BRITISH COLUMBIA
Ministry of Employment and Investment
Energy and Minerals Division
Geological Survey Branch

REGIONAL LAKE SEDIMENT AND WATER GEOCHEMISTRY OF PART OF THE FORT FRASER MAP AREA, BRITISH COLUMBIA (NTS 93K/9, 10, 15 AND 16)

By Stephen J. Cook, Wayne Jackaman, Martin W. McCurdy, Stephen J. Day and Peter W. Friske

GSC OPEN FILE 3305

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Canadian Cataloguing in Publication Data
Main entry under title:
Regional lake sediment and water geochemistry of part of the Fort Fraser map area, British Columbia (NTS 93K/9, 10, 15 and 16)

GSC open file ; 3305
Open file, ISSN 0835-3530 ; 1996-15

Issued by Geological Survey Branch and Geological Survey of Canada.
Includes bibliographical references: p.
ISBN 0-7726-3136-0

1. Water - Composition - British Columbia - Fort Fraser Region. 2. Sediments (Geology) - British Columbia - Fort Fraser Region. 3. Geochemistry - British Columbia - Fort Fraser Region. 4. Geology - British Columbia - Fort Fraser Region. I. Cook, S.J. (Stephen John). II. British Columbia. Ministry of Employment and Investment. III. British Columbia. Geological Survey Branch. IV. Geological Survey of Canada. V. Title. VI. Series: Open file (British Columbia. Geological Survey Branch) ; 1996-15. VII. Open file (Geological Survey of Canada) ; 3305.

QE515.R43 1997 551.9'09711'82 C97-960009-X

VICTORIA
BRITISH COLUMBIA
CANADA
JANUARY 1997

ABSTRACT

Results of a regional lake sediment and water geochemistry survey conducted in the Fort Fraser map area (NTS 93K) in 1995 highlight several new exploration targets in the northern Interior Plateau of British Columbia. The Pinchi Lake survey (NTS 93K/9, 10, 15, 16) covers an area of perceived high mineral potential in a region where exploration has previously been limited by extensive drift cover, poor exposure and an insufficient geological database.

Lake sediments and waters were collected from 413 sites in the survey area at an average density of one site per 8.7 square kilometres. On the basis of results from prior orientation studies, samples were collected from every lake and every sub-basin. These were analyzed for 15 elemental determinations by atomic absorption spectroscopy (AAS), and for a further 25 elements by instrumental neutron activation analysis (INAA). Standard Regional Geochemical Survey sampling, analytical and quality control procedures were used. Preliminary discussion of results for mercury, gold, arsenic, antimony, copper, molybdenum, zinc, silver, chromium and nickel indicate that the surveys confirm the locations of currently known prospects and outline new areas for prospective porphyry-style gold-copper and molybdenum deposits.

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INTRODUCTION

Open File 1996-15 presents new analytical data for 37 different elements from a regional lake sediment and water geochemistry survey (Figure 1) conducted by the British Columbia Geological Survey Branch and the Geological Survey of Canada in the Nechako Plateau region during 1995. The Pinchi Lake Survey covers four 1:50000 NTS map areas: 93K/9 (Pinchi Lake), 93K/10 (Stuart Lake), 93K/15 (Inzana Lake) and 93K/16 (Tezzeron Creek). Exploration in this region has been centred primarily on porphyry copper-gold targets such as the Tas (MINFILE 093K 080) and Lynx (MINFILE 093K 083) occurrences and, in the past, on epithermal mercury deposits. A total of 413 sites were sampled over an area of approximately 3584 square kilometres at an average density of 1 site per 8.7 square kilometres (Table 1). Data for gold, precious metal pathfinders, base metals and rare earth elements are provided here. Several new exploration targets are highlighted, and recomendations given for the interpretation and follow-up of geochemical anomalies. Another recent publication, Geological Survey of Canada Open File 3194 (Plouffe, 1995) presents new analytical data for a regional till geochemistry survey of this area.

The subdued topography, poor drainage and abundance of lakes in the northern Interior Plateau make lake sediments an ideal geochemical exploration sample medium. They are an effective tool to delineate regional geochemical patterns and anomalous metal concentrations related to mineral occurrences, and have been used successfully in the region for some 25 years. In the Nechako Plateau, for example, lake sediment geochemistry reflects the presence of a bulk silver prospect near Capoose Lake (Hoffman, 1976; Hoffman and Fletcher, 1981), porphyry molybdenum-copper mineralization near Chutanli Lake (Mehrtens, 1975; Mehrtens *et al.*, 1973), and epithermal precious metal prospects such as the Tsacha (Cook *et al.*, 1995) and Fawn (Hoffman and Smith, 1982) occurrences. Lake sediment geochemistry has also been successful in locating epithermal gold-silver mineralization at the Wolf prospect in the Nechako Plateau (Andrew, 1988) and, further to the north, porphyry molybdenum mineralization at the Mac deposit (Godwin and Cann, 1985; Cope and Spence, 1995). Orientation studies conducted near several epithermal gold and porphyry molybdenum prospects in the Nechako River map area to the south have shown that elevated concentrations of gold, arsenic, molybdenum and other elements occur in adjacent lake sediments (Cook, 1993, 1995, 1996).

The Interior Plateau Project is a multidisciplinary investigation of bedrock geology, glacial history, and till and lake sediment geochemistry of parts of the Nechako and Fraser plateaus in the Northern Interior. Mineral exploration of this area has been limited by extensive drift cover, poor exposure and, locally, a barren Tertiary volcanic cover. As well, the geological database is either nonexistent or obsolete. The project is part of the Canada-British Columbia Mineral Development Agreement (1991-1995), and results are summarized in B.C. Geological Survey Branch Paper 1996-2 "Interior Plateau Geoscience Project: Summary of Geological, Geochemical and Geophysical Studies". Open File 1996-15 is a contribution to the Interior Plateau Project and its successor, the Nechako NATMAP Project.

The Pinchi Lake survey was funded by the GSC and conducted jointly by GSB and GSC staff. This is the second open file release of Interior Plateau Project regional lake sediment survey data. Data for part of the Nechako River map area (NTS 93F) was released in 1994 (Cook and Jackaman, 1994b; Figure 1). Prior to that, the only publicly funded regional lake sediment surveys conducted in B.C. were the 1986 surveys of NTS map areas 93E (Whitesail Lake) and 93L (Smithers) (Johnson *et al.*, 1987a,b). Sample collection, preparation and analytical procedures conform to established standards of the National Geochemical Reconnaissance (NGR) and Regional Geochemical Survey (RGS) programs. Results will be incorporated at a later date into ongoing regional lake sediment surveys of the Fort Fraser map area (NTS 93K) as part of the RGS program. Analytical results and field observations compiled by the RGS program in British Columbia are used in the development of a high-quality geochemical database suitable for mineral exploration, resource assessment, geological mapping and environmental studies.

OPEN FILE FORMAT

Open File 1996-15 is divided into the following sections:

- Introduction, survey methodology and quality control
- Preliminary data interpretation and discussion
- Listings of field variables and analytical data (Appendix A)
- Listings of analytical duplicate data (Appendix B)
- Summary statistics; anomaly ratings (Appendix C)
- Element distribution, geology and sample location maps; multi-element anomaly maps (Appendix D)

Analytical and field data are included as an ASCII file on a 3.5-inch high density diskette. Data for each sample are listed in comma-delimited fields over one data record. Document files detailing format specifications and survey details are also included. The diskette, together with a 1:100000-scale sample location map, is located in the back pocket.

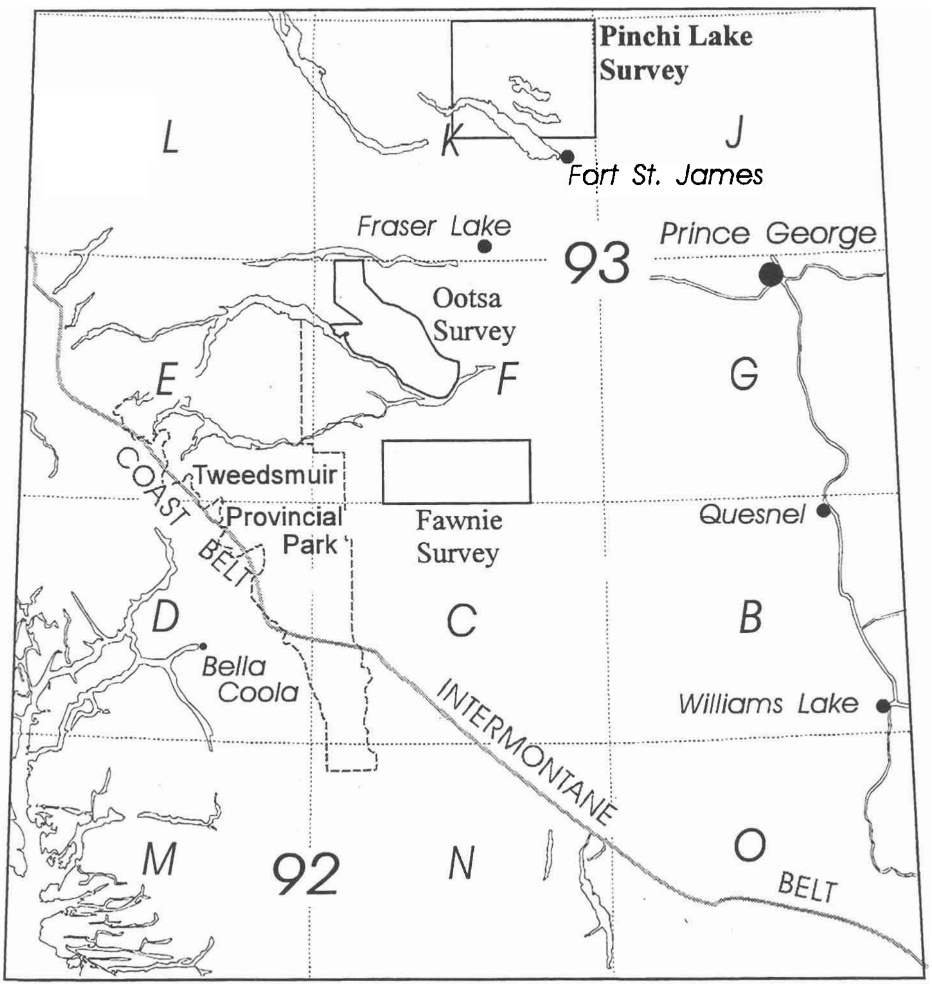


Figure 1. Location of the Pinchi Lake lake sediment survey area in the Fort Fraser map area (NTS 93K) of the Interior Plateau, British Columbia. Areas of prior data release in the Nechako River map area (NTS 93F) are also shown.

DESCRIPTION OF THE SURVEY AREA

LOCATION AND ACCESS

The Pinchi Lake survey area (NTS map areas 93K/9, 10, 15, 16) covers about 3760 square kilometres and is located immediately north of the town of Fort St. James in central British Columbia, approximately 110 kilometres northwest of Prince George. An extensive network of logging roads provide good access into much of the survey area from Fort St. James. The Germansen North road runs northward through the eastern part of the survey area to Germansen Landing and Mackenzie, while the Tachie and Leo Creek roads provide access to the northwestern part of the survey area. The southwest corner of the survey area, on the southwest side of Stuart Lake, is accessed via the Whitefish-Cunningham forestry road.

PHYSIOGRAPHY AND SURFICIAL GEOLOGY

The northeast and southwest portions of the Pinchi Lake survey area lie within the bounds of the Nechako Plateau, but most of the area is within the Nechako Plain and parts of the Fraser Basin (Holland, 1976). This relatively flat-lying area of low relief lies between 2500 to 3000 feet (762 to 914 m) elevation in most areas, well below that of the adjacent Nechako Plateau. Topography is dominated by Chuius Mountain (max. elevation: 1568 m) in the centre of the survey area, and by Mount Pope and Murray Ridge (max. elevations: 1472 m and 1399 m, respectively) in the southeast. Tchentsut Mountain and Pinchi Mountain are also prominent topographic highs. Extensive lowland areas are centred around Grostete Creek, northwest of Tezzeron Lake, and to the southeast and northeast of Pinchi Lake. Active first-order streams are relatively uncommon. Lakes are relatively uniformly distributed throughout the survey area, but there is considerable local variation in their abundance. For example, lakes are particularly numerous in the region between Tezzeron and Trembleur lakes, where they may form kettles, but are almost absent on the north side of Stuart Lake and in the Tezzeron Creek-Tsilcoh River-Hyman Creek-Ocock Creek lowland in the southeast part of the survey area.

The surficial geology and glacial history of the survey area have been documented by Plouffe (1994, 1995), Armstrong and Tipper (1948) and Armstrong (1949). The area is extensively drift-covered, and till and glacial lake sediments are the most widespread Quaternary deposits; glaciofluvial sediments are not extensive. Plouffe (1994) indicates that most of the area is covered with a till blanket at least 1 m thick. Thicker hummocky till is most commonly found in the eastern part of the survey area; thin till veneers and associated postglacial colluvium are restricted to a few areas of higher relief. Ice flow was dominantly from west to east (Plouffe, 1995), with a significant deflection toward the northeast in the Tezzeron Creek map area (NTS 93K/16). Extensive deposits of glacial lake sediments in the area are erosional remnants of what Armstrong and Tipper (1948) referred to as the Fort St. James basin, one of three short-lived glacial lake basins which formed in the Prince George region upon stagnation and retreat of the Cordilleran ice sheet. Recent mapping (Plouffe, 1994) has shown that the distribution of these light-coloured silts, with minor sand and clay, is less extensive than previously thought. They are confined to a discontinuous northwest-trending corridor extending from the southeastern corner of the survey area to Trembleur Lake. Stuart, Pinchi and Tezzeron lakes are present-day remnants of these lake basins, which lie between about 2200 and 2600 feet (670 and 792 m; Armstrong, 1949) elevation. Maximum thickness of the Fort St. James basin is at least 30 m (Armstrong, 1949), but most glacial lake sediments form a discontinuous veneer of about 1 m (Plouffe, 1994) over the underlying till moraine. Thicker (generally 2-4 m) silt blankets are restricted to the north side of Stuart Lake and to the region between Tezzeron and Trembleur lakes.

BEDROCK GEOLOGY

Bedrock geology of the Fort St. James region was first mapped by Armstrong (1941, 1949), and has been partially re-mapped to modern standards over the intervening half-century. Within the survey area, the Tezzeron Creek map area (NTS 93K/16) was mapped by Nelson *et al.* (1991a,b), while an area southwest of Stuart Lake (parts of NTS 93K/7, 8, 10 and 11) was mapped by Ash and Macdonald (1993a,b). Paterson (1973, 1977) mapped in the Pinchi Lake area. The recent compilation of Bellefontaine *et al.* (1995) is the most comprehensive map of the region (Appendix D-3), and is used as the geological base for this survey.

The survey area straddles the boundary between the Quesnel and Cache Creek Terranes, which are separated by the northwest-southeast trending Pinchi Fault zone. To the northeast of the Pinchi fault zone are Early Mesozoic Takla Group island arc rocks of the Quesnel

Terrane (Nelson *et al.,* 1991a,b). This assemblage of sedimentary, volcanic, pyroclastic and epiclastic rocks has been informally subdivided by Nelson *et al.* (1991a,b) and Nelson and Bellefontaine (1996) in this area into four informal successions: the Slate Creek, Inzana Lake, Witch Lake and Chuchi Lake successions. Of these, the Inzana Lake succession and, to a lesser extent, the underlying Slate Creek succession are most extensive within the survey area. The Inzana Lake succession largely comprises interlayered argillite and epiclastic volcanic units. The Slate Creek (formerly Rainbow Creek) succession comprises interbedded black argillite, greywacke, siltstone and other sedimentary units. Augite porphyry flows and agglomerate typify the Witch Lake succession, exposed in the northeastern part of the survey area. Coeval plutonic rocks, primarily Early Jurassic diorite intrusives such as the Kalder pluton and the Tas intrusive complex, are also exposed in this area. Miocene-Pliocene Chilcotin Group basalt flows occur in low-lying regions in the eastern part of the survey area.

To the southwest of the Pinchi fault zone are Late Paleozoic to Early Mesozoic pelagic sediments, carbonates, metabasalts and ultramafic rocks of the Cache Creek Terrane (Paterson, 1977; Ash and Macdonald, 1993a,b). A belt of glaucophane-lawsonite blueschist-facies metamorphism parallels the fault zone (Paterson, 1977) within the survey area. Pelagic sedimentary rocks are the most common units of this northwest-trending belt of Cache Creek Group oceanic rocks, named the Stuart Lake belt by Armstrong (1949). These are intruded north of Stuart Lake by a Middle Jurassic-Early Cretaceous Francois Intrusion. Felsic intrusive rocks of the Middle Jurassic Shass Mountain Pluton, which separates the Cache Creek and Stikine Terranes, are also exposed in the extreme southwestern corner of the survey area.

MINERAL DEPOSITS

The mineral deposits of the Pinchi Lake survey area and surrounding region include: (i) porphyry copper-gold deposits, (ii) epithermal mercury deposits, (iii) mesothermal gold-antimony-quartz vein deposits, and (iv) podiform chromite showings.

Porphyry copper-gold deposits have been the main focus of exploration in the area since the mid-1980's. They are associated with coeval alkaline intrusions in Late Triassic-Early Jurassic rocks of the Takla arc. The most prominant example in the region is the Mt. Milligan deposit, discovered in 1987, which is located just north of the survey area. Nelson and Bellefontaine (1996) have summarized the geological setting of the alkalic intrusives associated with these deposits. They are typically small, high-level to subvolcanic, contain densely-crowded, blocky plagioclase phenocrysts, and exhibit associated potassic-propylitic-pyritic alteration haloes. There are seven known porphyry prospects in Takla Group rocks within the survey area, all within the Tezzeron Creek map area (NTS 93K/16). The most signifiicant of these are the Max copper-gold prospect (MINFILE 93K 020), and the Tas gold-copper prospect (MINFILE 93K 080).

Epithermal mercury deposits associated with the Pinchi fault zone are, historically, the most important economic mineralization within the survey area. The Pinchi Lake Mercury mine (MINFILE 93K 049) produced approximately 6.2 million kilograms of mercury during the periods 1940-1944 and 1968-1975 (MINFILE, 1995). Seven epithermal mercury deposits and showings occur along the Pinchi fault zone within the survey area, forming part of what Armstrong (1942a,b) named the Pinchi Lake mercury belt. They are found from the northwest side of Tezzeron Lake to Murray Ridge, near Fort St. James. Most, including the former Pinchi Lake Mercury mine, occur within a relatively small area between Pinchi and Tezzeron lakes. These deposits are hosted within metamorphosed sedimentary, volcanic and ultramafic rocks of the Cache Creek Group, where they typically occur as quartz-carbonate-cinnibar veins, stockworks, breccia zones and disseminations within carbonatized alteration zones (Armstrong, 1942a,b, 1949; Stevenson, 1940). It has been suggested that they, and the Snowbird Au-Sb deposit (MINFILE 93K 036), may represent the near-surface expression of a deeper mesothermal gold system (Nesbitt *et al.,*1989; Albino, 1990).

There are no mesothermal vein deposits within the bounds of the survey area. However, the Snowbird Au-Sb deposit is located just south of the survey area near the southwest end of Stuart Lake. It is a mesothermal quartz-carbonate-stibnite vein deposit hosted in a shear zone within carbonatized serpentinite of the Cache Creek Group, and was briefly mined for antimony during 1938-1940 (Armstrong, 1949). More recently, a gold inventory of 227,000 tonnes at 6.86 g per tonne has been reported by Madu *et al.,* (1990). No similar gold-quartz vein mineralization is known in Cache Creek Group rocks of the survey area. Ash and Macdonald (1993a) attributed this to the rarity of exposed remnants of crustal and upper mantle ophiolitic rocks in the rest of the pelagic sedimentary sequence, although much of this area is obscured by a blanket of till and glaciolacustrine silt.

Chromite occurs as disseminations, wispy layers and rare lenses in obducted ultramafic rocks of the Cache Creek Group (Whittaker and Watkinson, 1981) at the Murray Ridge showing (MINFILE 93K 012) northeast of Fort St. James.

Photo 1. Regional lake sediment sampling in the Nechako Plateau.

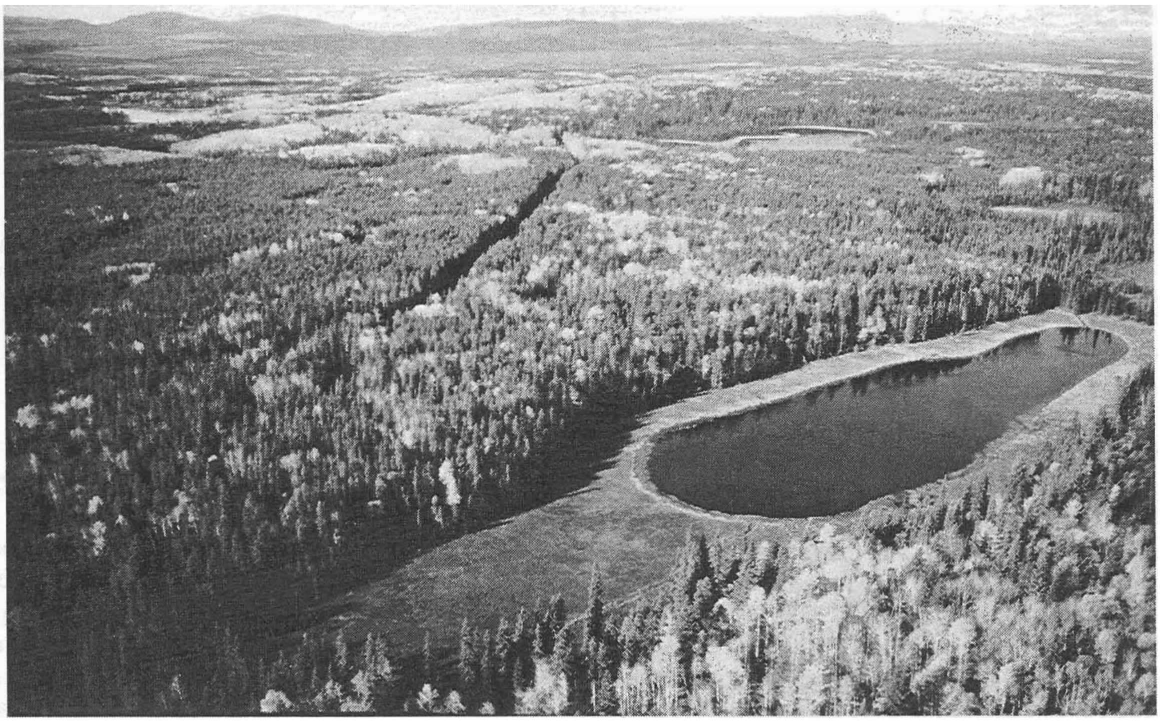


Photo 2. Typical landscape in Pinchi Lake survey area, northwest of Tezzeron Lake (October, 1995).

SURVEY METHODOLOGY

SAMPLE COLLECTION

Helicopter-supported sample collection in the Pinchi Lake survey area was conducted by the authors during the period October 4-9, 1995. A sediment sample and a water sample were systematically collected at each site using a float-equipped Bell 206 helicopter. A total of 438 sediment and water samples were collected from 413 sites (Table 1), at an average site density was approximately 1 per 8.7 square kilometres. Overall helicopter sampling rate averaged 10.4 sites per hour.

Survey	NTS	Area (square km)	Sampling Density	Sites	Samples
Fawnie	93F/2,3	1862.6	7.9	237	251
Ootsa	93F/6,11,12,13,14 (parts thereof)	1650	7.4	224	238
Pinchi Lake	93K/9,10,15,16	3584.2	8.7	413	438
Totals:		7096.8	8.1	874	927

Table 1. Summary of Interior Plateau lake sediment geochemistry surveys conducted under Canada-B.C. Mineral Development Agreement during the period 1993-1995. Sampling density is in sites per square kilometre.

SEDIMENTS

Sediments were sampled using a Hornbrook-type torpedo sampler and samples placed in large (5" x 6") Kraft paper bags. On the basis of results of prior orientation studies (Cook, 1993a,b), regional surveys in central British Columbia incorporate some departures from standard lake sediment sampling strategies used elsewhere in Canada for the National Geochemical Reconnaissance (NGR) program (Friske, 1991), particularly pertaining to overall site density and the number of sites sampled in each lake.

First, every lake in the survey area was sampled, rather than sampling only a selection of lakes at a fixed density (*ie.* one site per 13 km^2). Sediment in even small ponds may contain anomalous metal concentrations revealing the presence of nearby mineralization such as that at the Wolf prospect (Cook, 1995). In practice, some small ponds were not sampled due to unfavourable landing conditions. Samples were not collected from the centres of very large and deep lakes (> 10 km^2; > 40 m deep) such as Stuart, Tezzeron, Pinchi and Inzana lakes. In the case of Pinchi Lake, however, sediment was obtained from several sites in the lakes' northwest arm near the old Pinchi Lake mercury mine. Organic soils from shallow swamps and bogs were also avoided.

Secondly, centre-lake sediment samples were collected following standard NGR procedure, but sediment from the centres of all major known or inferred sub-basins was also collected to investigate the considerable trace element variations which may exist among sub-basins of the same lake. Consequently, several sites were sampled from some of the larger lakes. Lake bathymetry maps in unpublished reports of the Fisheries Branch, Ministry of Environment, Lands and Parks (Balkwill, 1991) were consulted prior to sampling several of the larger lakes such as Tarnezell, Grassham and Kaychek lakes to aid in site location and to avoid wasting helicopter time over extremely deep basins.

WATERS

Lake water samples were collected at each site in 250-millilitre high-density polyethylene (HDPE) Nalgene bottles using a custom-designed sampling apparatus. Waters were sampled from approximately 15 centimetres below the lake surface to avoid collection of surface scum, and precautions were taken to minimize suspended solids. These waters were collected for determination of the standard RGS analytical suite (pH, uranium, fluoride, sulphate). An additional 250-millilitre lake water sample was also collected at every second site for more extensive multi-element ICP-MS analysis of trace and major elements. This is the first application of ICP-MS hydrogeochemistry to RGS lake sediment surveys in British Columbia. A total of 217 sites were sampled; data will be released at a later date.

FIELD OBSERVATIONS

A variety of field variables and observations pertaining to sample media, site and local terrain were recorded at each site using Geological Survey of Canada lake sediment cards (Garrett, 1974). These included sample depth, colour and composition, as well as the general relief and potential sources of contamination. The absence or presence of suspended solids in water samples was also noted. Lake depth was measured with a depth sounder mounted to one of the helicopter floats.

Site locations were marked on 1:50000 scale NTS topographic maps in the field, transferred to master basemaps, and later digitized at the British Columbia Geological Survey Branch to obtain Universal Transverse Mercator (UTM) site coordinates (NAD27). Variables such as site geology, which reflects the dominant geological unit of the lake catchment, and lake area were coded after sample collection. Site geology was taken from Bellefontaine *et al.* (1995), and manually verified to ensure that lake watersheds corresponded to the coded geological unit. Common lake names used on either NTS topographic maps or the Fort St. James Forest District map were included where applicable. New features incorporated into this release include i) listings of both NAD27 and NAD83 UTM site coordinates, and ii) listings of area and perimeter values within the survey area for each lake, calculated from lake polygons from TRIM 1:250000 digital basemaps using a GIS subroutine.

SAMPLE PREPARATION

SEDIMENTS

Sediment samples were field dried and, when sufficiently dry to transport, shipped to Bondar-Clegg and Company, Ottawa, for final drying (max: 25-30^{o}C) and sample preparation. Preparation was conducted under Geological Survey of Canada supervision. The entire sample, to a maximum of about 250 grams, was pulverized in a ceramic ring mill and screened to minus 80 mesh (< 177 microns). Two analytical splits (20-30 grams each) were taken from the pulverized material for subsequent analysis.

WATERS

All lake water samples were kept cool following collection, and shipped to the Geological Survey of Canada, Ottawa, for insertion of control reference standards and distilled water blanks into the sample suite. No further preparation procedures were performed on routine raw lake water samples prior to analysis.

Samples collected for the expanded ICP-MS lake water geochemistry survey were filtered to 0.45 microns by the authors using MSI MicronSep filters (47 mm) and a Nalgene filtration apparatus with hand pump. Filtered waters were transferred to 250-millilitre I-Chem Certified high-density polyethylene (HDPE) acid-washed bottles, and acidified to approximately pH=2 with Merck Suprapure nitric acid as per standard methods for analysis of metals (APHA/AWWA/WEF, 1992). Water colour was also recorded at this time. Samples were transported from the field to the Analytical Sciences Laboratory,Victoria, in sealed plastic bags to ensure a high level of cleanliness. Distilled water blanks were inserted into the sample suite prior to analysis. Data will be reported at a later date.

SAMPLE ANALYSIS

Analysis of routine lake sediment and water samples was conducted by contract laboratories in accordance with established National Geochemical Reconnaissance (NGR) analytical methods. Analytical methods are strictly specified and carefully monitored to ensure consistent and reliable results regardless of the region, year or analytical laboratory. Element suites, detection limits and details of analytical procedures may differ slightly, however, from those reported by Cook and Jackaman (1994) for lake sediment surveys of the Nechako River map area. For example, only iron, molybdenum and nickel data for both analytical methods are reported here. No AAS data is available for arsenic or antimony in addition to the INAA data reported in Appendix A. Conversely, selenium AAS data is given in this report, but not in Cook and Jackaman (1994).

SEDIMENTS - AAS

A split of each prepared sediment sample was analyzed by CanTech Laboratories Inc., Calgary, Alberta for 15 elements: zinc, copper, lead, silver, molybdenum, cobalt, mercury, iron, manganese, nickel, fluorine, cadmium, vanadium, bismuth and selenium. Loss on ignition was also determined. Stated analytical detection limits for each element are listed in Table 2. Those concentrations below the stated detection limits are presented in data listings as a value equivilent to the detection limit.

- For the determination of cadmium, cobalt, copper, iron, lead, manganese, nickel, silver and zinc, a 1 gram sample was reacted with 3 millilitres of concentrated

HNO_3 for 30 minutes at 90°C. Concentrated HCl (1 millilitre) was added and the digestion was continued at 90°C for an additional 90 minutes. The sample solution was then diluted to 20 millilitres with metal-free water and mixed. Element concentrations were determined by atomic absorption spectroscopy (AAS) using an air-acetylene flame. Background corrections were made for lead, nickel, cobalt and silver.

- Mercury was determined by the Hatch and Ott procedure with some modifications. A 0.5 gram sample was reacted with 20 millilitres concentrated HNO_3 and 1 millilitre concentrated HCl in a test tube for 10 minutes at room temperature and then for 2 hours in a 90°C hot water bath. After digestion, the sample was cooled and diluted to 100 millilitres with metal-free water. The mercury present was reduced to the elemental state by the addition of 10 millilitres of 10% weight-to-volume $SnSO_4$ in H_2SO_4. The mercury vapour was then flushed by a stream of air into an absorption cell mounted in the light path of an atomic absorption spectrometer (CV-AAS). Measurements were made at 253.7 nanometres. This method is described by Jonasson *et al.* (1973).

- Molybdenum and vanadium were determined by aqua regia digestion - atomic absorption spectroscopy (AAS) using a nitrous oxide acetylene flame. A 0.5 gram sample was reacted with 1.5 millilitres concentrated HNO_3 at 90°C for 30 minutes. At this point 0.5 millilitres of concentrated HCl was added and the digestion continued for an additional 90 minutes. After cooling, 8 millilitres of 1250 ppm Al solution was added and the sample solution diluted to 10 millilitres before determination by AAS.

- Fluorine was determined by specific ion electrode as described by Ficklin (1970). A 250 milligram sample was sintered with a 1-gram flux consisting of two parts by weight sodium carbonate and 1 part by weight potassium nitrate. The residue was leached with water. The sodium carbonate was neutralized with 10 millilitres 10% weight-by-volume citric acid, and the resulting solution diluted with water to 100 millilitres. Fluoride was then measured with a fluoride ion electrode (ION) and a reference electrode.

- Bismuth and selenium were determined by aqua regia digestion - hydride generation atomic absorption spectroscopy. A 1 gram sample was reacted with 3 millilitres of concentrated HNO_3 for 30 minutes at 90°C. Concentrated HCl (1 millilitre) was added and the digestion was continued at 90°C for an additional 90 minutes. A 1 millilitre aliquot was diluted to 10 millilitres with 1.5M HCl in a clean test tube. The diluted sample solution was added to a sodium borohydride solution and the hydride vapour passed through a heated quartz tube in the light path of an atomic absorption spectrometer (AAS-H).

- Loss on ignition was determined using a 0.5 gram sample. The sample was weighed into a 30 millilitre beaker, placed in a cold muffle furnace and heated to 500°C over a period of 2 to 3 hours. The sample was maintained at this temperature for 4 hours, then allowed to cool to room temperature before weighing (GRAV).

SEDIMENTS - INAA

A 30 gram split of each sediment sample was analyzed for 25 elements including gold, arsenic, antimony, barium, bromine, cerium, cesium, chromium, cobalt, hafnium, iron, lanthanum, lutetium, molybdenum, nickel, rubidium, samarium, scandium, sodium, tantalum, terbium, thorium, tungsten, uranium and ytterbium by Becquerel Laboratories, Mississauga, Ontario using instrumental neutron activation analysis (INAA). Weighed and encapsulated samples 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 on a high-resolution germanium detector. Counting time was typically 500 seconds per sample. Results were compiled on a Microvax II computer and converted to concentrations. A complete list of the 25 elements and their stated instrumental detection limits are given in Table 2. Additional data for the nine elements silver, cadmium, europium, iridium, selenium, tin, tellurium, zinc and zirconium were not published because of inadequate detection limits and/or precision. Gold concentrations below the stated detection limits are presented in data listings as a value equivilent to one-half the detection limit. Sample weights are also reported.

WATERS (RGS SUITE)

Routine unfiltered lake waters were analyzed for the standard RGS water analytical suite of pH, uranium, fluoride and sulphate at CanTech Laboratories, Inc., Calgary. Stated detection limits are given in Table 2.

- Hydrogen ion activity (pH) was measured, on a separate sample aliquot, with a Corning pH meter with glass-calomel electrode (GCE).

- Uranium was determined by laser-induced fluorescence (LIF) using a Scintrex UA-3 uranium analyzer. A complexing agent, known commercially as Fluran and composed of sodium pyrophosphate and sodium monophosphate (Hall, 1979), is added to produce a uranyl pyrophosphate species which fluoresces when exposed to the laser. As organic matter in the sample can cause unpredictable behaviour, a standard addition method is used. A total of 500 microlitres of Fluran solution was added to a 5 millilitre sample and allowed to stand for 24 hours, as the reaction of uranium with the complexing agent may be delayed or sluggish. At the end of this period fluorescence readings were made with the addition of 0.0, 0.2 and 0.4 ppb uranium. For high-concentration samples, the additions were 0.0, 2.0 and 4.0 ppb uranium. All readings are taken against a sample blank.

- Fluoride was determined by ion selective electrode (ION). A 20 millilitre aliquot of the sample was mixed with 20 millilitres of TISAB II (total ionic strength adjustment buffer) buffer solution. Fluoride was determined with an Orion fluoride electrode in conjunction with a Corning ion meter.

- Sulphate was determined by a turbidimetric method (TURB). A 50 millilitre aliquot was mixed with barium chloride and an isopropyl alcohol-HCl-NaCl reagent, and turbidity of the resulting barium sulphate solution measured with a spectrophotometer at 420 nanometres. Note that lake water sulphate concentrations reported for the Nechako River map area (NTS 93F) by Cook and Jackaman (1994) were determined by either turbidimetry (Fawnie survey) or ion chromatography (Ootsa survey).

TABLE 2. ANALYTICAL METHODS AND STATED DETECTION LIMITS: LAKE SEDIMENTS AND WATERS

Element		**Detection Limit**	**Method**	**Element**		**Detection Limit**	**Method**
Bismuth	Bi	0.2 ppm	AAS-H	Gold	Au	2 ppb	INAA
Cadmium	Cd	0.2 ppm	AAS	Antimony	Sb	0.1 ppm	INAA
Cobalt	Co	2 ppm	AAS	Arsenic	As	0.5 ppm	INAA
Copper	Cu	2 ppm	AAS	Barium	Ba	50 ppm	INAA
Fluorine	F	40 ppm	ION	Bromine	Br	0.5 ppm	INAA
Iron	Fe	0.02%	AAS	Cerium	Ce	5 ppm	INAA
Lead	Pb	2 ppm	AAS	Cesium	Cs	0.5 ppm	INAA
Manganese	Mn	5 ppm	AAS	Chromium	Cr	20 ppm	INAA
Mercury	Hg	10 ppb	CV-AAS	Cobalt	Co	5 ppm	INAA
Molybdenum	Mo	2 ppm	AAS	Hafnium	Hf	1 ppm	INAA
Nickel	Ni	2 ppm	AAS	Iron	Fe	0.2%	INAA
Selenium	Se	0.2 ppm	AAS	Lanthanum	La	2 ppm	INAA
Silver	Ag	0.2 ppm	AAS	Lutetium	Lu	0.2 ppm	INAA
Vanadium	V	5 ppm	AAS	Molybdenum	Mo	1 ppm	INAA
Zinc	Zn	2 ppm	AAS	Nickel	Ni	10 ppm	INAA
Loss On Ignition	LOI	0.10%	GRAV	Rubidium	Rb	5 ppm	INAA
				Samarium	Sm	0.1 ppm	INAA
				Scandium	Sc	0.1 ppm	INAA
pH-water	pH	0.1	GCE	Sodium	Na	0.02%	INAA
Sulphate-water	SO4	1 ppm	TURB	Tantalum	Ta	0.5 ppm	INAA
Fluoride-water	FW	20 ppb	ION	Terbium	Tb	0.5 ppm	INAA
Uranium-water	UW	0.05 ppb	LIF	Thorium	Th	0.2 ppm	INAA
				Tungsten	W	1 ppm	INAA
				Uranium	U	0.2 ppm	INAA
				Ytterbium	Yb	1 ppm	INAA

AAS	atomic absorption spectrometry
CV-AAS	cold vapour-atomic absorption spectrometry
GCE	glass-calomel combination electrode
GRAV	gravimetry
INAA	instrumental neutron activation analysis
ION	ion selective electrode
LIF	laser-induced fluorescence
IC	ion chromatography

QUALITY CONTROL PROCEDURES AND RESULTS

METHODOLOGY

The ability to discriminate real geological and geochemical trends from those resulting from sampling and analytical variation is of considerable importance in the interpretation of geochemical data. Control reference standards and analytical duplicates are routinely inserted into sample suites to monitor and assess accuracy and precision of analytical results. Control reference standards are used to assess analytical accuracy. Sampling and analytical variation can be quantified using estimates of precision within and between sample sites determined by utilizing field and analytical duplicate data. In accordance with standard National Geochemical Reconnaissance (NGR) and Regional Geochemical Survey (RGS) quality control procedures, each block of 20 lake sediment samples contains (Figure 2):

- Seventeen routine samples,

- One field duplicate sample collected adjacent to one of the routine samples,

- One blind duplicate sample split from one of the 17 routine samples prior to analysis,

- One control reference standard containing sediment of known element concentrations.

The locations of blind duplicate and control reference samples are selected prior to sampling, whereas field duplicate sites are chosen randomly during fieldwork. At these sites, two samples are taken by successive drops of the torpedo sampler. These samples are used to monitor combined sampling and analytical precision, and are a measure of within-site variation. Blind, or analytical, duplicate samples are usually taken from the first sample of each field duplicate pair following sample preparation, and reinserted into the suite to monitor analytical precision. In practice, dry lake sediment samples are sometimes too small (as little as 50 grams) for a blind duplicate split. Here, 50 per cent of the blind duplicates are taken from the corresponding field duplicate sample; the remainder are taken from another routine sample within the block. Blind duplicates are not used in the water suite; a distilled water blank is instead inserted to monitor analytical contamination.

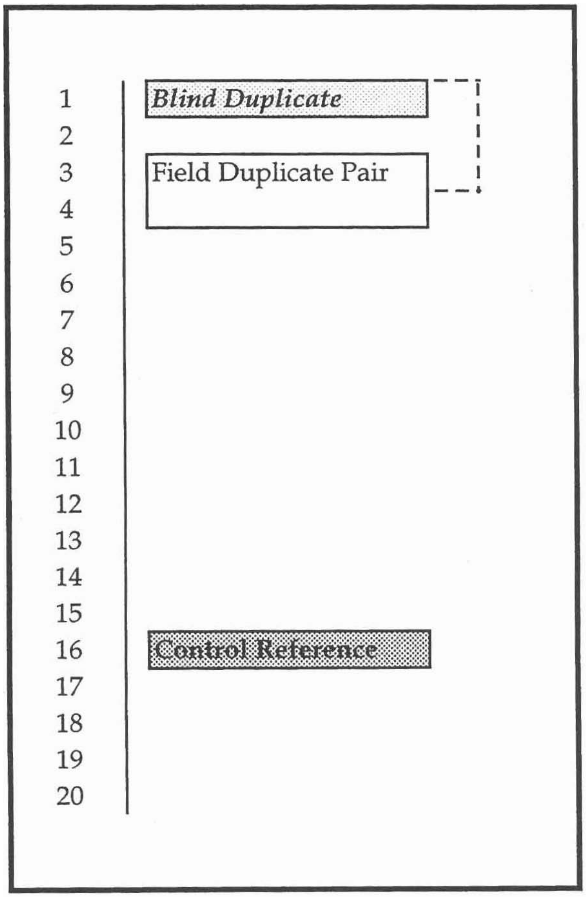


Figure 2. Typical Regional Geochemical Survey sample collection scheme used during the lake sediment survey. The 20-sample collection block incorporates 17 routine samples, a field duplicate sample, a blind duplicate sample and a control reference standard. Blind duplicates are routinely taken from the first sample of each field duplicate pair.

ANALYTICAL PRECISION AND ACCURACY

Variations in element concentrations in lake sediments may be due to regional geological and geochemical variations (different bedrock lithologies and surficial materials, absence or presence of mineralization, limnological variations), within-site variations (combined sampling, preparation and analytical variations), or analytical variation alone. As noted by Fletcher (1981), a high degree of analytical precision is of limited

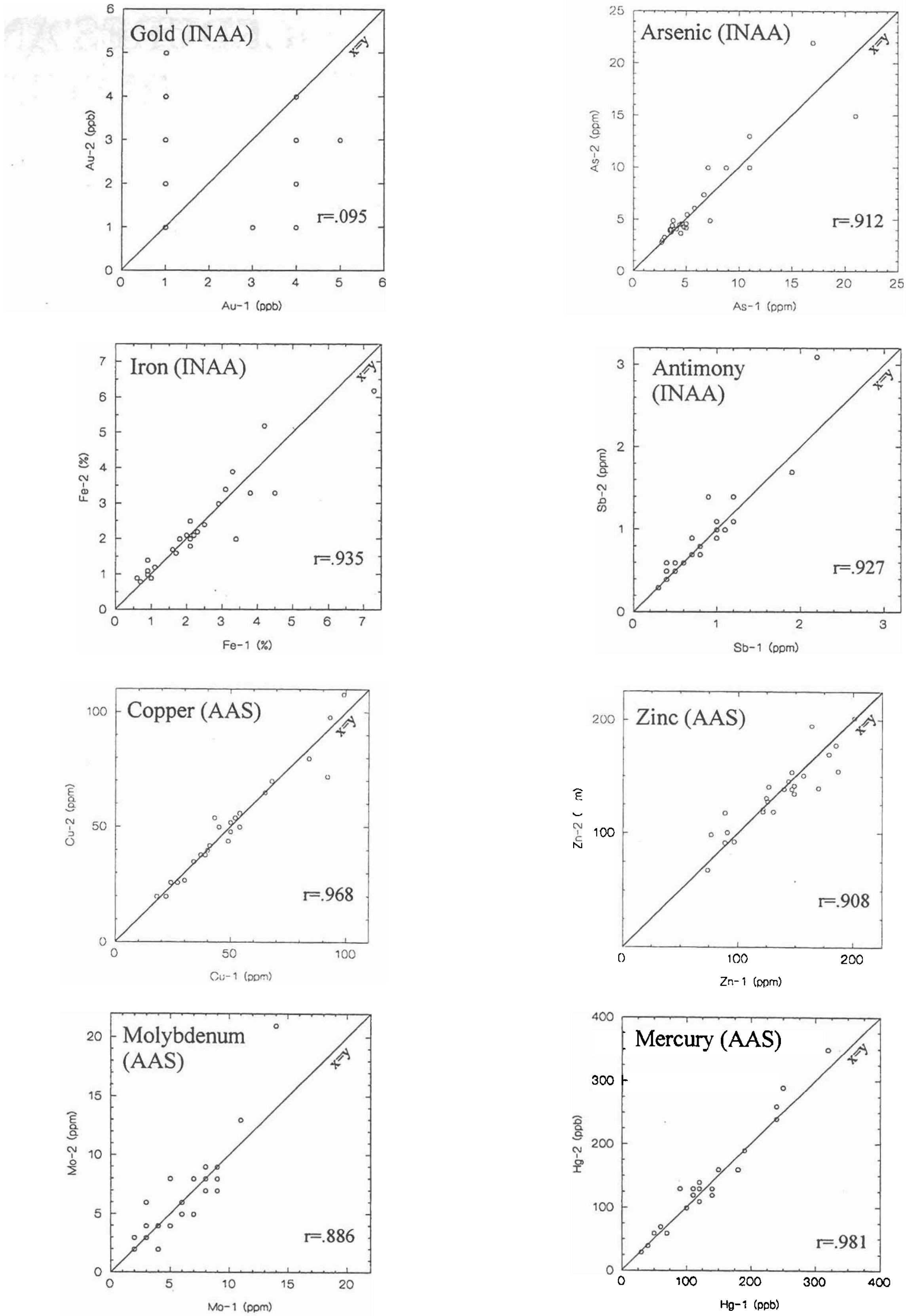


Figure 3. Scatterplots of field duplicate pairs (N=25) for gold, arsenic, iron and antimony (INAA) and for copper, zinc, molybdenum and mercury (AAS).

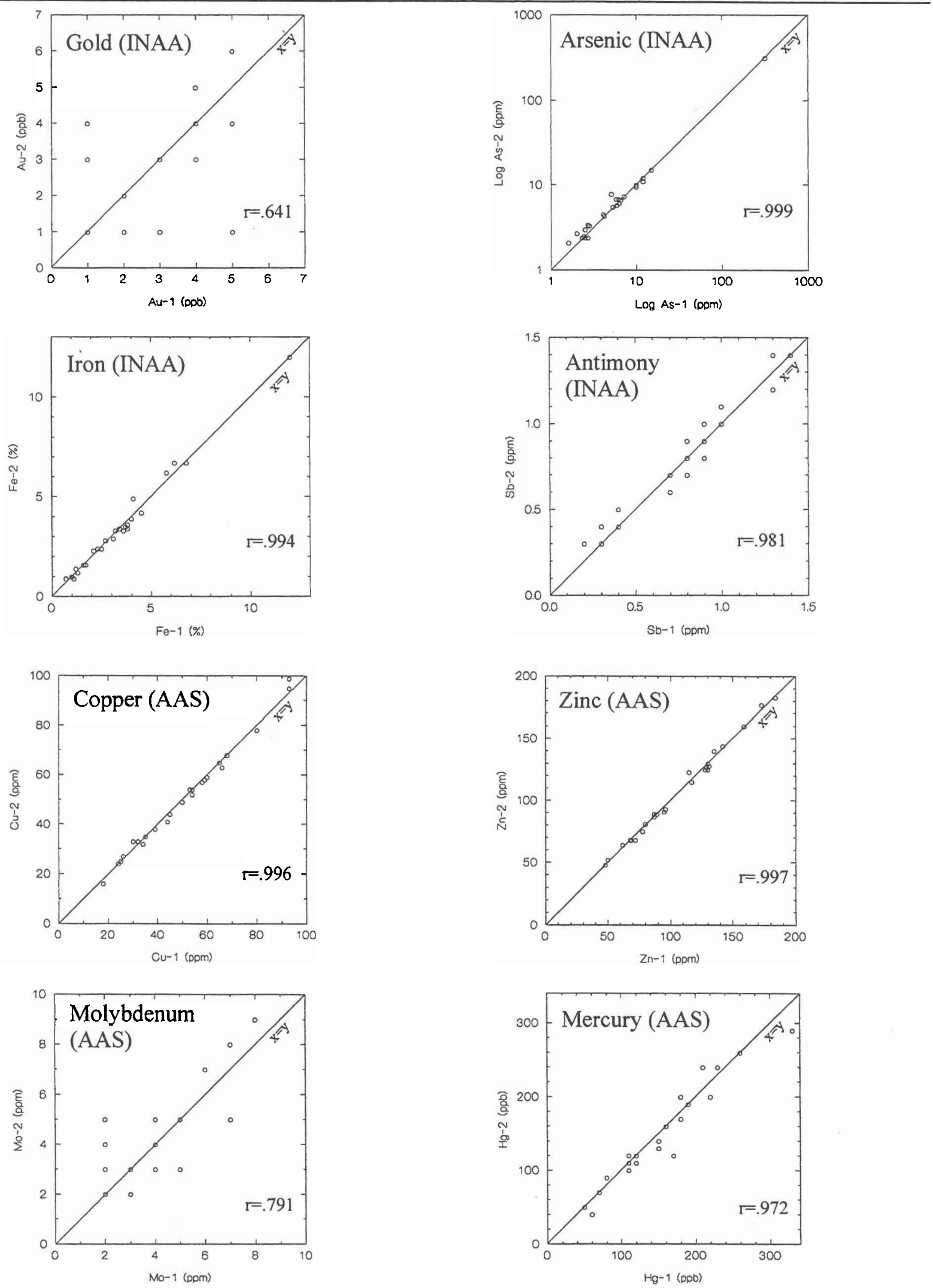


Figure 4. Scatterplots of blind duplicate pairs (N=25) for gold, arsenic, iron and antimony (INAA) and for copper, zinc, molybdenum and mercury (AAS).

importance if the sample collection and preparation error is so great as to be indistinguishable from the regional geochemical variation.

Scatterplots of analytical results for 25 field duplicate pairs (Figure 3) and 25 blind duplicate pairs (Figure 4) are shown for gold, arsenic, antimony and iron (INAA) and for copper, zinc, molybdenum and mercury (AAS). Very good reproducibility, particularly for those elements with concentrations well above detection limits, imparts a high degree of confidence in the quality of both the sampling and analytical procedures. Estimates of analytical precision at different concentration levels are not given for the 25 blind duplicate pairs, as this is fewer than the minimum of 50 pairs recommended by Thompson and Howarth (1978). However, mean relative standard deviation (RSD) values were calculated for both field and blind duplicate pairs of gold determinations by averaging the per cent RSD between each pair. Mean RSD for blind duplicate gold values (n=25 pairs) is 20.7%; mean RSD for field duplicate gold values (n=25 pairs) is higher at 36.9%. The greater precision attained with analysis of blind duplicate pairs is expected, as it is a measure of subsampling and analytical variability only. Analysis of field duplicate sample pairs, on the other hand, measures field sampling, preparation, subsampling and analytical variability. Field duplicate data for all elements are included within the data listings in Appendix A, and analytical duplicate data are listed in Appendix B.

Three internal lake sediment standards of the Geological Survey of Canada were used as control standards (n=25) for the Pinchi Lake survey. Analytical data for the control standards compare favourably with accepted values, indicating a high degree of analytical accuracy. For example, AAS analyses of the three standards returned mean copper concentrations of 17.9 ppm (n = 8), 25.1 ppm (n = 7) and 81.4 ppm (n = 10) copper relative to accepted values of 17.1 ppm, 23.2 ppm and 81.7 ppm, respectively. Regarding analytical precision of control standards results, several examples are given as follows. Seven to ten replicate analyses of each of three standards in the INAA suite returned relative standard deviations (RSD) of 3.3 - 9.4 % for arsenic, 4.6 - 8.2% for iron, and 2.9 - 7.7% for cerium. In the AAS suite, replicate analyses of the same three standards returned RSD values of 3.9 - 6.3% for copper, 4.4 - 5.6% for zinc, and 7.0 - 13.6% for mercury. Seven to ten replicate analyses of each of three GSC internal water standards returned RSD values of 3.5 - 10.9% for uranium, 4.3 - 7.0% for fluoride and 15.5 - 19.7% for sulphate.

Repeat INAA analyses are routinely conducted on samples reporting gold concentrations greater than the 90th percentile (Au-2 in the data listings). Here, repeat analyses were conducted on 47 samples with gold concentrations of at least 6 ppb (11.4% of total sites). All reanalyses were conducted on the original INAA sample capsule. Reanalysis of separate splits of the original pulverized sample material is generally preferable, as it provides a measure of both subsampling and analytical variability rather than simply analytical variability from one batch to another. However, there was insufficient original sample material remaining in this case to use new splits. Scatterplot results are shown in Figure 5. In all, 45 of 47 reanalyses yielded gold concentrations greater than the stated analytical detection limit of 2 ppb, and 33 of 47 returned gold concentrations of at least 6 ppb. Three of the four samples containing >10 ppb gold returned values >10 ppb upon reanalysis; the fourth returned a concentration of 10 ppb.

A mean relative standard deviation (RSD) of 19.6% was calculated for repeat gold analyses by averaging the per cent RSD between each of the 47 analytical pairs. Not surprisingly, this RSD is substantially identical to that determined for gold using blind duplicate pairs (20.7%), as both are largely measures of analytical precision. This is in spite of some considerable differences between the two data subsets. The repeats are the very highest gold concentrations in the Pinchi survey area, whereas the blind duplicate suite is a random collection of pairs of mostly low gold values (1-5 ppb) at or near the analytical detection limit.

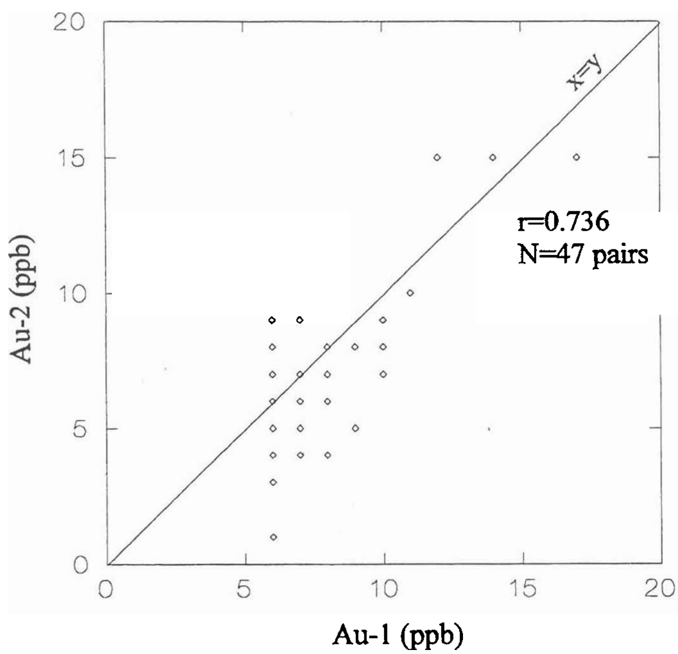


Figure 5. Scatterplot of results for 47 pairs of repeat gold analyses (ppb). Au-1 represents the original gold result; Au-2 represents the value obtained on reanalysis. Both values are reported in the data listings (Appendix A).

PRELIMINARY DATA INTERPRETATION

FIELD VARIABLES

Distribution of lake sediment sites by terrane in the Pinchi Lake survey area is shown in Figure 6. Approximately 55% of the sites are within Quesnellia; most of the remainder are in the Cache Creek Terrane (40%).

The majority of sites in the survey area (65%) are in lakes of pond size or smaller (*e.g.* < 0.25 km^2). This is similar to the proportion of pond-sized sites recorded to the south in the Fawnie and Ootsa lake sediment surveys of the Nechako River map area (NTS 93F; Cook and Jackaman, 1994b). Almost 21% of sites are in lakes in the range 0.25 to 1 km^2, but only 8.5% of sites are in large lakes (*e.g.* > 5 km^2). Median lake depth in the Pinchi Lake survey area is 4 metres. Shallow lakes are very common, and more than one-third of all sites are ponds with depths of 2 metres or less (Figure 7). More than three-quarters (78%) of the sites have depths of 10 metres or less. The deepest site recorded was 35 metres, but only 4% of the sites have depths of more than 20 metres. It should be noted that lake depth, measured with a float-mounted depth sounder, is not synonymous with sample depth, which is the distance from the water surface to the sample location within the sediment column. This is because the sampler typically penetrates a few metres into the sediment before coming to a stop. Generally, depth of penetration increases with increasing lake depth; it may be negligible in small ponds, but up to 3 or 4 metres in large, deep lakes.

Approximately 43% of sites were classed as being in areas of low relief, with a further 49% classed as areas of medium relief. Only 8% of lake sediment sites were categorized as being in areas of high relief. Field observations indicate that potential sources of anthropogenic contamination are likely minimal in spite of extensive logging activity in some parts of the survey area. Work or camp sites were recorded on the shores of 14% of sites sampled.

SEDIMENTS

The following data interpretation is of a preliminary nature. Discussions on the distribution and abundance of gold, arsenic, antimony, copper, molybdenum, zinc, silver, mercury, chromium and nickel are intended to highlight geochemical patterns that may be of interest to mineral explorationists, and are not exhaustive. Only raw data are used. Where applicable, unit designations of Bellefontaine *et al.* (1995) are used to identify geological units. Please refer to the appropriate 1:50000 scale NTS topographic maps or the Fort St. James Forest District map for lake and place names.

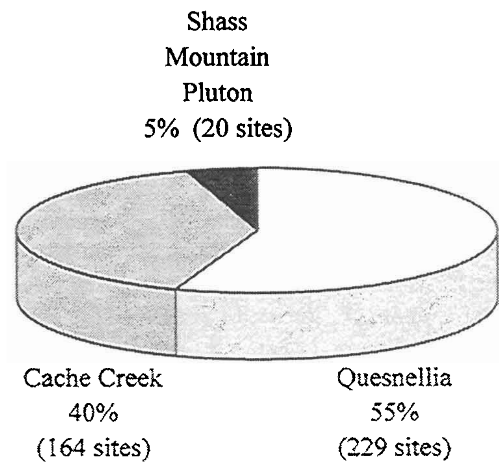


Figure 6. Distribution of lake sediment sample sites by terrane feature within the Pinchi Lake survey area. Sites within Quesnellia include those above Chilcotin Group volcanics (MPCv) and various intrusive units (Ktg, Ejd, TrJm, TrJd). Sites within the Cache Creek terrane include intrusive units (Jkgd) and the Sustut assemblage (KTS).

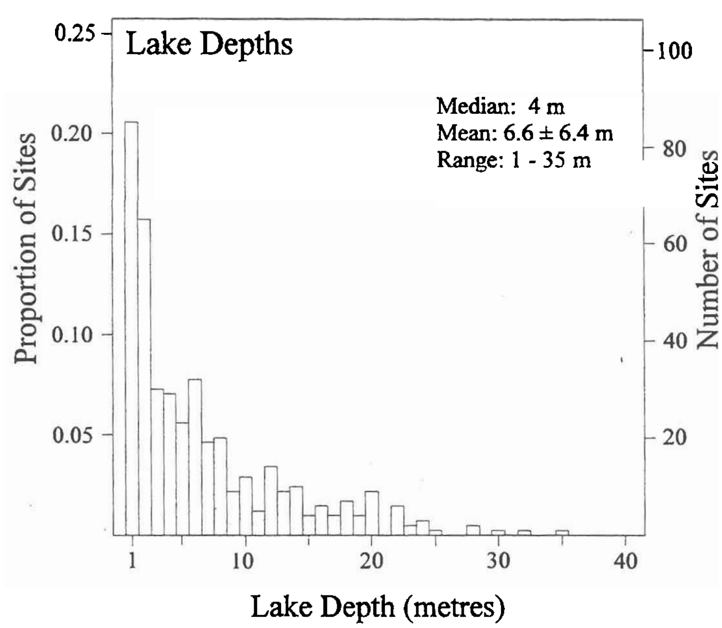


Figure 7. Histogram showing lake depths (413 sites) in the Pinchi Lake survey area.

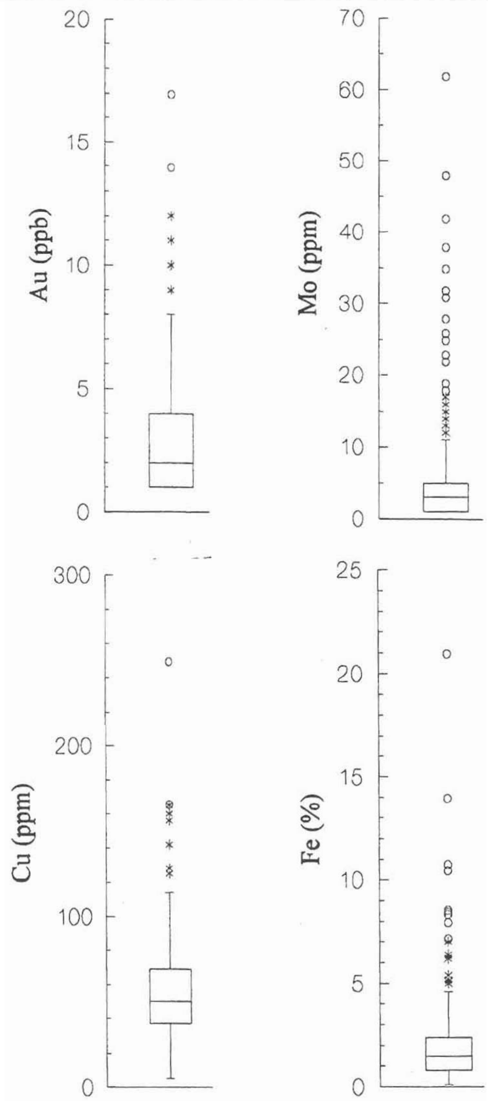


Figure 8. Boxplots showing distribution of gold and molybdenum (INAA), and copper and iron (AAS), in lake sediments of the Pinchi Lake survey area. Fifty per cent of the data lies within the box; the lower and upper bounds of each box define the first quartile and third quartile of data, respectively.

GOLD

Background gold concentration in lake sediments of the Pinchi Lake survey area, as expressed by median values, is 2 ppb. Only eight sites in the survey area contain at least 10 ppb gold. Elevated values (90th percentile: 6 ppb; max: 17 ppb) are associated with several geological units, but are primarily located within Takla Group sedimentary and volcanic assemblages (uTrTt, uTrTv). Median gold values of lake sediments above these two units (4 ppb) are at least twice that of most other units. Zones of elevated gold concentrations occur in three areas:

- A broad east-west trending zone approximately 16 kilometres x 5 kilometres, located northeast of Tezzeron Lake, which is centred on a Late Cretaceous-Early Tertiary rhyodacite/dacite intrusive and the adjacent Hat Lake copper (MINFILE 93K084) and Dem arsenic-antimony-gold (MINFILE 93K077) prospects. The zone of elevated gold concentrations extends from Dem Lake in the west to Chuzkeepah Lake in the east, and is mostly within the bounds of the Tezzeron Creek map area. Here, five sites contain 8-10 ppb gold, all of which are reproducible within a few ppb upon reanalysis. Two of the sites are immediately adjacent to, and downice of, the Hat Lake prospect. A third site is a few kilometres downice of the Dem prospect and associated potassic alteration. The remaining two sites are located relatively far, about 10-15 km, downice of the two prospects and may indicate the presence of new areas of mineralization. Several additional lake sediment sites contain lesser, but nevertheless elevated, gold concentrations.

- Three sites with elevated gold concentrations >95th percentile occur in the northeast part of the survey area near the margins of two Early Jurassic diorite bodies: the Kalder Pluton, and a smaller intrusive several kilometres to the south which is associated with the Tas (MINFILE 93K080) and Freegold (MINFILE 93K091) gold-copper prospects. Significantly, the two greatest sediment gold values in the survey area (14 and 17 ppb) occur in the north part of the zone on either side of the Kalder Pluton.

Two of the three sites with elevated gold concentrations occur on the southern margin of the poorly-exposed Kalder Pluton. One aforementioned site (1053) located just over 1 kilometre downslope of the intrusive contact contains 17 ppb gold in sediment, the highest gold concentration in the survey area. Sample reanalysis yielded a similar concentration of 15 ppb. A second site (1124), between the two plutons, contains 8 ppb gold and is both downice and downdrainage of the Tas prospect. It is also located approximately 1 km south of the intrusive contact of the Kalder Pluton. The third site with elevated gold concentrations in this zone occurs within Kalder Lake along the northern margin of the Kalder Pluton. This site (1119) contains 14 ppb gold, the second-highest gold concentration in the survey area; reanalysis returned a similar concentration of 15 ppb. Drainage into the lake basin where the sample was obtained is predominantly from the northeast, where two other sites with moderately elevated gold concentrations occur near the northern border of the survey area.

- An east-west trending zone approximately 8 km x 3 km south of Inzana Lake. The westernmost site (1274) contains the third-highest gold concentration (12 ppb) in the survey area; the easternmost site (1216; 8 ppb) is in the centre of Hatdudatehl Lake. Nelson *et al.* (1991b) report gold concentrations of 49 ppb and 99 ppb in small quartz carbonate veins in rocks exposed near Dolphin Lake, several kilometres to the southeast, which strike into the anomalous zone.

In addition to the above, several sites with elevated gold concentrations >95th percentile occur as isolated highs throughout the survey area, particularly within Quesnellia. For example, a single site (1192) containing 11 ppb gold occurs in the eastern end of Inzana Lake, perhaps reflecting pyrite-bearing quartz veinlets and silicified argillite (121 ppb gold) exposed nearby on the north shore of the lake (K.A. Bellefontaine, pers. comm., 1996). Nearly all such sites are located above rocks of the Quesnel Terrane, but one site (1311) containing 9 ppb gold occurs above Cache Creek Group rocks northeast of Trembleur Lake. As discussed in the section on quality control, results of reanalyses of those sediments with the highest gold concentrations confirms the reproducibility and validity of the initial analyses.

ARSENIC AND ANTIMONY

Median arsenic and antimony concentrations in the Pinchi Lake survey area are 5.9 ppm and 0.8 ppm, respectively. Maximum concentrations are 316 ppm for arsenic and 8.4 ppm for antimony. Note that all determinations are by INAA; no AAS data for arsenic and antimony is reported here.

Highest median arsenic concentrations (11.0 ppm) occur in lake sediments draining Cache Creek Group blueschists (PTrCCb), which are associated with deep-seated faults; background levels here are about twice that of the regional median. However, the highest individual sediment arsenic concentrations occur in lakes above Cache Creek Group pelagic sediments (PTrCCs). Those concentrations >95th percentile occur in two distinct areas:

- A roughly east-west trending zone of extremely high sediment arsenic concentrations in lakes immediately west of the northern end of Tezzeron Lake. This approximately 10 kilometre x 4 kilometre zone comprises 13 sites with arsenic >95th percentile, including the single greatest arsenic concentration in the Pinchi survey area (site 1343; 316 ppm). Several lakes contain more than 50 ppm arsenic. This zone occurs within a narrow glaciolacustrine plain which occupies the valley between Tezzeron Lake and Trembleur Lake. The plain is characterized by a generally 2-4 metre thick blanket of glacial lake sediments and numerous lakes and small kettle holes (Plouffe, 1994).

- A slightly smaller zone of elevated arsenic concentrations, up to 30 ppm, located near the east end of Trembleur Lake. This area is within the same glaciolacustrine plain as the first zone above.

Among other single lakes with elevated arsenic concentrations, the most notable is a site (1017; 103 ppm) near the eastern border of the survey area within a region presently mapped as Chilcotin Group basalts.

Highest median antimony concentrations (1.3 ppm) occur in Cache Creek Group volcano-sedimentary units (PTrCCvs). Elevated concentrations >95th percentile (2.4 ppm) occur in lakes over several units, but are most common in the aforementioned unit (PTrCCvs), Cache Creek Group blueschists (PTrCCb), and various sedimentary units of the Takla Group (uTrTt, muTrTs). There are two zones of elevated antimony values:

- Sediments in parts of Pinchi Lake, which contains the highest antimony concentrations in the Pinchi survey area. Antimony concentrations of eight of the nine samples obtained from Pinchi Lake fall within the upper 5 percentiles of the regional data set. Of these, the highest concentrations (3.5 - 8.4 ppm) are found in centre sediments of the northwest arm, immediately off the former Pinchi Lake mercury mine and known mercury prospects along the lakeshore. Unlike the distribution of mercury in this area, anomalous antimony concentrations are confined to Pinchi Lake itself and are not present in the small ponds on the north side of the lake.

- In areas underlain by Takla Group rocks along the Dem Lake fault, which parallels the Pinchi fault zone. Here, three small zones to the north and northeast of Tezzeron Lake comprise clusters of elevated antimony concentrations up to 4.3 ppm. These zones are roughly coincident with areas of anomalous gold in lake sediments near the Hat Lake prospect in the Dem Lake area, and near Hatdudatehl Lake.

Arsenic and antimony distributions in the Pinchi Lake survey area are not coincident. The arsenic distribution is similar to that of molybdenum, whereas the antimony distribution is, in places, closely related to that of gold above Takla Group rocks. Sites with elevated antimony concentrations also appear to be related to the location of the Dem Lake fault.

COPPER

The median copper concentration (AAS) in the Pinchi survey area is 50 ppm (maximum: 250 ppm), somewhat higher than that reported in prior surveys of the Nechako River area (NTS 93F) to the south (Cook and

Jackaman, 1994) and of the Whitesail and Smithers areas (NTS 93E, L) to the west (Johnson *et al.*, 1987a,b). Elevated copper values > 95th percentile (99 ppm) are most commonly associated with lakes draining Takla Group sedimentary rocks (uTrTt), and Early and Middle Jurassic plutonic units (EJd, MJt). There are three distinct zones of elevated copper concentrations in the Pinchi survey area, none associated with any known mineral deposits and each spatially associated with plutonic rocks of varying ages:

- A zone of three widely-spaced anomalous copper values within and near the margin of the Middle Jurassic Shass Mountain Pluton (MJt). The highest lake sediment copper concentration (site 1454; 250 ppm) occurs in a small pond in this area south of Whitefish Lake.

- Four closely-spaced sites within and along the western margin of the Middle Jurassic to Early Cretaceous Francois Intrusion located in the western part of the survey area. Lake sediment copper concentrations above this intrusive body, which forms a topographic high in the area between Stuart and Trembleur lakes, are in the range 105 - 110 ppm.

- A large region (approximately 15 x 10 kilometres) of elevated copper concentrations above Takla Group rocks in the eastern Inzana Lake area. The highest copper concentrations (125 - 166 ppm) occur here at three closely-spaced sites near the intrusive contact of the Kalder Pluton with the Inzana Lake succession (Nelson *et al.*, 1991b). Six additional sites containing up to 160 ppm copper, many with coincident selenium anomalies, are present north and south of Inzana Lake. Nelson *et al.* (1991b) report 105 ppb gold and 126 ppm copper from a stream sediment site in the northern part of this zone.

Among other sites with elevated copper concentrations are a lake (site 1127) immediately downice of the Tas and Freegold gold-copper prospects, and a second lake (site 1322) downice of the Dem prospect. Both sites are adjacent to small plutonic bodies.

MOLYBDENUM

The median molybdenum concentration in Pinchi Lake survey area sediments is 4 ppm by AAS and 3 ppm by INAA. Maximum concentrations are 65 ppm and 62 ppm, respectively, far in excess of background levels. Distribution patterns for molybdenum determined by the two methods are very similar; INAA concentrations are used in the following discussion.

Elevated molybdenum concentrations >95th percentile (AAS: 16 ppm; INAA: 15 ppm) are associated with several units of both the Takla and Cache Creek Group, but with the possible exception of one site downice of the Dem prospect, there is no spatial association with any presently known mineralization. In particular, highly anomalous molybdenum values are associated with both Upper Triassic and Middle to Upper Triassic Takla Group sedimentary assemblages (uTrTt, muTrTs), and with pelagic sedimentary rocks of the Cache Creek Group (PTrCCs). The most notable zone of elevated molybdenum concentrations is a tightly-spaced cluster of nine sites containing up to 38 ppm molybdenum located above Cache Creek Group rocks several kilometres west of Tezzeron Lake. This zone is coincident with, although slightly smaller than, the prominent zone of elevated arsenic within lake sediments situated above glaciolacustrine silt, sand and clay between Tezzeron and Trembleur lakes. Elsewhere in the survey area, almost no other sites with molybdenum >95th percentile occur above Cache Creek Group rocks. Above Takla Group rocks, however, several sites with elevated molybdenum occur in a scattered fashion and form no discernable trends. Several sites are located in the Inzana Lake region and, perhaps significantly, three others straddle the Dem Lake fault in the southeastern part of the map area. The single highest molybdenum concentration (62 ppm) occurs as a single site (1017) in an area mapped as underlain by Chilcotin Group volcanics. Elevated arsenic also occurs at this site.

ZINC

The median zinc concentration (AAS) in the Pinchi survey area is 131 ppm (maximum: 2600 ppm), slightly higher than that reported in prior surveys of the Nechako River area (NTS 93F) to the south (Cook and Jackaman, 1994) and of the Whitesail and Smithers areas (NTS 93E, L) to the west (Johnson *et al.*, 1987a,b).

Elevated zinc values >95th percentile (265 ppm) are associated with several units of both the Cache Creek and Takla Groups. The highest zinc concentration (2600 ppm) occurs in a pond above Takla Group sedimentary rocks (uTrTt) west of Hatdudatehl Lake, and two ponds east of Tezzeron Lake near the Dem Lake fault form a small zone containing 310 - 435 ppm zinc. However, the vast majority of elevated zinc values occur above Cache Creek Group pelagic sedimentary rocks (median: 149 ppm) and blueschist rocks (median: 153 ppm) where they are present as two distinct zones:

- The southeastern part of the narrow glaciolacustrine plain between Tezzeron and Trembleur lakes, where seven sites containing at least 266 ppm zinc, and numerous sites with lesser zinc, form a zone which is roughly peripheral to an extensive molybdenum-arsenic anomaly. Sediments here (max: 595 ppm zinc) may also contain elevated silver concentrations.

- The northwestern part of the same glaciolacustrine plain, where seven sites containing up to 480 ppm zinc form a zone which is roughly peripheral to a large arsenic anomaly at the east end of Trembleur Lake. Coincident elevated silver values are less common here than in the first zone above, and no elevated molybdenum values are present.

SILVER

The background silver concentration in the survey area, as expressed by the median, is 0.3 ppm. Median silver concentrations are in the range 0.2 - 0.4 ppm for most underlying geological units, but the highest median concentration (0.5 ppm) is for sediments of those lakes draining Early Jurassic diorite intrusives (EJd).

There are numerous sites in the survey area with elevated silver concentrations well in excess of background values. For example, twenty-one sites report silver concentrations in the range 0.8 - 2.0 ppm, considerably more than in parts of the Nechako River map area to the south (Cook and Jackaman, 1994) where elevated silver concentrations in lake sediments led to the staking of the Wolf prospect (Dawson, 1988) in the early 1980's. There are no large zones of contiguous anomalous sites, but several small clusters of elevated silver values >95th percentile (0.7 ppm) are present, particularly above Takla Group sedimentary and volcanic units in the Tezzeron Creek (93K/16) map area. Of these, the most notable is the Kalder Lake area, where elevated silver concentrations of 1.0 - 1.2 ppm occur at five sites north of, and within, the Early Jurassic Kalder Pluton. Elevated silver values also occur at four additional sites near the southwest and northeast margins of the smaller Early Jurassic intrusion immediately south of the Kalder Pluton. One of these sites (1127) is 3-4 kilometres downice of the Tas and Freegold gold-copper prospects; it contains the highest silver concentration (2.0 ppm) in the Pinchi survey area. Yet another anomalous lake sediment site in the Tezzeron Creek map area is located downice of the Hat Lake prospect.

Elevated silver concentrations up to 1.3 ppm are also associated with sedimentary and blueschist units of the Cache Creek Group (PTrCCs, PTrCCb). Several such sites occur in lake sediments within the glaciolacustrine plain between Tezzeron and Trembleur lakes. Interestingly, the three sites nearest the large molybdenum-arsenic anomaly in this area, just west of Tezzeron Lake, are marginal rather than coincident with that anomalous zone.

MERCURY

Median mercury concentration of Pinchi survey area lake sediments is 130 ppb, greater than those median values reported in the Nechako area (80-110 ppb) by Cook and Jackaman (1994). Maximum mercury concentrations here are also considerably greater, reaching values as high as 4150 ppb. The following discussion is based on raw data only and does not consider the role of organic scavenging in controlling lake sediment mercury concentrations.

Elevated mercury concentrations are associated with several geological units. The highest individual concentrations, including the maximum value, occur in lake sediments draining Cache Creek Group blueschists (PTrCCb); this unit also has the highest mean concentration at 590.6 ppb mercury (18 sites; median: 120 ppb). However, this is largely due to the presence of a few extremely high mercury concentrations at several sites in Pinchi Lake. Overall, the highest median mercury concentrations occur in lakes draining Takla Group sedimentary rocks (uTrTv; median: 210 ppb) and volcanic rocks (uTrTt; median: 170 ppb), and Early Jurassic diorite intrusives (EJd; median: 160 ppb). Elevated mercury concentrations >95th percentile (330 ppb; 21 sites) occur in four main areas: 1) in and around Pinchi Lake, in the vicinity of the Pinchi mercury belt; 2) the 93K/09,16 border area, 3) the Inzana Lake area, and 4) the area west of Inzana Lake.

- The five highest mercury values in the survey area are located within the Cache Creek Group in the northwest arm of Pinchi Lake, offshore of the former Pinchi Lake mercury mine (MINFILE 93K049) and several nearby mercury prospects. The single greatest value (4150 ppb) is located immediately offshore of the former minesite. Additional mercury concentrations of 1900 ppb and 2400 ppb occur in the centre of the lake immediately to the northwest; the latter is directly offshore of the Cin prospect (MINFILE 93K047). Somewhat lower concentrations of 600 ppb and 810 ppb mercury occur in embayments at the far northwest end of the lake. Two additional sites in this area with elevated mercury concentrations (360 ppb and 410 ppb) are located within the Cache Creek Group in the area between Pinchi and Tezzeron Lakes. Source of the mercury here is unknown, as the two lakes are located north of the presently-known mercury prospects near the shore of Pinchi Lake.

- Three closely-spaced lakes with sediment mercury concentrations in the range 380-410 ppb occur along the border between the Pinchi Lake (93K/09) and Tezzeron Creek (93K/16) map areas. This area is underlain by Takla Group volcanics.

- Numerous sites with elevated mercury concentrations are located immediately to the south, east and, to a lesser extent, north of Inzana Lake. These lakes are mostly underlain by Takla Group volcanics; a few occur within the Kalder Pluton. Those sites at the eastern end of Inzana Lake generally coincide with a zone of elevated mercury in till reported by Plouffe (1995a,b). There does not seem to be any close spatial relationship between most of these sites and the known porphyry copper-gold prospects in the area, although one site (1127; 410 ppb) with coincident copper and silver anomalies is downice of both the Tas and Freegold prospects. The source of the elevated mercury in sediments on the south side of Inzana Lake is unknown; there is no known mineralization here, and Plouffe (1995a,b) provide no data for this area. Their roughly linear trend suggests an unknown fault structure.

- A single site with 600 ppb mercury (Chu Lake) situated above Takla Group volcanics in the northwest corner of the survey area between Inzana and Kazchek lakes may be related to an extensive zone of elevated mercury in till just north of the Fort Fraser map area which was reported by Plouffe (1995a). This zone is located immediately north, and parallel to, the survey area boundary. The presence of two other sites with high mercury concentrations (290 and 320 ppb) to the north of Inzana Lake support this interpretation.

CHROMIUM AND NICKEL

Median chromium concentration (INAA) in lake sediments of the survey area is 57 ppm (max: 780 ppm). Median nickel concentrations are 34 ppm by INAA and 35 ppm by AAS; maximum values are 490 and 650 ppm, respectively. The following discussion of the nickel distribution in the survey area is based on the AAS data, but distribution patterns for the two analytical methods are essentially the same. Note that no AAS chromium data is available here.

Nickel and chromium distribution patterns are very similar. Lakes underlying Cache Creek Group volcano-sedimentary units (PTrCCvs) contain the highest median concentrations of chromium (120 ppm) and nickel (66 ppm) relative to other geological units listed in Appendix C. These values are approximately twice that of regional background concentrations. Highest individual chromium values are associated with this unit and with Cache Creek Group ultramafic rocks (PTrCCu). Mean chromium and nickel concentrations for the nine sites underlain by the ultramafic unit are 231 ppm and 230 ppm, respectively. No summary statistics are given for this unit in Appendix C as it contains less than 10 sample sites. In general, elevated concentrations of chromium (95th percentile: 150 ppm; max: 780 ppm) and nickel (95th percentile: 98 ppm; max: 650 ppm) are localized in two areas where slices of Cache Creek Group ultramafic rocks parallel the Pinchi fault zone:

- the Murray Ridge area southeast of Pinchi Lake, where five sites containing up to 780 ppm chromium, and six sites containing up to 575 ppm nickel, occur on and at the base of a prominent ridge of ultramafic rocks. The highest chromium (780 ppm) and nickel (575 ppm) concentrations here occur at two small ponds (sites 1434 and 1435) on the southeast flank of the ridge. The Murray Ridge chromium showing (MINFILE 93K012) is located on the south side of the ridge near the summit.

- the Pinchi Mountain area, where five sites containing up to 350 ppm chromium and eight sites containing up to 650 ppm nickel occur in the vicinity of an ultramafic unit located between Pinchi and Tezzeron lakes. Several of the sites with the highest chromium and nickel values are tightly clustered on the northwest side of Pinchi Mountain.

Among other sites in the survey area with elevated chromium concentrations are two sites in embayments on the northeastern side of Pinchi Lake which appear to be unrelated to either the two main zones of chromium concentrations, or the mapped distribution of ultramafic rocks. The geological map of the Pinchi Lake area of Paterson (1973) reveals no exposed ultramafic rocks in the watersheds of the two bays, although some basic rocks are indicated. The bays are downice of ultramafic units exposed along the Pinchi fault zone, however, which may account for the chromium content of the sediments. Elevated nickel concentrations also occur in the Tarnezell and Camsell lakes areas in the western part of the survey area.

WATERS

WATER pH

The pH of raw surface lake waters in the Pinchi Lake survey area are in the range 5.6 - 8.5. Most lake waters are slightly alkaline; median pH is 7.8, and only a small proportion of sites (18 of 413; 4.4%) exhibit a pH < 7.0.

Carbonate units of the Cache Creek Group are the likely source of the slightly alkaline lake waters. Median pH of lakes underlain by these units (PTrCCl) is 8.0 (max: 8.5). Elevated pH values are also present in areas underlain by lowermost Takla Group (muTrTs) sedimentary rocks (median: 7.9; max: 8.5), and by several other units.

Acidic pH values are most common in areas underlain by pelagic sediments and blueshists of the Cache Creek Group (PTrCCs, PTrCCb), particularly between Tezzeron and Trembleur lakes. Four of the five lowest pH values < 6.5 occur here, three of which (sites 1169-1171) are just west of Tezzeron Lake. Slightly acidic pH values < 7.0 are also present above Takla Group sedimentary rocks (uTrTt) east of Tezzeron Lake.

SULPHATE

Median sulphate concentration in lake waters is 3 ppm, similar to the median values of 0.6 - 4 ppm sulphate reported for the Nechako River area to the south (Cook and Jackaman, 1994). Maximum sulphate concentration in the Pinchi Lake survey area is 55 ppm. Thirteen sites have sulphate concentrations > 10 ppm (95th percentile), well in excess of background values.

Elevated sulphate concentrations occur in areas underlain by Takla Group sediments (uTrTt) in the eastern part of the survey area, and in the Pinchi fault area between Pinchi and Tezzeron lakes. However, lakes with elevated sulphate are most common above pelagic sedimentary units of the Cache Creek Group (PTrCCs) to the southwest of Stuart Lake. Lake waters at numerous sites in this area near the contact with the Shass Mountain pluton contain at least 8 ppm sulphate (>90th percentile). Two of the three highest sulphate concentrations in the Pinchi Lake survey area (site 1472: 27 ppm; site 1488: 55 ppm) occur here just upslope of Stuart Lake.

SUMMARY AND RECOMMENDATIONS

Results of the Pinchi Lake survey reveal several geochemical patterns and trends, particularly in regard to exploration potential for porphyry molybdenum, porphyry copper-gold and other precious metal deposits. The data also provide useful information on regional geochemical trends in the area, as well as new information on the environmental geochemistry of Pinchi Lake.

PORPHYRY MOLYBDENUM TARGETS

The extensive molybdenum-arsenic-zinc ± silver anomaly above Cache Creek Group rocks to the west of Tezzeron Lake should be prospected for its porphyry molybdenum potential. Here, coincident anomalous zones of molybdenum, arsenic, and fluoride (in water) in lakes within a glaciolacustrine plain occur within a larger, peripheral zone of elevated sediment zinc ± silver concentrations. A second, slightly smaller and more fluorine-rich zone immediately east of Trembleur Lake is similar, but lacks molybdenum.

There may be some similarity with the Mac porphyry molybdenum deposit some 30 kilometres to the west, approximately mid-way between the anomalous zone and the former Bell and Granisle copper-gold mines on Babine Lake. The Mac deposit was discovered while following up three molybdenum-copper-silver lake sediment geochemical anomalies. Data given by Cope and Spence (1995) indicate that the two lakes nearest the mineralized zones contain 16-24 ppm molybdenum and 89-105 ppm copper, and that these zones are associated with elevated fluorine in rocks. Molybdenum mineralization occurs along quartz stockwork veins associated with a granite stock of the Francois Lake suite intruding intermediate to basic volcaniclastic rocks of the Cache Creek Group (Cope and Spence, 1995; Godwin and Cann, 1985). Other granodiorite and ultramafic intrusive rocks are also present.

The molybdenum-arsenic-fluoride anomaly in the Pinchi Lake survey area is also underlain by Cache Creek Group rocks, in this case pelagic sediments (Bellefontaine *et al.*, 1995) such as argillite, chert and siltstone. No detailed mapping has been conducted in the area, and no intrusive rocks are presently known near the anomalous zone. However, Armstrong (1941) mapped a Mesozoic granite intrusive within the glaciolacustrine plain on the north side of the Kuzkwa River near Grand Rapids, several kilometres to the northwest. Molybdenum concentrations in lake sediments reported here are similar to, and slightly greater than, those adjacent to the Mac deposit. Elevated copper concentrations are not present here, but elevated silver values occur in some lakes.

The presence of a generally 2 - 4 metre thick blanket of glaciolacustrine silt (Plouffe, 1994) around the modern lakes and ponds might be expected to impede, rather than expedite, the hydromorphic transport of metals into lake basins in this relatively flat-lying area. However, the abundance of kettle lakes, which are typically deep, in this area suggests that many of the modern lake basins themselves likely intersect underlying till or are situated on buried bedrock masked beneath the Late Pleistocene glaciolacustrine plain. Elevated metal concentrations here presumably reflect the presence of elevated metals in bedrock, or dispersed within oxidized till, which have been subsequently transported hydromorphically into lake basins. Determination of the anomaly source must take into account both ice flow direction and the local hydrologic regime. Plouffe (1994) interpreted the glacial direction to be approximately east-southeast in the areas immediately north and south of the glaciolacustrine plain, indicating that a possible bedrock source may exist beneath, or upice to the west-northwest, of the anomaly.

PORPHYRY COPPER-GOLD AND OTHER PRECIOUS METAL TARGETS

Known porphyry mineralization is reflected by lake sediment geochemistry in the Quesnel Terrane. For example, an isolated copper-gold-mercury-silver anomaly in the Pinchi Lake survey area reflects the locations of the Tas and Freegold porphyry prospects, and a copper-arsenic-antimony anomaly in another lake reflects the location of the Dem prospect. In general, elevated gold concentrations in lake sediments of the survey area are largely confined to Takla Group rocks, and many lakes with elevated multi-element precious and base metal concentrations (>95th percentile) occur within this region.

Zones of elevated polymetallic precious and base metal concentrations in lake sediments occur in three main areas, providing new exploration data for porphyry gold-copper targets (*e.g.* Mt. Milligan) and other precious metal deposits. First, many sites with elevated mercury-copper ± gold ± antimony values occur within a broad zone around the eastern part of Inzana Lake. Elevated copper concentrations are quite common throughout this area, but elevated gold and antimony concentrations are largely restricted to the south side of Inzana Lake, in the Hatdudatehl Lake area. Secondly, elevated gold-mercury-silver ± copper concentrations occur in sediments of three closely-spaced lakes (Destlay to Chuzkeepah lakes) on the border between the Pinchi Lake (93K/9) and Tezzeron Creek (93K/16) map areas. Third, several small clusters of elevated silver ± gold ± mercury concentrations occur in the northeast corner of the survey area in and around the Kalder Pluton and a related intrusive. The Tas and Freegold prospects are within this broad zone, which extends from Kalder Lake to the south side of a smaller Early Jurassic pluton to the south. There is some overlap between this and the first zone above.

REGIONAL GEOCHEMICAL TRENDS

The distribution of elevated chromium and nickel concentrations in lake sediments outlines the regional distribution of obducted ultramafic rocks of the Cache Creek Group within the survey area.

PINCHI LAKE: MERCURY AND RELATED ELEMENTS

Pinchi Lake has long been of environmental interest because of the presence of elevated mercury levels in tissues of fish (Peterson *et al.,* 1970; Reid and Morley, 1975) netted offshore of the Pinchi Lake mercury mine. Pinchi Lake sediments obtained here contain elevated concentrations (>95th percentile of the entire survey area data set) of several elements, most notably mercury and antimony. Nine sites on the lake were sampled. However, sampling was confined to four sites opposite the Pinchi Lake mercury mine in the shallower northwest arm, and to five sites in various embayments; three sites in the eastern end of the lake, and and two more in the far western end. The deep profundal basin in the main part of the lake was not sampled.

Sample depths within the lake are in the range 6-17 metres; the four sites opposite the old minesite were sampled at fairly uniform depths of 12-15 metres. Pinchi Lake lies within the glaciolacustrine plain mapped by Plouffe (1994). Sediments sampled here are generally grey to grey-brown in colour and composed of a mixture of fine-grained clay and organic matter (see Appendix A), with correspondingly low LOI values in the range 5.4 - 18.3%. Clay-rich sediments are only rarely sampled during the course of regional lake sediment surveys in the Interior Plateau, which target the organic-rich gytjja of much smaller lakes and ponds. They are usually only obtained from isolated embayments on large lakes which are otherwise not sampled.

Pinchi Lake sediments contain elevated concentrations (> 95th percentile) of mercury, antimony, cobalt, barium, cesium, hafnium, rubidium, scandium and thorium at all or most of the nine sites. In addition, elevated concentrations of several other elements including ytterbium, tantalum, lead, fluorine and chromium are present in at least two of the sites. High, and generally highest, concentrations of mercury, antimony and most other elements are found immediately offshore of the old minesite and nearby prospects, but they are not restricted to only this part of the lake. In the case of cobalt, for example, concentrations of this metal (27 ppm; INAA) within the deep bay at the far eastern part of the lake (site 1239; 17 metres) are equal to that present off the old minesite (site 1154). Higher chromium and arsenic concentrations are also present in the bay, the drainage basin of which is underlain by different, primarily volcano-sedimentary and to a lesser extent ultramafic, units of the Cache Creek Group. Differences in sediment geochemistry here may reflect the varying element contributions of different rock units. Similarly, slightly higher concentrations of barium and cesium are present at the far western end of the lake than occur off the old minesite, although the two groups of sites are a shorter distance (approximately 4 kilometres) apart.

GOLD AND OTHER ELEMENTS IN LAKE SEDIMENTS OF THE NECHAKO PLATEAU

Lake sediments typically consist of organic gels, organic sediments and inorganic sediments (Jonasson, 1976). Organic gels, or gyttja, are mixtures of particulate organic matter, inorganic precipitates and mineral matter (Wetzel, 1983), and are mature green-grey to black homogenous sediments characteristic of deep-water basins. Organic sediments are immature mixtures of organic gels, organic debris and mineral matter occurring in shallow water and near drainage inflows (Jonasson, 1976). Inorganic sediments, by contrast, are clastic-rich mixtures of mineral particles with little organic matter. Of the three varieties of lake sediments, organic gels are the most suitable geochemical exploration medium because of their higher capacity for adsorbing metals and their greater homogeneity; deep-water basins where they accumulate have been favoured as ideal sites for regional geochemical sampling (Friske, 1991).

Lake sediments have proved to be an ideal geochemical exploration medium in the Nechako Plateau, where poor drainage has limited the use of stream sediment geochemistry. Earle (1993) has demonstrated the usefulness of lake sediment geochemistry in the area, and many regional surveys have been conducted, including those of various mineral exploration companies, Spilsbury and Fletcher (1974), Hoffman and Fletcher (1976) and Gintautas (1984). As a prelude to the implementation of regional lake sediment surveys in the northern Interior, a series of orientation surveys were conducted in the Nechako Plateau (Cook, 1993) to determine the most effective sampling, analytical and interpretive techniques. Results indicate that lake sediment geochemistry reflects the presence of nearby epithermal gold occurrences. In the Nechako River (NTS 93F) map area, located immediately south of the Pinchi Lake survey area, elevated gold concentrations occur in sediments of three lakes adjacent to three epithermal precious metal occurrences: the Wolf (MINFILE 93F045), Clisbako (MINFILE 93C016) and Holy Cross (MINFILE 93F029) prospects. The following discussion is taken largely from Cook (1995, 1997), which provide a more detailed account of the distribution of gold and related elements in sediments of these lakes.

GOLD CONTENT OF LAKE SEDIMENTS

Orientation studies conducted near the Wolf, Clisbako and Holy Cross epithermal precious metal occurrences indicate that elevated concentrations of gold (max: 56 ppb, 16 ppb and 9 ppb, respectively), arsenic and other elements occur in adjacent lake sediments. Median concentrations of gold and other elements in regional lake sediment surveys provide a useful estimate of regional background levels with which to compare these figures. For example, median gold and arsenic concentrations reported here for sediments of the Pinchi Lake survey area are 2 ppb and 5.9 ppm, respectively. Similarly, the median gold and arsenic concentrations in lake sediments in the Fawnie and Ootsa survey areas (461 sites) are 1 ppb and 2.1-2.7 ppm, respectively (Cook and Jackaman, 1994). Farther to the west, median gold and arsenic concentrations of RGS lake sediments (445 sites) from nearby NTS map areas 93E (Whitesail Lake) and 93L (Smithers) (Johnson *et al.*, 1987a,b) are 1 ppb and 4 ppm, respectively. These regional median values are far less than those reported for sediments adjacent to epithermal mineralization by Cook (1995), illustrating the very low concentrations of gold typically present in lake sediments. In the Whitesail and Smithers areas, only 22 of 421 sites contain more than 10 ppb gold. Element concentrations adjacent to epithermal gold occurrences are greater than regional background even when underlying bedrock variations are considered. For example, mean gold (1.8 - 2.6 ppb) and arsenic (4 - 5.1 ppm) concentrations in lake sediments over prospective rhyolite, tuff and volcanic breccia lithologies reported by Earle (1993) are still considerably less than those reported from near the Wolf, Clisbako and Holy Cross prospects.

DISTRIBUTION AND SOURCE OF GOLD IN LAKE SEDIMENTS

Centre-lake sediments may, but do not necessarily, contain the highest gold concentrations, and elevated gold values may be present in lake margin sediments and adjacent to stream inflows. The gold distribution in the small Wolf Pond basin is very uniform, and the small size of the watershed makes the source area relatively easy to discern. The Clisbako Lake and Bentzi Lake watersheds are considerably larger, but nevertheless the locations of alteration and mineralized zones are revealed by gold distribution patterns in the sediment (Cook, 1995). For example, gold distribution patterns at stream inflows of Clisbako Lake reflect the locations of alteration zones to the south and northwest of the lake. Available evidence suggests a hydromorphic, rather than clastic, origin for the high gold concentrations in sediments of these three lakes. Evidence includes the close association of gold with organic matter, the similarity of gold concentrations in field duplicate samples, the uniformity of gold concentrations at similar sediment depths, and the apparent absence of significant clastic input into the lake basins, particularly at Wolf Pond. Schmitt *et al.* (1993) have summarized studies relating to the mobility of gold in surface waters. Gold may form the hydroxide complex $AuOH(H_2O)^0$ in neutral sulphur-poor lake waters, as well as gold-humic complexes in suspended matter, permitting a limited degree of down-drainage hydromorphic dispersion. Hydromorphic gold dispersion distances of 200 to 300 metres were suggested by Fox *et al.* (1987) for lakes in the Canadian Shield, but results of Cook (1995, 1997) suggest considerably greater distances are likely. Perhaps the most interesting finding is the close association between gold and organic matter, whether in deep-water gyttja (Bentzi Lake) or shallow near-shore organic sediments (Clisbako Lake).

The association of gold and organic matter in lake sediments from Shield regions is well known. Several studies in Saskatchewan and Ontario (Schmitt *et al.*, 1993; Fox *et al.*, 1987; Coker *et al.*, 1982) have reported the presence of elevated gold concentrations in organic-rich sediments. Near-shore organic sediments may scavenge gold before it disperses to deeper parts of the lake. Both Coker *et al.* (1982) and Fox *et al.* (1987) noted that organic-rich sediments with highest gold concentrations may be near-shore sediments as well as those of the profundal basin. There is little relation between elevated gold concentrations and those of iron or manganese in either Clisbako or Bentzi Lake, suggesting scavenging by iron or manganese oxides to be relatively unimportant. Considerably higher iron concentrations are associated with anomalous concentrations of gold and other elements at eutrophic Wolf Pond, however.

FACTORS CONTROLLING THE ABUNDANCE AND DISTRIBUTION OF RELATED ELEMENTS

Lake sediment composition is influenced by a combination of factors including bedrock and surficial geology, climate, soils, vegetation, mineral occurrences and limnological considerations. In the case of lakes adjacent to epithermal precious metal occurrences, the presence or absence of multi-element geochemical signatures may be related to the level of the hydrothermal system exposed to the weathering cycle. Elevated concentrations of gold, silver, arsenic, zinc, molybdenum and antimony occur in sediments draining the Wolf prospect, but lake sediments at the Clisbako and Holy Cross occurrences contain elevated concentrations of only gold, arsenic and antimony. Base metal distributions increase with depth in epithermal systems, while near-surface arsenic and antimony may indicate potential precious metal deposits at lower levels (Panteleyev, 1986). Consequently, elevated levels of gold, arsenic and antimony alone in sediments, such as at Clisbako, may reflect the geochemistry of near-surface systems; a wider variety of precious and base metals may indicate a deeper position within the system. For purpose of comparison, molybdenum concentrations up to 23 ppm obtained from the centre basin of Wolf Pond are equivalent to the highest molybdenum concentrations present in sediment of Tatin Lake, adjacent to the Ken porphyry molybdenum-copper occurrence (MINFILE 093K 002) about 6 kilometres north of Endako (Cook, 1997).

Limnological variations in lakes may affect the accumulation of trace elements in lake sediments. The temperature and oxygen content of lake waters in northern temperate regions may stratify during the warm summer months, overturning with seasonal changes in the spring and fall. Of such thermally-stratified, or dimictic, lakes, eutrophic lakes are those small nutrient-rich lakes with high organic production and almost complete oxygen depletion with increasing depth. Conversely, oligotrophic lakes are deep, large, nutrient-poor lakes with low organic production and a much more constant oxygen content with depth. Polymictic or unstratified lakes are relatively shallow and are not thermally stratified. Earle (1993) and Hoffman and Fletcher (1981) have shown that there are distinct geochemical differences between the sediments of eutrophic and oligotrophic lakes, particularly with respect to the abundance of organic matter and of iron and manganese oxides. High organic matter content is characteristic of eutrophic lakes, while manganese and iron oxide precipitates are products of the oxygen-rich conditions of oligotrophic lakes.

Limnological classification, or trophic status, may consequently have a significant influence on interpretation of lake sediment geochemistry. Considerable variations may exist even among separate sub-basins and channels of the same lake. For example, molybdenum distributions vary between sub-basins in sediments of Tatin Lake, a large (4-5 km long) lake containing three distinct sub-basins (Cook, 1997). Molybdenum concentrations in centre-basin sediments vary from 7 ppm in the centre of the lake, to 12 ppm and 23 ppm in western and eastern sub-basins, respectively. These variations may be controlled, in part, by limnological differences between the sub-basins and, in part, by the location of stream and ground water input.

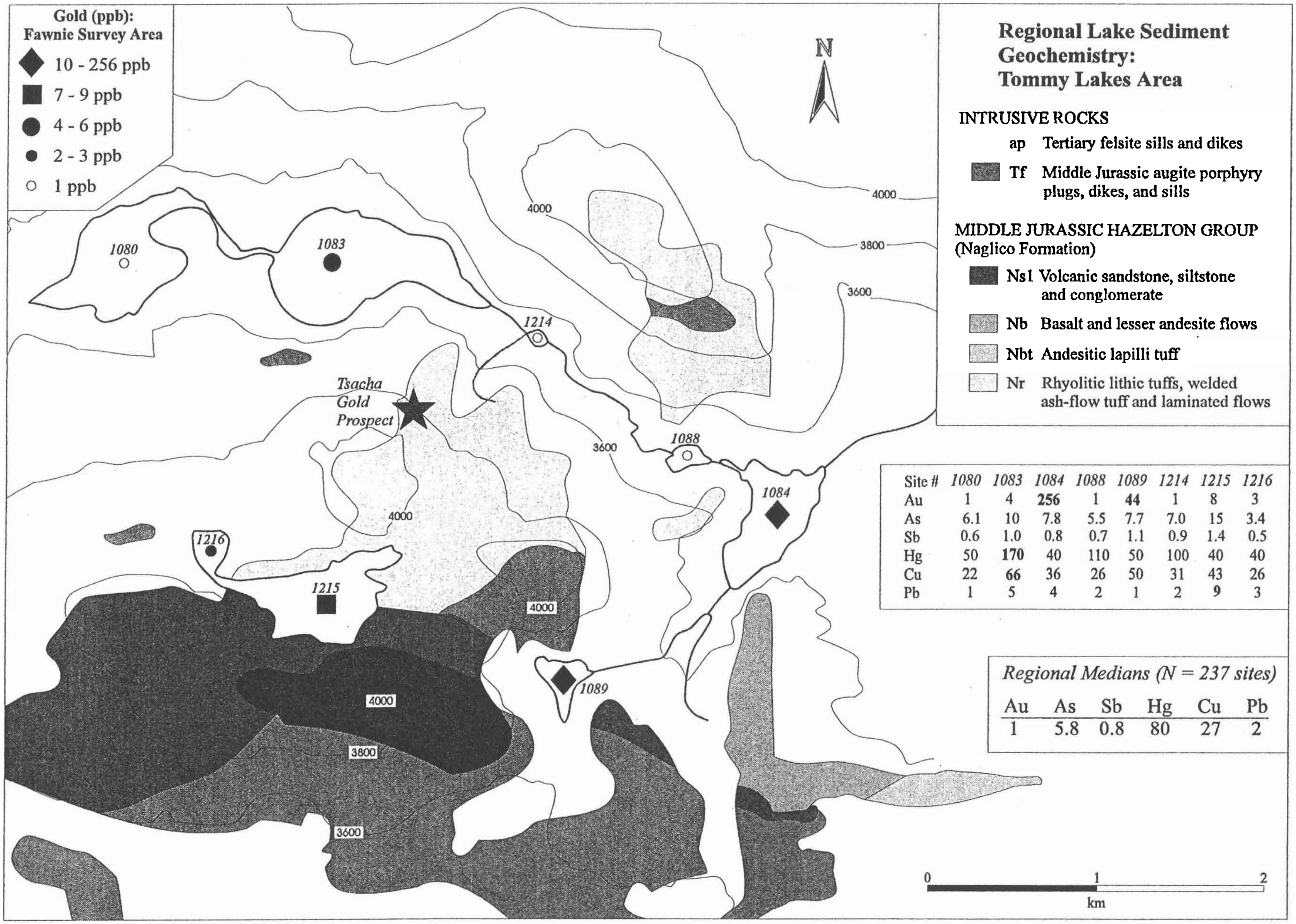
LAKE SEDIMENT GEOCHEMISTRY SUCCESSES: THE TSACHA EPITHERMAL GOLD PROSPECT

The discovery of the Tsacha epithermal gold prospect (MINFILE 093F 055), located immediately north of the Blackwater River in the Fawnie Creek map area (NTS 93F/3), is an example of the success of regional lake sediment geochemistry surveys in stimulating mineral exploration and development in the northern Interior Plateau. First reported as the Tommy prospect by Diakow *et al.* (1994) and subsequently staked by Teck Corporation, the discovery resulted from a British Columbia Geological Survey Branch regional bedrock mapping, lake sediment geochemistry and till geochemistry investigation conducted in the Fawnie Creek and adjacent Tsacha Lake map areas during the 1993 field season. A bedrock mapping party discovered an auriferous epithermal quartz vein system cropping out on hummocky, moss-covered knobs in the Tommy Lakes area of the Naglico Hills, and the subsequent release of lithogeochemical data (Diakow *et al.*, 1994) at the Cordilleran Roundup conference in Vancouver in January 1994 resulted in the initial staking of the prospect. Regional lake sediment and till geochemistry surveys had been undertaken concurrently during the summer, and the subsequent (June 1994) release of this data, showing elevated gold values in lake sediment and till (Cook and Jackaman, 1994; Levson *et al.,* 1994), resulted in further claim staking.

The location of the Tsacha prospect is clearly outlined by four small lakes, containing elevated sediment gold values of 4 to 256 ppb (Figure 9), which roughly encircle the mineralized zone. In comparison, background sediment gold concentrations in the region are 1 ppb. Reanalysis of sediment with the three highest gold concentrations (256 ppb, 44 ppb and 8 ppb) returned gold values of 970 ppb, 26 ppb and 7 ppb, respectively, confirming the validity of the initial gold anomalies. Sediment in a lake adjacent to the Wolf Prospect, the other significant epithermal showing in the area, is distinguished by a multi-element gold-arsenic-silver-zinc-molybdenum-mercury geochemical signature (Cook, 1997), but sediment in the four Tsacha-area lakes exhibit few geochemical similarities other than elevated gold and, to a lesser extent, copper concentrations. Elevated arsenic, zinc and lead concentrations occur in one lake (site 1215), and elevated mercury in another, but the area lacks an overall multi-element signature of what are commonly termed pathfinder elements.

The regional bedrock and surficial geology of the area has been mapped by Diakow *et al.* (1994, 1995) and Levson and Giles (1994). The lakes and their watersheds are floored by Early to Middle Jurassic rhyolitic rocks of the Hazelton Group. Naglico formation volcanic sandstone, siltstone and conglomerate and rhyolitic lithic and ash flow tuffs are exposed along the northern margin of felsic - intermediate Tertiary sills and dykes. Surficial geology in this part of the Naglico Hills is primarily exposed bedrock and till veneer in upland areas, with glaciofluvial outwash plains occupying low-lying valley bottoms between the lakes. Geology and development of the Tsacha prospect was summarized by Lane and Schroeter (1997), and the following is from their account. A program of soil geochemistry, prospecting, sampling and trenching was conducted by Teck in 1994, followed by diamond drilling in 1995 and 1996. The main (Tommy) vein is north trending, vertically dipping, and is composed primarily of quartz, calcite and chalcedony. It is up to 8 metres wide and has a strike length exceeding 600 metres. Massive vein mineralization may be flanked by quartz stringer, stockwork or breccia zones, but contains less than 1% metallic minerals including chalcopyrite, pyrite, stephanite, argentite, galena, native gold (± electrum), specularite and magnetite. Surface sampling across the vein has returned assays of up to 61.9 grams/tonne gold and 292.5 grams/tonne silver (Pautler, 1995).

The Tsacha prospect is only one example of the successful application of regional lake sediment geochemical surveys, both public and private, to mineral exploration in the northern Interior Plateau. As part of a comparative study of regional lake sediment and till geochemistry results from a single 1:50 000 scale map area, the Fawnie Creek map area, Cook *et al.* (1995) provide a broader account of the usefulness of lake sediment geochemical surveys in this region. Here, five of seven known mineral prospects were outlined by regional lake sediment geochemistry data of Cook and Jackaman (1994), using elevated combinations of seven elements (Au, As, Sb, Zn, Cu, Pb and/or Mo >95th percentile). The five prospects are the Wolf, Fawn (Gran), Buck, Paw and Tsacha occurrences. Only the relatively minor Malaput and Fawn-5 prospects, neither of which is located near a lake, were undetected by the regional lake sediment survey.



Site #	*1080*	*1083*	*1084*	*1088*	*1089*	*1214*	*1215*	*1216*
Au	1	4	**256**	1	**44**	1	8	3
As	6.1	10	7.8	5.5	7.7	7.0	15	3.4
Sb	0.6	1.0	0.8	0.7	1.1	0.9	1.4	0.5
Hg	50	**170**	40	110	50	100	40	40
Cu	22	**66**	36	26	50	31	43	26
Pb	1	5	4	2	1	2	9	3

Regional Medians (N = 237 sites)

Au	As	Sb	Hg	Cu	Pb
1	5.8	0.8	80	27	2

Figure 9. Locations of lakes with elevated sediment gold concentrations in the vicinity of the Tsacha epithermal gold prospect in the Nechako Plateau, central British Columbia. Concentrations of gold and other elements from data for 237 sediments sampled June 15-18, 1993 as part of the Fawnie regional lake sediment geochemistry survey (Cook and Jackaman, 1994). Elements in bold type exceed the 95th percentile for the Fawnie survey. Bedrock geology after Diakow *et al.* (1994, 1995).

EXPLORATION RECOMMENDATIONS FOR GOLD

Studies in other parts of Canada (Fox *et al.*, 1987; Davenport and McConnell, 1988; Rogers, 1988) have determined lake sediment geochemistry to be an effective gold exploration method. However, results of some studies in the Canadian Shield (Fox *et al.*, 1987; Coker *et al.*, 1982) concluded reconnaissance-scale (one site per 6 to 13 km^2) lake sediment exploration for gold to be inadequate for locating anomalous areas, and suggested that one to three samples per lake be collected. In Newfoundland, Davenport and Nolan (1991) considered a density of at least 1 site per 4 square kilometres to be necessary to ensure the detection of all significant near-surface gold mineralization. Results of geochemical studies in British Columbia (Cook, 1995, 1997) support the detailed sampling (*ie.* every lake) approach. The following recommendations are given for geochemical exploration for epithermal and other gold deposits in the northern Interior Plateau:

SAMPLE MEDIA AND SAMPLING STRATEGIES

- Lake sediment geochemistry is most effective for gold exploration if every lake and sub-basin in the survey area is sampled, a strategy employed in the Pinchi Lake and prior surveys. The high and homogenous gold content of, for example, Wolf Pond sediment (Cook, 1995) illustrates the importance of sampling even very small lacustrine drainages.

- A single centre-lake sample should be collected from the profundal basin in small lakes, and additional samples should be taken from the centres of all other major basins in multi-basin lakes. Although the lakes described by Cook (1995) do not, with the exception of Bentzi Lake, have more than one major basin, a wide range of copper and molybdenum concentrations occur between different sub-basins of lakes adjacent to porphyry molybdenum-copper occurrences (Cook, 1993).

- Collection of centre-lake gyttja samples is the most effective sampling method for trace elements such as copper and zinc, but evidence from studies in the Interior Plateau and elsewhere (Coker *et al.*, 1982; Fox *et al.*, 1987) suggests that gold may also be concentrated in near-shore organic-rich sediments, particularly near drainage inflows. Collection of samples from these areas, in addition to collection of centre-lake sediment, is recommended for detailed surveys.

SAMPLE PREPARATION AND ANALYSIS

- The very low concentrations of gold in lake sediments demand the use of an analytical technique with a low analytical detection limit of 1 or 2 ppb. No comparisons of INAA with either fire assay/GF-AAS or ICP-MS techniques were conducted. If using fire assay techniques, however, low gold detection limits require greater vigilance with respect to sample contamination during analysis. Irregardless of the analytical method, routine analysis of silica blanks inserted within sample suites is a useful means of calculating a working detection limit for each batch of samples.

- A rigourous quality control program is a necessity when using lake sediments for gold exploration due to the particle sparcity effect and the very low concentrations of gold typically found in lake sediments. Inclusion of field duplicates, analytical duplicates, and control standards with appropriate organic-rich matrices and low concentration levels is recommended

- Analysis for additional elements other than gold is recommended. Arsenic and antimony are useful pathfinder elements in the northern Interior, and elevated concentrations of base metals such as molybdenum, zinc and copper may be present in lakes adjacent to the erosional remnants of lower level hydrothermal systems. Nevertheless, studies in Newfoundland (McConnell and Davenport, 1989; Davenport and Nolan, 1991) determined gold itself to be the best pathfinder, with antimony a more useful pathfinder element than arsenic.

FOLLOW-UP OF ANOMALOUS SITES

- Results of Cook (1995) indicate that gold concentrations of 4 ppb or greater in centre-lake sediments may reflect the presence of adjacent epithermal gold occurrences. Lower gold concentrations are generally indistinguishable from the geochemical background, due to sampling and analytical variability. Similar conclusions were reported from Newfoundland by Davenport and McConnell (1988), who considered gold concentrations greater than 4 ppb to represent anomalies, and those greater than 8 ppb to be strong anomalies. The very subtle level of gold anomalies in lake sediment cannot be overemphasized. For example, sediment in a lake adjacent to the large Hemlo gold deposits in northern Ontario was reported by Friske (1991) to contain only 6 ppb gold in an area with a background of less than 1 ppb.

- Follow-up of anomalous lakes, involving both verification of the original anomaly and determination of a potential source direction, should include resampling of the centre-lake site, as well as the sampling of near-shore sediment from all sides of the lake. It is particularly important, during anomaly follow-up, to sample organic sediments near inflowing drainages. The collection of duplicate field samples is recommended. Delineating the watershed boundaries of anomalous lakes, particularly those small ponds with no apparent stream inflows, will assist in interpreting results of both the regional and follow-up surveys.

SUMMARY

A regional lake sediment and water geochemistry survey, the Pinchi Lake survey (413 sites), was conducted in the northeastern part of NTS map area 93K (Fort Fraser) in the northern Interior. The survey is a contribution to the ongoing objective of completing Regional Geochemical Survey lake sediment coverage of the Fort Fraser and Nechako River map areas in the northern Interior Plateau. This survey confirms the locations of several known mineral prospects, and outlines new areas for prospective porphyry-style molybdenum and gold-copper mineralization. The following points are of particular interest:

- A prominent zone of anomalous molybdenum-arsenic above Cache Creek Group rocks to the west of Tezzeron Lake should be explored for its porphyry molybdenum potential. A larger area of elevated zinc ± silver sediment concentrations is roughly peripheral to the molybdenum-arsenic distribution pattern. A second, slightly smaller, zone immediately east of Trembleur Lake is similar, but lacks molybdenum.

- Within the Takla Group, potential new porphyry copper-gold and other precious metal targets are indicated, particularly in the Tezzeron Creek (93K/16) map area.

- Elevated concentrations of mercury, antimony, and several additional elements are present in sediments in part of Pinchi Lake.

- Elevated mercury concentrations are not universally present in all lake sediments along the Pinchi Fault Zone within the survey area. In this area they are largely confined to the northwest part of Pinchi Lake, and to the region between Pinchi and Tezzeron lakes.

- The distribution of lake sediment sites with elevated antimony concentrations north of Tezzeron Lake coincides closely with the position of the Dem Lake fault.

- The regional distribution of elevated chromium and nickel concentrations in lake sediments outlines the distribution of Cache Creek Group ultramafic rocks in the survey area.

ACKNOWLEDGMENTS

Survey design and implementation was by the authors. Sample preparation and geochemical analyses were conducted by the following companies under the supervision of the Geological Survey of Canada:

PREPARATION:

Bondar-Clegg and Company, Ottawa, Ontario

SEDIMENT ANALYSIS:

CanTech Laboratories Inc., Calgary, Alberta (AAS)
Becquerel Laboratories, Mississauga, Ontario (INA)

WATER ANALYSIS:

CanTech Laboratories Inc., Calgary, Alberta

The Geological Survey of Canada was responsible for data quality control, and the British Columbia Geological Survey Branch for Open File production and interpretation. Duties were allocated as follows:

Survey Design: *SC*
Sample Collection: *SC, WJ, MM, SD*
Quality Control: *PF*
Data Interpretation: *SC*
Geochemical Map Production: *WJ*
Open File Production and Coordination: *WJ, SC*

Special thanks are extended to J. Meier, Northern Mountain Helicopters, Vanderhoof, for his skillful flying. The manuscript benefited from reviews by K.A. Bellefontaine and J.L. Nelson.

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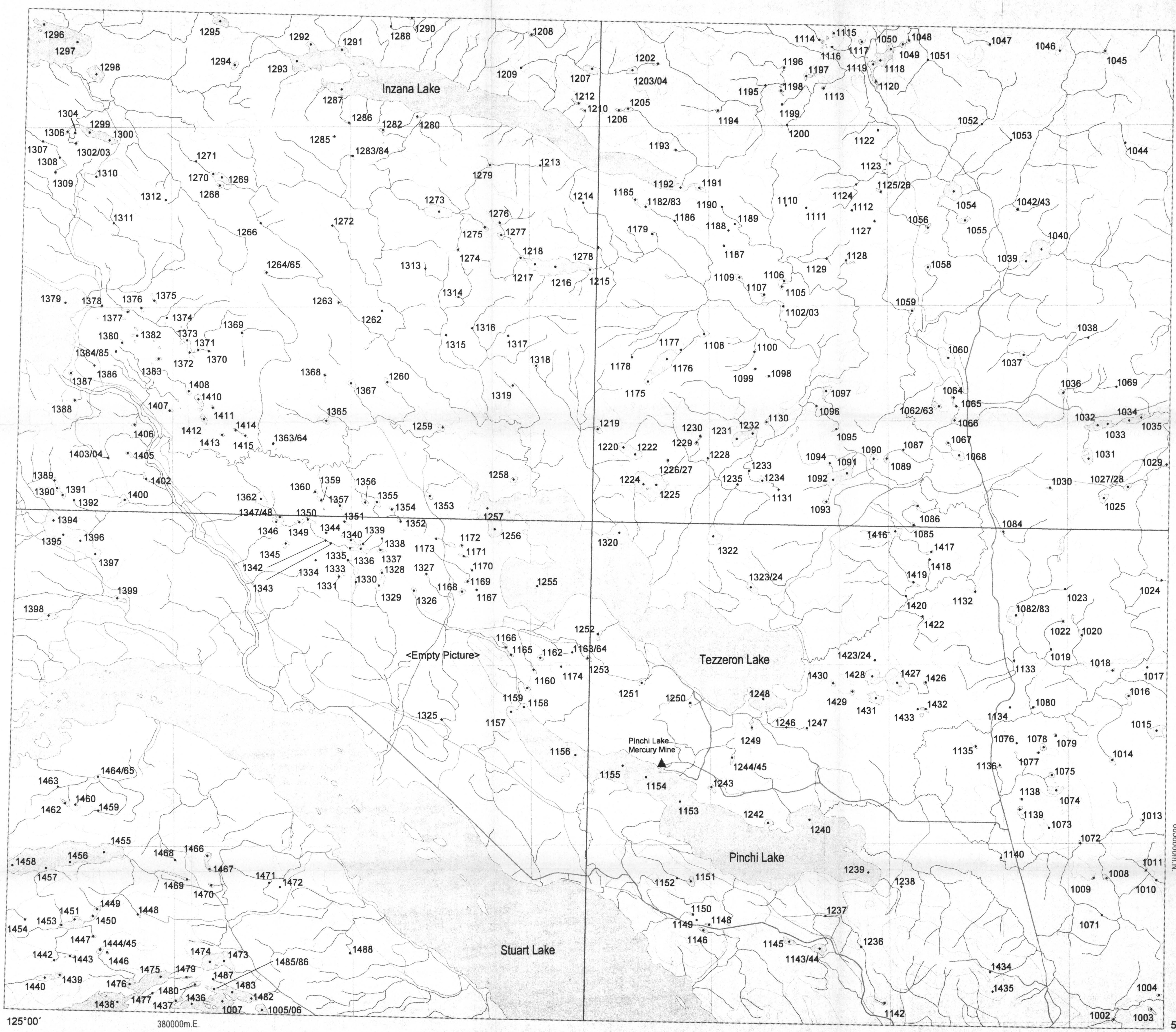

B.C. Geological Survey Branch

Open File 1996-15

Regional Lake Sediment and Water Geochemistry of part of the Fort Fraser Map Area

(NTS 93K/09,10,15,16)

Kilometres

0 5 10 15

Scale 1:100,000

UTM Zone 10
NAD 1983

Sample Location Map