BC

Province of British Columbia
Ministry of Energy, Mines and
Petroleum Resources
Hon. Anne Edwards, Minister

MINERAL RESOURCES DIVISION
Geological Survey Branch

0005044045

REGIONAL LAKE SEDIMENT AND WATER GEOCHEMISTRY OF PART OF THE NECHAKO RIVER MAP AREA

(93F/02, 03; 93F/06, 11, 12, 13, 14)

By Stephen J. Cook and Wayne Jackaman

OPEN FILE 1994-19

VICTORIA
BRITISH COLUMBIA
CANADA

May 1994

ABSTRACT

Results of regional lake sediment and water geochemistry surveys conducted in the Nechako River map area (NTS 93F) in 1993 highlight several new exploration targets in the northern Interior Plateau of British Columbia. The Fawnie survey (NTS 93F/2,3) and the Ootsa survey (parts of NTS map areas 93F/6,11,12,13,14) cover areas of perceived high mineral potential in a region where exploration has previously been limited by extensive drift cover, poor exposure and an inadequate geological database.

Lake sediments and waters were collected from 461 sites in the combined survey areas at an average density of one site per 7.7 square kilometres. On the basis of results from 1992 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 26 elements by instrumental neutron activation analysis (INAA). Standard Regional Geochemical Survey sampling, analytical and quality control procedures were used. Preliminary discussion of results for gold, silver, arsenic, antimony, copper, zinc and molybdenum indicate that the surveys confirm previously known lake sediment anomalies, enlarge target areas for currently known prospects, and outline new areas for prospective epithermal precious metal deposits.

TABLE OF CONTENTS

INTRODUCTION

Open File 1994-19 presents new analytical data for over 36 different elements from two regional lake sediment and water geochemistry surveys (Figure 1) conducted by the British Columbia Geological Survey Branch in the Nechako Plateau region during 1993. The **Fawnie Survey** covers 1:50000 NTS map areas 93F/2 (Tsacha Lake) and 93F/3 (Fawnie Creek), where exploration has been centred on precious metal prospects such as the Wolf (MINFILE 093F 045) and Blackwater-Davidson (MINFILE 093F 037) occurrences. The **Ootsa Survey** is centred on the Eocene volcanic basin south of Burns Lake and covers parts of NTS map areas 93F/6 (Natalkuz Lake), 93F/11 (Cheslatta Lake), 93F/12 (Marilla), 93F/13 (Takysie Lake) and 93F/14 (Knapp Lake). A total of 461 sites were sampled over a combined area of approximately 3530 square kilometres at an average density of 1 site per 7.7 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. A companion publication, Open File 1994-18 (Levson *et al.*, 1994) presents new analytical data for a till geochemistry survey conducted over NTS map area 93F/3 (Fawnie Creek).

The subdued topography, poor drainage and abundance of lakes in the Nechako Plateau make lake sediments an ideal geochemical exploration sample medium. They are an effective tool to delineate both regional geochemical patterns and anomalous metal concentrations related to mineral occurrences, and have been used successfully in the region for some 25 years. 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/skarn mineralization near Square Lake (Hoffman and Smith, 1982). Lake sediment geochemistry has also been successful in locating epithermal gold-silver mineralization at the Wolf prospect (Andrew, 1988). Orientation studies conducted in 1992 near the Wolf, Clisbako and Holy Cross epithermal precious metal prospects have shown that elevated concentrations of gold (max: 56 ppb, 16 ppb and 9 ppb, respectively), arsenic and other elements occur in adjacent lake sediments (Cook, 1994). These gold concentrations are far in excess of the 1 ppb regional background reported here.

The Interior Plateau Project, to which Open File 1994-19 is a contribution, 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. Matysek and van der Heyden (1994) provide an overview of the project. Mineral exploration of this area has been limited by extensive drift cover, poor exposure and a barren volcanic cover. As well, the geological database is either nonexistent or obsolete. The survey areas were selected on the basis of their perceived mineral potential. Concurrent bedrock and surficial geology mapping (Diakow and Webster, 1994; Giles and Levson, 1994) and mineral deposit studies (Schroeter and Lane, 1994) were conducted in NTS map area 93F/3 in the western half of the Fawnie survey area. The Eocene volcanic basin offers a favourable but relatively unexplored environment for epithermal precious metal deposits.

The surveys were funded by the B.C. Ministry of Energy, Mines and Petroleum Resources and conducted by Geological Survey Branch staff. They are the first such publicly funded surveys to be undertaken in British Columbia since the 1986 lake sediment 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 Regional Geochemical Survey (RGS) program. Results will be incorporated at a later date into ongoing regional lake sediment surveys of the Nechako River map area (NTS 93F) 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 resource assessment, mineral exploration, geological mapping and environmental studies.

OPEN FILE FORMAT

Open File 1994-19 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 (Appendix C)
- Element distribution, geology and sample location 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 1:100000-scale sample location maps, is located in the back pocket.
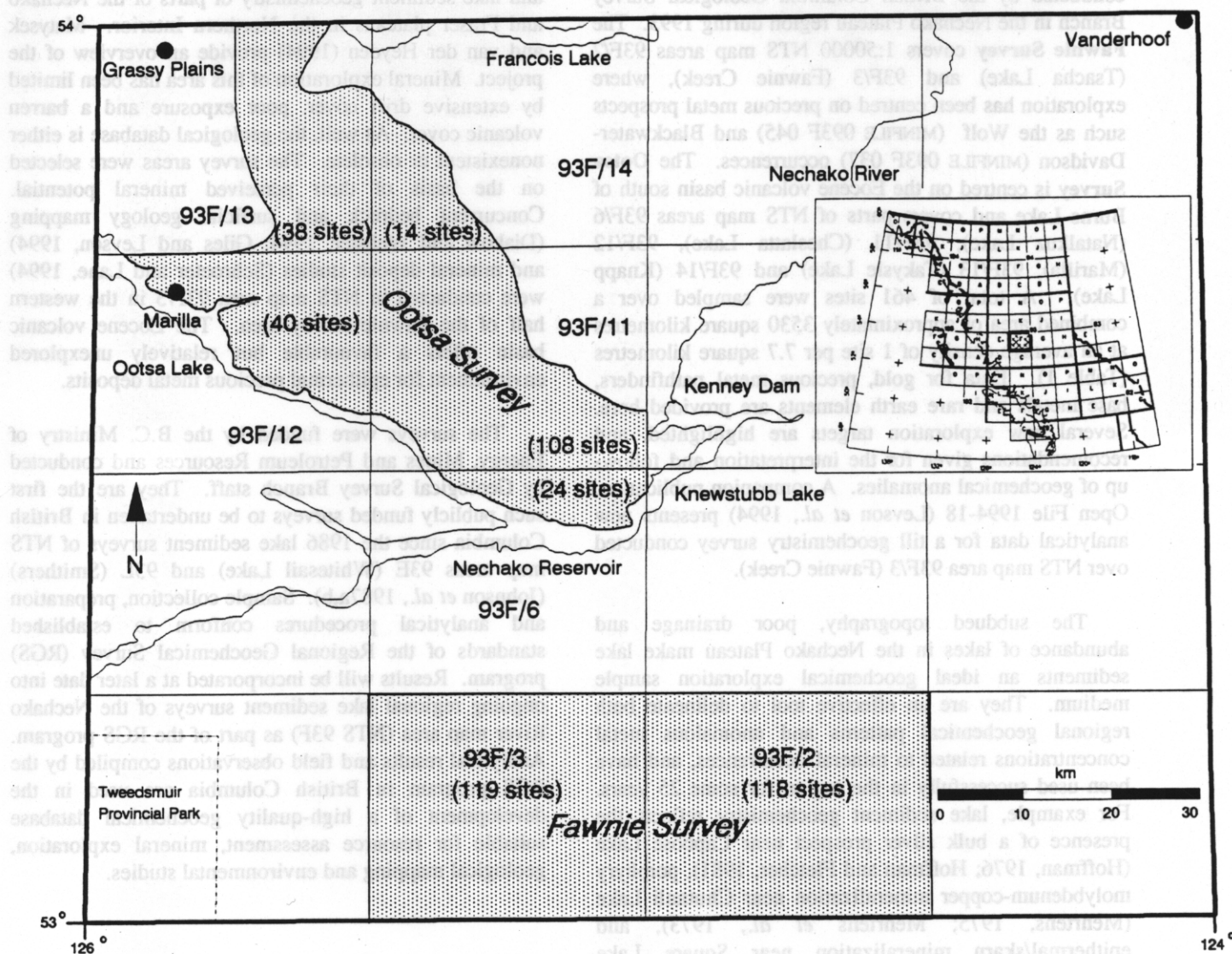

Figure 1. Location of Fawnie and Ootsa lake sediment surveys in NTS map area 93F (Nechako River) of the Interior Plateau, showing the number of sites sampled within each 1:50000 NTS map area.

DESCRIPTION OF THE SURVEY AREAS

LOCATION AND ACCESS

The Fawnie survey area covers about 1880 square kilometres and is located approximately 90 kilometres south of Highway 16 and the town of Fraser Lake. There is only limited road access into the field area. The Kluskus-Ootsa and Kluskus-Malaput Forest Service roads provide access to much of the northern part of 93F/3 from Vanderhoof and Fraser Lake, while the Blue Road extends into the easternmost part of the survey area in 93F/2. Two of the major mineral occurrences, the Wolf and Blackwater-Davidson prospects, are road accessible.

The Ootsa survey area lies north of the Fawnie area and covers about 1650 square kilometres south of Burns Lake. The irregular shaped area is bounded by Ootsa and Natalkuz lakes of the Nechako Reservoir in the south, and extends northwest to the Uncha Lake area. The northern boundary is about 25 kilometres south of Burns Lake. The Kluskus-Natalkuz ('500' road), Marilla and Holy Cross-Binta Forest Service roads cross the survey area and provide access from Vanderhoof, Fraser Lake and Burns Lake.

PHYSIOGRAPHY AND SURFICIAL GEOLOGY

Most of the Fawnie survey area lies within the Nechako Plateau, although a small area southeast of Tsacha Lake and the Blackwater River falls within the Fraser Plateau (Holland, 1976). Topography is dominated by the subparallel ridges of the Fawnie and Nechako ranges, with Mount Davidson (elev: 1852 m) and Kuyakuz Mountain (elev: 1781 m) forming maximum elevations, respectively. The Entiako Spur and Naglico Hills are also prominent topographic highs. A wide variety of physiographic regimes, ranging from rocky subalpine peaks to boggy lowlands along the Blackwater River and Fawnie Creek, occur throughout the area. Active first-order streams are relatively uncommon. Lakes are not uniformly distributed; they are numerous in parts of the Naglico Hills, but absent in large expanses of the Fawnie Range and Entiako Spur. The area within the Fraser Plateau is predominatly flat lying and characterized by abundant bogs but few lakes.

The glacial history and surficial geology of the Fawnie Creek map area (NTS 93F/3) have been documented by Giles and Levson (1994) and Levson and Giles (1994). Ice flow was dominantly toward the east-northeast. Much of the region is drift covered although some areas, particularly the Naglico Hills, have considerable outcrop. Morainal diamicton, predominantly basal till, is the most widespread Quaternary deposit and covers much of the area to depths of up to several metres. Glaciofluvial outwash sediments occur in major valleys such as Fawnie Creek, and postglacial colluvial veneers and diamicton are common on steeper slopes.

The Ootsa survey area lies wholly within the Nechako Plateau and, like the Fawnie area, has extensive drift cover. It is less mountainous than the Fawnie area, with most of the plateau surface at an elevation of 900 to 1100 metres. The Devils Thumb (elev: 1287 m) forms a prominent topographic high. The Ootsa area has a more rugged and hummocky topography; lakes are more evenly distributed across the landscape, and there are fewer small ponds and lowlands.

BEDROCK GEOLOGY AND MINERAL DEPOSITS

The survey areas lie within the Stikinia Terrane. Bedrock geology of the Fawnie survey area (Appendix D-4) has been mapped by Tipper (1963) and, in the Fawnie Creek map area (NTS 93F/3), by Diakow et al. (1994). Most of the area is underlain by volcanic flows, volcaniclastics and sedimentary rocks of the Middle Jurassic Hazelton Group. The informal name Naglico formation has been applied to these rocks in NTS 93F/3 (Diakow and Webster, 1994). These are intruded by the Late Cretaceous Capoose batholith and locally overlain by Eocene rhyolite, dacite and conglomerate of the Ootsa Lake Group. Miocene-Pliocene Chilcotin Group basalt flows occur in low-lying regions in the south and eastern parts of the study area. Diakow and Webster (1994) have inferred the Jurassic rocks exposed in the survey area to be part of a regional east-trending horst, the Nechako uplift.

In contrast, the Ootsa survey area to the north (Appendix D-5) covers most of an extensive northwest-trending belt of Ootsa Lake Group felsic volcanic rocks mapped by Tipper (1963) on the north side of the Nechako Reservoir. This unit, comprising a differentiated succession of Eocene andesitic to rhyolitic flows and pyroclastic rocks, underlies about 65 to 70% of the area. Other rock units, Oligocene-Miocene volcanics of the Endako Group and Middle Jurassic Hazelton

Group volcanics, are less extensively exposed. Only in the southernmost part of the survey area, however, has any detailed mapping been conducted (Diakow *et al.*, 1993).

The metallogeny and mineral deposits of the Fawnie area are outlined by Schroeter and Lane (1994). Epithermal precious metal deposits in Ootsa Lake Group volcanics, epithermal precious metal/magnetite skarn occurrences associated with the Capoose batholith, and transitional base and precious metal deposits are the most common exploration targets. Interest in the potential for epithermal deposits has increased in recent years, and both the Wolf and Blackwater-Davidson prospects occur within the Fawnie survey area. The Wolf prospect, a low sulphidation adularia-sericite epithermal gold-silver occurrence (Schroeter and Lane, 1994) currently under exploration, is hosted by felsic flows, tuffs and subvolcanic porphyries. Mineralization occurs in quartz-carbonate veins, silicified stockworks and hydrothermal breccia zones. Anomalous silver, zinc, arsenic and molybdenum concentrations in sediment of a nearby lake led to the discovery of the prospect (Dawson, 1988). The Blackwater-Davidson prospect is a structurally controlled transitional gold-silver-zinc-lead-copper occurrence (Schroeter and Lane, 1994) located on the north side of Mount Davidson in the Fawnie Range. Two new epithermal precious metal prospects within Hazelton Group rocks were discovered during the 1993 bedrock mapping program in NTS map area 93F/3 (Diakow and Webster, 1994; Diakow *et al.*, 1994). The Malaput occurrence comprises pervasively silicified Naglico formation volcanics near the margin of the Capoose batholith. The Tommy occurrence is a system of quartz veins and stockwork veinlets in Naglico Formation rhyolitic flows and ash-flow tuff near the southern border of the survey area. Assay results of grab samples (fire assay-ICP) returned concentrations of up to 3.7 ppm gold at this locality (Diakow *et al.*, 1994).

Exploration for bulk-tonnage epithermal precious metal deposits in Ootsa Lake Group volcanics occurred in the Ootsa survey area during the 1980's. Several occurrences are noted in assessment reports. These are located primarily in the southern part of the survey area and are briefly summarized here. At the Arrow Lake and Gus showings, zones of stibnite-bearing quartz veins and breccia stockworks occur in silicified rhyolite and sedimentary rock of the Ootsa Lake Group on the south side of Arrow Lake (Bohme, 1988a). Exploration is currently underway at the Yellow Moose occurrence in this area. Livingstone *et al.* (1982) reported the occurrence of quartz veining and clay alteration in Ootsa Lake Group volcanics west of the Devils Thumb. Zones of quartz veining and hydrothermal alteration also occur in Ootsa Lake Group volcanics at the Barb and Gusty showings in the central part of the survey area (Bohme, 1988b). Silica veins and fracture fillings, with associated kaolinite alteration, were mapped by Ireland (1981) in block faulted Ootsa Lake Group tuffs near Enz Lake, southeast of Chief Louis Arm. On the northwest fringe of the survey area, near Danskin, several zones of fluorite-bearing quartz veins and quartz-carbonate alteration were reported by Delancey (1987).

SURVEY METHODOLOGY

SAMPLE COLLECTION

Helicopter-supported sample collection in the Fawnie survey area was carried out by the authors during the period June 15-18, 1993, and collection in the Ootsa area was carried out in the period September 17-19. A sediment sample and a water sample were systematically collected at each site using a float-equipped Bell 206 helicopter. A total of 251 sediment and water samples were collected from 237 sites in the Fawnie area, and 238 sediment and water samples were collected from 224 sites in the Ootsa area (Table 1). Average site density was approximately 1 per 8.0 square kilometres in the Fawnie area *versus* 7.4 square kilometres in the Ootsa area. Helicopter sampling rates averaged 10.5 sites per hour in the Fawnie survey and 12 sites per hour in the Ootsa survey.

Survey	NTS	Area (square km)	Sampling Density	Sites	Samples
Fawnie	93F/2,3	1880	8	237	251
Ootsa	93F/6,11,12,13,14 (parts thereof)	1650	7.4	224	238
Totals		3530	7.7	461	489

Table 1. Summary of 1993 Interior Plateau lake sediment surveys. 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 1992 orientation studies in the region (Cook, 1993a,b), the surveys 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, 1994). 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 Tsacha, Uncha, Binta and Lucas lakes, nor from reservoir areas such as Ootsa or Cheslatta lakes which have been altered by the creation of the Nechako Reservoir. Organic soils from 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, up to five sites were sampled from some of the larger lakes in the Fawnie and Ootsa surveys. 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 Kuyakuz, Moose and Johnny lakes to aid in site location and to avoid wasting helicopter time over extremely deep basins.

WATERS

Lake water samples were collected in 250-millilitre polyethylene 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. The purpose of the water sampling differed between the two survey areas. Fawnie area waters were sampled as a pilot study to determine the usefulness of regional multi-element lake water geochemistry. Consequently, all Fawnie survey water bottles were rinsed three times with distilled water at the Analytical Sciences Laboratory, Victoria, prior to use, and transported to the field in sealed plastic bags to ensure a high level of cleanliness. Analytical tests conducted on acidified and unacidified distilled water blanks, prior to field work, showed no measurable contamination of the waters by the containing bottles. Only pH and sulphate results for Fawnie waters are

reported here. Lake waters from the Ootsa area were collected for the standard RGS analytical suite (pH, uranium, fluoride, sulphate) only.

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. Variables such as lithology, which reflects the dominant geological unit of the lake catchment, and lake area were coded after sample collection. Common lake names used on either NTS topographic maps or the Vanderhoof Forest District map were included where applicable.

SAMPLE PREPARATION

SEDIMENTS

Sediment samples were field dried and, when sufficiently dry to transport, shipped to Bondar-Clegg and Company, North Vancouver (Fawnie survey), and Rossbacher Laboratory Ltd., Burnaby (Ootsa survey) for final drying at 40°C. Sample preparation was performed by Bondar-Clegg and Company, North Vancouver (Fawnie Survey) and Bondar-Clegg and Company, Ottawa (Ootsa Survey). The entire sample, to a maximum of 250 grams, was pulverized to approximately -150 mesh (~100 microns) in a ceramic ring mill, and two analytical splits (10 g and 30 g) taken from the pulverized material.

WATERS

Fawnie area lake water samples were kept cool in a refrigerator and filtered to 0.45 micron at the Analytical Sciences Laboratory, Victoria. No extraordinary preparation procedures were performed on Ootsa area lake water samples prior to analysis.

SAMPLE ANALYSIS

SEDIMENTS - AAS

A split of each prepared sediment sample was analyzed by Barringer Magenta Laboratories, Calgary, for zinc, copper, lead, silver, molybdenum, cobalt, arsenic, antimony, mercury, iron, manganese, nickel, bismuth, cadmium and vanadium. Loss on ignition was also determined. Stated 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 one-half the detection limit.

- Antimony was determined as described by Aslin (1976). A 0.5 gram sample was placed in a test tube with 3 ml concentrated HNO_3 and 9 ml HCl. The mixture was allowed to stand overnight at room temperature prior to being heated to 90°C and maintained at this temperature for 90 minutes. The mixture was cooled and a 1 ml aliquot was diluted to 10 ml with 1.8M HCl. This dilute solution was determined by hydride evolution-atomic absorption spectroscopy (AAS).

- Arsenic and bismuth were determined on a 1 gram sample reacted with 3 ml of concentrated HNO_3 for 30 minutes at 90°C. Concentrated HCl (1 ml) was added and the digestion was continued at 90°C for an additional 90 minutes. A 1 ml aliquot was diluted to 10 ml with 1.5M HCl in a clean test tube. The diluted sample solution was added to a sodium borohydride solution and aspirated through a heated quartz tube in the light path of an atomic absorption spectrometer (AAS-H).

- For the determination of cadmium, cobalt, copper, iron, lead, manganese, nickel, silver, and zinc, a 1 gram sample was reacted with 3 ml of concentrated HNO_3 for 30 minutes at 90°C. Concentrated HCl (1 ml) was added and the digestion was continued at 90°C for an additional 90 minutes. The sample solution was then diluted to 20 ml with metal free water and mixed. Concentrations were determined by AAS using an air-acetylene flame. Background corrections were made for lead, nickel, cobalt and silver.

- Mercury was determined using a 0.5 gram sample reacted with 20 ml concentrated HNO_3 and 1 ml concentrated HCl in a test tube for 10 minutes at room temperature and for 2 hours in a 90°C water bath. After digestion the sample was cooled and diluted to 100 ml with metal free water. The mercury present was reduced to the elemental state by the

addition of 10 ml of 10% weight to volume $SnSO_4$ in H_2SO_4. The mercury vapor was flushed by a stream of air into an absorption cell mounted in the light path of an atomic absorption spectrometer (AAS-F). Measurements were made at 253.7 nm. This method is described by Jonasson *et al.* (1973).

• Molybdenum and vanadium were determined by AAS using nitrous oxide acetylene flame. A 0.5 gram sample was reacted with 1.5 ml concentrated HNO_3 at 90°C for 30 minutes. At this point 0.5 ml of concentrated HCl was added and the digestion continued for an additional 90 minutes. After cooling, 8 ml of 1250 ppm Al solution was added and the sample solution diluted to 10 ml before aspiration by AAS.

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

SEDIMENTS - INAA

A 30 gram split of each sediment sample was analyzed for gold, antimony, arsenic, barium, bromine, cerium, cesium, chromium, cobalt, europium, hafnium, iron, lanthanum, lutetium, molybdenum, neodymium, rubidium, samarium, scandium, sodium, tantalum, terbium, thorium, tungsten, uranium and ytterbium by Activation Laboratories, Ancaster, Ontario, using instrumental neutron activation analysis (INAA). This analytical technique involves irradiating the sample for 30 minutes in a neutron flux of 7×10^{11} neutrons/cm^2/second. After a decay period of approximately 1 week, gamma-ray emissions for the elements were measured using a gamma-ray spectrometer with a high-resolution, coaxial germanium detector. Counting time was approximately 15 minutes per sample and the results were compiled on a computer and converted to concentrations. A complete list of elements and their stated detection limits are given in Table 2. Gold concentrations below the stated detection limits are presented in data listings as a value equivilent to one-half the detection limit.

WATERS

Water pH was determined on samples from both areas, in the Analytical Sciences Laboratory, Victoria, using a Corning model Checkmate 90 pH meter with glass combination electrode (GCE).

Filtered Fawnie area water samples were analyzed for sulphate at Eco-Tech Laboratories, Kamloops. The stated detection limit is given in Table 2. Additional analytical data for 29 trace and major elements determined by inductively coupled plasma-atomic emission spectrometry (ICP-AES) will be published at a later date.

• Sulphate was determined by a turbidimetric method (TURB). A 20 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.

Unfiltered Ootsa area lake waters were analyzed for the routine RGS water analytical suite of uranium, fluoride and sulphate at Chemex Labs, North Vancouver. Stated detection limits are given in Table 2.

• Uranium was determined by laser-induced fluorescence analysis (LIF). A 5 millilitre sample was spiked with 0.5 millilitres of fluran solution for 24 hours and activated by laser energy to cause fluorescence. Uranium was determined with a Scintrex UA-3 uranium analyzer.

• Fluoride was determined by specific ion electrode (ION). A 10 millilitre sample was added to an equal volume of buffer solution. Fluoride was determined potentiometrically using a fluoride electrode in conjunction with a standard reference electrode.

• Sulphate was determined by ion chromatography (IC). The sulphate ion was separated and measured using a system comprised of a guard column, separator column, suppressor column and conductivity detector. A sample volume of 2 to 3 millilitres was used for analysis.

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

Element		Detection Limit	Method	Element		Detection Limit	Method
Antimony	Sb	0.2 ppm	AAS	Gold	Au	2 ppb	INAA
Arsenic	As	0.2 ppm	AAS-H	Antimony	Sb	0.1 ppm	INAA
Bismuth	Bi	0.2 ppm	AAS-H	Arsenic	As	0.5 ppm	INAA
Cadmium	Cd	0.2 ppm	AAS	Barium	Ba	50 ppm	INAA
Cobalt	Co	2 ppm	AAS	Bromine	Br	0.5 ppm	INAA
Copper	Cu	2 ppm	AAS	Cerium	Ce	3 ppm	INAA
Iron	Fe	0.02%	AAS	Cesium	Cs	1 ppm	INAA
Lead	Pb	2 ppm	AAS	Chromium	Cr	5 ppm	INAA
Manganese	Mn	5 ppm	AAS	Cobalt	Co	1 ppm	INAA
Mercury	Hg	10 ppb	AAS-F	Europium	Eu	0.2 ppm	INAA
Molybdenum	Mo	1 ppm	AAS	Hafnium	Hf	1 ppm	INAA
Nickel	Ni	2 ppm	AAS	Iron	Fe	0.01%	INAA
Silver	Ag	0.2 ppm	AAS	Lanthanum	La	0.5 ppm	INAA
Vanadium	V	5 ppm	AAS	Lutetium	Lu	0.05 ppm	INAA
Zinc	Zn	2 ppm	AAS	Molybdenum	Mo	1 ppm	INAA
LOI		0.10%	GRAV	Neodymium	Nd	5 ppm	INAA
				Rubidium	Rb	5 ppm	INAA
				Samarium	Sm	0.1 ppm	INAA
Fluoride-water	FW	0.02 ppm	ION	Scandium	Sc	0.1 ppm	INAA
Uranium-water	UW	0.05 ppb	LIF	Sodium	Na	0.01%	INAA
Sulphate-water	SO4	0.1 ppm	ION-C	Tantalum	Ta	0.5 ppm	INAA
(Ootsa survey)				Terbium	Tb	0.5 ppm	INAA
Sulphate-water	SO4	1 ppm	TURB	Thorium	Th	0.2 ppm	INAA
(Fawnie survey)				Tungsten	W	1 ppm	INAA
pH-water	pH	0.01		Uranium	U	0.5 ppm	INAA
				Ytterbium	Yb	0.2 ppm	INAA

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 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, and the remainder taken from a routine sample within the block. Blind duplicates are not used in the water suite; a distilled

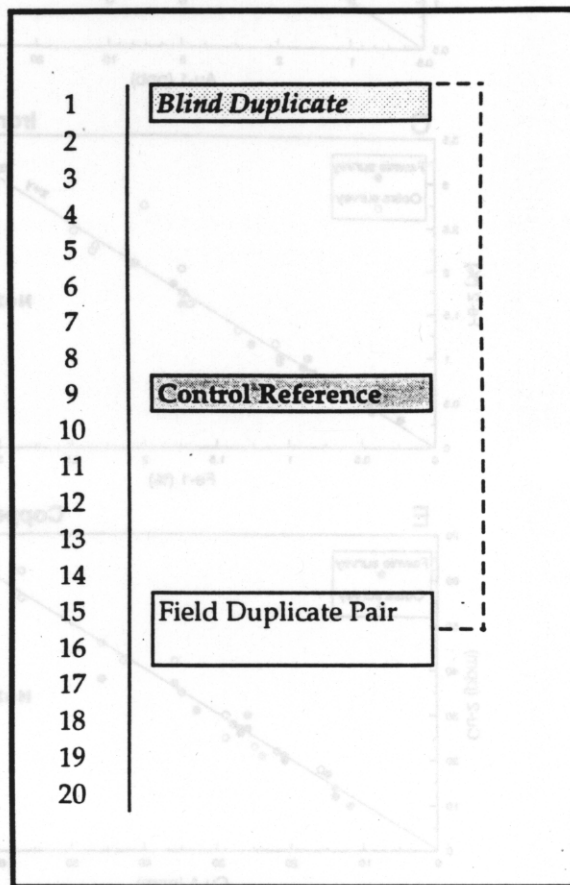water blank is instead inserted to monitor analytical contamination.

Figure 2. Typical Regional Geochemical Survey sample collection scheme used during the lake sediment surveys. 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

Scatterplots of analytical results for 28 field duplicate pairs (Figure 3) and 28 blind duplicate pairs (Figure 4) for the combined survey areas are shown for
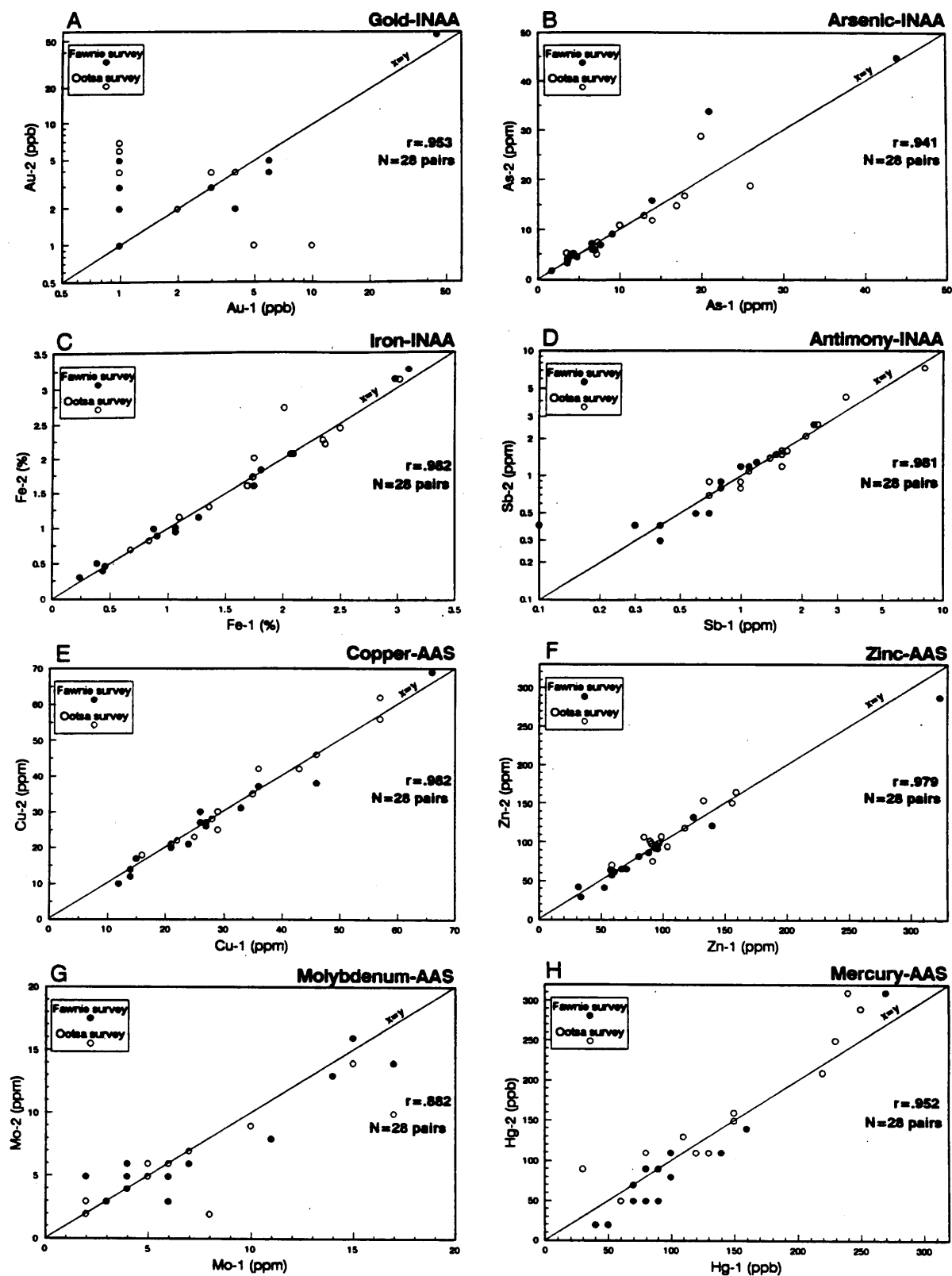
Figure 3. Scatterplots of field duplicate pairs for gold, arsenic, iron and antimony (INAA) and for copper, zinc, molybdenum and mercury (AAS).
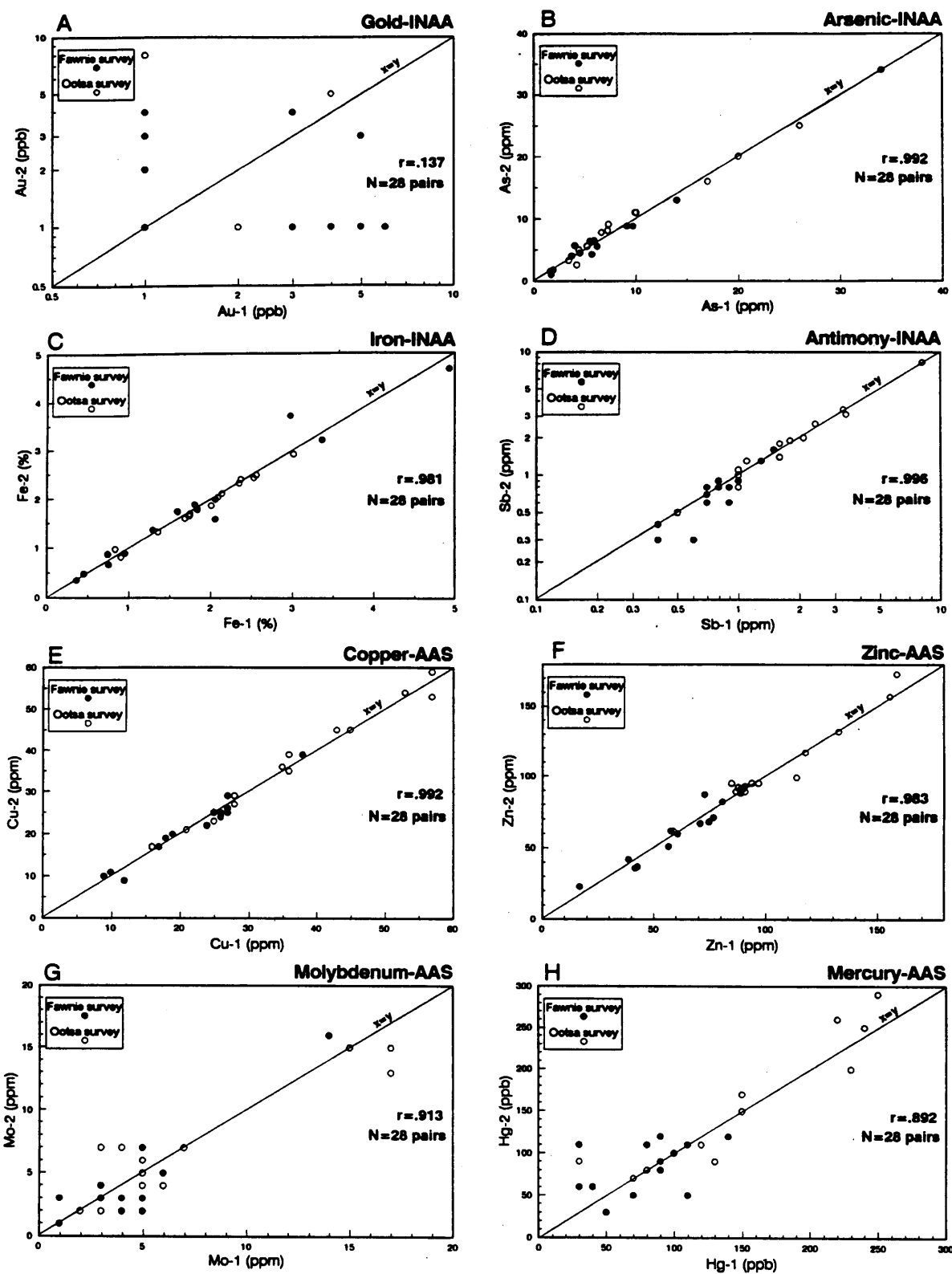
Figure 4. Scatterplots of blind duplicate pairs for gold, arsenic, iron and antimony (INAA) and for copper, zinc, molybdenum and mercury (AAS).

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. Correlation coefficients (r) for some elements are likely unnaturally high, however, due to the influence of lone outliers at high concentration levels. Correlation coefficients for field duplicate gold, arsenic and zinc (Figure 3) fall into this category. Estimates of analytical precision at different concentration levels are not given for the 28 blind duplicate pairs from the combined surveys, as this is fewer than the minimum of 50 pairs recommended by Thompson and Howarth (1978). Field duplicate data are shown within the data listings in Appendix A, and analytical duplicate data are listed in Appendix B.

The control standards used in the combined surveys range from CANMET certified reference materials to in-house standards of the Geological Survey Branch and the Geological Survey of Canada. Control standards analytical data compare favourably with accepted values, indicating a high degree of analytical accuracy. For example, five analyses (AAS) of the CANMET lake sediment standard LKSD-1 returned mean concentrations of 29.2 ± 1.5 ppm arsenic (accepted value: 30 ± 6 ppm), 10.6 ± 1.8 ppm molybdenum (accepted value: 12 ± 2 ppm), and 114 ± 20.7 ppb mercury (accepted value: 110 ± 15 ppb). Accepted values are from Lynch (1990). Ten analyses each (INAA) of in-house standards 'X' and 'Y' returned gold concentrations of 45.8 ± 8.7 ppb (accepted range: 41-52 ppb) and 12.2 ± 2.1 ppb (accepted range: 11-14 ppb), respectively. Regarding precision of standards results, up to ten replicate analyses of each of three standards in the INAA suite returned relative standard deviations (RSD) of 17.6-56.5 % for gold, and 5.2-11.0 % for arsenic. In the AAS suite, up to ten replicate analyses of each of four standards returned RSD values of 0.9-15.1 % for copper and 3.8-16.7 % for zinc.

Repeat INAA analyses are routinely conducted on samples reporting gold concentrations greater than the 90th percentile of each survey area (Au-2 in the data listings). Repeat analyses were conducted on 33 samples from the Fawnie survey area with gold concentrations of at least 6 ppb, and on 33 samples from the Ootsa area with gold concentrations of at least 5 ppb. The majority of the reanalyses were performed on separate splits of the original pulverized material. In a few cases where no sample remained, the repeat analysis was conducted with the original INAA sample capsule. For the Fawnie area, 24 of 31 reanalyses yielded gold concentrations greater than or equal to the stated detection limit of 2 ppb. In the case of two samples for which there was no remaining material, reanalysis of sample capsules returned one of

two gold concentrations greater than or equal to the detection limit. For the Ootsa area, 16 of 26 reanalyses yielded gold concentrations greater than or equal to the detection limit. In the case of seven samples for which there was no remaining material, reanalyses of the original INAA sample capsules all returned gold concentrations greater or equal to the detection limit. The greater precision attained on reanalysis of the original INAA capsule is expected, as it measures only analytical variability from one sample batch to another. Analysis of a new sample split, on the other hand, measures both analytical and subsampling variability.

ESTIMATES OF REGIONAL AND SITE VARIABILITY FOR SELECTED ELEMENTS

METHODS

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

Here, analysis of variance (ANOVA) tests are used to partition total variance between regional and within-site components for a selection of ten elements from the INAA suite (gold, arsenic, antimony, molybdenum, cobalt, iron, cerium, lanthinum, scandium and bromine) and ten elements from the AAS suite (copper, zinc, lead, silver, molybdenum, nickel, iron, arsenic, antimony and mercury). Log-transformed field duplicate sample data are used to determine total variance and combined sampling and analytical variance using the method of Garrett (1969, 1973). Regional variance is obtained here by subtracting the within-site variance from the total variance.

RESULTS

Site and regional variance components are shown in Figure 5 (INAA data) and Figure 6 (AAS data). For most elements, regional variance accounts for more than 90% of the total variance, with within-site variance accounting for less than 10%. Elements displaying greater sample site variance components are typically those which have a high proportion of analyses at or near the analytical detection limit (*ie.* gold, silver, molybdenum, lead). Although observed regional geochemical trends for these elements should be accorded less confidence, it is noteworthy that within-site variance does not exceed 50% for any of these elements. Variance components for four of the selected elements (arsenic, antimony, iron and molybdenum) were calculated for both INAA and AAS determinations. In each case, within-site variance is lower for INAA determinations.

F ratios (Figures 7 and 8) were calculated between regional and site variance components to determine if data reflect actual regional variations or are the product of combined sampling, preparation and analytical variations. The critical F value (95% confidence limit) for the given degrees of freedom (27, 28) is 1.89. F ratios for all selected elements exceed this value regardless of their within-site variance, indicating that there is a significant difference between regional and within-sample site variances.

There is only limited information documenting the extent of within-site variation for Cordilleran lake sediments. Using a small lake-sediment data set from the Whitesail Lake (NTS 93E) and Smithers (NTS 93L) map areas, Day *et al.* (1988) showed that regional trends were significant for AAS determinations of copper, nickel, cobalt, manganese, arsenic, iron and barium. However, regional trends for zinc and lead were not deemed significant due to high within-site sampling variability. Davenport (1990) and Friske *et al.* (1994) should be consulted for additional applications of analysis of variance techniques to regional lake sediment and water surveys conducted in eastern Canada.
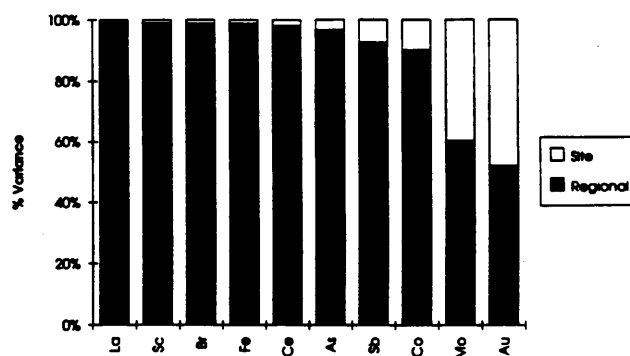

Figure 5. Variance components for selected elements (INAA): combined lake sediment survey areas.
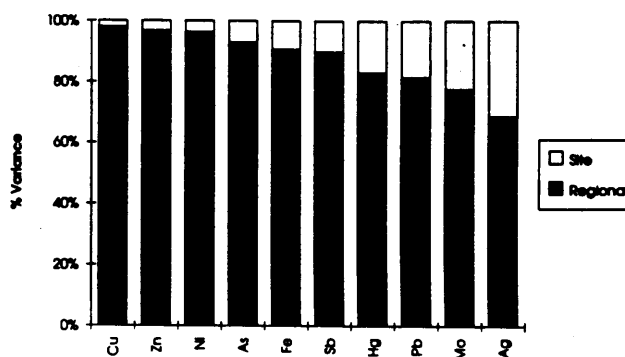

Figure 6. Variance components for selected elements (AAS): combined lake sediment survey areas.
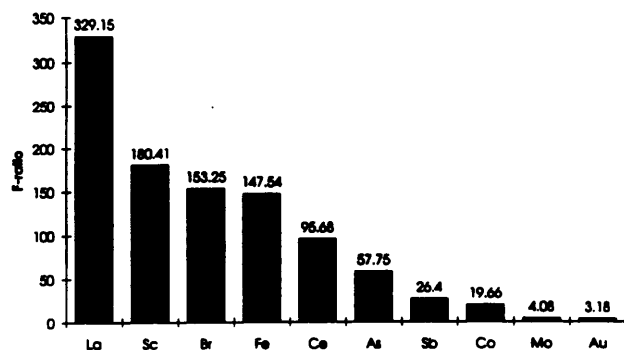
Figure 7. F ratios for selected elements (INAA): combined lake sediment survey areas.
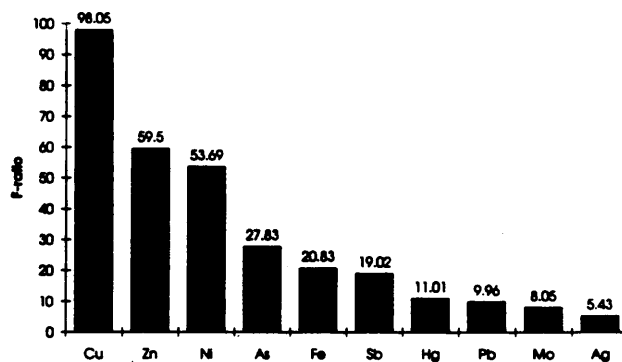

Figure 8. F ratios for selected elements (AAS): combined lake sediment survey areas.

PRELIMINARY DATA INTERPRETATION

FIELD VARIABLES

The majority of sites in both survey areas are in lakes of pond size or smaller (< 0.25 km²). For example, 60% of sites in the Fawnie area and 59% of sites in the Ootsa area are in this category. The lake area distribution differs slightly between the survey areas for larger lakes, however. Large lakes (> 5 km²) are most common in the Fawnie area; 8% of sites here are in large lakes, versus only 3% of Ootsa area sites. Conversely, small lakes of 0.25 - 1 square kilometre are more common in the Ootsa area (25%) than in the Fawnie area (17%).

Median sample depth is 4 metres in the Fawnie area and 6 metres in the Ootsa area. Very shallow lakes are most common in the Fawnie area where one-third of all sites are from ponds with depths of 2 metres or less. Most sites (71-76%) are from depths of 8 metres or less. Deepest sites sampled were 33 metres (Fawnie area) and 34 metres (Ootsa area). However, less than 3% of Fawnie sites and only 5% of Ootsa sites are deeper than 20 metres. It should be noted that sample depth measures the distance from the water surface to the sample location within the sediment column. It is *not* synonymous with lake depth (distance from water surface to the sediment-water interface), 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.

The proportion of sites classed as being in areas of low relief is approximately equal (41-42%) in both survey areas. However, there is a greater proportion of high-relief sites in the Fawnie area (5%) than in the Ootsa area (1%). Field observations indicate that potential sources of anthropogenic contamination are negligible. Work or camp sites were seen on the shores of only 4 to 5% of sites sampled.

SEDIMENTS

The following data interpretation is of a preliminary nature only. Discussions on the distribution and abundance of gold, silver, arsenic, antimony, copper, zinc and molybdenum in each survey area 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 Diakow *et al.* (1994) are used to identify geological units pertaining to the Fawnie area. Please refer to the appropriate 1:50000 scale NTS topographic maps or the Vanderhoof Forest District map for lake and place names.
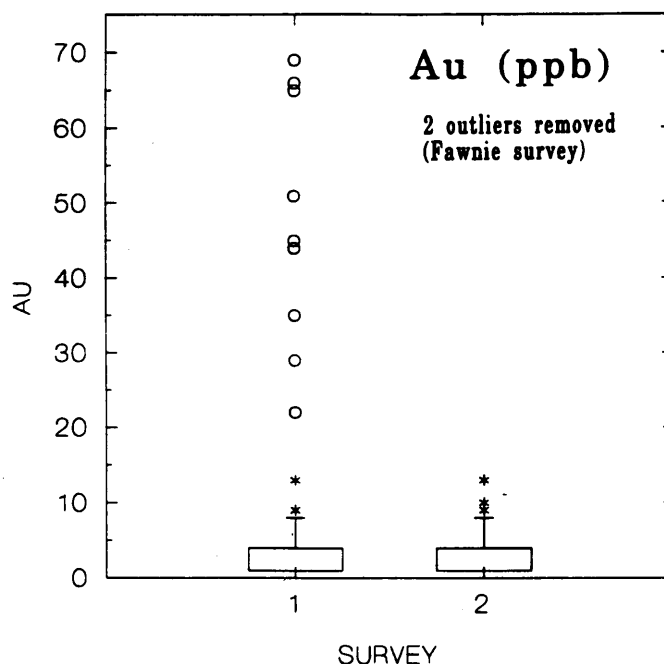

Figure 9. Boxplots showing distribution of gold (ppb) in lake sediments of the Fawnie (survey 1) and Ootsa (survey 2) areas. Median concentrations in each area are 1 ppb. Fifty per cent of the data for each survey lies within the box; the lower and upper bounds of each box define the first quartile and third quartile of data, respectively.

FAWNIE SURVEY (NTS 93F/2,3)

GOLD

Background gold concentration in lake sediments of the Fawnie survey area, as expressed by the median value, is 1 ppb. Elevated gold concentrations (90th percentile: 6 ppb; maximum: 256 ppb) are associated with drainages underlain by Middle Jurassic Hazelton Group rocks of the Naglico Formation and, to a lesser

extent, Eocene Ootsa Lake Group volcanics. Boxplots showing comparative gold distributions in the Fawnie and Ootsa survey are shown in Figure 9. Gold concentrations of at least 6 ppb occur at 33 sites, and groupings of sites with elevated gold concentrations occur in four main areas:

- The Wolf prospect-Johnny Lake region in the northwest part of the survey area, where elevated gold values in lake sediments draining both Eocene and Jurassic rocks enlarge considerably the potential target area for epithermal gold deposits. High gold concentrations occur in lake sediments on the northeast and northwest margins of the Eocene rhyolitic extrusive and intrusive rocks mapped by Diakow *et al.* (1994), and in sediment of Wolf Pond (45 ppb) adjacent to the Wolf prospect as previously documented by Cook (1994). However, very high gold concentrations also occur in parts of Cow Lake (69 ppb) and Johnny Lake (51 ppb) south of the Eocene volcanic centre, and in small lakes to the southeast (up to 256 ppb), where watersheds are underlain predominantly by poorly exposed basalt and lesser andesite flows (Nb) of the Naglico formation.

- The southwest corner of the survey area, where sediment at three sites in two unnamed lakes contain gold concentrations of 6 to 35 ppb. Watersheds of these remote lakes are underlain predominantly by Middle Jurassic sandstone and siltstone (Ns2) of the Naglico formation (Diakow *et al.*, 1994) along the eastern margin of Chilcotin Group basalts.

- The Tommy Lakes region, located in the southeast corner of NTS 93F/3 west of Tsacha Lake and immediately north of the Blackwater River, where two zones of elevated gold values occur in lake sediments near the contact between Middle Jurassic and Tertiary rocks. Three small adjacent lakes southeast of the Tommy Lakes contain high gold values of 8 to 256 ppb. Drainages of these lakes are underlain predominantly by Naglico formation volcanic sandstone, siltstone and conglomerate (Ns1) and rhyolitic lithic and ash flow tuffs (Nr) along the northern margin of Tertiary felsite sills and dikes. Elevated gold concentrations in bedrock and till have been reported from this area by Diakow *et al.* (1994) and Levson *et al.* (1994), respectively. Approximately 6 kilometres to the east, gold concentrations of 5 to 66 ppb occur in three closely spaced sites in a base-of-slope area near the contact of Ootsa Lake Group rocks mapped by Tipper (1963).

- The Kuyakuz-Euchiniko Lakes region on the east side of the survey area, where numerous gold concentrations in the range 6 to 65 ppb occur in

sediments draining Hazelton Group rocks exposed in the Nechako Range. Tipper (1963) mapped greywacke, argillite, conglomerate and lesser vocanic rocks in this area.

In addition to the above, numerous sites with elevated gold concentrations of 4 to 5 ppb and above occur throughout the Fawnie survey area. For example, several sites with 6 to 22 ppb gold occur at high elevations and on the southwest flanks of Tsacha Mountain and Mount Davidson in the Fawnie Range. Six sites with 5 to 8 ppb gold occur within the inferred bounds of the Capoose batholith. One of these (site 1142), on the south slope of the Entiako Spur northwest of Laidman lake, lies within the bounds of a gold dispersal train in till identified by Levson *et al.*, 1994.

SILVER

The background silver concentration, as expressed by the median value, is 0.2 ppm. The highest concentration, 1.8 ppm, occurs in sediment of Wolf Pond adjacent to the Wolf prospect. This is the only site in the Fawnie survey where strongly anomalous concentrations of silver and gold greater than the 95th percentile coincide. The second highest silver concentration (0.6 ppm) is in a small pond (site 1186) on the eastern flank of Mount Davidson, where it coincides with a 5 ppb gold value. Other elevated silver concentrations of 0.4 to 0.5 ppm occur in three general areas:

- Elevated silver concentrations of 0.4 ppm occur at several sites draining Hazelton Group rocks south of the Wolf prospect, and are particularly common in sediment of Johnny Lake. The westernmost site on Johnny Lake is coincident with both silver concentrations (0.4 ppm) greater than the 90th percentile, and gold concentrations (51 ppb) greater than the 95th percentile.

- The Naglico Hills, where sediment at several sites southeast of Moose Lake contain 0.4 to 0.5 ppm silver. These sites are underlain predominantly by basalt and lesser andesite flows (Nb) of the Naglico formation.

- Two small ponds between Euchiniko and Upper Kluskus lakes contain 0.4 to 0.5 ppm silver.

ARSENIC AND ANTIMONY

The median arsenic concentration in the Fawnie survey area is 5.8 ppm by INAA and 2.1 ppm by AAS. The median concentrations of antimony, less abundant than arsenic, are 0.8 ppm (INAA) and 0.3 ppm (AAS). Antimony concentrations are lower in Fawnie lake sediments than in those of the Ootsa area. The following discussion is based on INAA results. Maximum arsenic and antimony concentrations in Fawnie area lake sediments are 57 ppm and 3.5 ppm, respectively.

Arsenic and antimony exhibit similar distribution patterns, and high concentrations of the two elements are often coincident. Elevated concentrations of both elements in lake sediments are most common in the Fawnie Range, where four groupings of sites define a northwest-trending zone underlain by Hazelton Group rocks. These high-arsenic and antimony groupings are: the Van Tine Creek - Top Lake region; the northwest flank of Mount Davidson, where the highest concentrations of both elements in the survey area occur in high intermontane lakes and a small perched pond; the region between the summits of Mount Davidson and Tsacha Mountain; and the base-of-slope area on the east flank of Tsacha Mountain, near the eastern end of Tsacha Lake.

Although elevated concentrations of gold, arsenic and antimony occur together at a number of sites, coincident gold-arsenic-antimony anomalies greater than the 90th percentile for each element (at least 7 ppb Au, 14.1 ppm As and 1.6 ppm Sb) are uncommon. These occur at two sites: i) Wolf Pond (site 1143) adjacent to the Wolf prospect and; an unnamed lake (site 1163) in the draw between the summits of Mount Davidson and Tsacha Mountain. At several sites, gold and either antimony or arsenic are present in concentrations greater than the 90th percentile. For example, 2.2 ppm antimony coincides with a 13 ppb gold anomaly at site 1264 in an area mapped as underlain by Chilcotin Group basalts. Conversely, coincident gold and arsenic concentrations greater than the 90th percentile occur at three localities: site 1142 northwest of Laidman lake, which lies within the aforementioned gold dispersal train in till; site 1215 south of the Tommy Lakes, just west of a region of much higher gold concentrations in lake sediment; and site 1170 in the centre of Kuyakuz Lake.

COPPER AND ZINC

Median concentrations of copper and zinc (AAS) in Fawnie lake sediments are 27 ppm and 80 ppm, respectively. Maximum copper concentration is 397

ppm, while the maximum zinc concentration is 366 ppm. Most elevated copper and zinc values are associated with lakes draining units of the Middle Jurassic Naglico formation. Elevated copper values, in particular, are almost completely absent from the region underlain by the Capoose batholith. Groupings of copper concentrations greater than the 90th percentile (at least 48 ppm Cu) occur in three main areas:

• The Wolf prospect-Cow Lake region, where several sites north, south and east of Cow Lake drain areas underlain by both Ootsa Lake Group volcanics and Naglico formation basalts and lesser andesite flows (Nb). Many sites here also exhibit coincident zinc anomalies. The highest copper concentration in the Fawnie survey area occurs here in a small pond (site 1136) south of Cow Lake.

• The southwest part of the Naglico Hills, underlain by various units of the Naglico formation.

• The Van Tine Creek - Top Lake region, where copper distribution patterns are similar to those of arsenic and antimony. Among the sites is Square Lake (site 1158), which contains elevated concentrations of copper, zinc, lead and antimony and is located downslope of the Fawn (Gran) prospect. Anomalous concentrations of lead and other elements in this lake were reported by Hoffman and Smith (1982).

Groupings of zinc concentrations greater than the 90th percentile (at least 127 ppm Zn) occur in four main areas:
• The Wolf prospect-Cow Lake area, where the zinc distribution pattern is similar to that of copper.

• The Naglico Hills, where elevated zinc concentrations are tightly clustered in a group of small unnamed lakes draining Naglico formation basalt and lesser andesite flows (Nb).

• The Fawnie Range, where a northwest-trending zone of elevated zinc concentrations parallels the axis of the Fawnie Range and exhibits a distribution pattern similar to that of arsenic and antimony. The zone extends from the Van Tine Creek valley, where the maximum zinc concentration of 366 ppm occurs in sediment of Square Lake, to the eastern end of Tsacha Lake.

• The Tommy Lakes-west Tsacha Lake region, where some elevated zinc concentrations are coincident with gold values of 8 ppb (site 1215) and 5 ppb (site 1097) in areas of both Naglico formation and Ootsa Lake Group rock.

MOLYBDENUM

Median molybdenum concentrations in the Fawnie survey area are 5 ppm by AAS and 2 ppm by INAA. The AAS results are discussed here. While the AAS technique gives slightly higher concentrations, metal distribution patterns outlined by the two analytical methods are very similar. Elevated molybdenum concentrations greater than the 90th percentile (at least 12 ppm Mo) are predominantly associated with Middle Jurassic rocks of the Naglico formation and, to a lesser extent, Ootsa Lake Group rocks; they are almost completely absent from the area underlain by the Capoose batholith. Groupings of elevated molybdenum values occur in four main districts:

- The Wolf prospect-Cow Lake region, where elevated molybdenum values are coincident with gold concentrations of 5 to 256 ppb in small ponds at the Wolf prospect (15 ppm) and to the east of Cow Lake. These sites are underlain by both Hazelton and Ootsa Lake Group rocks.

- The Naglico Hills, where elevated molybdenum concentrations occur in the same group of small lakes, overlying Naglico formation basalt and lesser andesite flows, which have elevated zinc concentrations in sediments. Additional sites with elevated molybdenum concentrations occur to the southwest, near the border of the survey area.

- Tsacha Mountain, where elevated molybdenum concentrations occur near the summit, within the draw to the north, and in base-of-slope areas on the eastern flank of the mountain. The pattern is similar to that exhibited by arsenic, antimony and, to a lesser extent, zinc. The highest molybdenum concentration in the survey (22 ppm) occurs in this area (site 1239).

- Kuyakuz Lake, where elevated molybdenum concentrations occur in the centre of a large lake receiving drainage from Hazelton Group sedimentary rocks of the Nechako Range. One site (1170) is coincident with an 8 ppb gold concentration.

OOTSA SURVEY (NTS 93F/6,11,12,13,14)

GOLD

The median gold concentration in the Ootsa survey area is 1 ppb. There are far fewer lakes with high gold concentrations here (maximum: 13 ppb) than in the Fawnie area, but more than 25% of the sites contain at least 4 ppb gold, and 19% contain 4 to 5 ppb gold. The large number of sites with such moderately elevated gold concentrations make data interpretation less straightforward than for the Fawnie area. Groupings of elevated gold concentrations of at least 4 ppb are concentrated in two general regions, both of which are in the southern half of the survey area between Cheslatta Lake and the Nechako Reservoir:

- The Yellow Moose Lake district, where a zone of elevated gold concentrations extends along a west-northwesterly trend from roughly Yellow Moose Lake to the Saunders Hill area. The maximum gold concentration in the Ootsa survey (site 3031: 13 ppb) occurs in a small pond within this zone.

- The central part of the Ootsa survey area, where elevated gold concentrations occur in a west-trending zone extending from the west side of Bird Lake to Davidson Lake, and then trending northwest across the survey area towards Marilla. In the western part of this zone, for example, amost every lake in the Henson Hills area between Enz Lake and the East Ootsa logging camp contains 4 ppb gold in sediment.

Several high gold concentrations in the 8 to 10 ppb range also occur near Ligitiyuz Lake and Binta Lake in the northern part of the Ootsa survey area.

SILVER

The median silver concentration in Ootsa area lake sediments is 0.2 ppm, and the maximum concentration of 0.6 ppm silver occurs at two localities. Groupings of elevated silver concentrations greater than the 95th percentile (at least 0.5 ppb silver) occur in three districts:

- The Mackenzie Lake-Davidson Lake area, where four of five sites with elevated silver concentrations are clustered together on the north side of Deerhorn Hill. One of the highest silver concentrations (0.6 ppm) occurs here (site 3254), and another site (site 3252) is coincident with a 9 ppb gold concentration. Bedrock geology has been mapped as Endako Group.

- Saunders Hill near the Nechako Reservoir, where two small lakes west and southwest of the summit contain 0.5 ppm silver. One of these (site 3088) is coincident with a 7 ppb gold concentration.

• Two ponds northwest of Yellow Moose Lake, where one of the highest silver concentrations (0.6 ppm) is located at site 3020.

ARSENIC AND ANTIMONY

The median arsenic concentration in the Ootsa survey area is 8.1 ppm by INAA and 2.7 ppm by AAS, slightly higher than in the Fawnie survey. Median concentrations of antimony are 1.4 ppm (INAA) and 1.0 ppm (AAS), approximately double that of the Fawnie survey. The following discussion is based on INAA results. Maximum arsenic and antimony concentrations in Ootsa lake sediments are 110 ppm and 12 ppm, respectively. Arsenic and antimony distribution patterns are not as mutually similar here as in the Fawnie area. However, Ootsa arsenic patterns more closely reflect the distribution of elevated gold concentrations. Elevated arsenic concentrations greater than the 90th percentile (at least 16.1 ppm) are grouped in two main districts:

• The Yellow Moose Lake-Saunders Hill area, where several lakes with elevated arsenic concentrations occur in a strip paralleling the margin of the Nechako Reservoir. Two of these sites (3088, 3031) have coincident gold concentrations of 7 to 13 ppb. The latter site, in a pond located above Ootsa Lake Group rocks midway between Arrow Lake and Yellow Moose Lake, contains both the highest gold (13 ppb) and the highest arsenic (110 ppm) concentrations in the Ootsa survey area.

• The Bird Lake-Mackenzie Lake area, where 3 of 5 closely-grouped sites with elevated arsenic concentrations are coincident with gold concentrations of 5 to 10 ppb. These sites are situated within a roughly east-trending valley and their watersheds derive drainage from both north and south.

Most elevated antimony values greater than the 90th percentile (at least 3.0 ppm) are tightly clustered in an unnamed hummocky area which extends southwest from Lucas Lake to the edge of the Nechako Reservoir. Most lakes here are underlain by Middle Jurassic volcanic rocks of the Hazelton Group. Antimony concentrations in this region far exceed those present elsewhere in the survey area; the maximum antimony concentration of 12 ppm occurs in one of the westernmost sites (site 3084) in this group. Several sites contain elevated gold concentrations of 4 to 10 ppb, but most do not.

Coincident concentrations of gold, arsenic and antimony greater than the 90th percentile for each element (at least 6 ppb Au, 16.1 ppm As and 3.0 ppm Sb) occur at one site. Sediment at this locality, site 3031

between Yellow Moose Lake and Arrow Lake, also contains the highest mercury concentration (540 ppb) in the Ootsa survey area. At several sites, gold and either antimony or arsenic are present in concentrations greater than the 90th percentile. For example, coincident gold and arsenic concentrations greater than the 90th percentile for each element occur at three localities: site 3232 at the western end of Bird Lake; site 3238 near Mackenzie Lake; and site 3088 at the southwest base of Saunders Hill adjacent to the Nechako Reservoir. Coincident gold and antimony concentrations greater than the 90th percentile occur at two localities: site 3087 at the southwest base of Saunders Hill; and site 3073, 2 kilometres southwest of Lucas Lake.

COPPER AND ZINC

Background copper and zinc concentrations in Ootsa lake sediments, as expressed by median values, are 29 ppm and 85 ppm, respectively. These are similar to median values in the Fawnie area. The maximum copper concentration is 57 ppm, while the maximum zinc concentration is 1036 ppm. Groupings of copper concentrations greater than the 90th percentile (at least 44 ppm) are present in only two districts:

• Southwest of Lucas Lake. This area, extending to the Nechako Reservoir, is similar to the previously described zone of anomalous antimony concentrations. Watersheds of some, but not all, of the sites are located on Hazelton Group rocks. One of the highest copper concentrations (57 ppm) occurs at site 3082, and three sites contain elevated gold concentrations of 4 to 5 ppb.

• In and around Mollice Lake, near Danskin in the northernmost part of the survey area. Here, four sites with elevated copper concentrations are underlain by Ootsa Lake Group volcanic rocks. This is one of the few anomalous groupings of any metal discussed here that occurs on the north side of Cheslatta Lake. In addition to the foregoing, several other lakes with elevated copper concentrations are present in the central part of the Ootsa survey area between Mackenzie Lake and Uncha Lake. One of these (site 3249) also contains 5 ppb gold.

Zinc concentrations greater than the 90th percentile (at least 128 ppm) are grouped in three main districts:

• West of Arrow Lake, where lakes with elevated zinc concentrations are generally associated with Ootsa Lake Group rocks. One site here (site 3043) contains

367 ppm zinc, while another (site 3031) is coincident with the highest gold concentration of 13 ppb.

• Between Mackenzie Lake and the Henson Hills. Three sites in the western part of this area are coincident with elevated gold concentrations of 4 to 7 ppb; the westernmost of these (site 3118), near Chief Louis Arm, contains the highest zinc concentration in the Ootsa survey (1036 ppm). Notably, iron, manganese and organic matter (LOI) contents at this site do not differ appreciably from survey means. The area is underlain by Ootsa Lake Group volcanics.

• A small area near Tyee Butte on the north shore of Cheslatta Lake. Here, three lakes with elevated zinc concentrations are found at relatively high elevation.

In addition to the above, a single site (site 3167) near Getzuni Lake in the northern part of the survey area contains 376 ppm zinc and 52 ppm copper.

MOLYBDENUM

Median molybdenum concentrations in the Ootsa survey area are 5 ppm by AAS and 1 ppm by INAA. The AAS results are discussed here. Almost all elevated molybdenum concentrations greater than the 90th percentile (at least 11 ppm) are closely grouped on an east-west trend extending from Arrow Lake to the Nechako Reservoir near Saunders Hill. This area is centred on Hoult Lake and underlain predominantly by Ootsa Lake Group rocks, athough rocks of the Hazelton and Endako Groups are also present. The maximum molybdenum concentration in the Ootsa survey (34 ppm) occurs in sediment of a pond (site 3052) just west of Hoult Lake. Many sites, particularly those draining Ootsa Lake Group rocks on the east side of Hoult Lake, are coincident with elevated gold concentrations of 4 to 13 ppb. The molybdenum distribution pattern shows a better agreement with elevated gold concentrations in the Arrow Lake-Saunders Hill area than do either arsenic or antimony.

WATERS

A pH frequency distribution for the Fawnie area (Figure 10) shows that lake waters are predominantly of near-neutral to alkaline pH, with a median value of 7.91 (range: 6.80 to 9.95). One pond with an extremely alkaline pH of 9.95 is located on a hillside overlooking the Fawnie Creek valley near Top Lake. A pH frequency

distribution for the Ootsa area (Figure 11) shows that lake waters are predominantly of near-neutral pH, with a median value of 7.63 (range: 6.80 to 9.18). They are slightly less alkaline than waters of the Fawnie area. Nevertheless slightly alkaline pH values of 8.00 or greater occur at 27 sites, with pH values of 8.40 or greater at 12 of these. The highest pH (9.18) occurs in a small lake east of Yellow Moose Lake (93F/6) in the southernmost part of the survey area, while the largest grouping of slightly alkaline lake waters is near Marilla in the western part of the area.
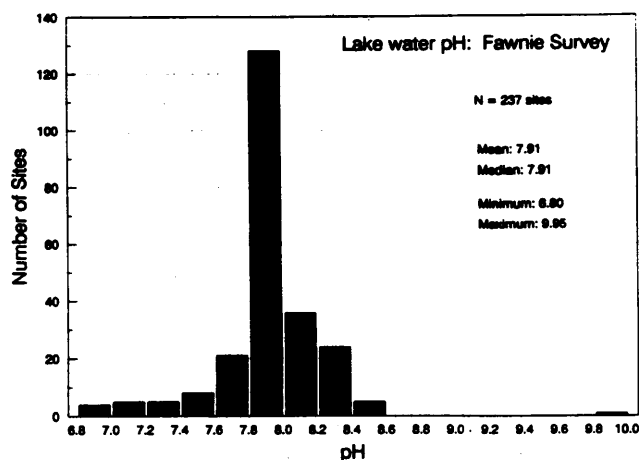

Figure 10. Frequency distribution of pH values in Fawnie survey lake waters.
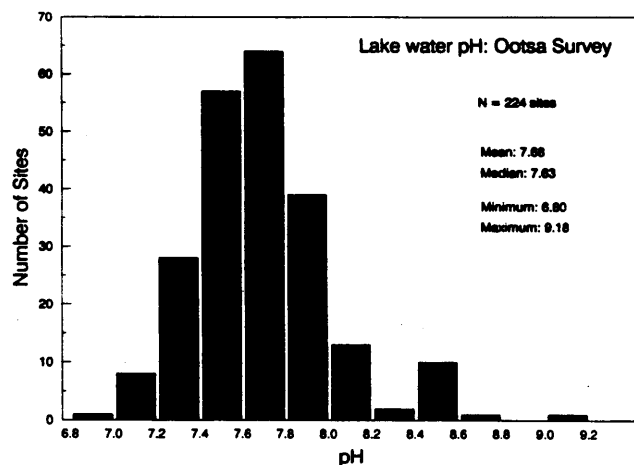

Figure 11. Frequency distribution of pH values in Ootsa survey lake waters.

DISCUSSION OF ORIENTATION STUDY RESULTS

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 mineral exploration companies, Spilsbury and Fletcher (1974), Hoffman and Fletcher (1976) and Gintautas (1984). As a prelude to ongoing regional lake sediment surveys in the northern Interior, a series of orientation surveys were conducted in 1992 (Cook, 1993) to determine the most effective sampling, analytical and interpretive techniques. Results indicate that sediment geochemistry reflects the presence of nearby epithermal gold occurrences, with elevated gold concentrations occurring in sediments of three lakes adjacent to the Wolf, Clisbako and Holy Cross prospects. The following discussion is taken largely from Cook (1994), which provides 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 in lake sediments in the Fawnie and Ootsa survey areas (N=461 sites) reported here are 1 ppb and 2.1-2.7 ppm, respectively. Median gold and arsenic concentrations of RGS lake sediments (N = 445) from nearby NTS map areas 93E (Whitesail Lake) and 93L (Smithers) (Johnson *et al.*, 1987a,b) to the west are 1 ppb and 4 ppm, respectively. These regional medians are far less than those reported for sediments adjacent to epithermal mineralization by Cook (1994), 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 rhyolite, tuff and volcanic breccia lithologies reported by Earle (1993) are considerably less than those reported 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. Gold distribution patterns in sediments near the Wolf, Clisbako and Holy Cross prospects indicate not only the presence of mineralization, but also the general direction toward its source. The gold distribution in the 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. For example, gold distribution patterns at stream inflows of Clisbako Lake reflect the locations of alteration zones mapped by Dawson (1991) to the south and northwest of the lake. Elevated gold concentrations in Bentzi Lake do not have such a direct spatial relationship to stream inflows as

exists at Clisbako. However, the shape of the gold pattern and its distribution on the northwest side of the deep channel suggest that gold entered the main basin from the northwest, probably through the NW Inlet where anomalous gold concentrations occur in stream sediments (Donaldson, 1988), and concomitantly dispersed toward the northeast part of the lake with the regional hydrologic flow. The more widespread distribution of other elements, such as arsenic, seems to render them less useful in determining anomaly source.

Preliminary evidence indicates a hydromorphic, rather than clastic, origin for the high gold concentrations in sediments of Wolf, Clisbako and Bentzi 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 absence of significant clastic input into the lake basins, particularly at Wolf Pond. Schmitt *et al.* (1993) have recently 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 (1994) 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). At Clisbako, there is a gradual decrease in gold concentrations in sediment toward the centre of the profundal basin from three separate sides of the lake. Similarly, gold concentrations in Bentzi Lake decrease toward the centre of the profundal basin, where organic matter decreases and iron content increases.

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 and Jackaman, 1994).

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 and Jackaman, 1994). 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.

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 orientation studies in British Columbia (Cook, 1994) support the detailed sampling (*ie.* every lake) approach. The following preliminary recommendations are given for geochemical exploration for epithermal gold deposits in the northern Interior Plateau.

SAMPLE MEDIA AND SAMPLING STRATEGIES

• Lake sediment geochemistry is most effective for gold exploration if every lake in the survey area is sampled, a strategy employed in the Fawnie and Ootsa surveys. The gold content of Wolf Pond sediment illustrates the importance of sampling even very small drainages. Studies of comparative regional sampling densities (one site per 7.5 km^2 versus one site per 13 km^2) and field sampling sizes are currently underway.

• 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 of Cook (1994) 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, 1993a) in the northern Interior Plateau.

• Collection of centre-lake gyttja samples is the most effective sampling method for trace elements such as copper and zinc, but evidence from this and other studies (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 low concentrations of gold in lake sediments demand the use of an analytical technique with a low 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 (P.W. Friske, personal communication, 1993).

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

• 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 (1994) indicate that gold concentrations of 4 ppb or greater in centre-lake sediments reflect the presence of adjacent epithermal gold occurrences, with lower concentrations being 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 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 sampling of near-shore sediment from all sides of the lake. Organic sediments near inflowing drainages are particularly important to sample. The collection of duplicate field samples is recommended. Delineating the watershed boundaries of anomalous lakes will assist in interpreting both the regional and follow-up surveys.

SUMMARY

Two regional lake sediment and water geochemistry surveys (461 sites) were conducted in parts of NTS map area 93F (Nechako River) in the northern Interior. These, the Fawnie and Ootsa surveys, are a contribution to the objective of completing Regional Geochemical Survey coverage of the Nechako River map area. The surveys corroborate earlier lake sediment anomalies adjacent to the Wolf and Fawn (Gran) occurrences, enlarge the target areas adjacent to currently known prospects, and outline new areas for prospective epithermal and transitional deposits.

Orientation studies show that lake sediments at Wolf Pond, Clisbako Lake and Bentzi Lake reflect the presence of nearby epithermal precious metal prospects, containing maximum gold concentrations of 56 ppb, 16 ppb and 9 ppb, respectively. These concentrations are far in excess of the regional background of 1 ppb gold determined in lake sediments of these and earlier surveys. Orientation studies also indicate that centre-lake sediments may, but do not necessarily, contain the highest gold concentrations. Instead, distinctive gold distribution patterns in Clisbako and Bentzi Lakes are more strongly influenced by high organic matter content and bathymetry than by basin depth, and their shapes and locations indicate the positions of stream and groundwater inflows draining upslope epithermal mineralization and alteration zones.

ACKNOWLEDGMENTS

REFERENCES

Andrew, K.P.E. (1988): Geology and Genesis of the Wolf
      Precious Metal Epithermal Prospect and the Capoose
      Base and Precious Metal Porphyry-style Prospect,
      Capoose Lake Area, Central British Columbia;
      unpublished M.Sc. thesis, *The University of British
      Columbia*, 334 pages.

Aslin, G.E.M. (1976): The Determination of Arsenic and
      Antimony in Geological Materials by Flameless Atomic
      Absorption Spectrophotometry; *Journal of Geochemical
      Exploration*, Volume 6, pages 321-330.

Balkwill, J.A. (1991): Limnological and Fisheries Surveys of
      Lakes and Ponds in British Columbia: 1915-1990; *B.C.
      Ministry of Environment, Lands and Parks*, Fisheries
      Technical Circular No.90, 157 pages.

Bohme, D.M. (1988a): Geological, Geochemical and
      Geophysical Report on the White Claim Group,
      Omineca Mining Division, B.C. (NTS 93F/11E,6E);
      *B.C. Ministry of Energy, Mines and Petroleum
      Resources*, Assessment Report 18191.

Bohme, D.M. (1988b): Geological, Geochemical and
      Geophysical Report on the Barb-Gusty Claim Group,
      Omineca Mining Division, B.C. (NTS 93F/11); *B.C.
      Ministry of Energy, Mines and Petroleum Resources*,
      Assessment Report 18092.

Coker, W.B., Fox, J.S. and Sopuck, V.J. (1982): Organic
      Centre-lake Sediments - Application in the Geochemical
      Exploration for Gold in the Canadian Shield of
      Saskatchewan; *in* Geology of Canadian Gold Deposits,
      Petruk, W. and Hodder, R.W., Editors, *Canadian
      Institute of Mining and Metallurgy*, Special Volume 24,
      pages 267-280.

Cook, S.J. (1993a): Preliminary Report on Lake Sediment
      Studies in the Northern Interior Plateau, Central British
      Columbia (93C, E, F, K, L); *in* Geological Fieldwork
      1992, Grant, B. and Newell, J.M., Editors, *B.C.
      Ministry of Energy, Mines and Petroleum Resources*,
      Paper 1993-1, pages 475-481.

Cook, S.J. (1993b): Controls on Lake Sediment Geochemistry
      in the Northern Interior Plateau, British Columbia:
      Applications to Mineral Exploration; *Canadian
      Quaternary Association*, Biennial Meeting, Program
      with Abstracts and Field Guide, page A10.

Cook, S.J. (1994): Gold Distribution in Lake Sediments near
      Epithermal Gold Occurrences in the Northern Interior
      Plateau, British Columbia; *in* Drift Exploration in
      Glaciated and Mountainous Terrain, *B.C. Ministry of
      Energy, Mines and Petroleum Resources*, Short Course
      Proceedings.

Cook, S.J. and Jackaman, W. (1994): Regional Lake Sediment
      and Water Geochemistry Surveys in the Northern
      Interior Plateau, B.C. (93F/2,3,6,11,12,13,14); *in*
      Geological Fieldwork 1993, Grant, B. and Newell, J.M.,
      Editors, *B.C. Ministry of Energy, Mines and Petroleum
      Resources*, Paper 1994-1, pages 39-44.

Davenport, P.H. (1990): Techniques to Determine the Quality
      of Geochemical Data: Examples from Regional Lake

Sediment Geochemical Surveys in Newfoundland; *in*
      Current Research 1990, *Newfoundland Department of
      Mines and Energy*, Geological Survey Branch Report 90-
      1, pages 95-105.

Davenport, P.H. and McConnell, J.W. (1988): Lake Sediment
      Geochemistry in Regional Exploration for Gold; *in*
      Prospecting in Areas of Glaciated Terrain-1988,
      MacDonald, D.R., Editor, *Canadian Institute of Mining
      and Metallurgy*, pages 333-356.

Davenport, P.H. and Nolan, L.W. (1991): Definition of Large-
      scale Zones of Hydrothermal Alteration by Geochemical
      Mapping Using Organic Lake Sediment; *Institution of
      Mining and Metallurgy*, Transactions, Volume 100,
      pages B111-B121.

Dawson, J.M. (1988): Geological and Geochemical Report on
      the Wolf Property, Omenica Mining Division, British
      Columbia; *B.C. Ministry of Energy, Mines and
      Petroleum Resources*, Assessment Report 16995.

Dawson, J.M. (1991): Geological and Geochemical Report on
      the Clisbako Property, Cariboo Mining Division, British
      Columbia; *B.C. Ministry of Energy, Mines and
      Petroleum Resources*, Assessment Report 20864.

Day, S.J., Matysek, P.F. and Johnson, W.M. (1988): The
      Regional Geochemical Survey: Evaluation of an ICP-ES
      Package; *in* Geological Fieldwork 1987, *B.C. Ministry of
      Energy, Mines and Petroleum Resources*, Paper 1988-1,
      pages 503-508.

Delancey, P.R. (1987): 1986/87 Boss Claims Report; *B.C.
      Ministry of Energy, Mines and Petroleum Resources*,
      Assessment Report 16797.

Diakow, L.J., Green, K., Whittles, J. and Perry, A. (1993):
      Geology of the Natalkuz Lake Area, Central British
      Columbia (NTS 93F/6); *B.C. Ministry of Energy, Mines
      and Petroleum Resources*, Open File 1993-14.

Diakow, L.J. and Webster, I.C.L. (1994): Geology of the
      Fawnie Creek Map Area (93F/3); *in* Geological
      Fieldwork 1993, Grant, B. and Newell, J.M., Editors,
      *B.C. Ministry of Energy, Mines and Petroleum
      Resources*, Paper 1994-1, pages 15-26.

Diakow, L.J., Webster, I.C.L., Levson, V.M. and Giles, T.R.
      (1994): Bedrock and Surficial Geology of the Fawnie
      Creek Map Area (NTS 93F/3); *B.C. Ministry of Energy,
      Mines and Petroleum Resources*, Open File 1994-2.

Donaldson, W. (1988): Geological and Geochemical Report on
      the Holy Cross Property (HC 1-5 Claims), Omineca
      Mining Division, NTS 93F/15W; *B.C. Ministry of
      Energy, Mines and Petroleum Resources*, Assessment
      Report 17807.

Earle, S. (1993): Assessment of the Applicability of Lake
      Sediment Geochemical Surveys for Mineral Exploration
      in the Nechako Plateau Area of British Columbia; *in*
      Exploration in British Columbia 1992, *B.C. Ministry of
      Energy, Mines and Petroleum Resources*, pages 69-106.

Fletcher, W.K. (1981): Analytical Methods in Geochemical Prospecting; Handbook of Exploration Geochemistry, Volume 1, Govett, G.V.S., Editor, *Elsevier*, 255 pages.

Fox, J.S., Eagles, T. and Brooker, E. (1987): The Use of Direct Lake Sediment Geochemical Sampling for Gold as a Reconnaissance Precious Metal Exploration Tool in the Canadian Shield: Preliminary Results; *Ontario Geological Survey*, Open File Report 5669, 49 pages.

Friske, P.W.B. (1991): The Application of Lake Sediment Geochemistry in Mineral Exploration; *in* Exploration Geochemistry Workshop, *Geological Survey of Canada*, Open File 2390, pages 4.1-4.20.

Friske, P.W.B., Hall, G.E.M. and Day, S.J.A. (1994): Comparison of Trace Element Distributions in Lake Sediments and Waters from the Florence Lake Area, Labrador; *in* Current Research 1994-C, *Geological Survey of Canada*, pages 367-376.

Garrett, R.G. (1969): The Determination of Sampling and Analytical Errors in Exploration Geochemistry; *Economic Geology*, Volume 64, pages 568-569.

Garrett, R.G. (1973): The Determination of Sampling and Analytical Errors in Exploration Geochemistry - A Reply; *Economic Geology*, Volume 68, pages 282-283.

Garrett, R.G. (1974): Field Data Acquisition Methods for Applied Geochemical Surveys at the Geological Survey of Canada; *Geological Survey of Canada*, Paper 74-52.

Giles, T.R. and Levson, V.M. (1994): Surficial Geology and Drift Exploration Studies in the Fawnie Creek Area (93F/3); *in* Geological Fieldwork 1993, Grant, B. and Newell, J.M., Editors, *B.C. Ministry of Energy, Mines and Petroleum Resources*, Paper 1994-1, pages 27-37.

Gintautas, P.A. (1984): Lake Sediment Geochemistry, Northern Interior Plateau, British Columbia; unpublished M.Sc. thesis, *University of Calgary*, 175 pages.

Hoffman, S.J. (1976): Mineral Exploration of the Nechako Plateau, Central British Columbia, Using Lake Sediment Geochemistry; unpublished Ph.D. thesis, *The University of British Columbia*, 346 pages.

Hoffman, S.J. and Fletcher, W.K. (1976): Reconnaissance Geochemistry of the Nechako Plateau, British Columbia, Using Lake Sediments; *Journal of Geochemical Exploration*, Volume 5, pages 101-114.

Hoffman, S.J. and Fletcher, W.K. (1981): Detailed Lake Sediment Geochemistry of Anomalous Lakes on the Nechako Plateau, Central British Columbia - Comparison of Trace Metal Distributions in Capoose and Fish Lakes; *Journal of Geochemical Exploration*, Volume 14, pages 221-244.

Hoffman, S.J. and Smith, M.D. (1982): The 1982 Geochemical and Geological Survey on the Gran and Laid Claim Group, Capoose Lake Area, Omineca Mining Division; *B.C. Ministry of Energy, Mines and Petroleum Resources*, Assessment Report 10832.

Holland, S.S. (1976): Landforms of British Columbia - A Physiographic Outline; *B.C. Ministry of Energy, Mines and Petroleum Resources*, Bulletin 48.

Ireland, J. (1981): Geological and Geochemical Survey of the Enz Claims, Omineca Mining Division (NTS 93F/12E); *B.C. Ministry of Energy, Mines and Petroleum Resources*, Assessment Report 9789.

Johnson, W.M., Hornbrook, E.H.W. and Friske, P.W.B. (1987a): National Geochemical Reconnaissance 1:250 000 Map Series - Whitesail Lake, British Columbia (NTS 93E); *B.C. Ministry of Energy, Mines and Petroleum Resources*, RGS 16.

Johnson, W.M., Hornbrook, E.H.W. and Friske, P.W.B. (1987b): National Geochemical Reconnaissance 1:250 000 Map Series - Smithers, British Columbia (NTS 93L); *B.C. Ministry of Energy, Mines and Petroleum Resources*, RGS 17.

Jonasson, I.R. (1976): Detailed Hydrogeochemistry of Two Small Lakes in the Grenville Geological Province; *Geological Survey of Canada*, Paper 76-13, 37 pages.

Jonasson, I.R., Lynch, J.J. and Trip, L.J. (1973): Field and Laboratory Methods Used by the Geological Survey of Canada in Geochemical Surveys: No. 12, Mercury in Ores, Rocks, Soils, Sediments and Water; *Geological Survey of Canada*, Paper 73-21.

Levson, V.M. and Giles, T.R. (1994): Surficial Geology and Quaternary Stratigraphy of the Fawnie Creek Area (NTS 93F/3); *B.C. Ministry of Energy, Mines and Petroleum Resources*, Open File 1994-9.

Levson, V.M., Giles, T.R., Cook, S.J. and Jackaman, W. (1994): Till Geochemistry of the Fawnie Creek Area, (NTS 93F/3); *B.C. Ministry of Energy, Mines and Petroleum Resources*, Open File 1994-18.

Livingstone, K.W., Richards, G.G. and Harivel, C. (1982): Geochemical Report - Angel Property, Omineca Mining Division (NTS 93F/11W); *B.C. Ministry of Energy, Mines and Petroleum Resources*, Assessment Report 10320.

Lynch, J. (1990): Provisional Elemental Values for Eight New Geochemical Lake Sediment and Stream Sediment Reference Materials LKSD-1, LKSD-2, LKSD-3, LKSD-4, STSD-1, STSD-2, STSD-3 and STSD-4; *Geostandards Newsletter*, Volume 14 (1), pages 153-167.

Matysek, P.F. and van der Heyden, P. (1994): 1993-94 Update-Interior Plateau Project; *in* Geological Fieldwork 1993, Grant, B. and Newell, J.M., Editors, *B.C. Ministry of Energy, Mines and Petroleum Resources*, Paper 1994-1, pages 9-14.

McConnell, J. and Davenport, P. (1989): Gold and Associated Trace Elements in Newfoundland Lake Sediment: Their Application to Gold Exploration; *Journal of Geochemical Exploration*, Volume 32, pages 33-50.

Mehrtens, M.B. (1975): Chutanli Mo Prospect, British Columbia; *in* Conceptual Models in Exploration Geochemistry, Bradshaw, P.M.D., Editor, *Association of Exploration Geochemists*, Special Publication No. 3, pages 63-65.

Mehrtens, M.B., Tooms, J.S. and Troup, A.G. (1973): Some Aspects of Geochemical Dispersion from Base-metal Mineralization within Glaciated Terrain in Norway, North Wales and British Columbia, Canada; *in* Geochemical Exploration 1972, Jones, M.J., Editor, *The Institution of Mining and Metallurgy*, pages 105-115.

MINFILE 093F, Bailey, D.G. and Jakobsen, D.E. (1989): Nechako River Mineral Occurrence Map; *B.C. Ministry of Energy, Mines and Petroleum Resources*, MINFILE, released Sept. 1989.

Panteleyev, A. (1986): A Canadian Cordilleran Model for Epithermal Gold-Silver Deposits; *Geoscience Canada*, Volume 13, Number 2, pages 101-111.

Rogers, P.J. (1988): Gold in Lake Sediments: Implications for Precious Metal Exploration in Nova Scotia; *in* Prospecting in Areas of Glaciated Terrain-1988, MacDonald, D.R., Editor, *Canadian Institute of Mining and Metallurgy*, pages 357-381.

Schmitt, H.R., Cameron, E.M., Hall, G.E.M. and Vaive, J. (1993): Mobilization of Gold into Lake Sediments from Acid and Alkaline Mineralized Environments in the Southern Canadian Shield: Gold in Lake Sediments and Natural Waters; *Journal of Geochemical Exploration*, Volume 48, pages 329-358.

Schroeter, T.G. and Lane, R.A. (1994): Mineral Resources: Interior Plateau Project (93F/3 and parts of 93F/2,6, and 7); *in* Geological Fieldwork 1993, Grant, B. and Newell, J.M., Editors, *B.C. Ministry of Energy, Mines and Petroleum Resources*, Paper 1994-1, pages 45-55.

Spilsbury, W. and Fletcher, W.K. (1974): Application of Regression Analysis to Interpretation of Geochemical Data from Lake Sediments in Central British Columbia; *Canadian Journal of Earth Sciences*, Volume 11, pages 345-348.

Tipper, H.W. (1963): Nechako River Map-area, British Columbia; *Geological Survey of Canada*, Memoir 324.

Tipper, H.W., Campbell, R.B., Taylor, G.C. and Stott, D.F. (1979): Parsnip River, British Columbia (Sheet 93); *Geological Survey of Canada*, Map 1424A.

Thompson, M. and Howarth, R.J. (1978): A New Approach to the Estimation of Analytical Precision; *Journal of Geochemical Exploration*, Volume 9, pages 23-30.

Wetzel, R.G. (1983): Limnology, Second Edition; *Saunders College Publishing*, Philadelphia, 767 pages.

Regional Lake Sediment and Water
Geochemistry of Part of the
Nechako River Map Area

(92F/2,3; parts of 93F/6,11,12,13,14)

Open File 1994-19

SAMPLE LOCATION MAP
(1 OF 3)

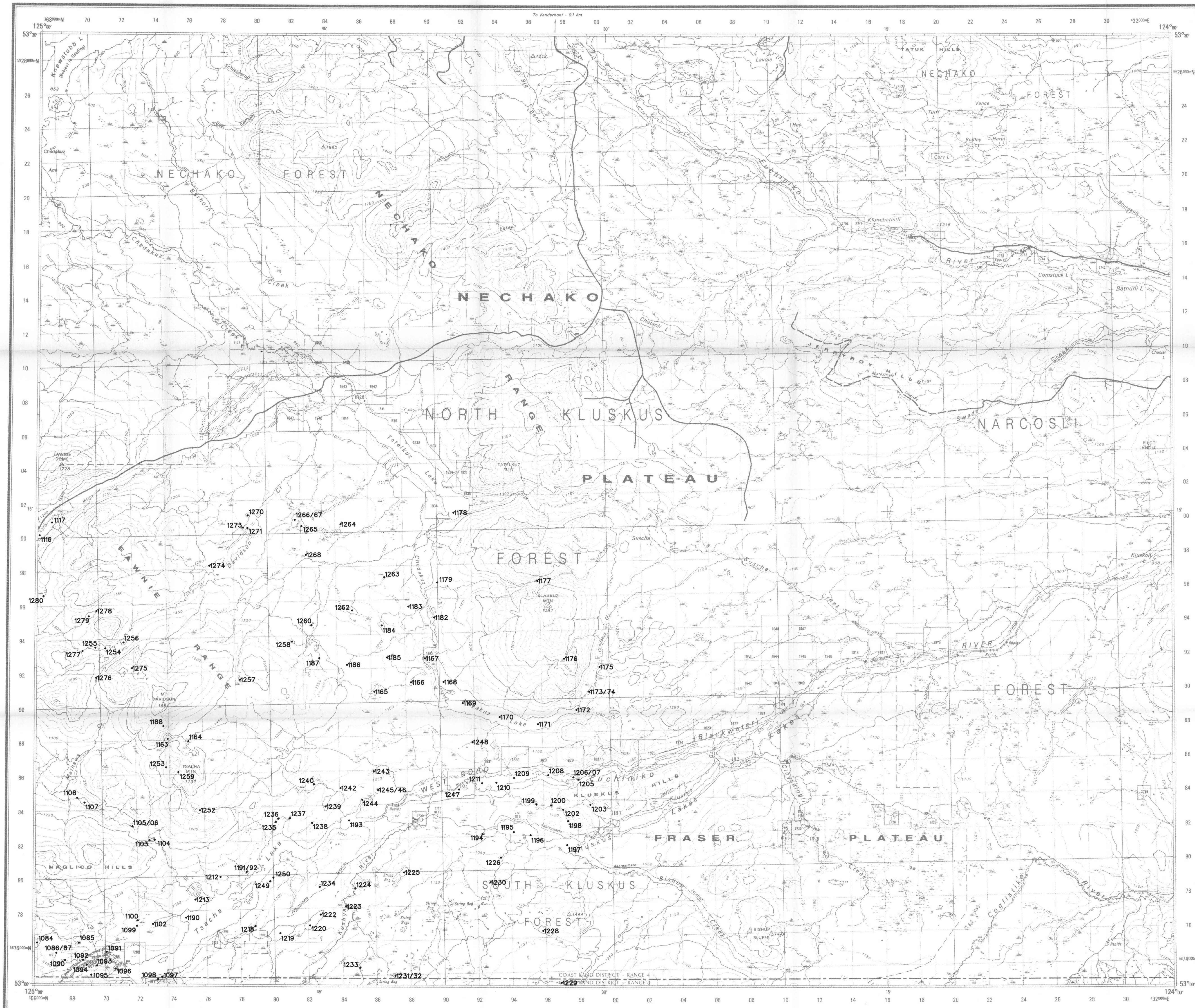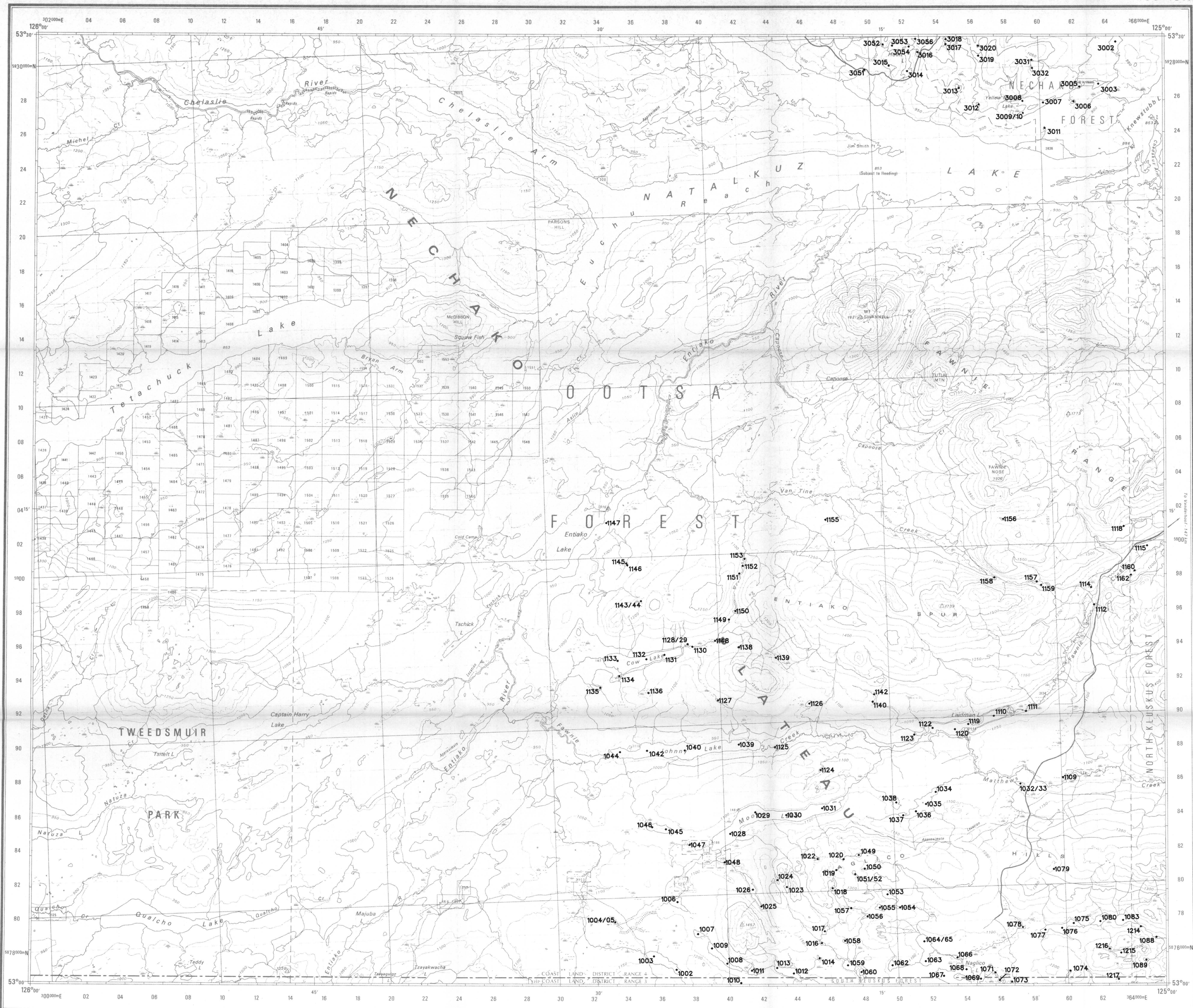Scale 1:100 000

0   4   8 km

Transverse Mercator Projection
North American Datum 1927

Approximate mean declination (1983) for center of map is 24° 18'.
Annual change decreasing .09'.

Contour interval 50 metre.
Elevations in metres above mean sea level.

Topographic base map compiled and produced by Mapping Section,
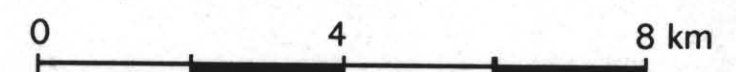Surveys and Resource Mapping Branch, Ministry of Environment, 1983.

Regional Lake Sediment and Water Geochemistry of Part of the Nechako River Map Area

(92F/2,3; parts of 93F/6,11,12,13,14)

Open File 1994-19

SAMPLE LOCATION MAP
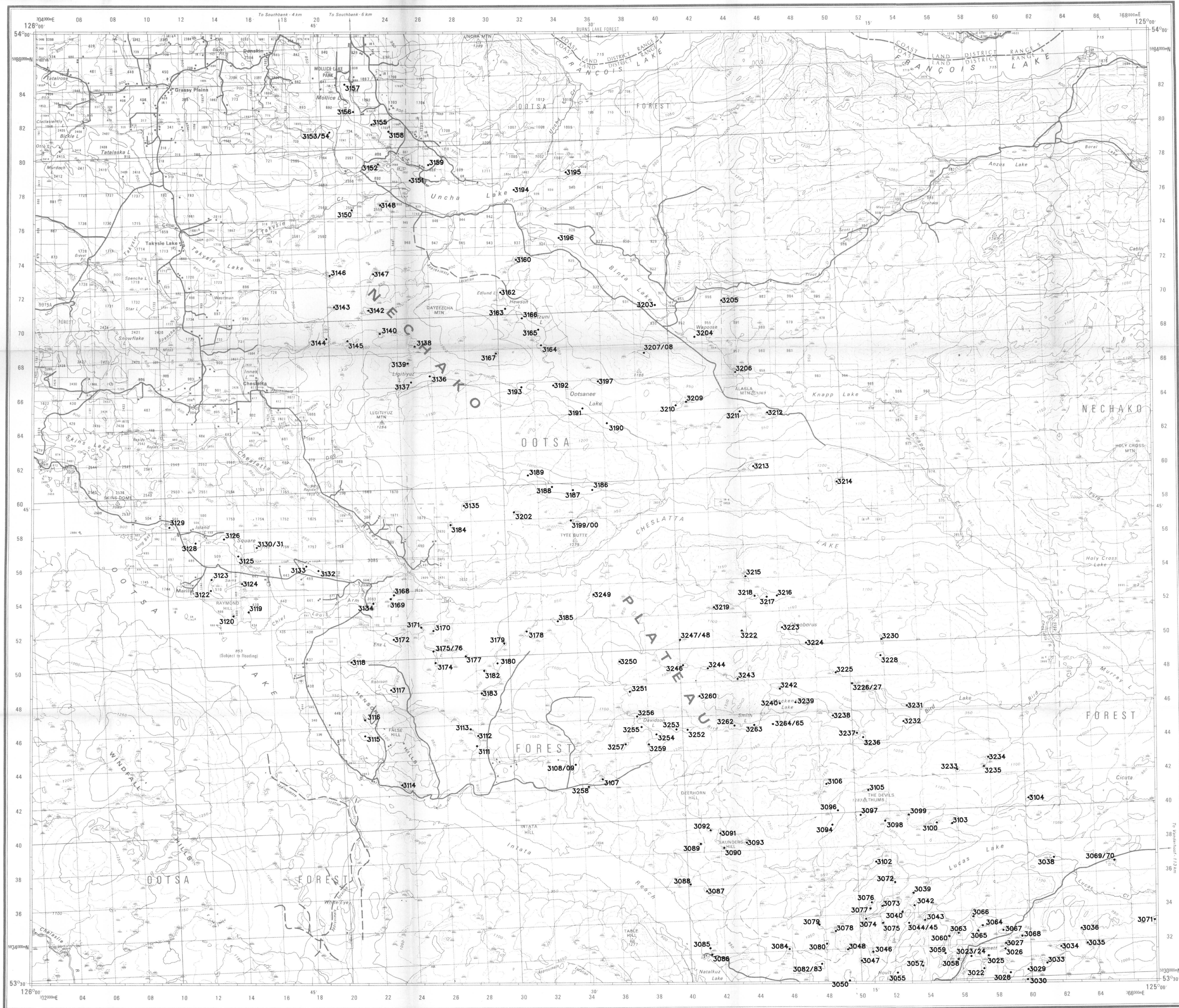(2 OF 3)

Scale 1:100 000

0   4   8 km

Transverse Mercator Projection
North American Datum 1927

Approximate mean declination (1983) for center of map is 24° 27'.
Annual change decreasing .09'.

Contour interval 50 metre.
Elevations in metres above mean sea level.

Topographic base map compiled and produced by Mapping Section,
Surveys and Resource Mapping Branch, Ministry of Environment, 1983.

Regional Lake Sediment and Water
Geochemistry of Part of the
Nechako River Map Area

(92F/2,3; parts of 93F/6,11,12,13,14)

Open File 1994-19

SAMPLE LOCATION MAP
(3 OF 3)

Scale 1:100 000

0   4   8 km

Transverse Mercator Projection
North American Datum 1927

Approximate mean declination (1983) for center of map is 24° 42'.
Annual change decreasing .09'.

Contour interval 50 metre.
Elevations in metres above mean sea level.

Topographic base map compiled and produced by Mapping Section,
Surveys and Resource Mapping Branch, Ministry of Environment, 1983.