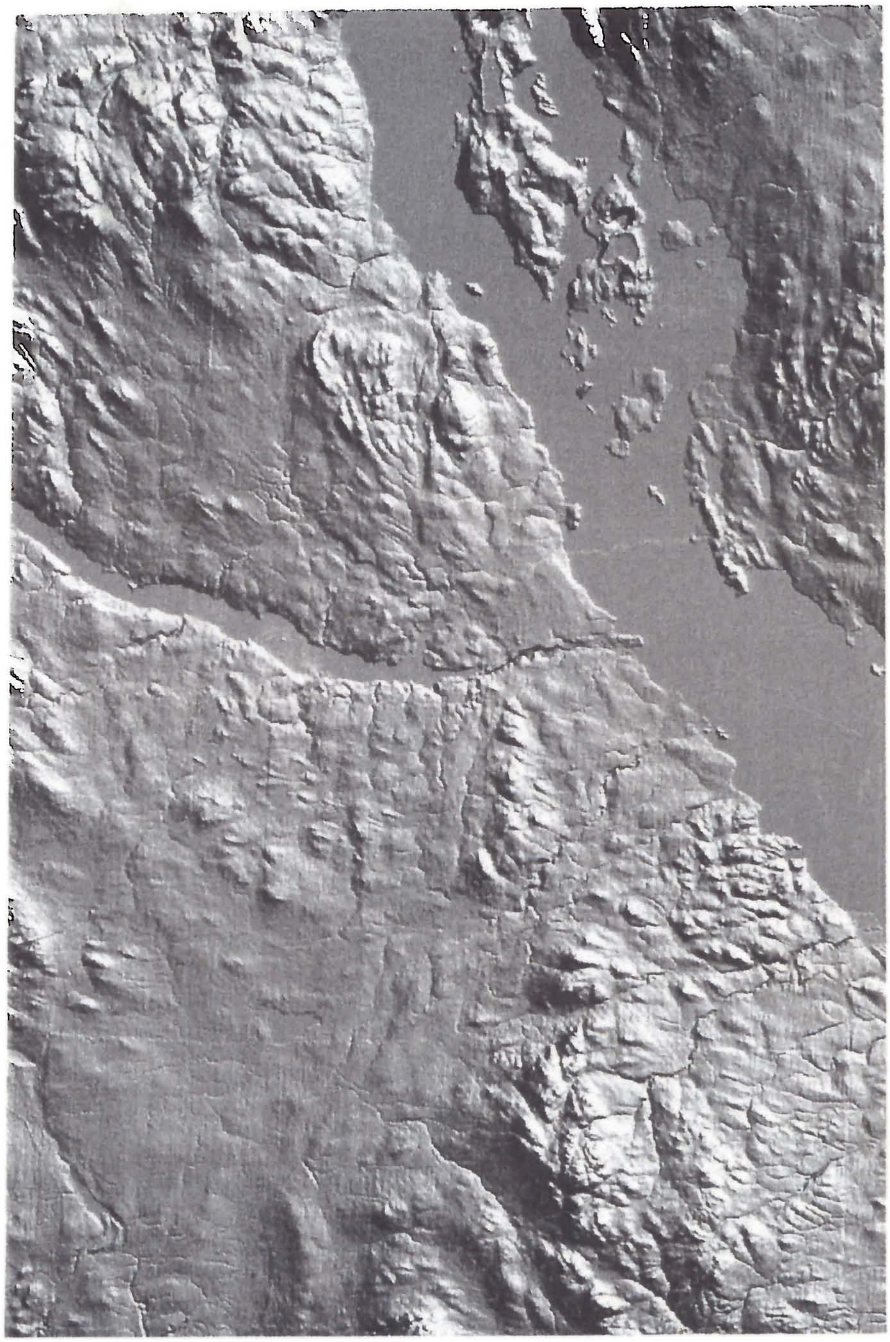
CORDILLERAN SECTION

GEOLOGICAL ASSOCIATION OF CANADA

NEW GEOLOGICAL CONSTRAINTS ON MESOZOIC TO TERTIARY METALLOGENESIS AND ON MINERAL EXPLORATION IN CENTRAL BRITISH COLUMBIA: NECHAKO NATMAP PROJECT



SHORT COURSE EXTENDED ABSTRACTS

A SHORT COURSE ORGANIZED BY THE
GEOLOGICAL ASSOCIATION OF CANADA,
CORDILLERAN SECTION
SIMON FRASER UNIVERSITY,
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VICTORIA

Nechako

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27 March, 1998
Simon Fraser University
Harbour Centre Campus

A Short Course Sponsored by the Cordilleran Section of the Geological Association of Canada

Course Program

08:25 Struik, L.C. and MacIntyre, D.G.
Introduction

08:30 Anderson, R.G.
Influence of Eocene tectonics and magmatism on the Mesozoic arc and orogenic collapse: New developments in Nechako River map area.

09:15 Dunn, C. and Cook, S.
Application of geochemical surveys to mapping and mineral exploration in the Nechako/Babine region.

10:00 Coffee

10:15 Levson, V.
Glaciation and its effects on the dispersal and burial of mineral deposits in west-central British Columbia.

10:50 Stumpf, A.
Ice-flow and its implications for drift prospecting in central British Columbia.

11:25 Plouffe, A.
History of glacial lakes and an overview of the till geochemistry as an aid for mineral exploration on the Nechako Plateau.

12:00 Lunch

13:00 Lowe, C. and Enkin, R.
New constraints on bedrock geology and mineral exploration in central British Columbia: analyses of aeromagnetic, paleomagnetic and gravity data

13:45 MacIntyre, D.G.
Late Cretaceous to Early Tertiary tectonics, magmatism and mineral deposits, central British Columbia.

14:30 Schiarizza, P.
Sitlika rocks of the Kutcho Assemblage and their tectonic relationship to the Cache Creek and Takla groups near Takla Lake.

15:15 Coffee

15:30 Struik, L.C. and Orchard, M.J.
Cache Creek Group: Its paleoenvironment, structural stacking, stratigraphy, and implications for the Pinchi Fault.

16:15 Anderson, R.G., Whalen, J.B. and Villeneuve, M.E.
Triassic to Eocene composite intrusions and molybdenum metallogeny: the Endako Batholith redefined.

17:00 End

SOME APPLICATIONS OF REGIONAL AND DETAILED LAKE SEDIMENT GEOCHEMICAL SURVEYS TO MINERAL EXPLORATION IN CENTRAL BRITISH COLUMBIA

Stephen J. Cook
British Columbia Geological Survey

INTRODUCTION

Regional lake sediment geochemical surveys carried out in central British Columbia over the past decade have been successful in helping focus mineral exploration in a region where it has historically been hampered by an extensive drift cover and poor bedrock exposure. These surveys were jointly conducted by the British Columbia Geological Survey and the Geological Survey of Canada from 1986 onwards as part of the B.C. Regional Geochemical Survey (RGS) program, and fall into two general groups. The first group consists of two relatively low-density lake sediment surveys (1 site per >30 square kilometres) of the Whitesail Lake (NTS 93E) and Smithers (NTS 93L) map areas in the western part of the Interior Plateau (Figure 1). They were carried out in conjunction with RGS stream sediment surveys of the same areas. The second group consists of a series of smaller high-density lake sediment surveys (1 site per <10 square kilometres) conducted in the Nechako Plateau area during the period 1993-1996 under the auspices of the Nechako NATMAP Project (1995-2000) and its predecessors. Regional lake sediment geochemical data is currently publicly available for some 1651 sites covering an area of more than 25,000 square kilometres (Figure 1), and it is anticipated that coverage will ultimately be extended to the remainder of the Nechako River (NTS 93F) and Fort Fraser (NTS 93K) map areas. In addition to the regional surveys, case study investigations have also been carried out at numerous Interior Plateau lakes to investigate sediment trace element distributions and formulate appropriate geochemical exploration models. The purpose of this paper is to briefly discuss regional sampling methods and techniques, document the application of lake sediment geochemical mapping to regional mineral exploration in the Nechako Plateau area, and to present some results and recommendations for the use of lake sediments for more detailed property-scale exploration.

FIELD SAMPLING AND ANALYTICAL METHODS

Sample Collection

Regional lake sediment surveys in British Columbia are typically conducted with float-equipped Bell 206 helicopters using a two-man crew consisting of a sampler and a navigator/water sampler. Profundal centre-basin organic-rich sediments, or gyttja, are the preferred sample medium for regional surveys because of their affinity for trace metals and their homogeneity relative to more clastic-rich near-shore sediments. All lakes are

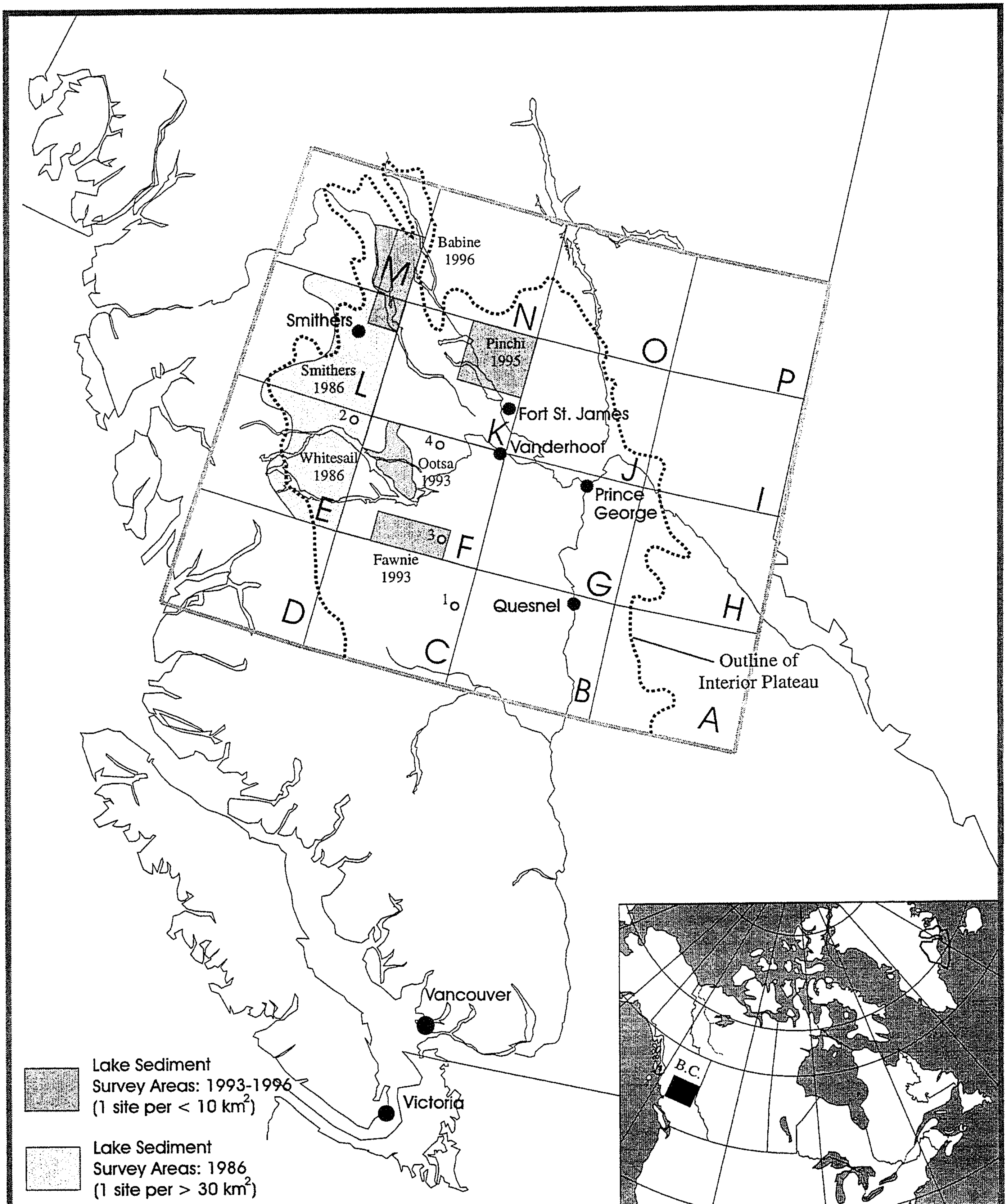

Figure 1. Map showing locations of regional lake sediment geochemical surveys conducted in the Interior Plateau region of central British Columbia during the period 1986-1996. Locations of case study areas cited in the text are indicated: 1) Clisbako Lake, 2) Hill-Tout Lake, 3) Kuyakuz Lake, and 4) Counts Lakes. Physiographic outline of the Interior Plateau (dotted line) after Holland (1976).

sampled, rather than just a selection of lakes sampled at a fixed density. Sediment is also obtained from the centres of all major known or inferred sub-basins of each lake, as significant variations in trace element content may occur among separate sub-basins of the same lake. Conversely, samples are not collected from the centres of very large and deep lakes (>10 km^2, >40 m deep) or from artificial reservoirs. Organic soils present in swamps and bogs are also avoided.

Sediment samples are collected at each site with a Hornbrook-type torpedo sampler and placed in large Kraft paper bags. A field duplicate sample is also collected at one site in every group of twenty samples. In addition, centre-lake surface water samples are obtained at all sites. These samples are collected from approximately 15 cm below the lake surface using 250 ml polyethylene bottles. A variety of field variables and observations pertaining to sample media, site and local terrain are recorded at each site. These parameters include sample depth, sediment colour and composition, general relief and potential sources of contamination. Lake depth is measured with a marked sampling rope or a depth sounder mounted to one of the helicopter floats. Readers are referred to individual open file reports (*e.g.* Cook and Jackaman, 1994) for a more complete account of field sampling procedures.

Sample Preparation and Analysis

Preparation and analysis of routine lake sediment and water samples are conducted by contract laboratories in accordance with established National Geochemical Reconnaissance (NGR) and B.C. Regional Geochemical Survey (RGS) analytical methods and procedures. These methods are carefully monitored to ensure consistent and reliable results from survey to survey regardless of the region, year or laboratory. Sediment samples are initially field dried and then shipped to a commercial laboratory for final drying at approximately 40°C. The entire sample, to a maximum of about 250 grams, is then disaggregated in a ceramic ring mill and screened to minus 80 mesh (<177 microns) to remove any remaining aggregate material. Two analytical splits are taken for geochemical analysis: one subsample (approximately 30g) for determination of gold and a suite of additional precious metal pathfinder and rare earth elements by instrumental neutron activation analysis (INAA), and a second subsample for determination of zinc, copper, lead, nickel, silver and several additional trace elements by atomic absorption spectroscopy (AAS) following an aqua regia digestion. Sediment Loss on Ignition (LOI) is also determined, and pH, uranium, fluoride and sulphate are determined on raw unfiltered lake water samples. Complete details of analytical procedures and associated quality control methods are provided in open file reports (*e.g.* Cook et al., 1998).

APPLICATIONS OF REGIONAL GEOCHEMICAL SURVEYS TO MINERAL EXPLORATION

The potential of lake sediment geochemical surveys for delineating the dispersed remnants of buried mineral deposits in the drift-covered expanses of the Interior Plateau was recognized early by the exploration industry, which first conducted proprietary surveys during the 1960's and 1970's. As a component of the RGS program, publicly-available lake sediment geochemical data for this area has become progressively more available over the past decade (Figure 1) to stimulate and guide exploration activity by a wide range of explorationists. Its role, for example, in the discovery of the Tsacha epithermal gold prospect (MINFILE 093F 055) in the southern Nechako Plateau has previously been discussed by Cook *et al.* (1997). Several examples of the use of regional geochemical survey data in generating new exploration targets and reviving interest in older ones will be discussed here, with an emphasis on new results from some of the more recent surveys in the Pinchi fault zone area and the Babine Porphyry Belt. For example, the distribution of molybdenum (AAS) in lake sediments of the Pinchi survey area (median: 4 ppm; max: 65 ppm) is shown in Figure 2. The most prominent grouping of elevated molybdenum concentrations >95th percentile (16 ppm) here is a tightly-spaced cluster of nine sites containing up to 38 ppm molybdenum. These sites, which are not associated with any known mineralization, occur above pelagic sedimentary rocks of the Cache Creek Group. They are situated within a narrow glaciolacustrine plain which occupies the valley between Tezzeron Lake and Trembleur Lake. The plain is characterized by a generally 2-4 metre thick blanket of glacial lake sediments and numerous lakes and small kettle holes (Plouffe, 1994). Coincident anomalous zones of molybdenum, arsenic, and fluoride (in waters) occur within a larger, peripheral zone of elevated sediment zinc ± silver concentrations. The geochemical signature suggests the presence of a buried porphyry molybdenum deposit, perhaps similar to the Mac porphyry molybdenum deposit some 30 kilometres to the west. The Mac deposit was discovered in the early 1980's by Riocanex Inc. during follow up of three molybdenum-copper-silver lake sediment anomalies. Data given by Cope and Spence (1995) indicate that the two lakes nearest the mineralized zones at the Mac contain 16-24 ppm molybdenum and 89-105 ppm copper in sediment, and that these zones are associated with elevated fluorine in rocks.

The most recent regional geochemical survey in the Interior Plateau was conducted over the Babine Porphyry Belt in the summer of 1996, and the data released in January 1998 (Cook *et al.*, 1998). The distribution of copper (median: 40 ppm; max: 230 ppm) and molybdenum (median: 3 ppm; max: 16 ppm) in the Babine belt are shown in Figures 3 and 4. This area includes the past-producing Bell (MINFILE 93M 001) and Granisle (MINFILE 93L 146) copper mines; other porphyry copper prospects such as the Hearne Hill, Morrison, Nak and Lennac prospects remain the primary exploration targets in the region. There are four distinct zones of elevated sediment copper concentrations > 95th percentile (75 ppm) in the Babine survey area: (i) the area around the Lennac prospect in the southern part of the survey area, where two sediment sites associated with Bulkley intrusive and Hazelton Group Telkwa Formation rocks contain 82-230 ppm copper; (ii) the Port Arthur-Deasy Creek area to the east, where three sites in an area of coincident copper-molybdenum-antimony±arsenic values within largely Topley intrusive rocks contain 89-100 ppm copper; (iii) the Skinhead Lake-Bonehead Lake area west of Granisle, where five sites in a group of closely-spaced sites contain 72-83 ppm copper; and (iv) the Sparrowhawk area on the northwest side of Babine Lake, where four sites near the Sparrowhawk and Snoopy copper showings contain 81-123 ppm copper.

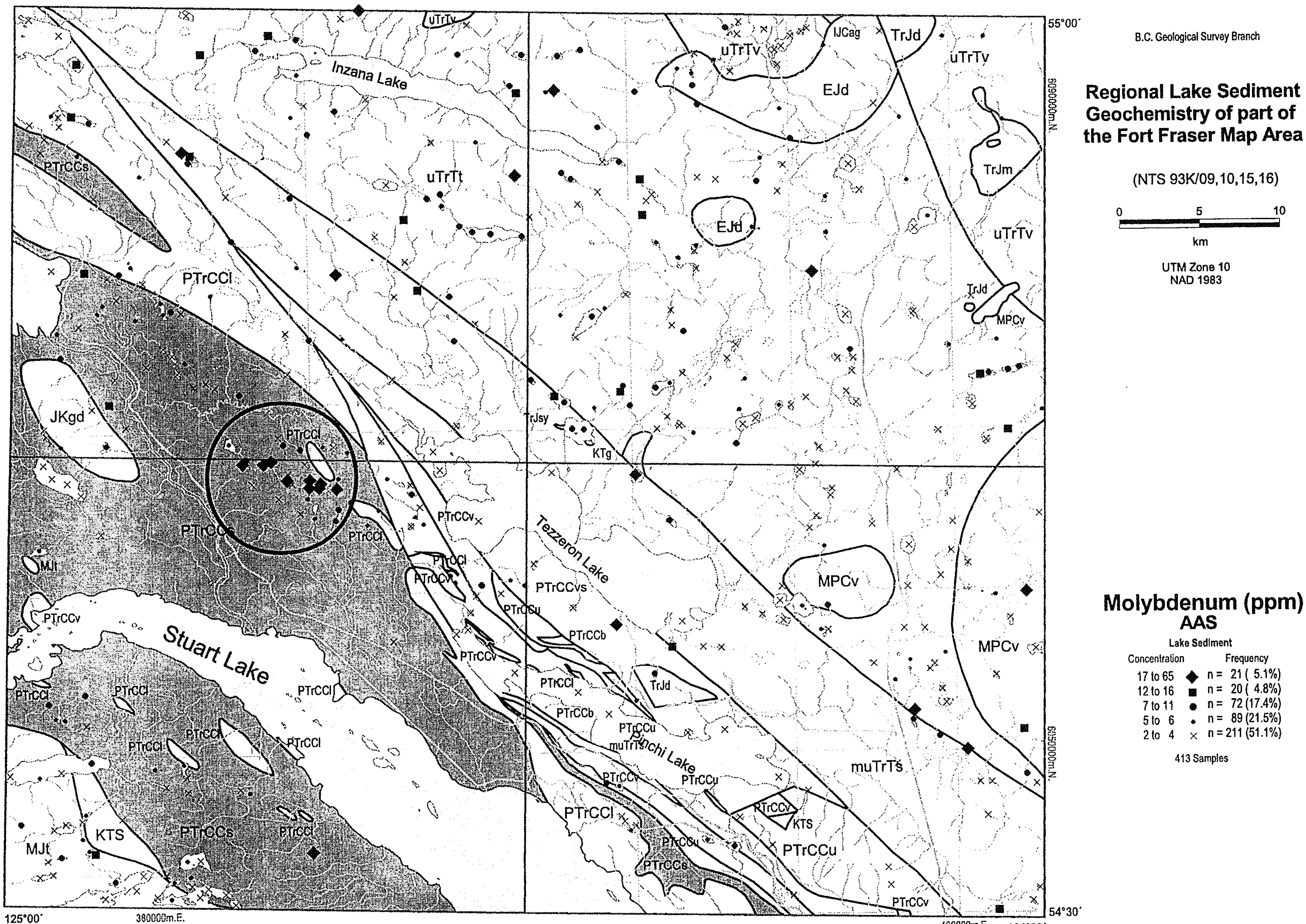

Figure 2. Distribution of molybdenum (AAS) in lake sediments of the Pinchi survey area, central British Columbia. Cache Creek Group sedimentary rocks (PTrCCs) are highlighted. Zone of elevated molybdenum values are circled. After Cook et al. (1997); geology after Bellefontaine et al. (1995).

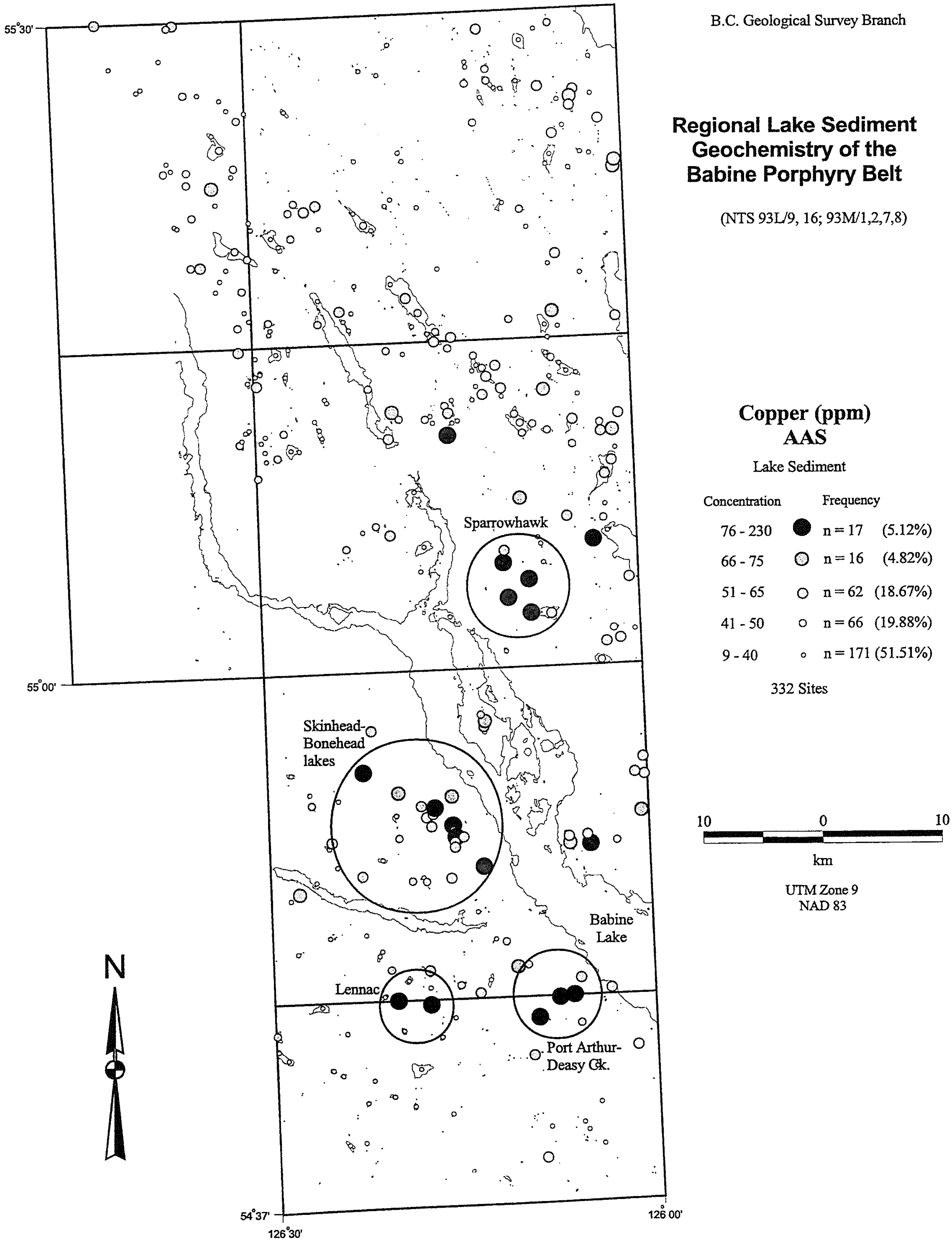

Figure 3. Distribution of copper (AAS) in lake sediments of the Babine Porphyry Belt, central British Columbia. Zones of elevated copper concentrations > 95th percentile (75 ppm) are indicated. From Cook et al. (1998).

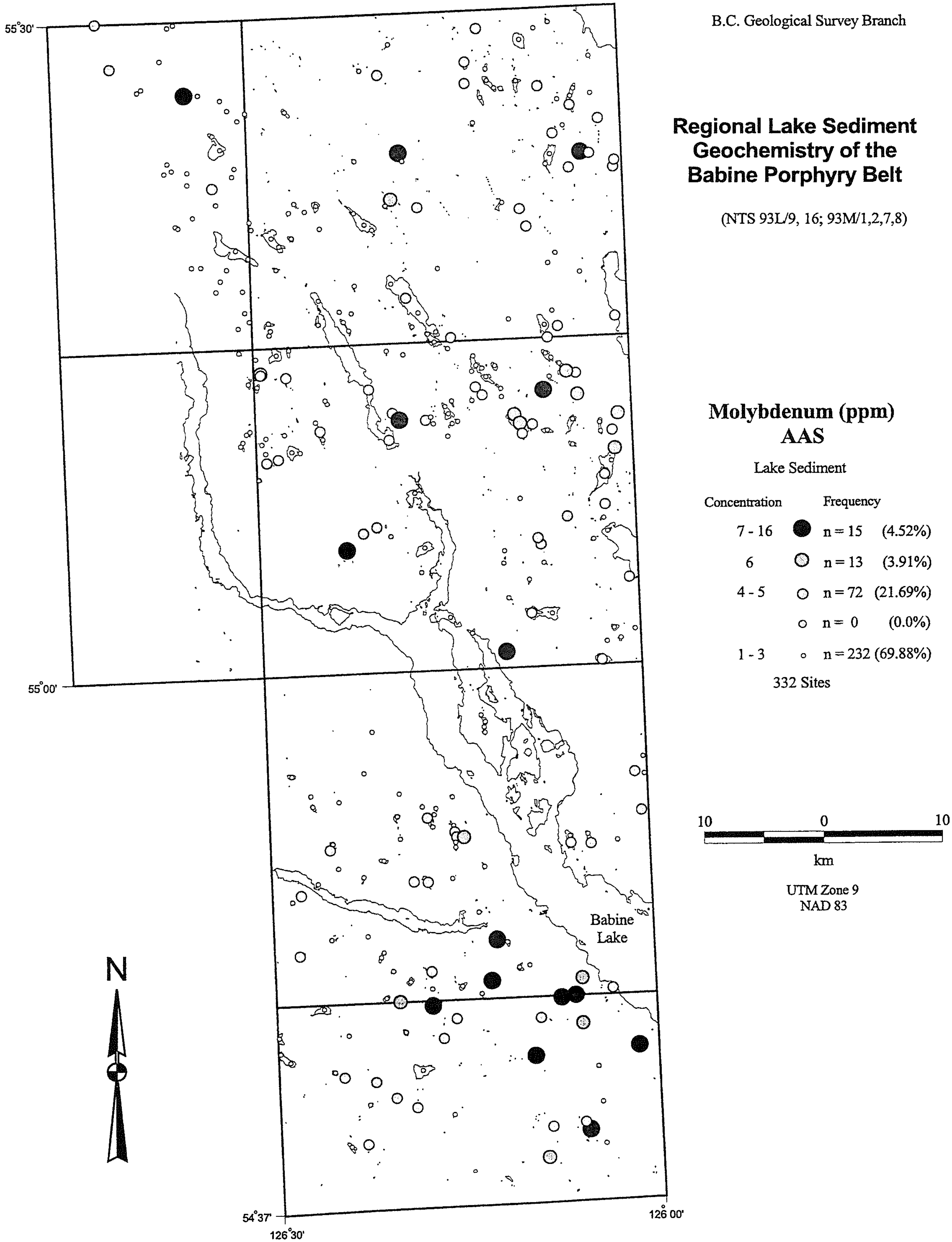

Figure 4. Distribution of molybdenum (AAS) in lake sediments of the Babine Porphyry Belt, central British Columbia. Most elevated molybdenum concentrations > 95th percentile (6 ppm) occur in the southern part of the survey area. From Cook et al. (1998).

Elevated molybdenum concentrations >95th percentile (6 ppm) for the Babine belt are shown in Figure 4. Although relatively low compared to those found in parts of the Pinchi area (Figure 2), the most notable zone of elevated molybdenum concentrations in sediments are a group of several widely-spaced sites containing 7-15 ppm molybdenum in the Deasy Creek-Lennac area. This large zone, on the west side of Babine Lake, is roughly coincident with smaller zones of elevated copper and antimony in sediments. Most sites are associated with the Early Jurassic Topley Intrusions (EJT) or Hazelton Group Telkwa Formation rocks (lJT). Several copper-molybdenum prospects occur nearby; one showing, the Port Arthur molybdenum showing near Deasy Creek, was first reported by MacIntyre *et al.* (1996) following its discovery during a regional bedrock mapping program.

LAKE SEDIMENT SURVEYS AND PROPERTY-SCALE MINERAL EXPLORATION

Lake sediment geochemical surveys have primarily been viewed as a regional-scale method for generating exploration targets in areas of poor bedrock exposure. However, detailed sediment sampling to map metal zoning patterns within individual lakes may also be a useful tool in the property-scale follow-up of regional geochemical anomalies. The shapes and locations of any such elevated metal distribution patterns in lake sediments are influenced by such factors as the location of the mineral deposit, if any, within the watershed, the drainage regime, variations in the organic matter content of the sediment, basin morphometry and within-lake limnological variations. Some detailed-scale exploration recommendations for this have been given by Cook (1997a). In all cases, the original centre-basin sediment sites should be resampled in order to verify the anomaly, particularly in the case of gold and other elements that are susceptible to the 'nugget effect'. Subsequently, however, different types of anomalous lakes (*i.e.* open-system drainage lakes vs. closed-system seepage lakes and ponds) may require different follow-up exploration strategies.

Detailed sediment sampling of anomalous drainage lakes should be conducted to map out the presence of any metal zoning patterns, as detailed survey results from several such lakes adjacent to epithermal and porphyry prospects in central B.C. show that metal zoning patterns, in near-shore sediments and near drainage inflows, may indicate general directions toward mineralization and alteration zones (Cook, 1995, 1997a). Some examples are shown here for Clisbako, Hill-Tout and Kuyakuz lakes (Figures 5-7) from widely separated parts of the Interior Plateau. All three of these lakes, although differing in basin morphology, have well-defined input and output stream drainage and exhibit distinct metal zonation patterns. These patterns are interpreted to represent the local accumulation of metals originating from down-slope and down-drainage hydromorphic dispersion from nearby mineralization, or its dispersed remnants in till.

Sediments of Clisbako Lake, located about 100 km west of Quesnel in the Fraser Plateau, contain three zones of gold (INAA) concentrations >10 ppb (Figure 5; Cook, 1995, 1997a,b). Two of these, located at relatively shallow-water stream inflows, indicate the presence of updrainage argillic alteration and/or epithermal gold zones of the Clisbako prospect mapped by Dawson (1991). The regional background here is 1 ppb, the median gold concentrations reported by nearby surveys (Cook and Jackaman, 1994).

Hill-Tout Lake, located in the Nadina Lake area south of Houston, is situated about 2 km down drainage of the Dual copper-molybdenum showing, a pyrite-chalcopyrite-molybdenite occurrence within a quartz monzonite porphyry. A single lake sediment site from the 1986 RGS survey of the Whitesail Lake area (NTS 93E) reported 105 ppm copper, and a subsequent detailed sediment survey of the lake revealed the presence of two discrete zones of elevated copper up to 151 ppm (ICP) in the two westernmost sub-basins of the lake (Figure 6). The two basins are adjacent to stream inflows which drain the Dual showing, although even the shallower and more distal eastern basin of the lake contains sediment copper values which are considerably greater than the 34 ppm median background for the combined Whitesail and Smithers map areas (Johnson *et al.*, 1987a,b).

Kuyakuz Lake, a large unstratified lake in the Nechako Range south of Vanderhoof, is not located near any presently known mineralization. However, molybdenum (median: 4.5 ppm; Figure 7) and arsenic (median: 9.2 ppm) sediment zonation patterns near a stream inflow at the western end of the lake suggest a possible buried source in the heavily-forested region to the west, where Diakow and Levson (1997) reported a large buried intrusive body near Tsacha Mountain. Sediment molybdenum (INAA) and arsenic concentrations in this part of Kuyakuz Lake reach levels of 12 ppm and 20 ppm, respectively, and elevated gold and zinc concentrations also occur at some sites.

Seepage lakes and ponds receive predominantly ground water or spring input below the lake surface, and lack significant stream outflow. They are generally smaller than drainage lakes, and centre-basin geochemical results are likely to be more representative of the entire lake and watershed than any site within the more heterogeneous drainage lakes (Cook, 1997a). As a result of this more uniform sediment distribution of metals, detailed sampling of seepage lakes may be a less useful tool for the property-scale follow-up of regional geochemical anomalies. Delineation of watershed boundaries, followed by surface prospecting and till geochemical surveys, may instead be a more useful procedure in locating any potential metal sources. Some examples of small seepage lakes are shown in Figure 8. The five mostly eutrophic small lakes are part of the Counts lakes, an east-west trending chain of interconnected lakes and ponds occupying Counts lakes valley on the south side of Nithi Mountain near Fraser Lake. They are notable for their extremely high sediment molybdenum concentrations, up to 165 ppm (ICP), in a region where background molybdenum values in lake sediments are more typically in the range 1-5 ppm. Overall median molybdenum for the five lakes is 42 ppm; median values for individual lakes are in the range 12-119 ppm. The highest sediment molybdenum concentrations occur in the three westernmost lakes. These are located directly downslope of numerous porphyry molybdenum prospects exposed on Nithi Mountain, where molybdenite occurs as disseminations and in narrow quartz veins.

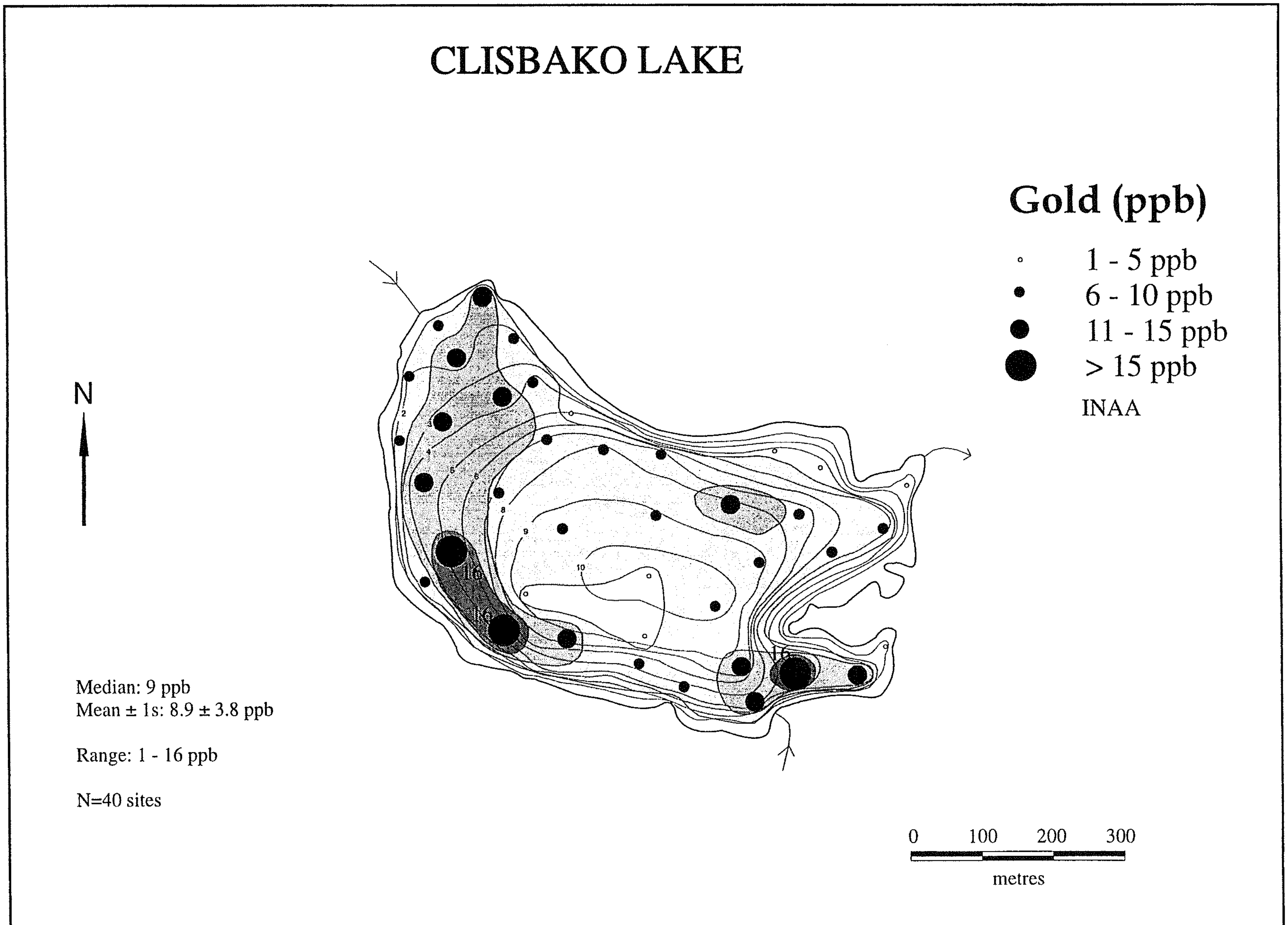

Figure 5. Distribution of gold (ppb) in sediments of Clisbako Lake, in the Fraser Plateau area of central British Columbia. Creeks entering the lake from the south and the northwest drain epithermal mineralization and/or alteration zones of Dawson (1991). From Cook (1997b).

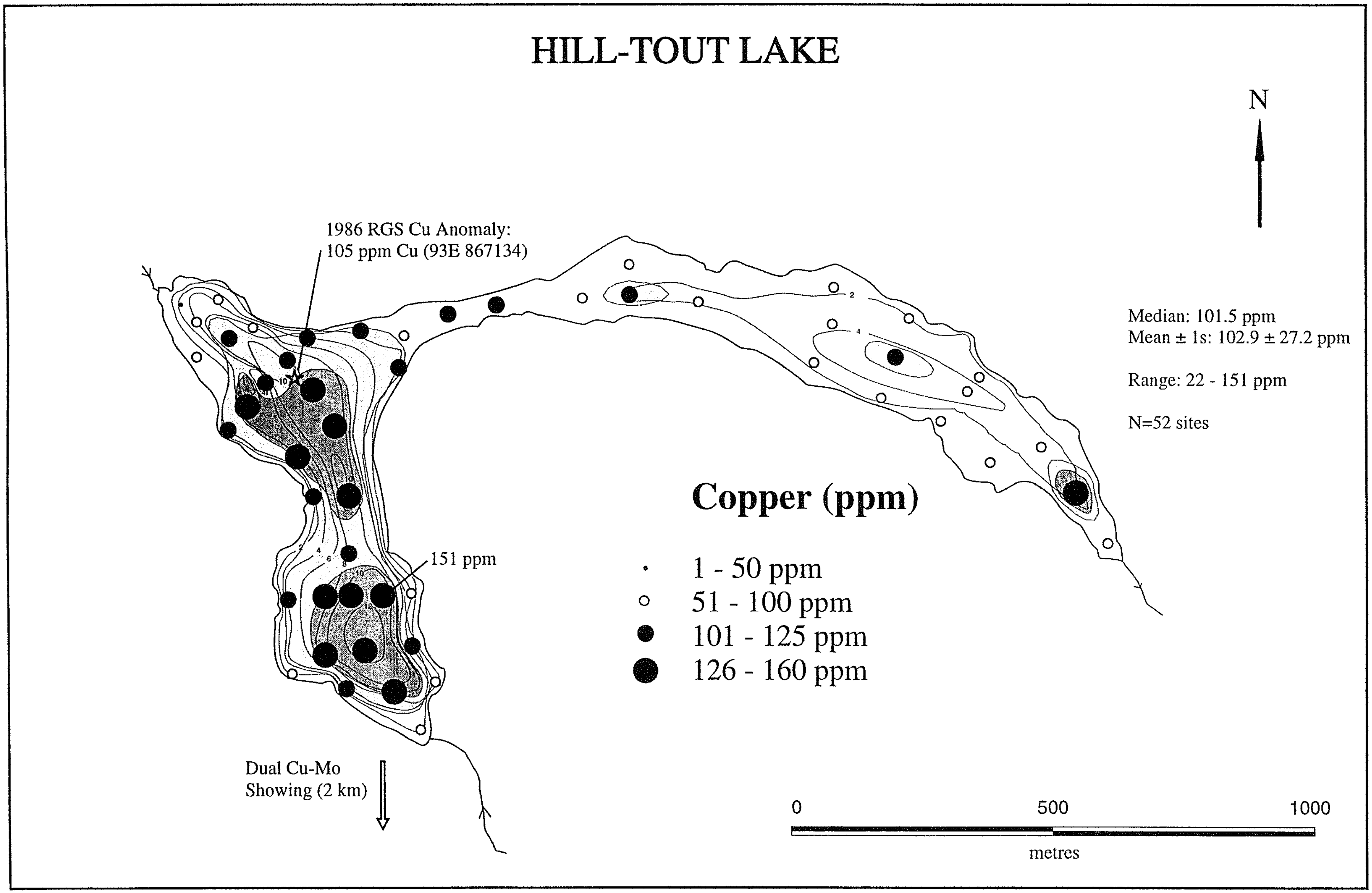

Figure 6. Distribution of copper (ppm) in sediments of Hill-Tout Lake, in the western part of the Interior Plateau. Creeks entering the lake from the south and the northwest drain the area of the Dual copper-molybdenum showing. Lake bathymetry after Webber (1984).

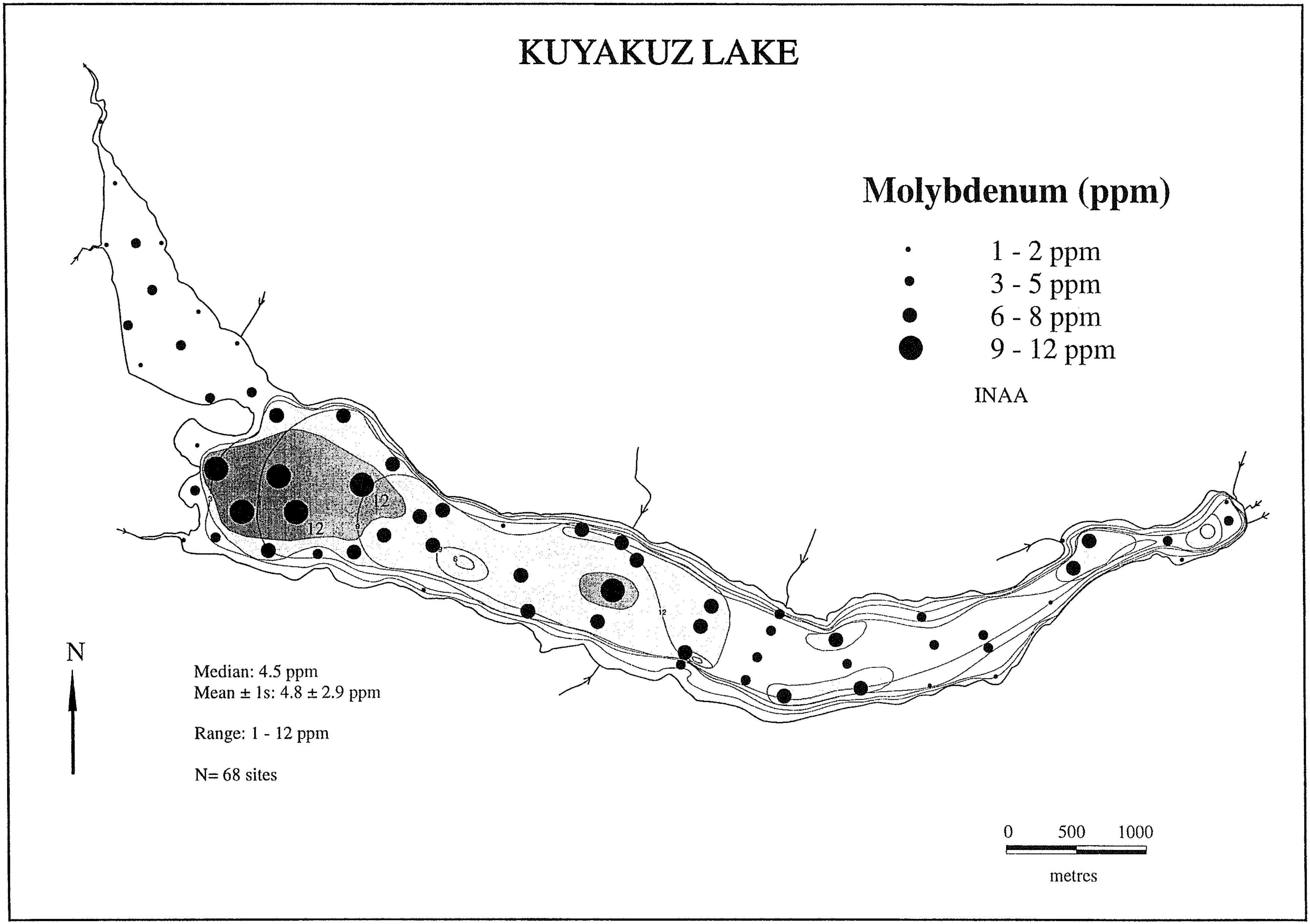

Figure 7. Distribution of molybdenum (INAA) in sediments of Kuyakuz Lake in the southern Nechako Plateau. There is no known source for the zone of elevated molybdenum and several additional metals which is present in the western part of the lake. Lake bathymetry after Burns (1978).

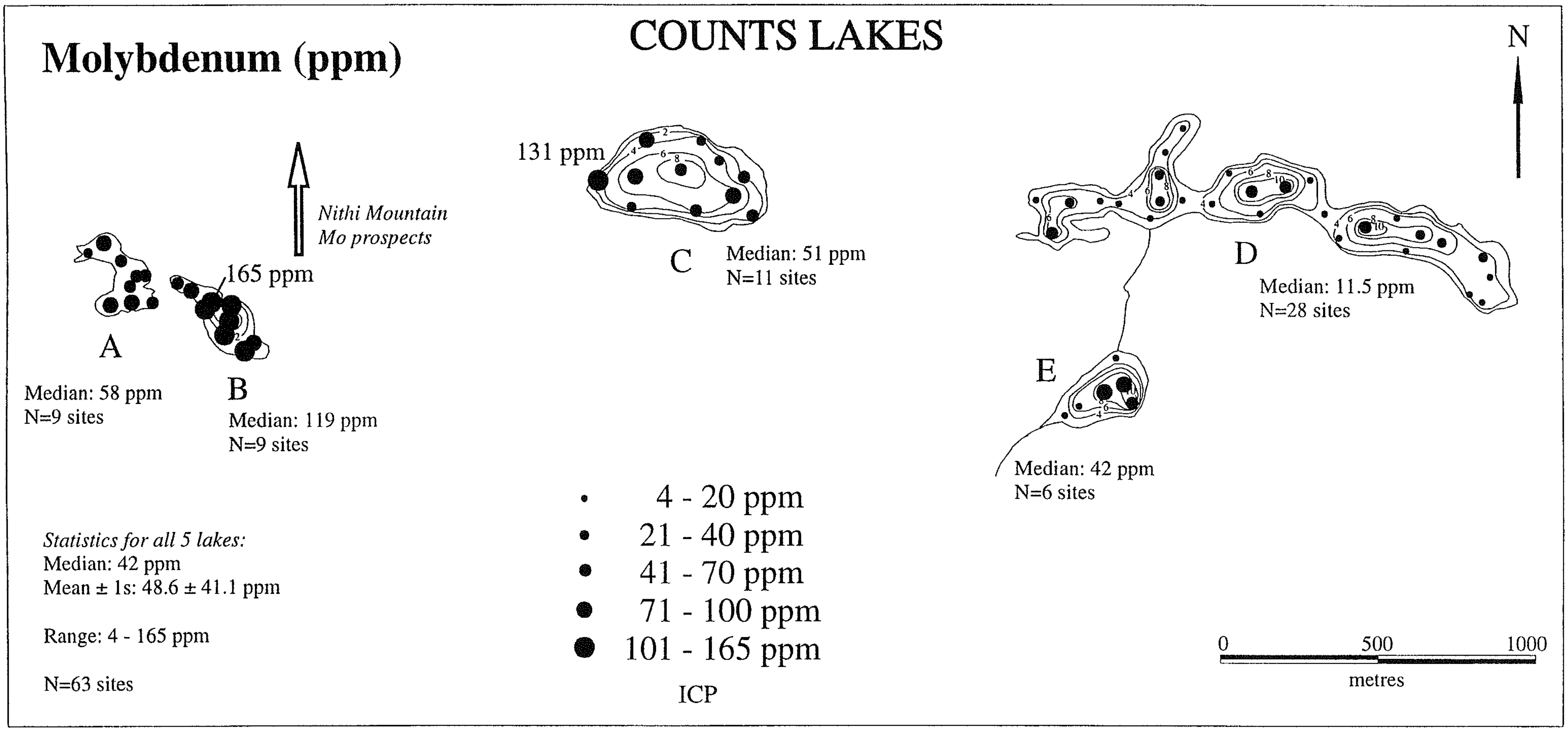

Figure 8. Distribution of molybdenum (ppm) in sediments of five of the Counts lakes, located on the south side of Nithi Mountain in the Fraser Lake area. The three westernmost lakes are downslope of numerous porphyry molybdenum showings on the side of Nithi Mountain. Contours (m) indicate sample depth.

SUMMARY

Lake sediment geochemical surveys are an effective exploration tool at both regional and property-scale levels in the Interior Plateau, where poor exposure and an extensive drift cover have impeded mineral exploration. Regional surveys using centre-lake organic sediments, including both those conducted by industry and the publicly-funded surveys carried out under the RGS program, have successfully contributed to the discovery of buried mineral deposits here for three decades. However, their implementation is still at an early stage relative to much of the rest of Canada, and large areas of central British Columbia remain unsurveyed.

Case study investigations have also been carried out at numerous Interior Plateau lakes to investigate sediment trace element distributions and formulate appropriate geochemical exploration models for future regional and property-scale surveys. These studies have shown that while centre-lake sediments may contain the most homogenous concentrations of trace and precious metals, they do not always necessarily contain the greatest. General directions toward potential areas of buried mineralization within the watersheds of these lakes may be inferred from the presence and orientation of any sediment zoning patterns, as shown here for several lakes.

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