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PRELIMINARY REPORT ON LAKE SEDIMENT STUDIES IN THE NORTHERN INTERIOR PLATEAU, CENTRAL BRITISH COLUMBIA (93 C, E, F, K, L)

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*(Contribution to the Interior Plateau Program
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INTRODUCTION

Stream sediments are the preferred sampling medium for reconnaissance-scale Regional Geochemical Surveys (RGS) over most of British Columbia, but the subdued topography, abundance of lakes and relatively poor drainage of the Nechako Plateau in the northern Interior suggest that lake sediments may be a more appropriate medium in this area. Mineral exploration in the region has been limited by extensive drift cover and poor exposure, and lake sediment geochemistry may provide an effective tool to delineate both regional geochemical patterns as well as anomalous metal concentrations related to potentially economic deposits.

Lake sediment orientation studies are an important prelude to successful application of the technique to exploration in the Cordillera. Most Canadian studies of lake sediment geochemistry have focused on Shield and Appalachian environments where there are considerable differences in climate, physiography and surficial geology relative to British Columbia. Publicly funded regional lake sediment surveys, covering an area of 1.2 million square kilometres (Friske, 1991), have been conducted primarily in central and Atlantic Canada. These, run to the standards of the Geological Survey of Canada's National Geochemical Reconnaissance (NGR) program, have provided a wealth of high-quality geochemical data for mineral exploration and contributed to the discovery of deposits such as the Strange Lake yttrium-zirconium-beryllium deposit in Labrador. Regional lake sediment surveys in British Columbia, jointly undertaken by the Geological Survey Branch and the Geological Survey of Canada have, in contrast, been restricted to relatively small areas of NTS map sheets 93E (Whitesail Lake) and 93L (Smithers) in the west-central Interior (Johnson *et al.*, 1987a, b), and 104N (Atlin) in the Teslin Plateau. There is consequently tremendous potential for the effective use of lake sediment geochemistry in central British Columbia, both for reconnaissance and detailed mineral exploration. Several regional surveys have been carried out in the northern Interior, including those of mineral exploration companies, Spilsbury and Fletcher (1974), Hoffman (1976) and Gintautas (1984). The scope and results of the latter three have been summarized by Earle (1992) in a study of the applicability of regional lake sediment surveys in the area. Prospects such as the Wolf gold-silver occurrence have been discovered through the use of lake sediment geochemistry. Nevertheless there is a paucity of detailed orientation studies and case histories on which to formulate exploration models.

The purpose of the Interior Plateau lake sediment studies program, part of the federal-provincial mineral development agreement (MDA), is to evaluate the effectiveness of lake sediment geochemistry as a sample medium for a proposed reconnaissance survey (Figure 4-9-1) of 1:250 000 NTS map sheets 93C (Anahim Lake), 93F (Nechako River) and 93K (Fort Fraser). Results of the study will increase our understanding of controls on Cordilleran trace element geochemistry and optimize sampling and interpretive techniques for the proposed RGS survey, thus increasing the possibility of new mineral deposit discoveries in the northern Interior. It fulfills an important part of the Interior Plateau project objective of upgrading the existing geological database to assess the mineral potential of the region. This paper outliness the objectives of the study, describes fieldwork performed in 1992, and outlines the scope of planned work.

LAKE SEDIMENTS AND THEIR USE IN MINERAL EXPLORATION

Lake sediments 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). They are mature green-grey to black homogenous sediments charac-

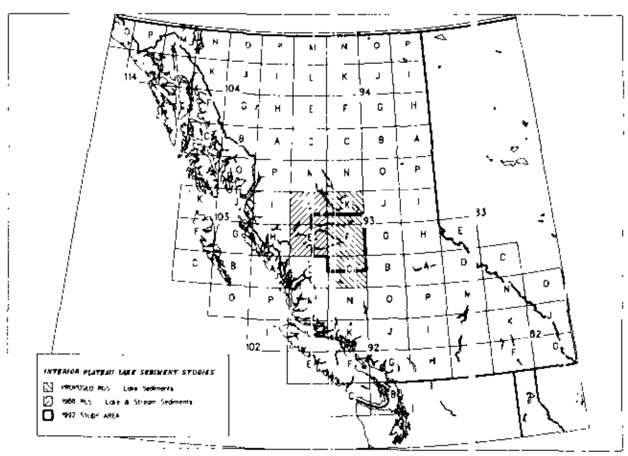

Figure 4-9-1. Location of proposed Regional Geochemical Survey, utilizing lake sediments, of NTS map sheets 93C, F and K, and of the 1986 lake and stream sediment RGS survey of NTS map sheets 93E and L. Outlined area indicates the extent of the current lake sediment study shown in Figure 4-9-2.

teristic 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 mixtures of mineral particles with little organic matter. Of the three, organic gels have been found the most suitable as a geochemical exploration medium; deep-water basins where they accumulate have been favoured as ideal sites for regional geochemical sampling (Friske, 1991).

Lake sediment composition is influenced by bedrock geology, surficial geology, climate, soils, vegetation, mineral occurrences and limnological factors. Sediment geochemistry in the Nechako Plateau, as in other areas of Canada, generally reflects bedrock variations (Hoffman, 1976; Gintautas, 1984). Sediment geochemistry also reflects the presence of weathering sulphide minerals from prospects near Capoose (Hoffman, 1976; Hoffman and Fletcher, 1981) and Chutanli (Mehrtens, 1975; Mehrtens *et al.*, 1972) lakes, and has been successful in locating potentially economic gold-silver mineralization at the Wolf occurrence (Andrew, 1988). The effect of limnological variations on trace element abundance and mineral exploration has, however, received relatively little attention in the Cordillera. 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 (1992) 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. Both may scavenge trace elements, and their abundance in lake sediments is largely influenced by water productivity, oxygen stratification in the water column and the rate of clastic sedimentation (Gintautas, 1984). 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. The effect of within-lake limnological variations on these constituents, and on the transport and accumulation of trace elements, studied in southern Shield regions, has been summarized by Timperley and Allan (1974).

Limnological classification, or trophic status, may consequently have a major influence on interpretation of lake sediment geochemistry. Earle (1992) has recognized nine such classes in the Nechako Plateau. In the present study, trophic status was found to vary considerably even within separate sub-basins and channels of the same lake. As lakes in NTS map areas 93C, F and K for which limnological data are available are almost equally divided among the four most common classifications (oligotrophic, mesotrophic, eutrophic and polymictic types; Earle, 1992), the geochemical responses of each must be evaluated prior to carrying out a regional survey.

OBJECTIVES OF THE INTERIOR PLATEAU LAKE SEDIMENT STUDY

The main objective of this study is to assess the effect of limnological variations on sediment geochemistry in the Nechako Plateau region in order to optimize sampling and interpretive techniques for regional geochemical surveys:

Problems to be addressed include:

- The effect of limnological variations on sediment geochemistry of lakes within and between different geological units.
- The extent to which sediment geochemistry reflects the presence of nearby mineral occurrences.
- Operational problems concerning sample media and sampling strategies for a proposed RGS survey of the Nechako Plateau.

The first two problems are being addressed by evaluation of a systematic collection of case studies which, together with interpretation of regional lake sediment data from adjoining NTS map sheets 93E and L, will facilitate the development of interpretive models for lakes of varying trophic status in each geological unit. Operational problems to be resolved for future RGS surveys of the Nechako area include choice of the most suitable sample media, determination of minimum and maximum lake size, optimum sampling location, optimum number of samples per lake, and optimum size of field samples and analytical subsamples necessary to detect and reproduce anomalies related to potentially economic mineral deposits. Whereas a standard sampling methodology has been used to evaluate geochemical responses and limnological variations at each lake, some of the operational problems are the subject of specific substudies.

SCOPE OF 1992 FIELD STUDIES

Orientation studies of 16 lakes at 11 localities (Figure 4-9-2) were carried out in the period late July to mid-September, 1992. The program design was based partly on recommendations of Earle (1992). A total of 625 sediment samples were collected at 437 sites (Table 4-9-1). The lakes are characteristic of eutrophic, mesotrophic, oligotrophic and unstratified limnological environments above two different geological rock types. These units, areally extensive within the proposed survey area and of considerable economic interest, are:

- Jurassic, Cretaceous and Eocene plutonic rocks of the Francois Lake, Bulkley and Nanika plutonic suites, respectively, hosting porphyry copper-molybdenum deposits and occurrences.
- Eocene Ootsa Lake Group volcanic rocks, hosting epithermal gold-silver occurrences.

The lakes are adjacent to the Hanson Lake, Ken, Nithi Mountain and Dual copper-molybdenum and molybdenum occurrences, and to the Clisbako, Wolf and Holy Cross gold-silver prospects (Table 4-9-1). Lakes within each geological grouping were chosen on the basis of documented trophic status (Balkwill, 1991), proximity to known

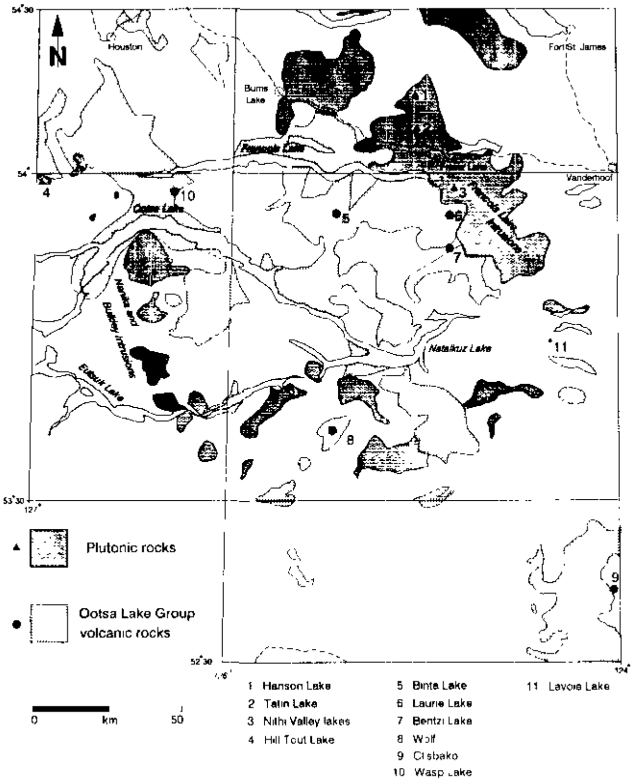

Figure 4-9-2. Locations of lake sediment survey areas in the Nechako Plateau, showing their relation to Eocene-Jurassic plutonic rocks and Eocene Ootsa Lake Group volcanic rocks (geology modified from Tipper *et al.*, 1979).

mineral occurrences, exploration industry lake sediment data and road access. Most were chosen from NTS map sheets 93C, F and K, but two lakes from map sheets 93E (Johnson *et al.*, 1987a) were also included on the basis of available RGS sediment geochemistry. These, Hill-Tout Lake and Wasp Lake, contain anomalous concentrations of copper and gold, respectively. One lake underlain by Miocene-Pliocene basalts was also surveyed as being representative of lakes above a widely occurring rock unit generally devoid of known mineral occurrences.

DESCRIPTION OF THE STUDY AREA

LOCATION, PHYSIOGRAPHY AND SURFICIAL GEOLOGY

The study area (Figures 4-9-1 and 4-9-2) is bounded east and west by Vanderhoof and Houston, respectively, and extends northward from the Clisbako River to the Babine and Stuart lakes area. Most of the area lies on the Nechako Plateau, the northernmost subdivision of the Interior Plateau (Holland, 1976), although its southern limit extends onto the Fraser Plateau. The low and rolling terrain generally lies between 1000 to 1500 metres elevation. The area is thickly forested and bedrock is obscured by extensive drift cover. Tipper (1963) noted that over 90 per cent of the Nechako River map area is drift covered. Till and glaciofluvial outwash are the predominant materials. Giles and Kerr (1993) and Proudfoot (1993) provide more detailed information on the surficial geology of the southernmost part of the proposed survey area.

TABLE 4-9-1
SUMMARY LISTING OF LAKES SURVEYED OVER CONTRASTING ROCK UNITS

Bedrock Lithology	Lake Name	NTS	Trophic Status	Lake Size (km2)	Maximum Depth (m)	Sediment Sites	Sediment Samples	Temperature and Oxygen Profiles	Adjacent Mineral Occurrences
Eocene - Jurassic Plutonic Rocks (Cu, Mo)									
	Hanson	93K03	Unstratified	1 to 5	7	44	62	5	Hanson Lake (Mo, Cu)
	Tatin	93K03	Oligotrophic	1 to 5	22	38	52	6	Ken (Mo, Cu)
	Hill-Tout	93E14, 15	Mesotrophic	1/4 to 1	14	52	74	5	Deal (Cu, Mo)
	Nithi Lakes (4)	93F15	Eutrophic	1/4 to 1	12	63	99	9	Nithi (Mo)
Eocene Ootsa Lake Group Volcanic Rocks (Au, Ag)									
	Binta	93F13, 14	Oligotrophic	> 5	> 40	37	50	3	*None*
	Bentzi (2)	93F15	Mesotrophic	1 to 5	35	66	92	7	Holy Cross (Au, Ag, Cu, Zn)
	Laurie	93F15	Eutrophic	1 to 5	22	25	35	5	*None*
	Wolf	93F03	Eutrophic	Pond	8	7	12	1	Wolf (Au, Ag)
	Clisbako	93C09		1/4 to 1	10.5	40	57	3	Clisbako (Au, Ag)
	Wasp (2)	93E 16		1/4 to 1	6	13	19	1	*None*
Miocene-Pliocene Volcanic Rocks									
	Lavoie	93F08	Unstratified	1 to 5	9	52	73	4	*None*
					Total:	**437**	**625**	**49**	

Regional Geology

The area covered by NTS map sheets 93C, F and K is almost entirely within the Intermontane Belt with the exception of the southwest corner which is in the Coast Belt. The area includes parts of the Stikinia, Cache Creek and Quesnellia terranes. Within the study area (Figure 4-9-2), volcanic and sedimentary rocks of the Lower to Middle Jurassic Hazelton Group are intruded by Late Jurassic, Late Cretaceous and Tertiary felsic plutonic rocks. These are overlain by Eocene volcanics of the Ootsa Lake Group, Oligocene and Miocene volcanics of the Endako Group, and Miocene-Pliocene basalt flows. The Anahim volcanic belt, a 600-kilometre belt of Miocene-Quaternary continental volcanic rocks (Souther, 1977), runs east-west through the southern part of the area.

Geology And Metallogeny

FRANCOIS LAKE , BULKLEY AND NANIKA PLUTONIC SUITES

Three of the lakes associated with plutonic rocks were sampled above Late Jurassic Francois Lake intrusions (133-155 Ma), the fourth is adjacent to quartz monzonite of either the Late Cretaceous Bulkley intrusions (70-84 Ma) or the Eocene Nanika intrusions (47-54 Ma). The Francois Lake Plutonic Suite, predominantly of quartz monzonite composition, hosts many porphyry molybdenum deposits and occurrences. The most significant is the Endako orebody west of Fraser Lake, where molybdenite is hosted by east-trending subparallel quartz veins (Kimura *et al.*, 1976). The Bulkley and Nanika intrusions comprise northwesterly belts of granodiorite, quartz monzonite and granite stocks in the western part of the study area (Figure 4-9-2). They are two of the four subparallel belts of plutonic rocks known to host porphyry copper-molybdenum deposits in west-central British Columbia (Carter, 1981).

OOTSA LAKE GROUP

Eocene continental volcanic rocks of the Ootsa Lake Group are exposed in two general regions of the study area. The first extends from the Nechako River to the west side of Francois Lake (Figure 4-9-2); the second, smaller area is west of Quesnel between the Chilcotin and West Road rivers (Duffell, 1959; Tipper, 1963). Diakow and Mihalynuk (1987) recognized six lithologic divisions in the Ootsa Lake Group, which comprises a differentiated succession of andesitic to rhyolitic flows and pyroclastic rocks. Sedimentary rocks, although not common, are interspersed throughout the sequence. Potassium-argon ages of approximately 50 Ma have been obtained from Ootsa Lake rocks (Diakow and Koyanagi, 1988).

Interest in the precious metal potential of the Ootsa Lake Group has increased in recent years. The Wolf and Clisbako prospects are epithermal gold-silver occurrences currently under exploration. The Wolf prospect is hosted by felsic flows, tuffs and subvolcanic porphyries, and is a low-sulphur silicified stockwork deposit (Andrew, 1988). The Clisbako prospect is hosted by Eocene basaltic to rhyolitic tuffs, flows and volcanic breccias exhibiting intense silicification and argillic alteration. Gold mineralization in both areas is associated with low-sulphide quartz stockwork zones. The Clisbako prospect has been interpreted to be a high-level volcanic-hosted epithermal system similar to those in the western United States (Dawson, 1991; Schroeter and Lane, 1992).

FIELD AND LABORATORY METHODOLOGY

Sample Collection

Systematic collection of lake sediments and waters, and measurement of temperature and dissolved oxygen content of the water column was performed at each lake (Table 4-9-1). Sediment sampling was the main focus of activity; waters were collected primarily as a reconnaissance for possible future study of metal distribution in lake waters. Oxygen and temperature measurements were made to verify pre-existing Fisheries Branch (Ministry of Environment, Lands and Parks) data, to determine the trophic status of smaller lakes for which no data are otherwise available, and to investigate the variability of these measurements within separate sub-basins of individual lakes.

SEDIMENTS

Lake sediments were sampled from a zodiac or canoe with a Hornbrook-type torpedo sampler. Standard sampling procedures, as discussed by Friske (1991), were used. Samples were collected in kraft paper bags and sample depth, colour, composition and odour recorded at each site. Sites were located along profiles traversing deep and shallow-water parts of main basins and sub-basins, and at all stream inflows. The number of sites on each lake (Table 4-9-1) ranged from a minimum of seven in small ponds to a maximum of fifty-eight in larger lakes in order to evaluate the relationship between trace element patterns and mineral occurrence location, bathymetry, organic matter content, drainage inflow and outflow, and sediment texture.

Two substudies were incorporated into the sampling design to address specific sampling problems. First, an unbalanced nested sampling design similar to that described by Garrett (1979) was used to assess sampling and analytical variation. A modified version of the Regional Geochemical Survey sampling scheme was used for this. Each block of twenty samples (Figure 4-9-3) comprises twelve routine samples and:

- Five field duplicate samples, to assess sampling variability;
- Two analytical duplicate samples, inserted after sample preparation to determine analytical precision;
- One control reference standard, to monitor analytical accuracy.

Two of the five field duplicate samples in each block were randomly selected for further use as analytical duplicate splits.

Secondly, one lake was chosen for a comparative study of field sample size. At this locality, adjacent to the Clisbako gold-silver prospect (Figure 4-9-2), two samples were taken at each of 36 sites: one standard sample obtained from one

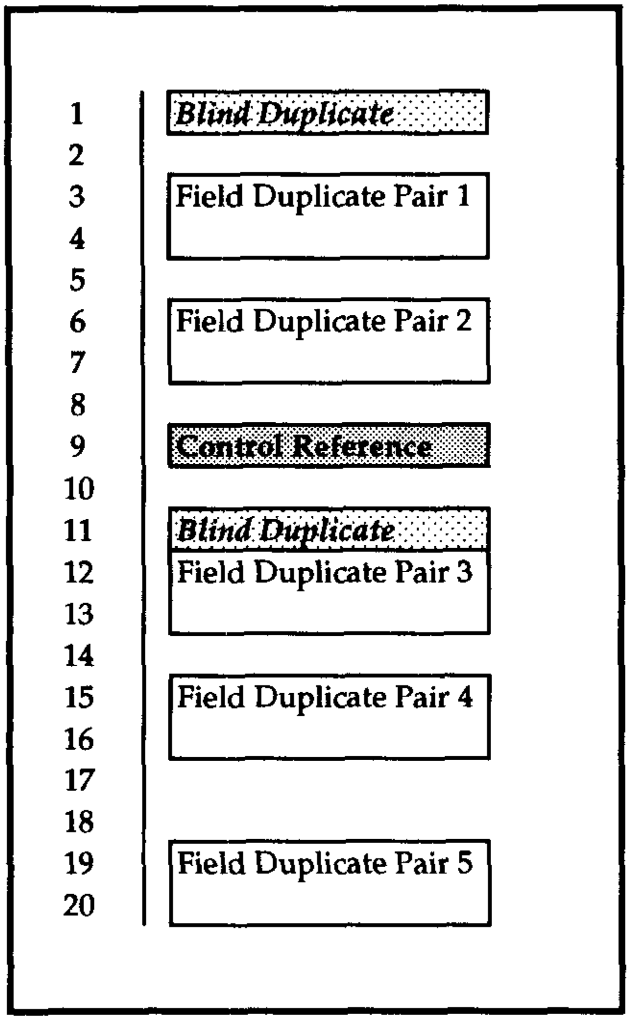

Figure 4-9-3. Typical sample collection scheme. The modified 20-sample collection block incorporates twelve routine samples and five field duplicates. Two blind duplicates and a control reference standard are inserted in the laboratory prior to analysis.

drop of the sampler, and a larger sample obtained from two drops. Standard lake sediment samples typically weigh 50 to 100 grams when dry (Friske, 1991). Due to the particle sparsity effect, larger field samples might be more representative of gold concentrations in sediments above auriferous Ootsa Lake Group rocks. The objective is to ascertain whether or not there are significant differences in gold concentrations with increasing sample size.

WATERS

Two water samples were collected in 250-millilitre polyethylene bottles from the centre of each lake: a surface sample and a deep sample. The first was taken approximately 15 centimetres beneath the surface, to minimize collection of surface scum, whereas the second was collected with a Van Dorn sampler 1 to 2 metres above the lake bottom. Bottles were rinsed in the water to be sampled prior to collection, and observations of water colour and suspended matter recorded. The boat was anchored in place during both water sampling and temperature/oxygen profiling to prevent movement. Waters were stored in a cooler and refrigerator prior to analysis.

DISSOLVED OXYGEN AND TEMPERATURE MEASUREMENTS

Water column profiles of dissolved oxygen content and temperature were measured at one to five sites on each lake, using a YSI Model 57 oxygen meter with cable probe. Measurements were generally made, at 1-metre intervals, in the centre of all major sub-basins and at two near-shore sites to a maximum depth of 29 metres. A total of 49 profiles were surveyed (Table 4-9-1), comprising 619 sets of measurements. The instrument was calibrated for lake elevation and air temperature prior to measurement at each lake, and data collected only during the afternoon period so as to standardize measurement conditions. Prevailing weather conditions were also recorded at the beginning of each profile. Measurements generally corraborated earlier Fisheries Branch data at most lakes, although considerable within-lake variations were encountered. Measurements at the last two lakes surveyed (Clisbako and Wasp) were inconclusive due to the onset of cold weather in mid-September.

Sample Preparation And Analysis

SEDIMENTS

Lake sediment samples were initially field dried and, when sufficiently dry to transport, shipped to Rossbacher Laboratory, Burnaby, for final drying at 60°C. Sample preparation was done at Bondar-Clegg and Company, North Vancouver. Dry sediment samples were disaggregated inside a plastic bag with a rubber mallet. The entire sample, to a maximum of 250 grams, was pulverized to approximately –150 mesh in a ceramic ring mill, and two analytical splits taken from the pulverized material. The first was submitted to Activation Laboratories, Mississauga, for determination of gold and 34 additional elements by instrumental neutron activation analysis (INAA) on a 30-gram subsample. The second was analyzed for 30 trace elements (including Zn, Cu, Pb, Co, Ag, Mn, Mo, Fe and Cd) by inductively coupled plasma - atomic emission spectrometry (ICP - AES) and for loss on ignition. Blind duplicates and appropriate ranges of copper and gold-bearing standards were inserted into each of the two analytical suites as part of a rigorous quality control program (Figure 4-9-3) to monitor analytical precision and accuracy.

WATERS

Water samples were filtered with 0.45 micron filters and submitted to Eco-Tech Laboratories, Kamloops. They were acidified and analyzed for 30 elements by inductively coupled plasma - atomic emission spectrometry (ICP-AES). Sulphate and pH were also determined. Standards and distilled water blanks were inserted into the sample suite to monitor analytical accuracy.

FUTURE WORK

No analytical results for lake sediments and waters from the 1992 field season are available at the time of writing. Analysis of regional lake and stream sediment data (Johnson *et al.*, 1987a, b) from adjoining NTS map sheets 93E and 93L comprises the second component of the study and is currently in progress. It will show the extent to which sediment geochemistry reflects bedrock geology, whereas the individual orientation studies have been designed to show how mineralization is reflected by trace element patterns in sediments, and how these patterns are modified by limnological factors. Recommendations regarding the suitability of the Nechako Plateau for lake sediment geochemistry, and the area, size and density of the proposed 1993 RGS survey, will be an important product of the study.

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