GEOLOGICAL SURVEY OF CANADA
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Geochemical, Mineralogical and Kimberlite Indicator Mineral Data for Silts, Heavy Mineral Concentrates and Waters, Duggan Lake Area, Nunavut (NTS 76-H and 76-I South)

M.W. McCurdy, R.G. Berman, D.E. Kerr, J.E. Vaive

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

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Geochemical, Mineralogical and Kimberlite Indicator Mineral Data for Silts, Heavy Mineral Concentrates and Waters, Duggan Lake Area, Nunavut (NTS 76-H and 76-I South)

INTRODUCTION

A regional stream sediment, heavy mineral and water geochemical survey was carried out around Duggan Lake, southeast of Bathurst Inlet, in the central part of the Kitikmeot administrative region of Nunavut in 2012 (Fig. 1). This report consists of field observations and analytical data from 244 sites for 65 elements in stream silts by a partial method of analysis (aqua regia digestion), 35 elements in stream silts by a total method (Instrumental Neutron Activation) and 62 elements in waters. Mineralogical data derived from 114 heavy mineral concentrate samples are included with this report.

Funds for the collection and analysis of stream sediments, heavy minerals and waters were made available under the Geo-mapping for Energy and Minerals (GEM) Program at NRCan. The GEM Program is a 5-year investment by the Government of Canada in geoscience information leading to the discovery of new energy and mineral resources in Canada. GEM is delivered at the federal level by Natural Resources Canada (NRCan) and the Polar Continental Shelf Project (PCSP). The major focus is on large areas of Canada's North where insufficient public geoscience information exists to attract and guide effective private sector investment.

The GEM Minerals component (MGM) of the GEM Program is designed to raise the level of geoscience knowledge of Canada's North, with emphasis on the acquisition and rapid release of data for mineral exploration and land-use planning. Supported by geochemical and geophysical information, multidisciplinary teams (federal, territorial/provincial, university-based collaborators and students) are targeting areas with high potential for base and precious metals, diamonds and rare metals.

The Geo-mapping Frontiers project was initiated in 2011 within the Geo-mapping for Energy and Minerals (GEM) program in order to improve geological understanding and help evaluate resource potential of some of the most remote and poorly understood regions of Canada's north. One such region is the Thelon tectonic zone (TTZ), which separates the Slave and Rae cratons, and has received very little attention since the first detailed mapping projects in the 1980s (Frith, 1982; Henderson et al., 1987; Thompson et al., 1986; James et al., 1988). This publication reports geochemical survey data across TTZ between latitude 65°and 66° 30'. These results complement geochemical studies of till samples collected in the northern part of this study area along a transect of the TTZ, Queen Maud block, and adjacent Rae craton to the east (Fig. 2; McMartin et al., 2013).

Analytical results and field observations form part of a national geochemical database used for resource assessment, mineral exploration, geological mapping, and environmental studies. Sample collection, preparation procedures and analytical methods are strictly 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.

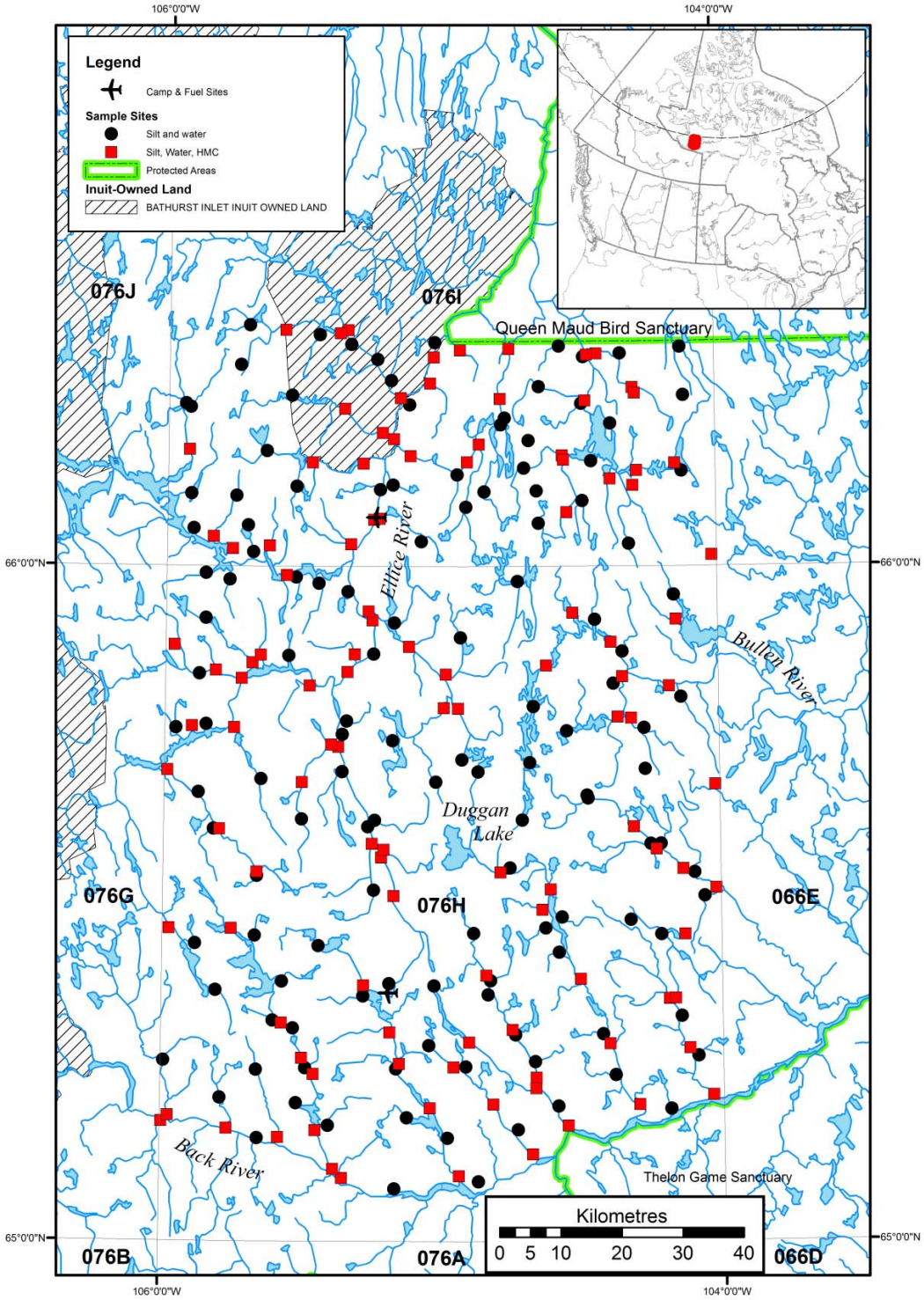

Figure 1. Stream sediment, heavy mineral concentrates and water sampling sites in 2012, Duggan Lake area, Nunavut

REGIONAL SETTING

Location and Physiography

The survey falls within the Garry Lake Lowland ecoregion extends across dominantly granitic Archean and Paleoproterozoic rocks, forming a broad, level to gently sloping plain that reaches about 300 m asl in elevation. 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 200-275 mm. This ecoregion is classified as having a low arctic ecoclimate. 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).

Geological Setting

The geochemical survey is located within the TTZ and western part of the Queen Maud block (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 and appear to continue to Prince of Wales and western Somerset Island. Similarities in magnetic fabrics and age of plutonic rocks suggest that the TTZ may have continuity with the Taltson magmatic zone to the south (Hoffman, 1988). The Thelon zone has been postulated to represent a continental arc built on the western flank of Rae craton and subsequently intensely deformed during collision of the Slave craton (Hoffman, 1988). An alternative model based on compositions of plutonic rocks proposes that the Taltson-Thelon zone formed an intracontinental mountain belt far removed from an active plate boundary (Chacko et al., 2000; Schultz et al., 2007).

The bedrock geology of the TTZ has been investigated in three widely separated areas: a southern region between the MacDonald fault and 65°N (Henderson et al., 1987; van Breemen et al, 1987a, van Breemen and Henderson, 1988, James et al., 1988, Henderson and van Breemen, 1992), a central region between 65 ^{o}N and 67°N (Thompson et al., 1986; van Breemen et al., 1987b; Frith and van Breemen, 1990; Davis et al., 2013) that in part coincides with the region of this geochemical survey, and a single outcrop along the coast of Queen Maud Gulf (Tersmette, 2012). The region as a whole is dominated by granitic to tonalitic metaplutonic rocks that include homogenous granitoid, migmatitic gneiss, and layered migmatite. In widespread granulite-facies regions, clinopyroxene and/or orthopyroxene replace hornblende and biotite as the primary mafic minerals. Supracrustal rocks occur as long, narrow lenses or belts (> 10 km) and include pelitic, psammitic, calc-silicate, and mafic volcanic rocks.

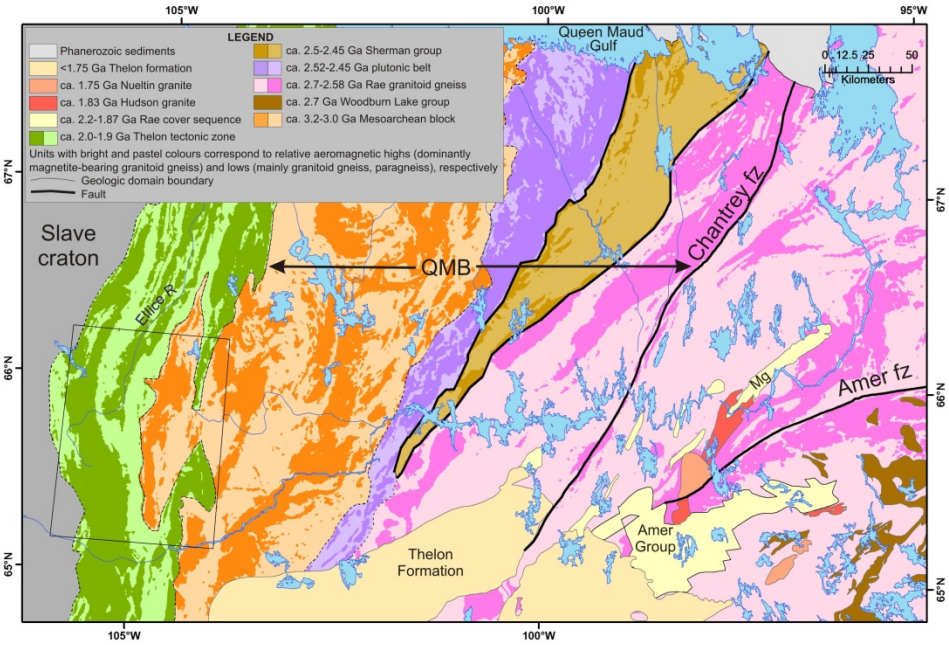

Figure 2. Regional geology of the Chantrey region (adapted from Berman et al., 2013). Box shows region of geochemical survey. Abbreviations: Ag = Amer group, Md = Meadowbank mine, Mg = Montressor group; QMB = Queen Maud block

The pronounced, north to NNE-striking aeromagnetic fabric of the TTZ reflects strong Paleoproterozoic deformation that also produced high strain zones in the eastern Slave craton. Geochronological data in each area document high-grade metamorphism and/or granitoid plutonism at 2.01-2.00 Ga. In the southern region, syn-tectonic plutonism occurred at 1957 +9/-5 (James et al., 1988) and 1920 ± 4 Ma (van Breemen et al, 1987a). In the central region, hornblende granodiorite crystallized at 2005 ± 10 Ma (Davis et al., 2013), K-feldspar megacrystic granite at 1994 +6/-4 Ma (Frith and van Breemen, 1990), massive to weakly foliated clinopyroxene granodiorite at 1978 ± 2 Ma (Frith and van Breemen, 1990), and syntectonic, S-type granite was emplaced at 1908 ± 2 Ma (van Breemen et al., 1987b) during granulite-facies metamorphism dated at 1906 ± 2 Ma (Roddick and van Breemen, 1994).

The western part of the Queen Maud block consists dominantly of Mesoarchean granitoid gneisses with crystallization ages between ca. 3.25 and 3.1 Ga (Tersmette, 2012; Davis et al., 2013). The aeromagnetic fabric of this region is more variable than that of the TTZ, with aeromagnetic lows that appear to correlate with metasedimentary rocks, migmatitic gneiss, and ca. 2.7 Ga plutonic rocks (Tersmette, 2012; Davis et al., 2013).

Surficial Geology

Preliminary surficial geology studies, based on air photo interpretation and limited field data, were undertaken to provide an understanding of the distribution and nature of surficial materials,

and regional glacial history. In the Overby Lake map area (NTS 76-I), much of the western area is characterized by rubble-covered bedrock containing shallow glacially scoured lake basins. Streamlined bedrock and till landforms indicate ice flow towards the northwest and north-northwest. Till blankets and veneers have a pebbly silty-sand matrix, but their surfaces tend to be bouldery where they were affected by glacial meltwater. Subglacial meltwater corridors consisting of eskers, washed till, boulder lags and scoured bedrock, cross the entire area. The MacAlpine Moraine in the southeast formed during glacial recession about 8200 years ago, and is defined by hummocky till, kames, and related glaciofluvial outwash. Sandy postglacial marine sediments extend up the Ellice River to 220 m a.s.l. In the northeast, below 190 m a.s.l., silty marine deposits form extensive plains between drumlinoid ridges towards the Queen Maud Bird Sanctuary (Dredge and Kerr, 2013). The Duggan Lake map area (NTS 76-H) is extensively covered by a variety of glacial deposits and landforms, though bedrock outcrops can be found throughout the region. Widespread till veneer, blanket and streamlined till are common in the central and eastern areas, whereas hummocky till occurs in the west. Tills are dissected by northwest-southeast trending glaciofluvial corridors consisting of eskers, ice-contact sediments, outwash plains and terraces, and locally elongated zones of scoured bedrock. Small isolated glacial lakes were formed by ponding of meltwater during deglaciation. In the northwest map region, a discontinuous end moraine complex, consisting of glaciofluvial sediments and ridged till segments, forms the western extremity of the MacAlpine Moraine. Drumlinoids and striations record a regional northwestward ice flow during the last glaciation (St-Onge and Kerr, 2013).

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. 3). 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 field duplicate pair of silt samples, assigned sequential sample numbers, was collected within each block of 20 samples. The first sample of the pair was assigned a replicate status value of 10 and the second was assigned a replicate status value of 20. Routine (non-duplicate) field samples were assigned replicate status values of 0. Field observations are noted on pre-printed water-resistant paper forms.

Figure 3: Pre-labelled synthetic cloth bags and plastic bottles (inset) are used to collect samples of stream silts and stream waters. A bulk sample, for heavy mineral processing, is collected by wet-sieving coarse-grained stream sediment using a US Sieve Series 12-mesh (1.68 mm) sieve and collecting <12 mesh grains 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 archive, 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 pH and conductivity were measured using hand-held units. Waters were sampled in mid-channel, from flowing water where possible. One water sample was collected at each site. After rinsing, water was drawn into a 60ml plastic syringe and filtered into a 60ml HDPE bottle (Fig. 3, inset) through a 0.45 µm disposable filter unit. Field duplicate pairs of water samples, assigned sequential sample numbers, were collected within each block of 20 samples. The first sample of each pair was assigned a replicate status value of 10 and the second was assigned a replicate status value of 20. Routine (non-duplicate) field samples were assigned replicate status values of 0.

Heavy Mineral Concentrates

Ideal sites for the collection of sediments for the heavy mineral concentrate fraction are located at the upstream ends of mid-channel boulder bars and behind mid-stream boulders (Prior et al.,

2007). 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 polyethylene bag measuring 46x61 cm (18x24 inches, 4 Mil). Material was wet-sieved into the pail through a 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). Control reference and duplicate samples were inserted into each block of twenty samples.

Stream Waters

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

Heavy Mineral Concentrates

Before processing, a 500-g 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 table concentrate was prepared from each of the samples. Gold grains were observed at this stage and were counted, measured and classified as to degree of wear (reflecting distance of transport). The table reject was re-tabled to scavenge possible unrecovered kimberlite indicator minerals and magmatic massive sulphide indicator minerals. The concentrate from both tabling runs 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, moderately, weakly and non-paramagnetic fractions.

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* Filter (sample) blanks are 60-ml bottles filled with deionized water used in the field that has been filtered and acidified at the same time as routine samples; acid blanks are samples of the deionized water used in the field and acidified (but not filtered) at the same time as routine samples; travel blanks are bottles of deionized water pre-filled at the GSC lab in advance of field sampling and acidified in the field with the survey samples.

ANALYTICAL PROCEDURES

Stream Sediment (Silt)

Instrumental Neutron Activation Analysis (INAA)

Weighed and encapsulated samples, normally 30 g, were packaged for irradiation along with international 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 INAA are listed in Table 1.

Table 1. Variables determined by INA analysis of stream silt samples

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**	0.1	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

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

For the determination of 65 elements listed in Table 2, a 0.5 gram sample was leached with 6mL/g of concentrated HCl, HNO_3 and demineralised water (2:2:2 v/v) at 95° C in a beaker for one hour. After cooling the solution was made up to a final volume with 5% HCl. The ratio of sample weight to solution volume was 0.5 g per 10 ml. The sample solution was analysed by

inductively coupled plasma emission spectroscopy and inductively coupled plasma mass spectroscopy.

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

Table 2 Variables in stream silts determined by Inductively Coupled Plasma – Emission Spectroscopy (ICP-ES)/Mass Spectroscopy (ICP-MS)

Element	Detection Limit	Units of Measurement	Analytical Method	Element	Detection Limit	Units of Measurement	Analytical Method
Ag	2	ppb[1]	ICP-MS	**Mo**	0.01	ppm	ICP-MS
Al	0.01	pct[2]	ICP-MS	**Na**	0.001	pct	ICP-MS
As	0.1	ppm[3]	ICP-MS	**Nb**	0.02	ppm	ICP-MS
Au	0.2	ppb	ICP-MS	**Nd**	0.02	ppm	ICP-MS
B	20	ppm	ICP-MS	**Ni**	0.1	ppm	ICP-MS
Ba	0.5	ppm	ICP-MS	**P**	0.001	pct	ICP-MS
Be	0.1	ppm	ICP-MS	**Pb**	0.01	ppm	ICP-MS
Bi	0.02	ppm	ICP-MS	**Pd**	10	ppb	ICP-MS
Ca	0.01	pct	ICP-ES	**Pt**	2	ppb	ICP-MS
Cd	0.01	ppm	ICP-MS	**Pr**	0.02	ppm	ICP-MS
Ce	0.1	ppm	ICP-MS	**Rb**	0.1	ppm	ICP-MS
Co	0.1	ppm	ICP-MS	**Re**	1	ppb	ICP-MS
Cr	0.5	ppm	ICP-MS	**S**	0.02	pct	ICP-MS
Cs	0.02	ppm	ICP-MS	**Sb**	0.02	ppm	ICP-MS
Cu	0.01	ppm	ICP-MS	**Sc**	0.1	ppm	ICP-MS
Dy	0.02	ppm	ICP-MS	**Se**	0.1	ppm	ICP-MS
Er	0.02	ppm	ICP-MS	**Sm**	0.02	ppm	ICP-MS
Eu	0.02	ppm	ICP-MS	**Sn**	0.1	ppm	ICP-MS
Fe	0.01	pct	ICP-ES	**Sr**	0.5	ppm	ICP-MS
Ga	0.1	ppm	ICP-MS	**Ta**	0.05	ppm	ICP-MS
Gd	0.02	ppm	ICP-MS	**Tb**	0.02	ppm	ICP-MS
Ge	0.1	ppm	ICP-MS	**Te**	0.02	ppm	ICP-MS
Hf	0.02	ppm	ICP-MS	**Th**	0.1	ppm	ICP-MS
Hg	5	ppb	ICP-MS	**Ti**	0.001	pct	ICP-MS
Ho	0.02	ppm	ICP-MS	**Tl**	0.02	ppm	ICP-MS
In	0.02	ppm	ICP-MS	**Tm**	0.02	ppm	ICP-MS
K	0.01	pct	ICP-ES	**U**	0.1	ppm	ICP-MS
La	0.5	ppm	ICP-MS	**V**	2	ppm	ICP-MS
Li	0.1	ppm	ICP-MS	**W**	0.1	ppm	ICP-MS
LOI	0.1	pct	GRAV[4]	**Y**	0.01	ppm	ICP-MS
Lu	0.02	ppm	ICP-MS	**Yb**	0.02	ppm	ICP-MS
Mg	0.01	pct	ICP-ES	**Zn**	0.1	ppm	ICP-MS
Mn	1	ppm	ICP-ES	**Zr**	0.1	ppm	ICP-MS

[1] parts per billion
[2] percent
[3] parts per million
[4] Gravimetric (see below)

Stream Waters

pH and Conductivity

The pH of stream waters was determined on site using Oakton Waterproof pHTestr 30 Pocket pH testers with automatic temperature compensation and an accuracy of ±0.01 pH. Meters were calibrated daily using commercial buffer solutions with pH values of 4.0, 7.0 and 10.0.

The conductivity of stream waters was determined on site using Oakton ECTestr 11+ multi-range, cup-style pocket conductivity testers with a range of 0 µS/cm to 20.00 mS/cm and an accuracy of ±1% full-scale. Meters were calibrated daily using commercial conductivity standards with values of 84 µS/cm and 1413 µS/cm.

Trace and Major Elements

Acidified and filtered 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 3.

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.

Major element analysis was performed using an axial Spectro Arcos, inductively coupled plasma optical emission spectrometer (ICP-ES) using a 1% CsNO3 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.

Table 3: Major and trace elements determined in stream waters

ELEMENT		DETECTION LEVEL		LABORATORY METHOD
Waters –Filtered, Acidified (FA-Water)				
Al	Aluminum	2	ppb	ICP-MS
As	Arsenic	0.1	ppb	ICP-MS
B	Boron	0.5	ppb	ICP-MS
Ba	Barium	0.2	ppb	ICP-MS
Be	Beryllium	0.005	ppb	ICP-MS
Br	Bromium	0.05	ppb	ICP-ES
Ca	Calcium	0.02	ppm	ICP-ES
Cd	Cadmium	0.02	ppb	ICP-MS
Ce	Cerium	0.01	ppb	ICP-MS
Cl	Chlorine	0.1	ppm	ICP-ES
Co	Cobalt	0.05	ppb	ICP-MS
Cr	Chromium	0.1	ppb	ICP-MS
Cs	Cesium	0.01	ppb	ICP-MS
Cu	Copper	0.1	ppb	ICP-MS
Dy	Dysprosium	0.005	ppb	ICP-MS
Er	Erbium	0.005	ppb	ICP-MS
Eu	Europium	0.005	ppb	ICP-MS
Fe	Iron	0.005	ppm	ICP-ES
Ga	Gallium	0.01	ppb	ICP-MS
Gd	Gadolinium	0.005	ppb	ICP-MS
Ge	Germanium	0.02	ppb	ICP-MS
Ho	Holmium	0.005	ppb	ICP-MS
K	Potassium	0.05	ppm	ICP-ES
La	Lanthanum	0.01	ppb	ICP-MS
Li	Lithium	0.02	ppb	ICP-MS
Lu	Lutetium	0.005	ppb	ICP-MS
Mg	Magnesium	0.005	ppm	ICP-ES
Mn	Manganese	0.1	ppb	ICP-MS
Mo	Molybdenum	0.05	ppb	ICP-MS
Na	Sodium	0.05	ppm	ICP-ES
Nb	Niobium	0.01	ppb	ICP-MS
Nd	Neodymium	0.005	ppb	ICP-MS
Ni	Nickel	0.2	ppb	ICP-MS
P	Phosphorus	0.05	ppm	ICP-ES
Pb	Lead	0.01	ppb	ICP-MS
Pr	Praseodymium	0.005	ppb	ICP-MS
Rb	Rubidium	0.05	ppb	ICP-MS
Re	Rhenium	0.005	ppb	ICP-MS
S	Sulphur	0.05	ppm	ICP-ES
Sb	Antimony	0.01	ppb	ICP-MS
Si	Silicon	0.02	ppm	ICP-ES
Sm	Samarium	0.005	ppb	ICP-MS
Sn	Tin	0.01	ppb	ICP-MS
Sr	Strontium	0.5	ppb	ICP-MS
Tb	Terbium	0.005	ppb	ICP-MS
Te	Tellurium	0.02	ppb	ICP-MS
Ti	Titanium	0.5	ppb	ICP-MS
Tl	Thallium	0.005	ppb	ICP-MS
U	Uranium	0.005	ppb	ICP-MS
V	Vanadium	0.1	ppb	ICP-MS
W	Tungsten	0.02	ppb	ICP-MS
Y	Yttrium	0.01	ppb	ICP-MS
Yb	Ytterbium	0.005	ppb	ICP-MS
Zn	Zinc	0.5	ppb	ICP-MS

Analytical results are presented in an Excel® workbook included with this report: **Appendix 1 GSC OF 7471 FIELD & ANALYTICAL DATA**. There are three worksheets in this file:

Worksheet	Contents
Field Data	site specific field observations including geographic coordinates
Silt Data (ICP&INA)	ICP-MS/ES and INA analytical data for silt samples
Water Data	ICP-MS/ES and pH and conductivity of water samples

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, counted and hand-picked from each of three non-ferromagnetic size fractions (0.25-0.5 mm, 0.5 mm-1.0 mm, 1.0-2.0 mm). Fractions exceeding a 100 g threshold were characterized by a 100 g split and normalized to represent the total sample weight. Following removal of the indicator minerals listed above, 100 grains were randomly selected from each 0.25-0.5 mm fraction and identified. After 100 grains were identified they were recombined with the source sample fraction. The 0.25-0.5 mm fraction was then examined under ultra-violet light to identify fluorescent grains. The 0.25-0.5 mm, 0.5-1.0 mm and 1.0-2.0 mm fractions (minus indicator minerals) were archived.

Heavy mineral concentrate data are presented in an Excel® workbook included with this report: **Appendix 2 GSC OF 7471 HMC DATA**. There are 15 worksheets in this file, one for each map sheet (76-H and 76-I) for the categories listed below and a separate worksheet listing abbreviations:

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 Mineral (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
Lamping	Fluorescent mineral grains identified in >0.25 mm 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 in published reports

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), standard reference materials (SRM) in the sample suite submitted to the labs. Table 4 provides information on the number of each quality control sample within the sample suite. Analytical data for control reference standards, analytical and field duplicates, and blanks are included with this report in Appendix 3.

Duggan Lake (76-H, 76-I)				
244 sites				
FD Pairs	AD Pairs	SRM (STSD-1)	SRM (STSD-2)	SRM (STSD-4)
16	19	6	6	7

Table 4. Quality control samples included with Duggan Lake area stream sediment samples.

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.

Worksheets 1 through 3 in **Appendix 3 GSC OF 7471 QUALITY CONTROL** can be used to estimate the quality of analysis for almost every element listed in Tables 1 and 2 above. Elements are grouped based on their position in the Periodic Table.

Accuracy

Accuracy of analytical data was evaluated by inserting Canadian Certified Reference Materials STSD-1, STSD-2 and STSD-4 at random locations throughout the sample suite. STSD-1 consists of the -80 mesh (<180 micron) fraction of sediment collected from Lavant Creek, about 75 km southwest of Ottawa, ON (NTS 31F). STSD-2 is a composite sample prepared by mixing stream sediments collected from a stream in the Cassiar gold mining district (NTS 104P) and unused portions of regional survey samples collected throughout NTS map sheets 93A and 93B. STSD-4 is a composite sample made up from stream sediments collected throughout NTS map sheet 31F and 93A and 93B. 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 3**, Worksheet 'Accuracy', the means and standard deviations (MEAN ± SD) for control reference standards STSD-1, STSD-2 and STSD-4 for which provisional values have been published by Lynch (1990, 1999) are compared with the means of these elements determined by total and partial methods in Duggan Lake area samples (Tables 5, 6, 7). Accepted values in square brackets are derived from unpublished data ($n \geq 40$) collected from recent projects at the GSC. The Lower Detection Limits (LDL) used by the commercial laboratories that analysed the Duggan Lake area samples are also listed.

For elements with an accepted mean, excepting Ti and Ba (aqua regia digestion), almost all elements are within one or two Standard Deviations of the accepted mean. Other elements with possible analytical problems such as Ag, Y and Ce (STSD-1; aqua regia digestion), Lu (STSD-1; INAA) and Ca (STSD-2 and STSD-4; aqua regia digestion) are shown in bold type. However, means falling outside ±2 SD, suggesting poor repeatability, may also be an indication that analytical results are close to the detection limit for the element. Results may also be an indication of the mineralogy of a region, that is, an element such as Ti may be present in refractory minerals in Duggan Lake area samples that are relatively unaffected by an aqua regia digestion, whereas Ti may be present in more available forms in the reference materials.

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 $N = 19$ duplicate pairs. The sum of these values was divided by the number of samples ((2*N) = 38) 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 3**, Worksheet 'AD Precision', Table 8, 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 or and method of analysis are the Lower Detection Limit (LDL), the percentage of data below the Lower Detection Limit (% Below LDL), the Range and the Mean. This information provides context for the estimate of precision under 'RSD%' in Table 8.

Elements with precisions poorer than 25% in **Appendix 3**, Worksheet 'AD Precision, Table 8 tend towards generally low concentrations in samples, as indicated by the Range, the Mean and the percentage of data below the detection limit. Such is the case for elements such as Ag, Cd, Au, Ar, Bi, Be, Tm, Lu, Th, and As using an aqua regia ('partial') digestion. Results for Au (and possibly Ag) by a partial method are affected by the particulate nature of gold ('nugget effect') and should be considered accordingly.

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 9 in **Appendix 3 GSC OF 7471 QUALITY CONTROL** shows results from an ANOVA undertaken on 16 field duplicate pairs collected for the Duggan Lake area survey.

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 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 3**, Worksheet 'ANOVA', Table 9. 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, Hf and Lu (INAA) and Lu, As, and Sb (aqua regia) in Table 9. From this it is inferred that maps of the distribution of these elements will display the true spatial variability of those elements.

Worksheet	Contents
Accuracy	Compares accepted values for three international reference standards with results from analysis of Duggan Lake area samples
AD Precision	Provides an estimate of precision using analytical duplicate pairs
ANOVA	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

* Values must be log-transformed for elements with a range of observations exceeding 1.5 orders of magnitude.

HIGHLIGHTS

Sulphides (sphalerite, chalcopyrite, and arsenopyrite-loellingite) were identified in heavy mineral concentrates from several sites along a tributary of the Ellice River, west of Duggan Lake (Fig. 4). Concentrations of base metals (Cu, Pb, Zn) with Ag are elevated in stream silts in the same area (Fig. 5). Rare-earth element concentrations are elevated within this area as well. Elevated concentrations of these base metals and rare-earth elements are also present in water samples, but offset downstream of silt results (Fig. 6). Elevated U outlines a northwest-trending lineament that in part coincides with the same enriched tributary (Fig. 7).

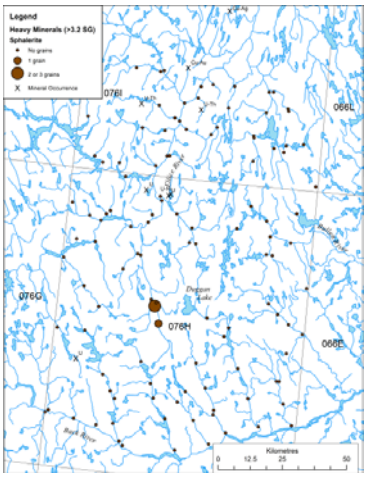

Figure 4. Previously unrecorded, sulphides (sphalerite, chalcopyrite, arsenopyrite, loellingite) were identified in heavy mineral concentrates from stream sediments in a tributary of the Ellice River, west of Duggan Lake.

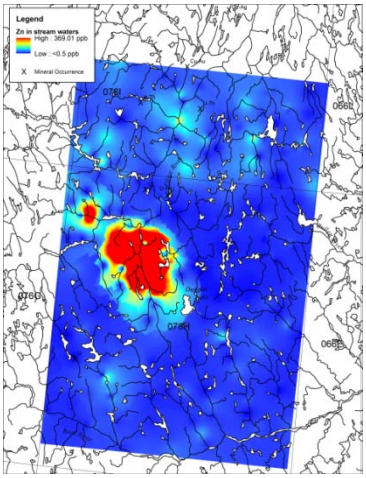

Figure 6. Elevated values of base metals (Cu, Pb, Zn) in stream waters are shifted downstream of high values in sediments.

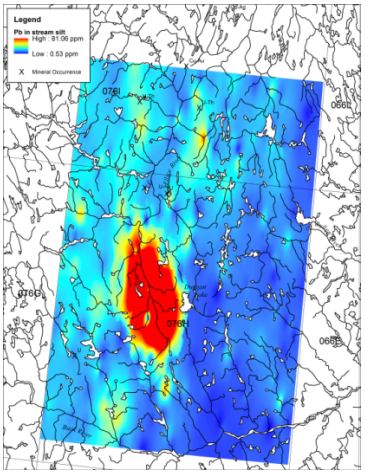

Figure 5. Anomalous Cu, Pb, Zn and Ag concentrations are present in stream silts over a significant area west of Duggan Lake.

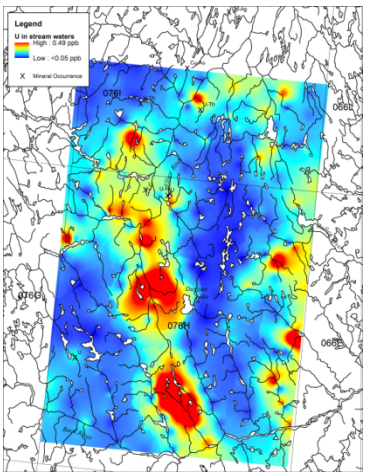

Figure 7. U in waters defines a northwest-trending lineament that may reflect a bedrock fault.

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