crucibles transferred to a desiccator followed by cooling to room temperature. The crucibles were re-weighed to determine the loss-on-ignition.

F was determined with the GC840 procedure (‘Trace Level F by specific ion electrode’) using a 0.2 g sample.

Element	Detection Limit	Units of Measurement	Element	Detection Limit	Units of Measurement
Ag	2	ppb	**Mo**	0.01	ppm
Al	0.01	pct	**Na**	0.001	pct
As	0.1	ppm	**Nb**	0.02	ppm
Au	0.2	ppb	**Nd**	0.02	ppm
B	20	ppm	**Ni**	0.1	ppm
Ba	0.5	ppm	**P**	0.001	pct
Be	0.1	ppm	**Pb**	0.01	ppm
Bi	0.02	ppm	**Pd**	10	ppb
Ca	0.01	pct	**Pt**	2	ppb
Cd	0.01	ppm	**Pr**	0.02	ppm
Ce	0.1	ppm	**Rb**	0.1	ppm
Co	0.1	ppm	**Re**	1	ppb
Cr	0.5	ppm	**S**	0.02	pct
Cs	0.02	ppm	**Sb**	0.02	ppm
Cu	0.01	ppm	**Sc**	0.1	ppm
Dy	0.02	ppm	**Se**	0.1	ppm
Er	0.02	ppm	**Sm**	0.02	ppm
Eu	0.02	ppm	**Sn**	0.1	ppm
F (ISE)	10	ppm	**Sr**	0.5	ppm
Fe	0.01	pct	**Ta**	0.05	ppm
Ga	0.1	ppm	**Tb**	0.02	ppm
Gd	0.02	ppm	**Te**	0.02	ppm
Ge	0.1	ppm	**Th**	0.1	ppm
Hf	0.02	ppm	**Ti**	0.001	pct
Hg	5	ppb	**Tl**	0.02	ppm
Ho	0.02	ppm	**Tm**	0.02	ppm
In	0.02	ppm	**U**	0.1	ppm
K	0.01	pct	**V**	2	ppm
La	0.5	ppm	**W**	0.1	ppm
Li	0.1	ppm	**Y**	0.01	ppm
LOI (GRAV)	0.1	pct	**Yb**	0.02	ppm
Lu	0.02	ppm	**Zn**	0.1	ppm
Mg	0.01	pct	**Zr**	0.1	ppm
Mn	1	ppm			

Table 3 Variables in stream silts determined by Inductively Coupled Plasma –Mass Spectroscopy (ICP-MS). Analytical methods other than ICP-MS are in brackets. ‘ISE’ is an abbreviation of ‘ion specific electrode; ’GRAV’ is an abbreviation of ‘Gravimetric’.

Analytical results are presented in an Excel® workbook included with this report: **Appendix 1 GSC OF 7887 FIELD OBSERVATIONS & SILT DATA.xlsx**. The two worksheets in this file are described below in Table 4.

Worksheet	Contents
Field Data	Site-specific field observations including geographic coordinates
Silt Analytical Data	Analytical data, including ICP-MS and INAA data, for silt samples
Abbreviations	Abbreviations used in 'Sample Media' column in 'Field Data' worksheet

Table 4 Worksheets in Appendix 1 (silt data) with a brief description of the contents of each worksheet.

Stream Waters

Trace and Major Elements

Filtered and acidified (FA) and unfiltered, un-acidified (UA) stream water samples were analyzed for trace metal and major elements at GSC laboratories in Ottawa. A complete list of elements and stated detection limits are given in Table 5.

Trace metal analysis was performed using a Thermo X Series 2 quadrupole inductively coupled plasma mass spectrometer (ICP-MS) with Xt cones, PlasmaScreen fitted, standard concentric nebulizer and Peltier cooled conical impact bead spray chamber (3°C) using Rh and Ir as internal standards. Most isotopes measured and corrections for spectral interferences are detailed in Hall et al. (1995, 1996). Data for hafnium and zirconium are not published because these elements are not sufficiently stabilized in waters by the addition of nitric acid. Data for indium, selenium, silver, tantalum and thulium are not published because of inadequate detection limits and/or precision.

Element	Detection Limit	Units of Measurement	Analytical Method	Element	Detection Limit	Units of Measurement	Analytical Method
Al	2	ppb	ICP-MS	**Mn**	0.1	ppb	ICP-MS
As	0.1	ppb	ICP-MS	**Mo**	0.05	ppb	ICP-MS
B	0.5	ppb	ICP-ES	**Na**	0.05	ppm	ICP-ES
Ba	0.2	ppb	ICP-MS	**Nb**	0.01	ppb	ICP-MS
Be	0.005	ppb	ICP-MS	**Nd**	0.005	ppb	ICP-MS
Bi	0.02	ppb	ICP-MS	**Ni**	0.2	ppb	ICP-MS
Br	0.05	ppm	ICP-ES	**P**	0.05	ppm	ICP-ES
Ca	0.02	ppm	ICP-ES	**Pb**	0.01	ppb	ICP-MS
Cd	0.02	ppb	ICP-MS	**Pr**	0.005	ppb	ICP-MS
Ce	0.01	ppb	ICP-MS	**Rb**	0.05	ppb	ICP-MS
Cl	0.1	ppm	ICP-ES	**Re**	0.005	ppb	ICP-MS
Co	0.05	ppb	ICP-MS	**S**	0.05	ppm	ICP-ES
Cr	0.1	ppb	ICP-ES	**Sb**	0.01	ppb	ICP-MS
Cs	0.01	ppb	ICP-MS	**Si**	0.02	ppm	ICP-ES
Cu	0.1	ppb	ICP-MS	**Sm**	0.005	ppb	ICP-MS
Dy	0.005	ppb	ICP-MS	**Sn**	0.01	ppb	ICP-MS
Er	0.005	ppb	ICP-MS	**Sr**	0.5	ppb	ICP-MS
Eu	0.005	ppb	ICP-MS	**Tb**	0.005	ppb	ICP-MS
Fe	0.005	ppm	ICP-ES	**Te**	0.02	ppb	ICP-MS

Element	Detection Limit	Units of Measurement	Analytical Method	Element	Detection Limit	Units of Measurement	Analytical Method
Ga	0.01	ppb	ICP-MS	**Th**	0.02	ppb	ICP-MS
Gd	0.005	ppb	ICP-ES	**Ti**	0.5	ppb	ICP-MS
Ge	0.02	ppb	ICP-MS	**Tl**	0.005	ppb	ICP-MS
Ho	0.005	ppb	ICP-MS	**U**	0.005	ppb	ICP-MS
K	0.05	ppm	ICP-ES	**V**	0.1	ppb	ICP-MS
La	0.1	ppb	ICP-MS	**W**	0.02	ppb	ICP-MS
Li	0.02	ppb	ICP-MS	**Y**	0.01	ppb	ICP-MS
Lu	0.005	ppb	ICP-MS	**Yb**	0.005	ppb	ICP-MS
Mg	0.005	ppm	ICP-ES	**Zn**	0.5	ppb	ICP-MS

Table 5 Major and trace elements determined in stream waters.

Major element analysis was performed using an axial Spectro Arcos, inductively coupled plasma optical emission spectrometer (ICP-ES) using a 1% $CsNO_3$ buffer (1:5 ratio) as a matrix modifier with a Burgener Teflon Mira Mist Nebulizer (uptake rate 1 mL/min) and a cyclonic spray chamber. The argon flow-rates are: Coolant 14.5 L/min-1, Auxiliary 0.9 L/min-1, and Nebulizer 0.8 L/min-1. The RF power is 1500 watts. Inter-element correction factors were applied as required to correct for various spectral interferences. Data for scandium are not published because of inadequate detection limits and/or precision.

Anions

Anion analysis was done at GSC laboratories in Ottawa by a Dionex ICS 2100 Ion Chromatograph fitted with an AS-AP auto-sampler. Bromide, chloride, fluoride, nitrate, phosphate and sulphate were separated using a three-step gradient elution (12 to 52 mm potassium hydroxide eluant) with an AS-18 column. The anion concentrations were quantified using conductivity in comparison with known concentration calibration standards and Dionex Chromeleon software. Variables, lower detection limits, units of measurement and methods are listed in Table 6 for anions, dissolved organic carbon and alkalinity.

Anions	Lower Detection Limit	Units of Measurement	Analytical Method
Br	0.02	ppm	Ion Chromatography (ICS-2100)
Cl	0.01	ppm	Ion Chromatography (ICS-2100)
F	0.01	ppm	Ion Chromatography (ICS-2100)
NO_3	0.02	ppm	Ion Chromatography (ICS-2100)
PO_4	0.02	ppm	Ion Chromatography (ICS-2100)
SO_4	0.02	ppm	Ion Chromatography (ICS-2100)
DOC	1	ppm	Combustion
Alkalinity	1	ppm	Titration

Table 6 Methods used to detect anions, Total Organic Carbon (TOC) and alkalinity in filtered, un-acidified waters (FU).

Dissolved organic carbon

Total Organic Carbon (TOC) analysis was completed at GSC laboratories in Ottawa with a Shimadzu TOC-L analyser using a 680°C combustion catalytic oxidation method combined with NDIR detection. This is reported as DOC on a 0.45-µm Durapore®-filtered (FU) sample. In environmental and water samples where the inorganic carbon (IC) concentration may be high, the (total or dissolved) organic carbon is measured by a non-purgeable organic carbon (NPOC) method. This method is the same as the TOC combustion measurement method with the addition of acidification and sparging to remove the inorganic carbon (IC) in the sample prior to TOC analysis.

Alkalinity

Alkalinity measurements were done at GSC laboratories in Ottawa using a Man-Tech PC-TitrateTM system with a Titra-SipTM Module on the FU samples. The total alkalinity was measured by potentiometric titration with 0.02N sulphuric acid. The software determined the volume of acid required to reach the bicarbonate equivalence point. Alkalinity results are reported as equivalents of $CaCO_3$ in ppm.

Analytical results are presented in an Excel® workbook included with this report: **Appendix 2 GSC OF 7887 WATER DATA.xlsx**. There are 4 worksheets in this file described below in Table 7.

Worksheet	Contents
Field Observations	Data collected on-site with YSI-Pro plus multi-parameter meter
FA Data	Concentrations of 56 trace and major elements in filtered, acidified water samples by ICP-ES and ICP-MS
UA Data	Concentrations of 56 trace and major elements in unfiltered, acidified water samples by ICP-ES and ICP-MS
FU Data	Concentrations of selected anions (ion chromatography), alkalinity (titration) and DOC (combustion) in filtered, un-acidified water samples

Table 7 Worksheets in Appendix 2 (water data) with a brief description of the contents of each worksheet.

Heavy Mineral Concentrates

Gold and sulphide mineral grains, potential oxide and silicate indicators of massive sulphide deposits and kimberlite indicator minerals (KIMs) were visually identified at Overburden Drilling Management Limited, Ottawa, counted and hand-picked from each of three non-ferromagnetic size fractions (0.25-0.5 mm, 0.5-1.0 mm, 1.0-2.0 mm). Following identification and removal of the indicator minerals listed above, 100 grains were randomly identified in a 0.2 g split (~500 grains) from each 0.25-0.5 mm fraction. The 0.25-0.5 mm, 0.5-1.0 mm and 1.0-2.0 mm fractions (minus indicator minerals) were archived. See Figure 6 for a flow chart outlining the above procedures.

Heavy mineral concentrate data are presented in an Excel® workbook included with this report: **Appendix 3 GSC OF 7887 HMC DATA.xlsx**. There are 7 data worksheets in this file for each category listed below in Table 8 and a separate worksheet listing abbreviations. Data worksheets were modified versions of worksheets received from Overburden Drilling Management.

Worksheet	Contents
Tabling Data	Description of original bulk sample as received at laboratory
Gold Summary	Gold grain data
KIM Data	Kimberlite Indicator Mineral (KIM) data
MMSIM	Magmatic or Metamorphosed Massive Sulphide Indicator Minerals (MMSIM) data
<0.25 mm HM Fraction	Components (‘Total’, ‘Light’, ‘Total (>3.2 SG)’, ‘Mag(netic)’ and Non Mag(netic) fractions (g) of the <0.25 mm Table Concentrate
Non-ferromagnetic HM Fraction	Weight of non-ferromagnetic mineral fraction in the 0.25 to 0.5 mm heavy mineral concentrate
100 Grain Count	Visual identification data for common minerals in representative fraction of heavy mineral concentrate
Abbreviations	Abbreviations used by Overburden Drilling Management Ltd. in published reports

Table 8 Worksheets in Appendix 3 (heavy mineral concentrate data) with a brief description of contents of each worksheet.

QUALITY CONTROL FOR GEOCHEMICAL RESULTS (SILT SAMPLES)

Reliability (accuracy and precision) of analytical data returned from commercial laboratories was determined by incorporating field duplicates (FD pairs) within the sampling protocol, and including analytical (‘blind’) duplicates (AD), control reference materials (CRMs) in the sample suite submitted to the labs. Analytical data for CRMs, analytical and field duplicates are included with this report in **Appendix 4 GSC OF 7887 QUALITY CONTROL.xlsx.**

Data quality was estimated using control reference materials to evaluate accuracy and analytical duplicate samples to evaluate analytical precision. Field duplicate data were used to carry out an Analysis of Variance (ANOVA) in order to compare the estimated sampling and analytical variability for mapping purposes.

Tables 10 through 15 in Appendix 4 (Quality Control) can be used to estimate the quality of analysis for elements listed in Tables 2 and 3 above. Elements are grouped based on their position in the Periodic Table. Data used for calculations are included in separate worksheets (Table 9).

Worksheet	Contents
Accuracy (Tables 10, 11, 12, 13)	Compares accepted values for four control reference standards with results from analysis of Duggan Lake-Ellice River area samples
AD Precision (Table 14)	Provides an estimate of precision using analytical duplicate pairs
ANOVA (Table 15)	Simple pair ANOVA estimates proportion of total variability due to each of sampling and analysis
Control Reference Data	Analytical data used to estimate accuracy
Analytical Duplicate Data	Analytical data used to estimate precision
Field Duplicate Data	Field duplicate data used for ANOVA

Table 9 Worksheets in Appendix 4 (quality control) with a brief description of contents.

Accuracy

Accuracy of analytical data was evaluated by inserting Canadian Certified Reference Materials STSD-1, STSD-2, STSD-3 and STSD-4 at random locations throughout the sample suite. STSD-1 consists of the -80 mesh

(<177 micron) fraction of sediment collected from Lavant Creek, about 75 km southwest of Ottawa, ON (NTS 31-F). STSD-2 is a composite sample prepared by mixing stream sediments collected from Hirok Stream in the Cassiar gold mining district (NTS 104-P) and unused portions of regional survey samples collected throughout NTS map sheets 93-A and 93-B in British Columbia. STSD-3 is a composite sample prepared from Lavant Creek, Hirok Stream and unused portions of regional survey samples from NTS map sheets 93-A and 93-B. STSD-4 is a composite sample made up from stream sediments collected throughout NTS map sheet 31-F and 93-A and 93-B. All -80 mesh material was ball-milled and sieved through a -200 mesh (<74 micron) screen prior to homogenisation and bottling (Lynch, 1990).

In Appendix 4 (Quality Control), Worksheet ‘Accuracy’, the means and standard deviations (MEAN ± SD) for control reference standards STSD-1, STSD-2, STSD-3 and STSD-4 for which provisional values have been published by Lynch (1990, 1999) and Burnham and Schweyer (2004) are compared with the means and standard deviations for these elements determined by total and partial methods in Duggan Lake-Ellice River area samples (Tables 10, 11, 12, 13). Accepted values in square brackets are derived from published and unpublished data (n > 30) collected from recent projects at the GSC. The lower detection limits (LDL) for each element estimated by the commercial laboratories are also listed. A per cent Relative Standard Deviation (RSD %) is calculated for each element with values above detection limits; however, given the small sample size for each CRM, these statistics should be regarded with some caution.

Several elements have concentrations below detection in all four CRMs, including Pd (AR), Ag (INAA), Cd (INAA), Ta (AR), Ir (INAA), Sn (INAA), Se (INAA), B (AR) and Te (INAA) and no RSD % is calculated. For several of these elements, the lower detection limits are relatively high. The lower detection limit for Zr (INAA) for example, is 200 ppm. Relatively high RSD values (>20%) in some CRMs for elements such as Nb (AR) can be the result of elemental concentrations held within discrete, often refractory, minerals, including spinels, beryl, tourmalines, chromite, zircon, monazite, niobates, tungstates, topaz, tantalite and cassiterite (Crock and Lamothe, 2011).

For similar reasons, concentrations of a number of elements in CRMs are at or just above detection, such as Zr (AR), Zr (INAA), Mo (INAA), Hf (AR), Re (AR), W (AR), W (INAA), Se (AR), Lu (INAA), Ge (AR), Sb (AR) and Te (AR), resulting in an RSD greater than 20 % in one or more CRMs. For Pt (AR), Au (AR) and Au (INAA), RSD % will be relatively high (>20%) due to the difficulty of creating homogeneous standard materials (Harris, 1982).

Precision

Precision is considered in terms of the closeness of agreement between analytical duplicate samples analyzed by the same method, i.e. independent test results obtained using the same equipment within short intervals of time on duplicate project samples. In order to provide an estimate of precision for each element or analyte, the squared difference between two analytical duplicates was calculated for N = 25 duplicate pairs from the Duggan Lake-Ellice River survey. The sum of these values was divided by the number of samples ((2*N) = 50) to estimate a measure of variability (variance). A Standard Deviation was then obtained by calculating the square root of this variance. The resulting numerical estimates of precision are shown in Appendix 4, Worksheet ‘AD Precision’, Table 14, represented by the Relative Standard Deviation (RSD), where the Standard Deviation is divided by the overall mean of the samples and multiplied by 100 to obtain a percentage (Reimann et al., 2008). Elements are grouped based on their position in the Periodic Table. Included with the element and method of analysis are the Lower Detection Limit (LDL), the percentage of data below the Lower Detection Limit (% Below LDL), the number of duplicate pairs removed from the calculations because one or both values are below detection (‘Duplicate

Pairs Removed') the Range and the Mean. This information provides context for the estimate of precision under 'RSD%' in Table 14.

Elements with precisions poorer than 20% in Table 14 tend towards generally low concentrations in samples, as indicated by the number of duplicate pairs removed, Range, the Mean and the percentage of data below the detection limit. Such is the case for elements such as Zr, Ag, Cd, Hf, W, Pt, Au, Tl, Bi, Be, B, Ge, As and Te using an aqua regia ('partial') digestion, and Mo and Au by INAA, a 'total' method. Results for Au (and possibly Ag) by a partial method can also be affected by the particulate nature of gold ('nugget effect') and should be considered accordingly (Harris, 1982).

Analysis of Variance (ANOVA)

Precision and accuracy are 'external' criteria against which geochemical survey data are evaluated. In order to establish that these data are 'fit for purpose,' an Analysis of Variance (ANOVA) is required. Table 15 in **Appendix 4 GSC OF 7887 QUALITY CONTROL.xlsx** shows results from an ANOVA undertaken on up to 22 field duplicate pairs collected for the Duggan Lake-Ellice River area survey. Duplicate pairs of which one or both values of an element are below detection are removed from the calculations. Calculations are only carried out if the number of duplicate pairs with both values above detection exceeds 1.

Field duplicates are used to estimate the combined variation due to sampling and analysis between samples collected within a few metres of each other. Field duplicate samples were collected at 16 field sites in 2012 and 6 sites in 2014 to provide means of estimating variability introduced by field sampling procedures and by sediment heterogeneity. The combined analytical and sampling variability was estimated from these sample pairs using Analysis of Variance (ANOVA). Using the 'anova2' function found in the 'rgr' package running under the R system, a random effects model Analysis of Variance (ANOVA) determines the combined sampling and analytical variability between sets of duplicate field samples (Garrett, 2011). This combined variability is more important than analytical variability alone because if the combined sampling and analytical variability is not significantly smaller than the field survey variability, it cannot be stated that there are statistically significant spatial patterns in the data, and thus the data are likely not suitable for mapping (Garrett, 2011), nor are sophisticated methods of data manipulation recommended (Reimann et al., 2008; Garrett, 1969).

The Analysis of Variance (ANOVA) of field duplicates partitions variability into two components, 'Between Sites' and 'Within Sites' in Appendix 4, Worksheet 'ANOVA', Table 15. The variance ratio, F, is calculated in 'anova2' to gauge whether the variance 'within' is significantly smaller than the variation 'between'. As a 'rule of thumb' this ratio should exceed 4.0 for sampling and analytical errors to be significantly smaller at the 95% confidence level. The p-value is a measure of the exact level of confidence in the results. Generally an acceptable p-value is less than 0.05 (>95th percentile), i.e. there is a <5% probability the observed F ratio could have occurred due to chance alone. It should be noted that in cases where an element is evenly distributed throughout all samples, 'F' and 'p-values' may fall below levels of confidence.

The ANOVA indicates that the sampling and analytical variability is significantly lower than the field survey variability, at the $p < 0.05$ level (>95% confidence level) for all but Zr, Ta and Lu (INAA) and Pt, Au, Bi, Ge, and Te (AR) in Table 15. From this it is inferred that maps of the distribution for all but the eight elements listed above will display the true spatial variability of those elements.

HIGHLIGHTS

Ni-Cu-PGE Potential

The potential for Ni-Cu-PGE mineralization in these rocks within or adjacent to watersheds draining the 2014 survey area is suggested by the distribution of (mostly) visually identified low-Cr diopside grains (0.25-2.0 mm) and visible gold grains in the <2.0 mm heavy mineral concentrate fraction of 2012 and 2014 bulk sediment samples from NTS map sheet 76-I (Fig. 6), in combination with elevated concentrations of several elements in stream silt (Ag, Ni, Cu ± Co, Sb, Zn) downstream and/or down-ice of rock units mapped as metavolcanic or mafic-ultramafic metavolcanic (see Fig. 2 for bedrock legend. Additional potential Ni-Cu-PGE indicator minerals (Averill, 2009) identified in samples from this survey includes hercynite, ruby corundum, chromite and chalcopyrite.

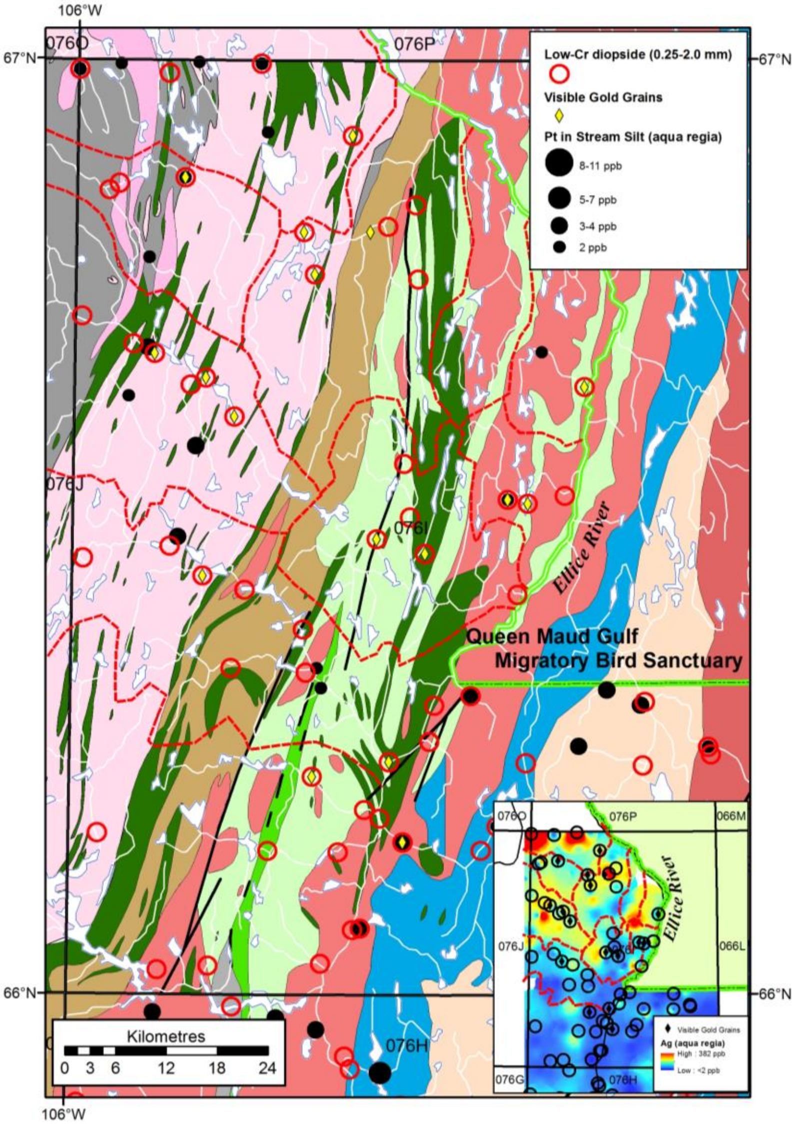

Figure 7 Sample locations (2012 and 2014) at which low-Cr diopside grains (red circles) and gold grains (yellow diamonds) were identified; proportional dots represent relative Pt (aqua regia digestion) concentrations in stream silt samples: only sites with Pt concentrations above detection (2 ppb) are shown. Red dashed lines demarcate sampled drainage areas. The inset map shows relative concentrations of Ag (aqua regia digestion), contoured using an Inverse Distance Weighting (IDW) algorithm, with low-Cr diopside (black circles) and gold (black diamonds) grain locations. Bedrock legend is shown in Figure 2.

U-Th-REE Potential

Thorianite-uraninite series mineral grains were identified in nine 2014 bulk stream sediment samples by panning approximately 30-60 g of the <2.0 mm table concentrate (Fig. 8). Concentrations of both uranium and REEs are elevated in stream silt samples adjacent to, downstream and/or down-ice from mineral grain locations and may be associated with contact zones between granitoid units and metavolcanic units (see Fig. 2 for bedrock legend). Minerals commonly found in pegmatites and present in stream sediment samples include red rutile and topaz.

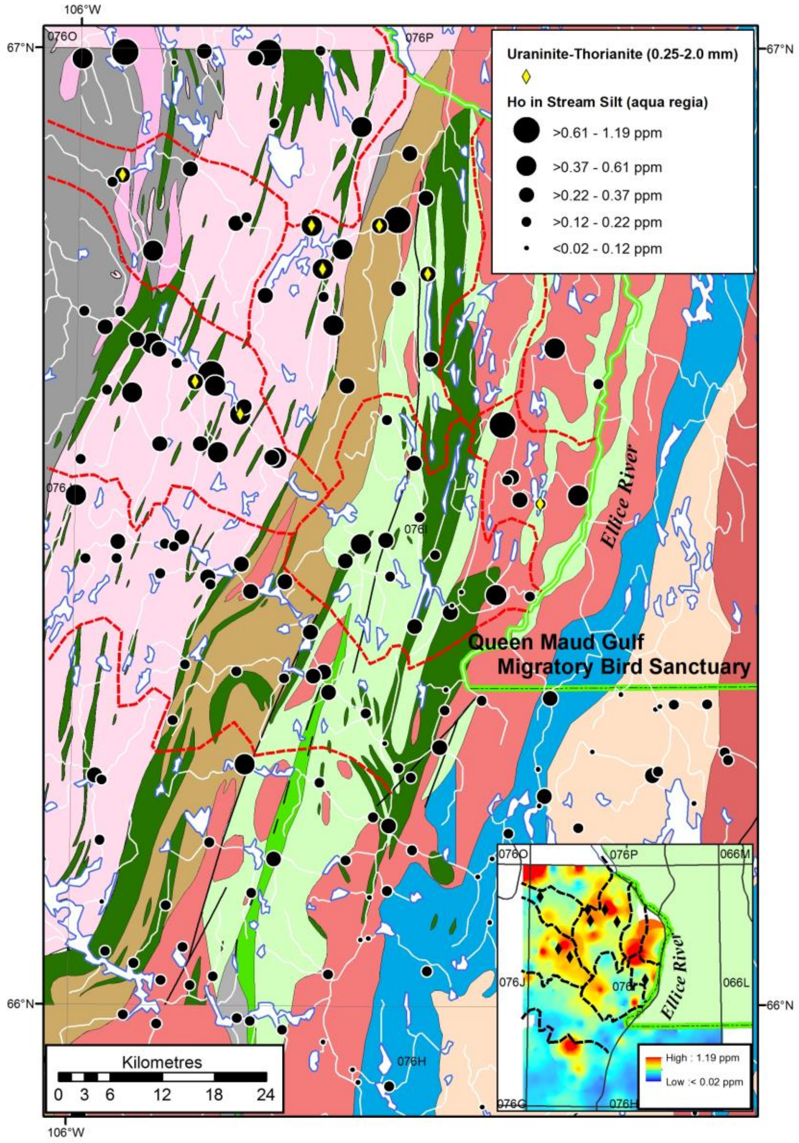

Figure 8 Sample locations (2012 and 2014) at which uraninite-thorianite series grains (yellow diamonds) were identified in the <2.0 mm fraction of table concentrate; proportional dots represent relative concentrations of Ho (aqua regia digestion), a heavy rare earth element, in stream silt samples. Red dashed lines (black on inset) demarcate sampled drainage areas. The inset map shows relative concentrations of Ho, contoured using an Inverse Distance Weighting (IDW) algorithm, with uraninite-thorianite (black diamonds) grain locations. Bedrock legend is shown in Figure 2.

Base Metal (Cu, Pb, Ni, Zn) Potential

Chalcopyrite grains (0.25-2.0 mm) were identified in the heavy mineral fraction of 12 stream sediment samples collected in 2014 (Fig. 8). Elevated values of Cu in stream silt are associated with chalcopyrite in drainage areas ‘B’, ‘D’, ‘E’, and ‘G’. Chalcopyrite is marginally stable in surficial sediments and can be used as an indicator mineral for Ni-Cu-PGE mineralisation (Averill, 2009). The pattern of distribution of element concentrations in stream silts is similar for Ag, Ni, Cu, Pb ± Co, Sb, Zn in the drainage areas listed above and may be associated with metavolcanic or mafic-ultramafic units.

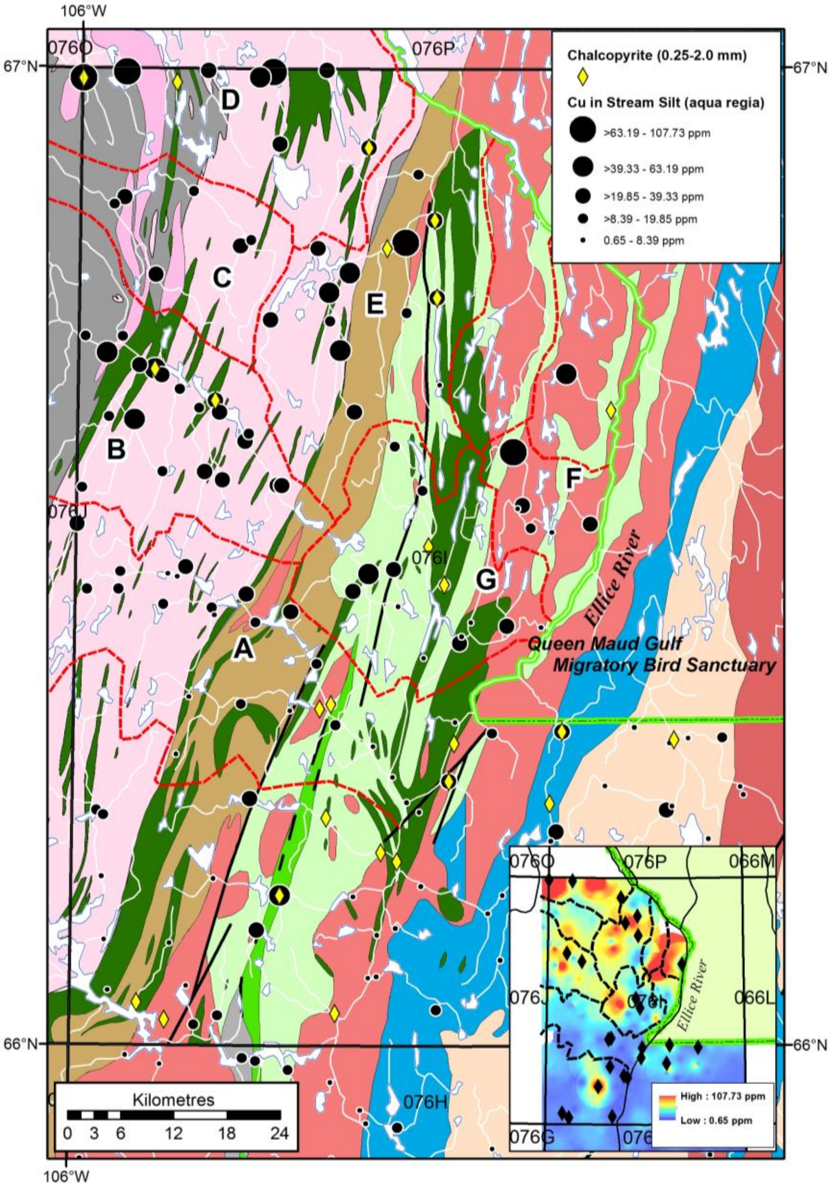

Figure 9 Sample locations (2012 and 2014) at which chalcopyrite grains (yellow diamonds) were identified in the 0.25 to 2.0 mm fraction; proportional dots represent relative concentrations of Cu (aqua regia) in stream silt samples. Red dashed lines demarcate sampled drainage areas and are identified by a letter. The inset map shows relative concentrations of Cu, contoured using an Inverse Distance Weighting (IDW) algorithm, with chalcopyrite (black diamonds) grain locations. Bedrock legend is shown in Figure 2.

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REFERENCES

Adcock, S.W., Spirito, W.A., and Garrett, R.G., 2013. Geochemical data management: issues and solutions; Geochemistry: Exploration, Environment, Analysis, 13, 337-348.

Averill, S.A., 2009. Useful Ni-Cu-PGE versus kimberlite indicator minerals in surficial sediments; similarities and differences. *In*: R.C. Paulen and I. McMartin (eds.), Application of Till and Stream Sediment Heavy Mineral and Geochemical Methods to Mineral Exploration in Western and Northern Canada; Geological Association of Canada, GAC Short Course Notes 18, p. 125-139.

Aylsworth, J. M. and Shilts, W. W., 1989. Glacial features around the Keewatin Ice divide: Districts of MacKenzie and Keewatin; Geological Survey of Canada, Paper 88-24, 21 p.

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., 2015a. 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, v. 7693, 14 p, doi:10.4095/295644.

Berman, R.G., Nadeau, L., Davis, W.J., McCurdy, M., Craven, J., McMartin, I., Whalen, J., Sanborn-Barrie, M., Carr, S., Pehrsson, S., Percival, J.A., and Girard, E., 2015b. New insights into the geological evolution and economic potential of the Thelon tectonic zone and western Rae craton, Nunavut; Geological Survey of Canada, Open File, v. 7901, 1 poster.

Burnham, O.M. and Schweyer, J., 2004. Trace element analysis of geological samples by inductively coupled plasma mass spectrometry at the Geoscience Laboratories: revised capabilities due to improvements to instrumentation *in* Summary of Field Work and Other Activities 2004; Ontario Geological Survey, Open File Report 6145, p. 54-1 to 54-20.

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.

Crock, J.G. and Lamothe, P.J. 2011. Inorganic chemical analysis of environmental materials – A lecture series: U.S Geological Survey Open-File Report 2011-1193, 117 p.

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, 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, v. 7652, p. 41 pages, doi:10.4095/295177.

Dredge, L.A. and Kerr, D.E., 2013. Reconnaissance surficial geology, Overby Lake, NTS 76-I, Nunavut, Geological Survey of Canada, Canadian Geoscience Map-143, (preliminary), 1:125 000 scale.

Dyke, A. S. and Prest, V. K., 1987. Late Wisconsinan and Holocene history of the Laurentide Ice Sheet; Géographie physique et Quaternaire, v. 41, p. 237-263.

Ecoregions Working Group. 1989. Ecoclimatic regions of Canada, first approximation. Ecological Land Classification Series, No. 23. Sustainable Development Branch, Conservation and Protection, Environment Canada, Ottawa, Ont. 199 pp. Report with map at 1:7.5 million scale.

Frith, R.A., 1982, Second preliminary report on the geology of the Beechey Lake-Duggan Lakes map areas, District of Mackenzie, Geological Survey of Canada Paper, v. 82-1A, p. 203-211.

Garrett, R.G., 1969. The determination of sampling and analytical errors in exploration geochemistry; Economic Geology 64(4): 568-569.

Garrett, R.G., 2011. The GSC Applied Geochemistry EDA Package, http://cran.r-project.org/web/packages/rgr/index.html

Girard, I, Klassen, R.A., and Laframboise, R.R., 2004. Sedimentology Laboratory Manual, Terrain Sciences Division; Geological Survey of Canada, Open File 4823.

Hall, G.E.M., Vaive, J.E., and McConnell, J.W., 1995. Development and application of a sensitive and rapid analytical method to determine the rare-earth elements in surface waters; Chemical Geology, Vol. 120, Nos. 1-2, pp. 91-109.

Hall, G.E.M., Vaive, J.E., and Pelchat, J.C., 1996. Performance of inductively coupled plasma – mass spectrometric methods used in the determination of trace elements in surface waters in hydrogeochemical surveys; Journal of Analytical Atomic Spectrometry, Vol. 11, pp. 779-786.

Harris, J.F., 1982. Sampling and analytical requirements for effective use of geochemistry in exploration for gold; In: A.A. Levinson (Ed.), Precious Metals in the Northern Cordillera, proceedings of a symposium sponsored by the Association of Exploration Geochemists and the Cordilleran Section of the Geological Association of Canada, pp. 53-67.

Hoffman, P.F., 1988, United plates of America, the birth of a craton: Early Proterozoic assembly and growth of Laurentia, AREpS, v. 16, p. 543– 603.

Hoffman, P.F., and Hall, L., 1993. Geology, Slave Craton and environs, District of Mackenzie, Northwest Territories; Geological Survey of Canada, Open File, v. 2559, p. 1 sheet; 1 CD-ROM, doi:10.4095/183951.

Lynch, J.J., 1990. Provisional elemental values for eight new geochemical lake sediment and stream sediment reference materials, LKSD-1, LKSD-2, LKSD-3, LKSD-4, STSD-1, STDS-2, STSD-3 and STSD-4; Geostandards Newsletter, Vol. 14 (1), p. 153-167.

Lynch, J.J., 1999. Additional provisional elemental values for LKSD-1, LKSD-2, LKSD-3, LKSD-4, STSD-1, STDS-2, STSD-3 and STSD-4; Geostandards Newsletter, Vol. 23 (2), p. 251-260.

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 (NTS 76-H and 76-I South); Geological Survey of Canada, Open File 7471. doi:10.4095/293044

McCurdy, M.W., Spirito, W.A., Grunsky, E.C., Day, S.J.A., McNeil, R.J., and Coker, W.B., 2014. The evolution of the Geological Survey of Canada's regional reconnaissance geochemical drainage sediment and water surveys; Explore, v. 163, p. 1, 3-4, 6-10.

McMartin, I. and Henderson, P.J., 2004. Evidence from Keewatin (Central Nunavut) for paleo-ice divide migration; Géographie physique et Quaternaire, v. 58, p. 163-187.

McMartin, I., Normandeau, P., Berman, R.G., and Percival, J., 2013. Till composition of a transect across the Thelon tectonic zone, Queen Maud block, and adjacent Rae craton: results from the Geo-Mapping Frontiers' Chantrey project; Geological Survey of Canada Open File 7418, 26 p. doi:10.4095/292801.

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. doi:10.4095/296833

Prest, V.K., Grant, D.R. and Rampton, V.N., 1968. Glacial Map of Canada; Geological Survey of Canada, Map 1253A, Scale 1:5 000 000.

Prior, G.J., McCurdy, M.W. and Friske, P.W.B., 2009. Stream sediment sampling for kimberlite-indicator minerals in the Western Canada Sedimentary Basin: the Buffalo Head Hills survey, north-central Alberta; in Application of till and stream sediment heavy mineral and geochemical methods to mineral exploration in western and northern Canada: Geological Association of Canada Short Course Notes 18, R.C. Paulen and I. McMartin (ed.), p. 91-103.

Reimann, C., Filzmoser, P., Garrett, R.G., Dutter, R., 2008. Statistical Data Analysis Explained. John Wiley & Sons, Ltd.: 343 p.

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, Volume 35, p. 707-710.

St-Onge, D.A. and Kerr, D.E. 2013: Reconnaissance surficial geology, Duggan Lake, NTS 76-H, Nunavut, Geological Survey of Canada, Canadian Geoscience Map-P113, (preliminary), 1:125 000 scale.

Thompson, D.L., 1992. Proterozoic evolution of the northern Thelon tectonic zone; Princeton, Princeton University, 311 p.

Thompson, P.H., Culshaw, N., Buchanan, J.R., and Manojlovic, P., 1986, Geology of the Slave Province and Thelon tectonic zone in the Tinney Hills-Overby Lake (west half) map area, District of Mackenzie, Geological Survey of Canada Paper, v. 86-1A, p. 275-289.