Geological Survey of Canada Open File 6271

Yukon Geological Survey Open File 2009-26

Regional Stream Sediment and Water Geochemical Data, eastern Yukon and western Northwest Territories (NTS 105I)

McCurdy, M.W., Friske, P.W.B., McNeil, R.J., Day, S.J.A. and Goodfellow, W.D.

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Cover illustration
Sediment sampling an unnamed stream, *courtesy of Rick McNeil (GSC)*

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INTRODUCTION

A reconnaissance geochemical survey of stream sediments and waters in the Little Nahanni River (NTS 105I) map area was carried out in 1981 by the Geological Survey of Canada (GSC) as part of the Nahanni Integrated Multidisciplinary Pilot Project (NIMPP). NIMPP was established by the Geological Survey of Canada to focus the efforts of personnel from different geological disciplines (Goodfellow, 1982). In addition to stream sediment and water geochemical data released in GSC Open File 868, mineral deposit studies and detailed studies of plutonic rocks were carried out (Gordey & Andersen, 1993). Information included in GSC Open File 868 was used primarily to determine areas of high potential for Pb, Zn, Ba and W.

In 2000, under the terms of the Canada/Yukon Geoscience Program, the Government of Yukon, the Department of Indian and Northern Affairs and the Geological Survey of Canada agreed to conduct a joint research project consisting of reanalysis of previously collected stream sediments for gold and 25 other elements. Gold and many of the lithophile elements associated with felsic plutons in continental arc environments (Lang et al., 1997) were added to the existing suite of elements to identify potential areas of large tonnage - low grade gold mineralization within the Little Nahanni River map area. Data files in GSC Open File 4016 (Friske et al., 2001) included original field and analytical data for stream sediments and waters and new Neutron Activation analytical data for stream sediments.

A Joint Research Agreement between the Yukon Geological Survey (YGS) and the Geological Survey of Canada was signed in 2006. The purpose of this agreement was to provide geochemical data in support of the research activities of the Yukon Geological Survey and the Environment and Health Program within the Earth Sciences Sector (ESS) of Natural Resources Canada. Under the agreement, new stream sediment and water surveys were carried out as well as archive stream sediment samples, from previous surveys, were reanalysed by more sensitive analytical techniques to add elements and improve detection levels of key elements such as silver, copper, zinc, nickel and lead. These activities were funded by YGS and managed by the GSC.

Original and re-analysis geochemical data from a total of 984 sites sampled in 1981 are included in this report.

Location and Physiography

The Little Nahanni River (National Topographic System (NTS) 105I) map area covers 11,489 km^2 (Sebert & Munro, 1972) between latitude 62ºN and 63ºN and longitude 128ºW and 130ºW. The border between Yukon Territory and Northwest Territories (District of Mackenzie) divides the map sheet roughly diagonally from northwest to southeast (Fig. 1). The valley of the South Nahanni River separates the Mackenzie Mountains in the northeast from the Selwyn Mountains (and Logan Mountains within the Selwyn Mountains) and Yukon Plateau in the southwest half of the survey area.

The land surface is rugged and consists mainly of slope, summit and plateau (Jackson, 1987). Elevations range from 762 m to 2590 m (Gordey & Anderson, 1993), and more than 75% of the survey area lies between elevations of 1220 and 1820 m (Jackson, 1987). Glaciers are found at higher elevations of the Ragged Range, in the southeast corner of the map sheet. The timberline is located between elevations 1375 m to 1525 m, below which bedrock exposure is rare (Gordey & Anderson, 1993).

A major drainage divide between the Little Nahanni River and the Pelly, Ross and Hyland Rivers is delineated by the Yukon-Northwest Territories border. Streams in Yukon drain west to southwest and in the Northwest Territories flow southeast towards the Mackenzie River. Thousands of small streams flow from higher elevations, forming dendritic drainage patterns.

The Little Nahanni map sheet lies almost entirely within the Selwyn Mountains ecoregion of the Taiga Cordillera Ecozone. The climate of this ecoregion varies with elevation. A summer mean temperature of 9.5°C and winter mean of -19.5°C is typical in major valley systems. Precipitation ranges from 600 mm at lower elevations to 750 mm at higher elevations. Vegetation is characteristic of alpine tundra at higher elevations (crustose lichens, mountain avens, dwarf willow and ericaceous shrubs). Subalpine open woodland vegetation consists of discontinuous open stands of stunted white spruce, with willow, dwarf birch, and northern Labrador tea, ground cover moss and lichens.

Bare rock outcrop and rubble are present at higher elevations, and bare talus slopes are common: little bedrock is exposed below 1500 m. The most common glacial deposits are tills deposited as blankets or veneer over bedrock. Glaciofluvial deposits consisting primarily of gravel form kames, eskers and planar deposits in most valleys. Glaciolacustrine deposits are present mainly in the South Nahanni River valley, especially near Mt. Wilson. Bogs form in areas of poor drainage (Jackson, 1987). Dystric and Eutric Brunisols are developed on alluvial, fluvioglacial and morainal veneers. Static and Turbic Cryosols with Dystric Brunisols and Regosols form on steeply sloping colluvium at upper elevations. Permafrost is permanent and continuous.

Land use is limited to hunting, trapping, ecotourism and mineral exploration (Ecological Stratification Working Group, 1995). There are no major permanent settlements. **http://www.ec.gc.ca/soer-ree/english/ecozones.cfm**

Collection Procedures and Sample Management (Original Surveys)

Stream sediment and water samples were collected from 984 sites at an average density of one sample per 12 km^2 throughout the 11,489 km^2 comprising the Little Nahanni River mapsheet (NTS 105I). For the purposes of sampling, preparation and analytical control, sample numbers were divided into blocks of 20, with each block consisting of 17 routine samples, one field duplicate, one blind duplicate and one control reference standard. Further details can be obtained from Garrett (1974) and Figure 2.

At GSC laboratories in Ottawa, field-dried stream sediment samples were air-dried, sieved to minus-80 mesh (177 μm) and ball-milled to minus-150 mesh. Control reference and blind duplicate sample positions were filled during sample preparation. In the case of stream waters, the control reference positions were filled in the field with one of three control standards collected near base camp. The blind duplicates for stream waters were left blank.

All stream waters were filtered through 0.45 μm filter paper before analysis.

Analytical Procedures

Analytical results are presented in a single file in a spreadsheet format included with this report: OF_6271_Data.xls.

Original Analytical Procedures (from Goodfellow, 1982)

Stream Waters

Uranium was determined by laser-induced fluorescence using a Scintrex UA-3. A 5 ml sample was pipetted into a quartz cell and a metaphosphate-phosphate solution (500 μl) added. The fluorescence of the uranyl phosphate formed and excited by the laser was measured. The method of standard additions was used.

Fluoride was measured using a specific ion electrode and an Orion meter. A 5 ml sample of water and a 5 ml aliquot of buffer (TISAB) were measured using UV readings. Alkalinity and pH were determined simultaneously using a Radiometer TTT 81 digital titrator and pH meter respectively.

Anions Cl, NO_3, PO_4, SO_4 were measured using ion chromatography. A 100 μl sample was separated on an exchange resin and the resulting solution passed through a high-capacity cation exchange resin to a conductivity cell. The eluent used was 0.003 M Na_2CO_3/0.0024 M $NaHCO_3$. A Dionex System 12 was used.

Major cations Na, K, Ca, Mg, Mn, Fe, and Zn were determined by direct aspiration using a Perkin-Elmer 5000 atomic absorption spectrophotometer. An air-acetylene flame was used in all cases. A 2000 ppm potassium solution was used as an ionization buffer for Na analyses; 2000 ppm sodium for K analyses, and 2000 ppm lanthanum was used as a releasing agent for Ca analyses.

A summary of the methods used and detection limits for water analyses are shown in Table 1.

Table 1 Summary of analytical data and methods for Waters

ELEMENT		DETECTION LEVEL		METHOD
T-Alk	Alkalinity	2.0	ppm	TIT
Ca	Calcium	0.5	ppm	AAS
Cl^-	Chloride	0.1	ppm	IC
F	Fluoride	25	ppb	ISE
Fe	Iron	40	ppb	AAS
K	Potassium	0.2	ppm	AAS
Mg	Magnesium	0.2	ppm	AAS
Mn	Manganese	10	ppb	AAS
Na	Sodium	0.2	ppm	AAS
NO^{3-}	Nitrate	0.2	ppm	IC
pH	-	0.01	-	GCM
PO^{4-}	Phosphate	0.15	ppm	IC
SO^{4-}	Sulphate	0.5	ppm	IC
U	Uranium	0.10	ppb	LIF
Zn	Zinc	5	ppb	AAS

AAS	atomic absorption spectrometry
GCM	glass Calomel electrode and pH meter
IC	ion chromatography
ISE	ion selective electrode
LIF	laser-induced fluorescence
TIT	titration

Stream Sediment (Silt) Geochemical Analyses

Zn, Cu, Pb, Ni, Co, Ag, Cd, Mn, Fe, Mo and V were determined by atomic absorption spectrophotometry (AAS) after decomposition with a multi-acid total digestion. A 500 mg sample was leached over a period of four hours using a 5-ml aliquot of HF-HCl-HNO_3-$HClO_4$ (ratio 1:1:1:1). A final solution of 5% HCl was made up to a volume of 20 ml. All elements, with the exception of Mo, were atomized using an air-acetylene flame: a nitrous oxide-acetylene flame and a 1000 ppm Al solution as ionization buffer were used for Mo analyses. Background corrections were made on Ni, Cd, Ag, Pb and Mo analyses.

F was determined using an ion selective electrode (ISE) and total ionic strength adjustment buffer (TISAB). A 500 mg sample was fused with Na_2O_3-KNO_3 (9:1) at 800º C for 10 minutes.

Ba was analysed by x-ray fluorescence (XRF) using pressed powder disks.

Colorimetric methods (COL) employing the standard dithiol method were used to measure W. The sample was fused at 800º C in nickel crucibles along with a mixture of Na_2CO_3, NaCl and $KN0_3$ (5:4:1).

P_2O_5 was determined colorimetrically (COL) using the H_2SO_4 and ammonium molybdate method after sample decomposition using HNO_3-HCl-$HClO_4$.

Loss-on-ignition (LOI) was recorded as a measure of the weight percent loss of volatiles after igniting a known weight at 450º C for four hours (GRAV).

U was determined by neutron activation analysis (NADNC) using delayed neutron counting on a 3 g sample. The flux density used was 2 x 10^{11} neutrons/cm^2/s to 1 x 10^{12} neutrons/cm^2/s.

For the determination of As, Sb and Hg, a 750 ml sample was digested overnight in aqua regia (3 HCl:1 HNO_3). It was then treated in a water bath for approximately four hours during which time the temperature was raised to 90º C. The final volume was 15 ml. Subsequently, As and Sb were measured by atomic absorption spectrophotometry using a silica tube heated to 900º C. The hydride of the element was formed with a sodium borohydride reducing agent (HY-AAS). Mercury was determined similarly by measuring Hg vapour atomized in a silica tube heated to 100º C (CV-AAS).

A summary of the elements analysed in stream sediments is shown in Table 2.

Table 2: Elements in stream sediments determined by various methods of analysis in 1981

ELEMENT		DETECTION LEVEL	
Ag	Silver	0.2	ppm
As	Arsenic	0.4	ppm
Ba	Barium	0.02	pct
Cd	Cadmium	0.2	ppm
Co	Cobalt	2	ppm
Cu	Copper	2	ppm
F	Fluorine	20	ppm
Fe	Iron	0.2	pct
Hg	Mercury	30	ppb
LOI	Loss-on-ignition	1.0	pct
Mn	Manganese	2	ppm
Mo	Molybdenum	2	ppm
Ni	Nickel	10	ppm
P_2O_5	Phosphorus pentoxide	0.04	pct
Pb	Lead	2	ppm
Sb	Antimony	0.4	ppm
U	Uranium	1	ppm
V	Vanadium	20	ppm
W	Tungsten	2	ppm
Zn	Zinc	2	ppm

Instrumental Neutron Activation Analysis (INAA)

Weighed and encapsulated samples, normally 30 g, were packaged for irradiation along with internal standards and international reference materials. Samples and standards 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 3.

Table 3: Elements in stream sediments determined by Instrumental Neutron Activation analysis in 2000.

ELEMENT		DETECTION LEVEL	
As	Arsenic	0.5	ppm
Au	Gold	2	ppb
Ba	Barium	50	ppm
Br	Bromine	0.5	ppm
Ce	Cerium	5	ppm
Co	Cobalt	5	ppm
Cr	Chromium	20	ppm
Cs	Cesium	0.5	ppm
Eu	Europium	1	ppm

Fe	Iron	0.2	pct
Hf	Hafnium	1	ppm
La	Lanthanum	2	ppm
Lu	Lutetium	0.2	ppm
Na	Sodium	0.02	pct
Rb	Rubidium	5	ppm
Sb	Antimony	0.1	ppm
Sc	Scandium	0.2	ppm
Sm	Samarium	0.1	ppm
Ta	Tantalum	0.5	ppm
Tb	Terbium	0.5	ppm
Th	Thorium	0.2	ppm
U	Uranium	0.2	ppm
W	Tungsten	1	ppm
Yb	Ytterbium	1	ppm

INAA data for silver, cadmium, iridium, molybdenum, nickel, selenium, tin, tellurium, titanium, zinc, and zirconium are not published because of inadequate detection limits and/or precision.

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

For determination of the 38 elements listed in Table 4, a one-gram sample was leached with a 6 ml mixture of HCl, HNO_3, and distilled, deionized water (2:2:2 v/v) at 95° C for one hour. The sample solution was diluted with de-ionized water to 20 ml and analysed by inductively coupled plasma emission spectroscopy on a Jarell-Ash instrument and inductively coupled plasma mass spectroscopy on a Perkin-Elmer Elan instrument.

Table 4 Variables in stream silts determined by Inductively Coupled Plasma - Mass Spectrometry.

VARIABLE		DETECTION LEVEL	
Ag	Silver	2	ppb
Al	Aluminum	0.01	pct
As	Arsenic	0.1	ppm
Ba	Barium	0.5	ppm
Bi	Bismuth	0.02	ppm
Ca	Calcium	0.01	pct
Cd	Cadmium	0.01	ppm
Co	Cobalt	0.1	ppm
Cr	Chromium	0.5	ppm
Cu	Copper	0.01	ppm
Fe	Iron	0.01	pct
Ga	Gallium	0.2	ppm
Hg	Mercury	5	ppb
K	Potassium	0.01	pct
La	Lanthanum	0.5	ppm
Mg	Magnesium	0.01	pct
Mn	Manganese	1	ppm
Mo	Molybdenum	0.01	ppm
Na	Sodium	0.001	pct
Ni	Nickel	0.01	ppm
P	Phosphorus	0.001	pct
Pb	Lead	0.01	ppm
S	Sulphur	0.01	pct
Sb	Antimony	0.02	ppm
Sc	Scandium	0.1	ppm
Se	Selenium	0.1	ppm
Sr	Strontium	0.5	ppm
Te	Tellurium	0.02	ppm
Th	Thorium	0.1	ppm
Ti	Titanium	0.001	pct
Tl	Thallium	0.02	ppm
U	Uranium	0.1	ppm
V	Vanadium	2	ppm

W	Tungsten	0.1	ppm
Zn	Zinc	0.1	ppm

ACKNOWLEDGEMENTS

W.D. Goodfellow, GSC, directed a regional stream sediment and water survey carried out in 1981 by Marshall, Macklin and Monaghan Ltd. Sediment samples were prepared for analysis by staff at the Geological Survey of Canada. Bondar-Clegg and Company, Ottawa, determined the following elements in stream sediments: Zn, Cu, Pb, Ni, Co, Ag, Mn, Fe, Mo, V, W, F, and Ba. Loss-on-ignition (LOI) and P_2O_5 were also determined. Nova Track Ltd., Vancouver, measured U in stream sediments using a delayed neutron activation method. A. I. MacLaurin, G. Gauthier and W. M. Alexander carried out the rest of the analytical work under the supervision of G. E. M. Hall. J.J. Lynch monitored analytical results.

Stream sediment samples were reanalysed by Instrumental Neutron Activation Analysis (INAA) in 2000 by Becquerel Labs, Mississauga, Ontario, under the direction of P.W.B. Friske.

Stream sediment samples were reanalysed by Inductively Coupled Plasma Mass Spectrometry (ICP-MS) in 2008 by Acme Analytical Laboratories (Vancouver) Ltd., Vancouver, British Columbia, under the direction of P.W.B. Friske.

S. Day edited and compiled this open file.

W.A. Spirito of the GSC reviewed this open file and provided many useful comments and suggestions.

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Figure 1: ***NGR coverage in Yukon, NWT and western Nunavut***

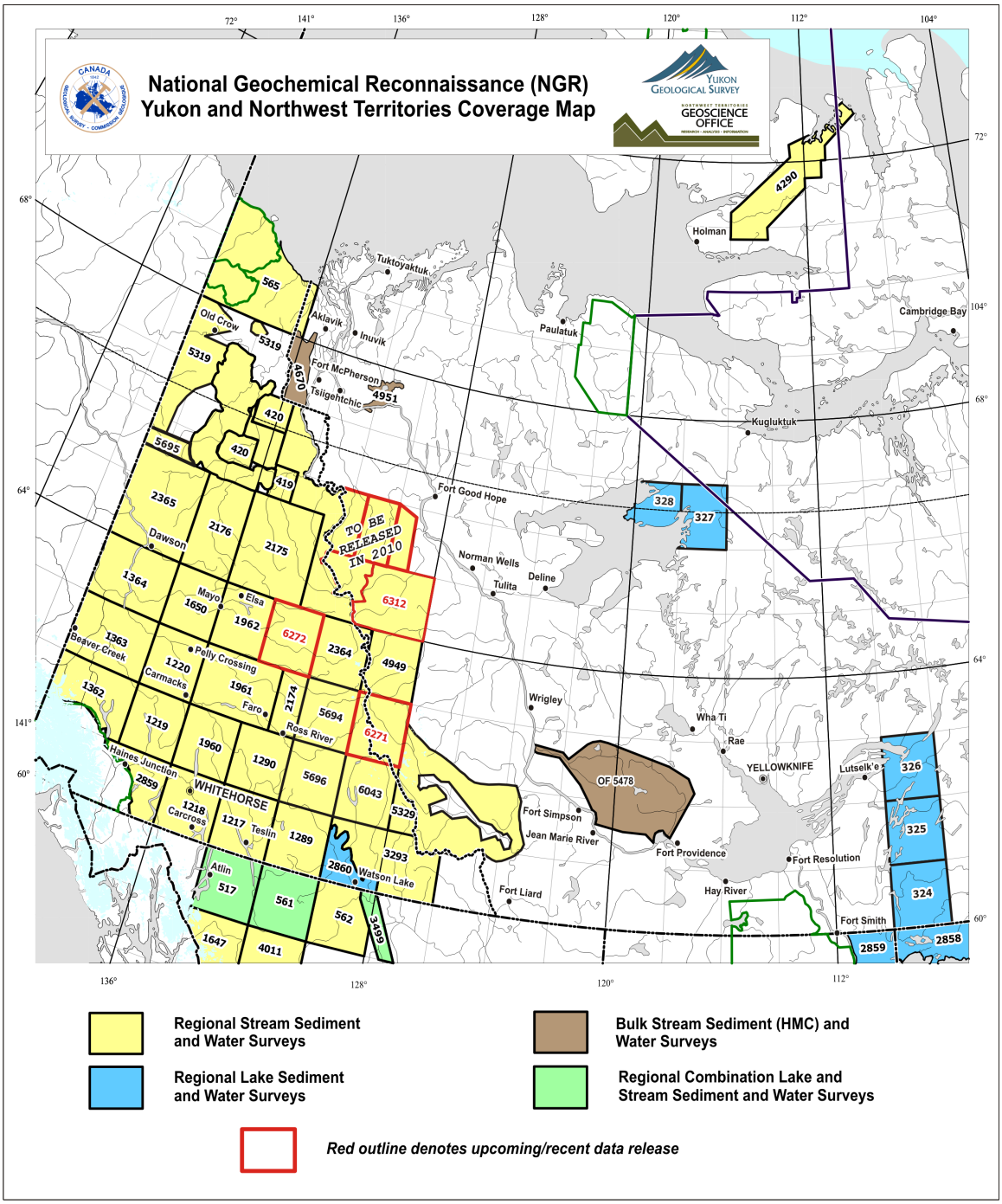

Figure 2: ***Card used to capture site-specific field observation data (Garrett, 1974)***