A COMPARISON OF REGIONAL LAKE-SEDIMENT AND TILL GEOCHEMISTRY IN THE FAWNIE CREEK AREA, CENTRAL BRITISH COLUMBIA: A CASE STUDY

S.J. Cook, V.M. Levson, T.R. Giles, W. Jackaman

British Columbia Geological Survey Branch,
Victoria, B.C. V8V 1X4

ABSTRACT

Results of regional lake-sediment and till geochemistry surveys conducted in central B.C. are compared for seven elements: gold, arsenic, antimony, copper, zinc, molybdenum, and lead. Samples were collected from a total of 171 till sites and 119 lake-sediment sites in a 1:50000-scale map-sheet in the Fawnie Creek region (NTS 93F/03). Surficial and bedrock-geology mapping and mineral-deposit studies, also conducted in the same region, are used here to help evaluate the geochemical results. Basal tills are selected as the preferred sample medium over other surficial sediment types as they typically contain dispersal plumes that are both relatively large and comparatively easy to trace to source. Lake-sediment sample sites include every lake and pond in the survey area, and all major sub-basins in large lakes. The two geochemical methods provide data that are both corroborative and complementary. All existing mineral occurrences in the map-region are detected in the till geochemical data, including those 'blind' sites not identified prior to sampling. Likewise, the lake-sediment results identify all known mineral occurrences, except two prospects that have no nearby lakes. Anomalous concentrations of these elements in lake sediments and tills generally occur within a few kilometres down-slope and down-ice, respectively, of mineralized areas. In addition to detecting several areas of known mineralization, eleven new exploration targets with multi-element geochemical anomalies are highlighted by the two surveys. Six of the target areas are indicated by both the lake-sediment and the till geochemical data, three by till data alone, and two by lake-sediment data alone. These targets include highly anomalous (greater than 95th percentile) concentrations of gold in six areas, lead and zinc in five areas, copper in five areas, and molybdenum in four areas. Highly anomalous concentrations of arsenic and antimony occur in one area, with gold, and in four of the five areas that have elevated lead and zinc. Anomalous gold also occurs with copper, lead, and molybdenum. Lake-sediment and till data are complementary in at least two ways. First, geologic interpretations from each can be integrated to constrain the location of potential mineralized source-areas. Second, helicopter-supported lake-sediment surveys and ground-based till surveys are commonly best suited for different areas because of the typically variable access and terrain conditions in any one region; thus, the two survey types are commonly geographically complementary.

INTRODUCTION

Lake-sediment and till geochemical studies have been conducted by the Geological Survey Branch in central British Columbia since 1992 to address mineral-exploration problems resulting from an extensive drift cover. These studies are part a multidisciplinary investigation which includes bedrock geology (Diakow *et al.* 1994) and surficial geology mapping (Giles and Levson 1994a; Levson and Giles 1994a), mineral-deposit investigations (Schroeter and Lane 1994), and till (Levson *et al.* 1994), lake-sediment, and water (Cook 1993, 1994; Cook and Jackaman 1994b) geochemistry studies which have led to the discovery of a number of new mineral prospects. In this paper, results of lake-sediment and till geochemistry surveys conducted during 1993 in the Fawnie Creek map area (NTS 93F/03) are compared to evaluate the usefulness of different geochemical exploration techniques integrated with surficial and bedrock-geology mapping. The results of the lake-sediment and till geochemistry surveys are corroborative and complimentary, each indicating known mineral occurrences and identifying new areas of potential mineralization.

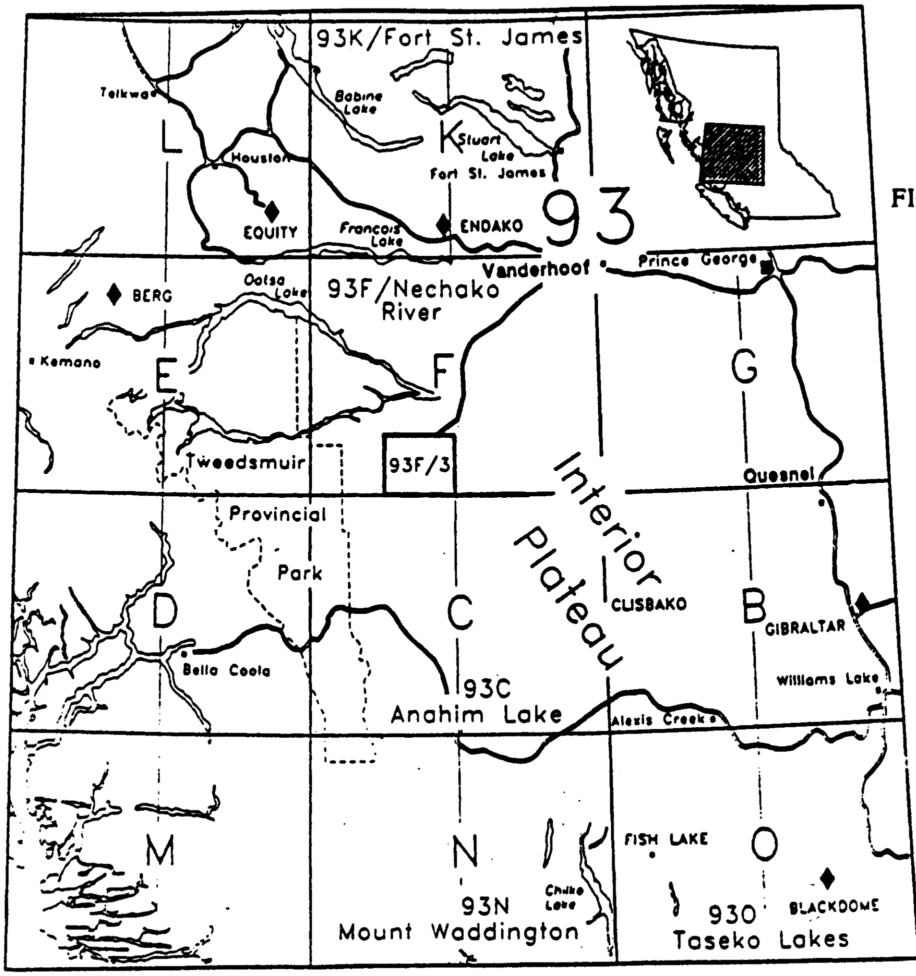
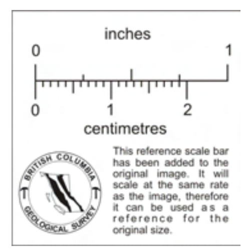


FIG. 1. Location of the Fawnie Creek map-area, central B.C.



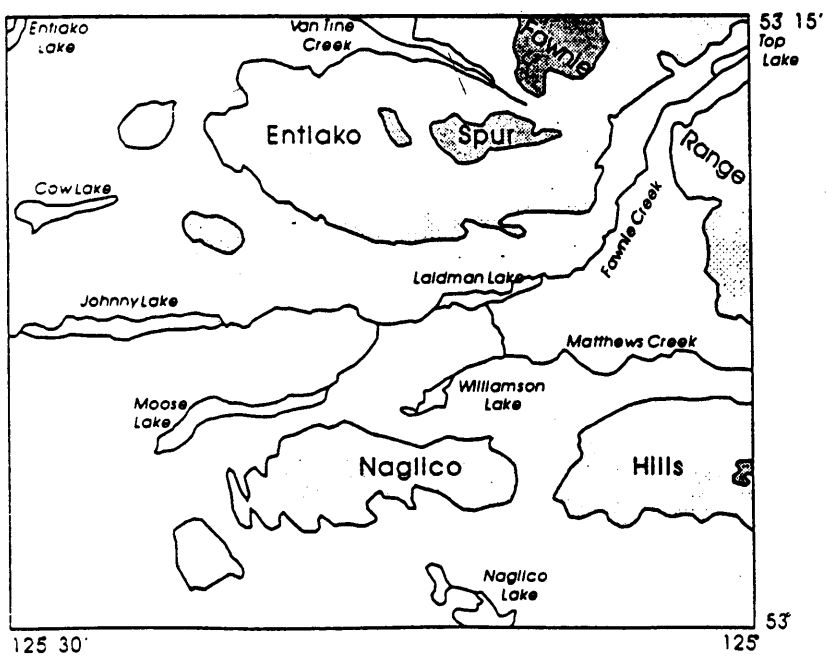


FIG. 2. General physiography of the Fawnie Creek map-area.

DESCRIPTION OF THE SURVEY AREA

The Fawnie Creek map-area lies within the southern Nechako Plateau, in the west-central part of the Interior Plateau (Holland 1976). The area is approximately 150 km southwest of Vanderhoof (Fig. 1). The Fawnie Range dominates the northeast corner of the area, reaching elevations of > 1775 m (Fig. 2). The Entiako Spur extends across the northern half of the region, with elevations declining westward from 1750 m to < 1200 m. The Fawnie Creek valley occupies the centre of the map-area. It drains from Top Lake (elevation 1070 m) southwest through Laidman and Johnny Lakes. The Naglico Hills, reaching elevations of 1550 m in the east and 1370 m in the west, are bounded to the north and south by the Fawnie Creek and Blackwater River valleys. All large valleys in the area are broad, with gently inclined sides which reflect glacial modification; an excepttion is Van Tine Creek, with is perpendicular to ice flow and has a large V-shaped valley.

BEDROCK GEOLOGY AND MINERAL DEPOSITS

The bedrock geology of the Fawnie Creek map-area was initially mapped by Tipper (1963) at 1:250,000, and more recently by Diakow *et al.* (1994) at 1:50000 (Fig. 3). Most of the area is underlain by volcanic flows, volcaniclastics, and sedimentary rocks of the Middle Jurassic Hazelton Group. The name Naglico Formation has been informally applied to these rocks within the map area (Diakow and Webster 1994). The rocks are intruded by the Late Cretaceous Capoose batholith, and are 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 southern part of the map-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.

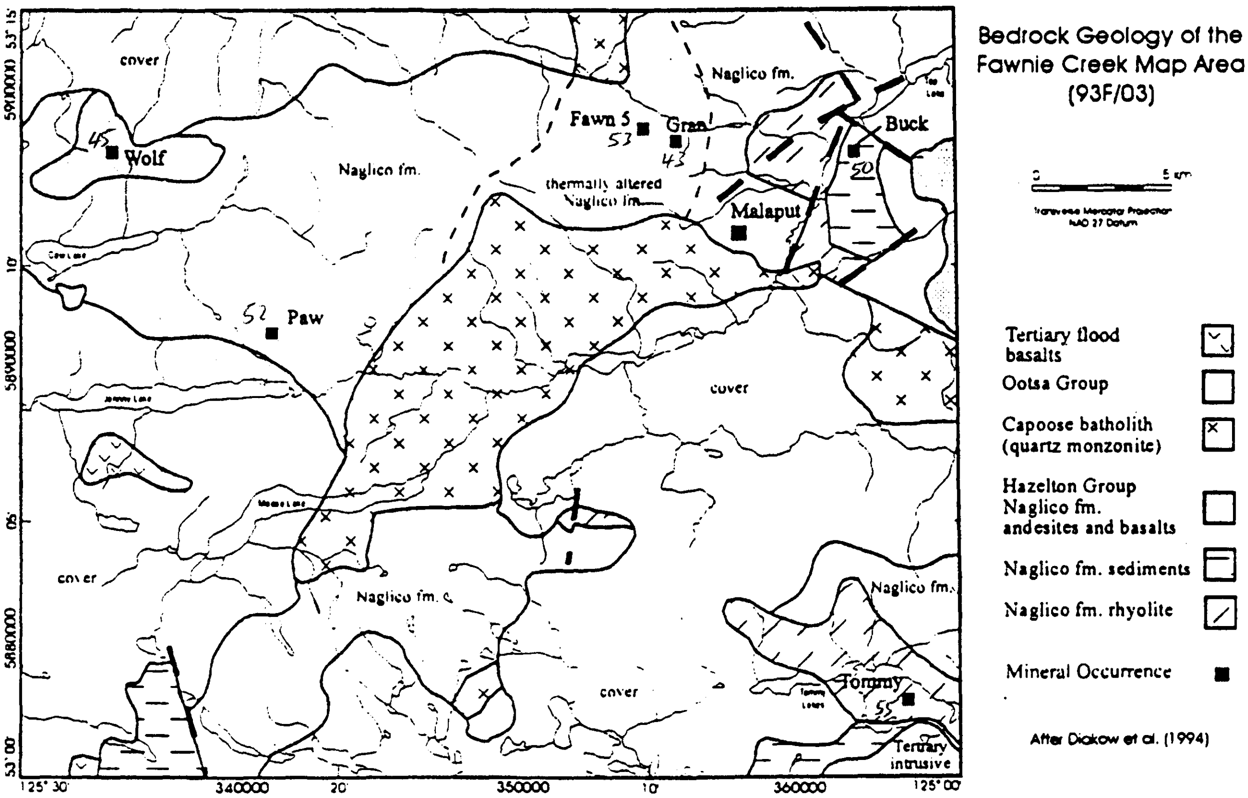
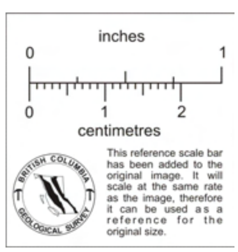


FIG. 3. Bedrock geology of the Fawnie Creek map-area (modified from Diakow *et al.* 1994).



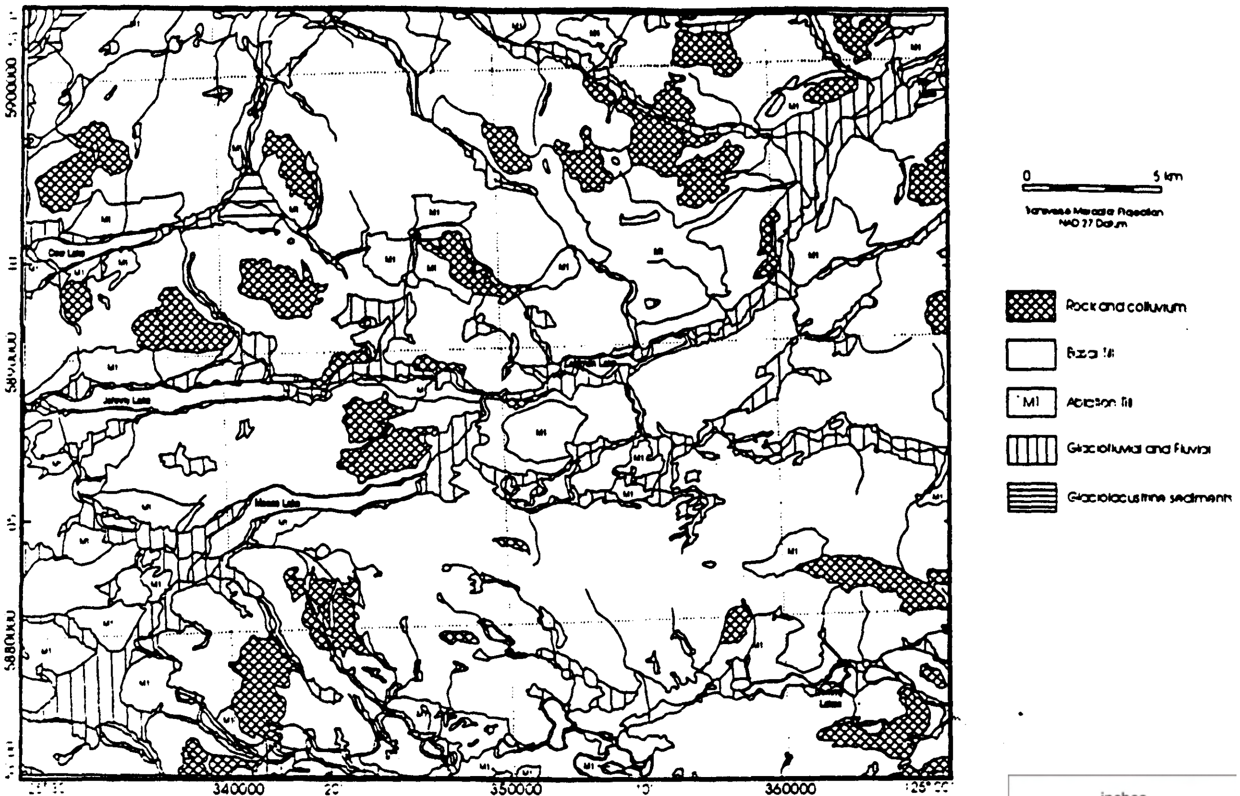


FIG. 4. Surficial geology of the Fawnie Creek map-area.

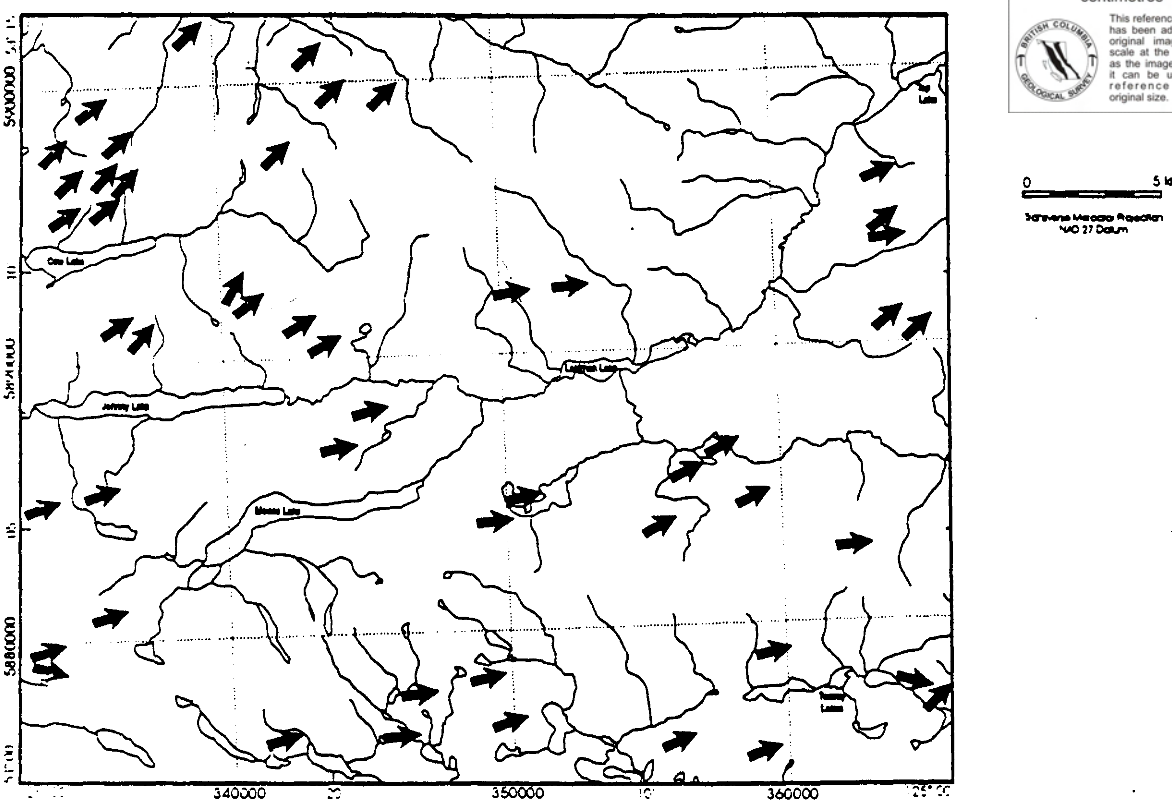


FIG. 5. Ice-flow directions in the Fawnie Creek map-area.

Exploration targets in or near the map-area (Fig. 3) include epithermal precious-metal deposits in Ootsa Lake Group volcanics (*e.g.*, Wolf – MINFILE 93F 045), Hazelton Group rocks (*e.g.*, Gran/Fawn – MINFILE 93F 043), transitional base/precious-metal prospects (*e.g.*, Blackwater-Davidson – MINFILE 93F 037 and Capoose – MINFILE 93F 039), porphyry base-metal prospects (*e.g.*, CH – MINFILE 93F 004 and Paw – MINFILE 93F 052), stratabound sulfide prospects (*e.g.*, Buck – MINFILE 93F 050), and magnetite skarn (*e.g.*, Fawn 5 – MINFILE 93F 053). Interest in epithermal precious-metal deposits in particular has increased in recent years. The Wolf prospect, a low-sulfidation adularia-sericite epithermal gold-silver occurrence (Schroeter and Lane 1994), 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), and results of the current lake-sediment survey (Cook and Jackaman 1994b) show the potential target area for epithermal gold deposits to be widened considerably to include systems hosted within Jurassic as well as Eocene rocks. The Gran (Fawn) prospect occurs in Hazelton Group rocks and includes a northwest-trending zone of intense silica, sericite, and clay alteration cut by north- to northeast-trending quartz-carbonate-pyrite$\pm$barite veinlets (Schroeter and Lane 1994). Two new epithermal precious-metal prospects within Hazelton Group rocks (Tommy and Malaput) were discovered during the 1993 bedrock-mapping program by Diakow and Webster (1994). The Malaput occurrence consists of pervasively silicified volcanics of the Naglico Formation 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 southeastern corner of the map-area. Analysis (fire assay–ICP) of rock samples from this locality gave concentrations of up to 3.7 ppm gold (Diakow *et al.* 1994). More complete descriptions of these occurrences, as well as other prospects in the region, are provided by Diakow and Webster (1994) and Schroeter and Lane (1994).

SURFICIAL GEOLOGY

Morainal sediments of the last glaciation are widespread in the Fawnie Creek region (Levson and Giles 1994a) and form a cover from a few to several metres thick in low-lying areas, to <2 m thick in upland regions (Fig. 4). Glaciofluvial sediments are also common, occurring as eskers, kames, terraces, fans, and outwash plains in valley bottoms and along valley flanks. They consist mainly of poorly to well-sorted, stratified, pebble and cobble gravels and sands in deposits up to 10 m thick. Glaciolacustrine sediments are rare. During the last glaciation, the one dominant ice-flow direction in the region, towards the east-northeast (Fig. 5), was modified by topographic control during both the early and late stages of glaciation. Interpretation of data with respect to glaciation may provide the explorationist with new avenues to explore for bedrock sources of mineralized float or geochemically anomalous samples (Giles and Levson 1994b).

A basic understanding of ice-flow direction, glacial dispersal patterns, transportation distances, Quaternary stratigraphy, and the origin of different sampling media are considered essential for successful drift exploration programs (Boyle and Troup 1975; Shilts 1976; Gleeson *et al.* 1989; Fox *et al.* 1987; Kerr and Levson 1994). Geochemical anomalies associated with glacial dispersal of mineralized bedrock in the map-area are up to a few kilometres in length and several hundred metres or more in width, but isolated anomalies associated with the trains may cover much larger areas (Levson and Giles 1994b). Erratics trains in the region are up to several kilometres long, and are more readily detected than till anomalies. The trains show a pronounced elongation parallel to ice-flow direction, with mineralized source-rocks occurring at or near the up-ice end of the dispersal trains. Till geochemistry reflects up-ice bedrock sources and not the immediately underlying bedrock. In areas of thick till, near-surface anomalies may be displaced by 500 m or more down-ice from their bedrock source.

METHODOLOGY

Basal till and lake-sediment geochemistry surveys are effective tools to delineate anomalous metal concentrations related to mineral occurrences (Shilts 1973a,b, 1976; DiLabio 1990; Friske 1991; Earle 1993; Levson *et al.* 1994; Cook and Jackaman 1994b). The till-geochemistry program included regional sampling in the Fawnie

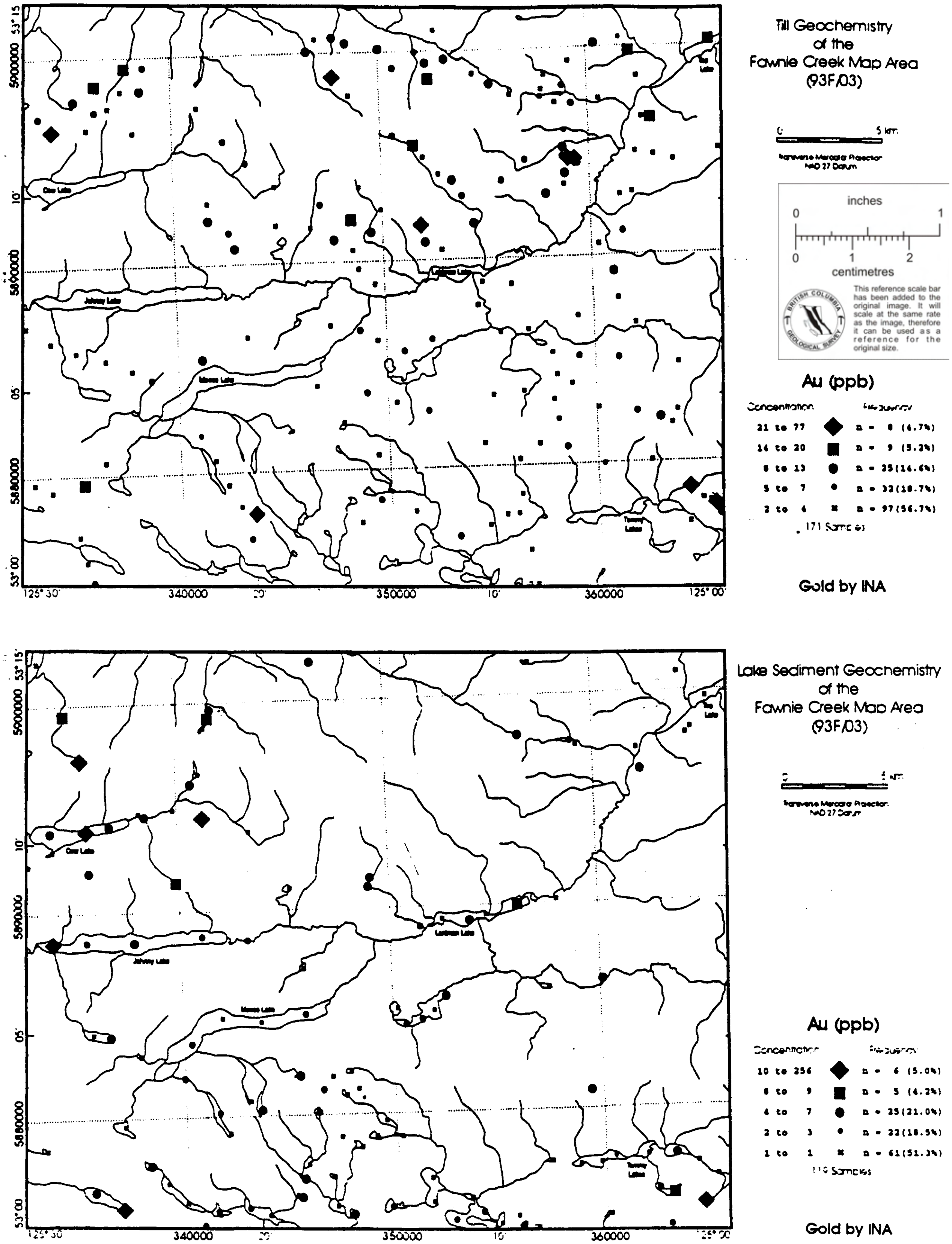


FIG. 6. Gold (INAA) in lake sediments and till.

Creek map area (93F/3), and detailed case studies around known mineral occurrences. A total of 171 till samples was collected (average site density: 1 per 5.4 km^2) from the C soil horizon during the regional survey. Helicopter-supported regional lake-sediment surveys were conducted in the Fawnie Creek map-area, the adjacent Tsacha Lake (93F/02) map-area, and in parts of several other 1:50000 map-areas in the northern half of the Nechako River map-sheet (NTS 93F). Only data from the Fawnie Creek area are considered in this paper. Lake-sediment samples were collected from 119 sites in this area at an overall survey density of approximately 1 site per 8 km^2. Complete analytical data listings, summary statistics, and element-distribution maps for the lake-sediment and till surveys are given by Cook and Jackaman (1994b) and Levson et al. (1994), respectively.

Some parts of the Fawnie Creek map-area have few lake-sediment sites because of local topography. Among these are the Entiako Spur, the eastern Naglico Hlls, and various low-lying stretches along the Matthews Creek and Fawnie Creek drainages. However, there are numerous till sites in some of these areas, particularly the Entiako Spur region; these till sites complement the lake-sediment data by providing information for regions in which information would otherwise not be available. Conversely, helicopter-supported lake-sediment surveys can reach areas inaccessible by road to ground-based till sampling crews. In the Fawnie Creek area, there are relatively few till sites along the southern and western margins of the map-area, and lake-sediment geochemistry complements the till database in these regions.

SURVEY DESIGN

On the basis of results of prior orientation studies (Cook 1993, 1994), the lake-sediment survey incorporates some departures from standard regional lake-sediment sampling strategies used elsewhere in Canada for the National Geochemical Reconnaissance (NGR) program, particularly pertaining to overall site density and the number of sites sampled per lake. First, every lake and pond in the survey area was sampled, rather than sampling only a selection of lakes at a fixed density. Sediment in even small ponds may contain anomalous metal concentrations revealing the presence of nearby mineralization, such as that at the Wolf prospect. Secondly, centre-lake sediment samples were collected as per standard NGR procedure, but sediments from the centre of all major known or inferred sub-basins were also collected to investigate the considerable trace-element variations which may exist among sub-basins of the same lake.

Basal tills were selected as the preferred sample medium, and other types of surficial sediment were avoided. Basal tills are deposited in areas directly down-ice from their source; therefore, mineralized material dispersed within the tills can be more readily traced to its origin than can anomalies in other sediment types (Shilts 1976, 1993) . Processes of dispersal in ablation tills, glaciofluvial sands and gravels, and glaciolacustrine sediments are more complex, and they are typically more distally derived than basal tills.In addition, due to the potential for the development of large dispersal trains, mineral anomalies in basal tills may be readily detected in regional surveys (DiLabio 1990). Basal tills in the area typically consist of overconsolidated, matrix-supported, sandy-silt diamicton, commonly exhibiting moderate to strong subhorizontal fissility. Till sample-sites were selected to provide complete coverage of the map-area, with the greatest density of samples along transects perpendicular to established ice-flow direction. Along transects parallel to ice flow, where samples repeatedly represent the same terrain directly up-ice and therefore duplicate each other, widespaced sampling was used. An intermediate sample spacing was used on transects oblique to flow. Sample sites consisted of natural and man-made exposures (roadcuts, borrow pits, soil pits, and trenches).

Sample Collection, Preparation, and Analysis

Collection, preparation, and analysis of lake-sediment samples were conducted in accordance with standard NGR (Friske 1991) and Regional Geochemical Survey (RGS) procedures. Helicopter-supported sample collection was carried out during June, 1993. Sediment samples were collected with a Hornbrook torpedo sampler, were placed in large Kraft paper bags, and were field-dried prior to transport to preparation facilities. Dry sediment samples were pulverized in entirety in a ceramic ring mill. Splits were analyzed by instrumental neutron activation analysis (INAA) for 26 elements, including gold, arsenic, and antimony. Fifteen elements, including copper, zinc, lead, and molybdenum were analyzed by atomic absorption spectroscopy (AAS) after aqua regia digestion. All till

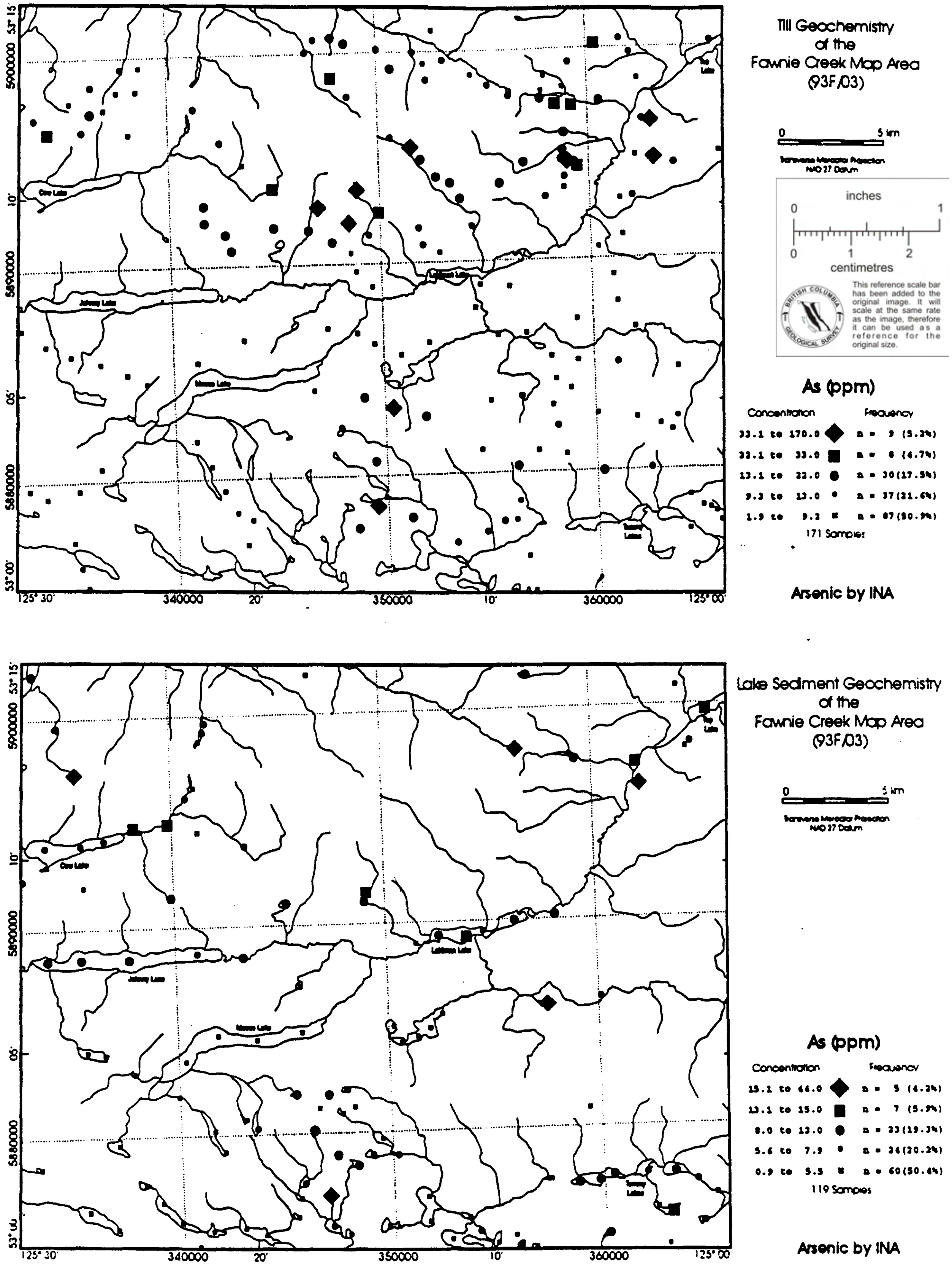


FIG. 7. Arsenic (INAA) in lake sediments and till.

samples were air-dried, split, and sieved. The minus 230-mesh (<63 μm) fraction was analyzed for 43 trace and precious metals by INAA, and by inductively coupled plasma – atomic emission spectrometry (ICP-AES) following aqua regia digestion. Till samples were also analyzed for major oxides to determine regional till compositions. Full details of sampling, preparation, and analytical procedures and stated detection limits are given by Cook and Jackaman (1994a,b) and Levson *et al.* (1994).

QUALITY CONTROL

The discrimination of real geochemical trends from those resulting from sampling and analytical variation is of considerable importance in the interpretation of geochemical data. In accordance with standard quality-control procedures, 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. Each block of twenty lake-sediment samples contains: seventeen routine samples, one field duplicate sample, one blind duplicate sample split from one of the 17 routine samples prior to analysis, and 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. 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 are reinserted into the suite to monitor analytical precision. Complete details of quality-control methodology and results are given by Cook and Jackaman (1994b) and Levson *et al.* (1994).

RESULTS AND DISCUSSION

Summary statistics for selected elements from till and lake-sediment suites are shown in Table 1. Comparative percentile values for gold, arsenic, antimony (INAA), copper, zinc, molybdenum, and lead are given in Table 2. Accompanying till and lake-sediment element-distribution maps (Figs. 6 through 11) indicate areas of elevated concentrations in each medium. Till geochemistry maps are from Levson *et al.* (1994); lake-sediment geochemistry maps are revised versions of Fawnie survey-area maps of Cook and Jackaman (1994b).

Concentrations of gold, arsenic, antimony, and lead are higher at the 50th, 70th, 90th, and 95th percentile levels in tills than in lake sediments (Table 2). Conversely, concentrations of copper, zinc, and molybdenum at the

Table 1. Summary statistics: lake sediment and till geochemistry.

Survey		Au (ppb) *INAA*	As (ppm) *INAA*	Sb (ppm) *INAA*	Cu (ppm)	Mo (ppm)	Pb (ppm)	Zn (ppm)	Ag (ppm)	Ni (ppm)	Fe (%)	Mn (ppm)
LAKE SEDIMENT	Median	**1**	**5.5**	**0.8**	**31**	**5**	**2**	**81**	**0.2**	**11**	**1.60**	**273**
119 sites	Range	(1-256)	(0.9-44)	(0.1-2.5)	(10-397)	(1-20)	(1-61)	(17-366)	(0.1-1.8)	(3-20)	(0.20-8.50)	(47-2020)
TILL	Median	**4**	**9.2**	**1.2**	**24**	**1**	**8**	**65**	**0.2**	**12**	**3.65**	**508**
171 sites	Range	(1-77)	(1.9-170)	(0.4-4.3)	(6-66)	(1-7)	(2-58)	(29-168)	(0.1-0.7)	(5-35)	(1.48-5.68)	(164-1259)

Cu, Mo, Pb, Zn, Ag, Ni, Fe, Mn determined by AAS on lake sediments; ICP on till

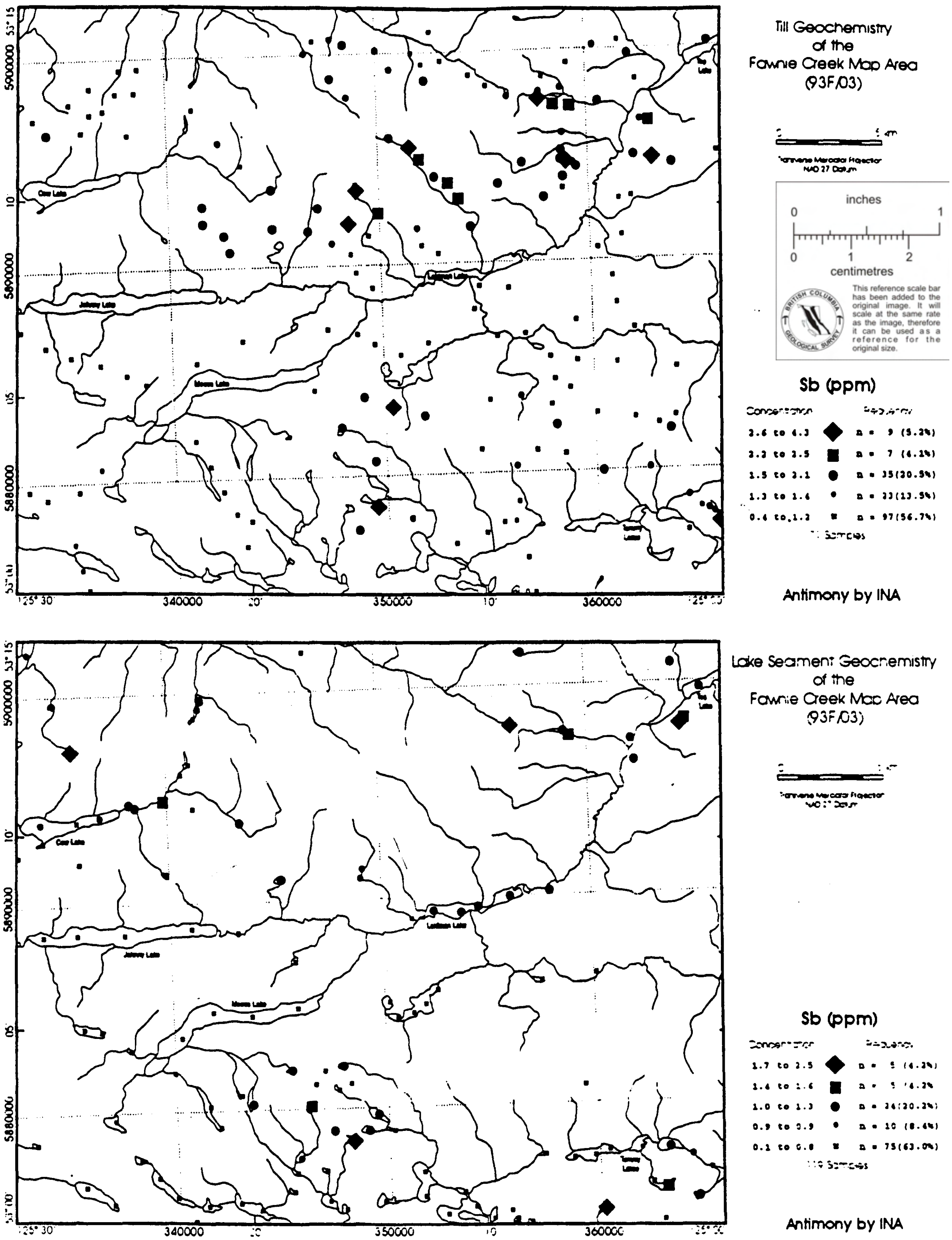


FIG. 8. Antimony (INAA) in lake sediments and till.

Table 2. Comparative percentile values for selected elements: lake-sediment and till geochemisty.

		Lake Sediment *(119 sites)*	Till *(171 sites)*
Au (INAA)	50th	1	4
	70th	3	7
	90th	7	13
	95th	9	20
	Maximum	256	77
As (INAA)	50th	5.5	9.2
	70th	7.9	13
	90th	13	22
	95th	15	33
	Maximum	44	170
Sb (INAA)	50th	0.8	1.2
	70th	0.9	1.4
	90th	1.3	2.1
	95th	1.6	2.5
	Maximum	2.5	4.3
Mo	50th	5	1
	70th	7	1
	90th	11	2
	95th	14	3
	Maximum	20	7
Cu	50th	31	24
	70th	36	31
	90th	51	42
	95th	67	46
	Maximum	397	66
Pb	50th	2	8
	70th	3	10
	90th	6	14
	95th	7	18
	Maximum	61	58
Zn	50th	81	65
	70th	94	76
	90th	125	96
	95th	148	104
	Maximum	366	168

same percentile levels are higher in lake sediments. With regard to concentration ranges, minimum values in tills are higher or equal to those in lake sediments for every element shown in Table 1 except copper. Maximum values are lower in tills for every element except arsenic, antimony, and nickel. This relatively wide range in element concentrations in lake sediments compared with tills probably reflects the more complicated geochemical evolution of organic lake-sediments. Higher maximum element concentrations in lake sediments probably reflect the variety of processes affecting the transport and accumulation of metals which are not significant in basal tills. In particular, limnological characteristics of the lake may affect the metal contents of sediments. Scavenging of metals by hydrous iron and manganese oxides is common in large, deep, oligotrophic lakes, wherein the persistence of oxygen-rich conditions to the lake bottom permits the formation of such oxides within sediments. Conversely, organic matter is relatively more effective in absorbing metals in the oxygen-poor sediment environment of small eutrophic lakes and ponds. These relationships were demonstrated by Earle (1993) in the Whitesail Lake (NTS 93E) and Smithers (NTS 93L) map-areas to the west; iron and manganese are more abundant in oligotrophic lakes, whereas organic matter content (as measured by Loss on Ignition) is more abundant in eutrophic lakes. Available data for the Cordillera are minimal, but in Finland it was reported that the mean zinc, copper, lead, and molybdenum contents of small lakes (length <200 m) are 2-3 times greater than that of large lakes (length >1 km) (Tenhola 1989). Similar relations are evident in the Fawnie Creek lake-sediment data, but Hoffman and Fletcher (1976) have noted that anomalous metal concentrations related to mineralization in the Nechako Plateau are nevertheless not obscured by limnological or other variability.

Some parts of the Fawnie Creek map-area have few lake-sediment sites because of local topography. Among these are the Entiako Spur, the eastern Naglico Hills, and various low-lying stretches along the Matthews Creek and Fawnie Creek drainages. However, there are numerous till sites in some of these areas, particularly the Entiako Spur, which complement the lake-sediment data by providing information in a region where otherwise none would be available. Conversely, helicopter-supported lake-sediment surveys can reach areas otherwise inaccessible by road to truck-supported till-sampling crews. In the Fawnie Creek area, there are fewer till sites along the southern and western margins of the map-area, and lake-sediment geochemistry complements the till database in these regions.

It is unlikely that any significant differences between lake-sediment and till results for copper, zinc, molybdenum, or lead can be attributed to the different analytical methods used. Ongoing comparative studies of various Interior Plateau lake sediments, analyzed both by AAS and ICP−AES techniques following aqua regia digestions, indicate negligible differences for copper, zinc, and molybdenum; AAS, however, returned somewhat greater results for low-end molybdenum

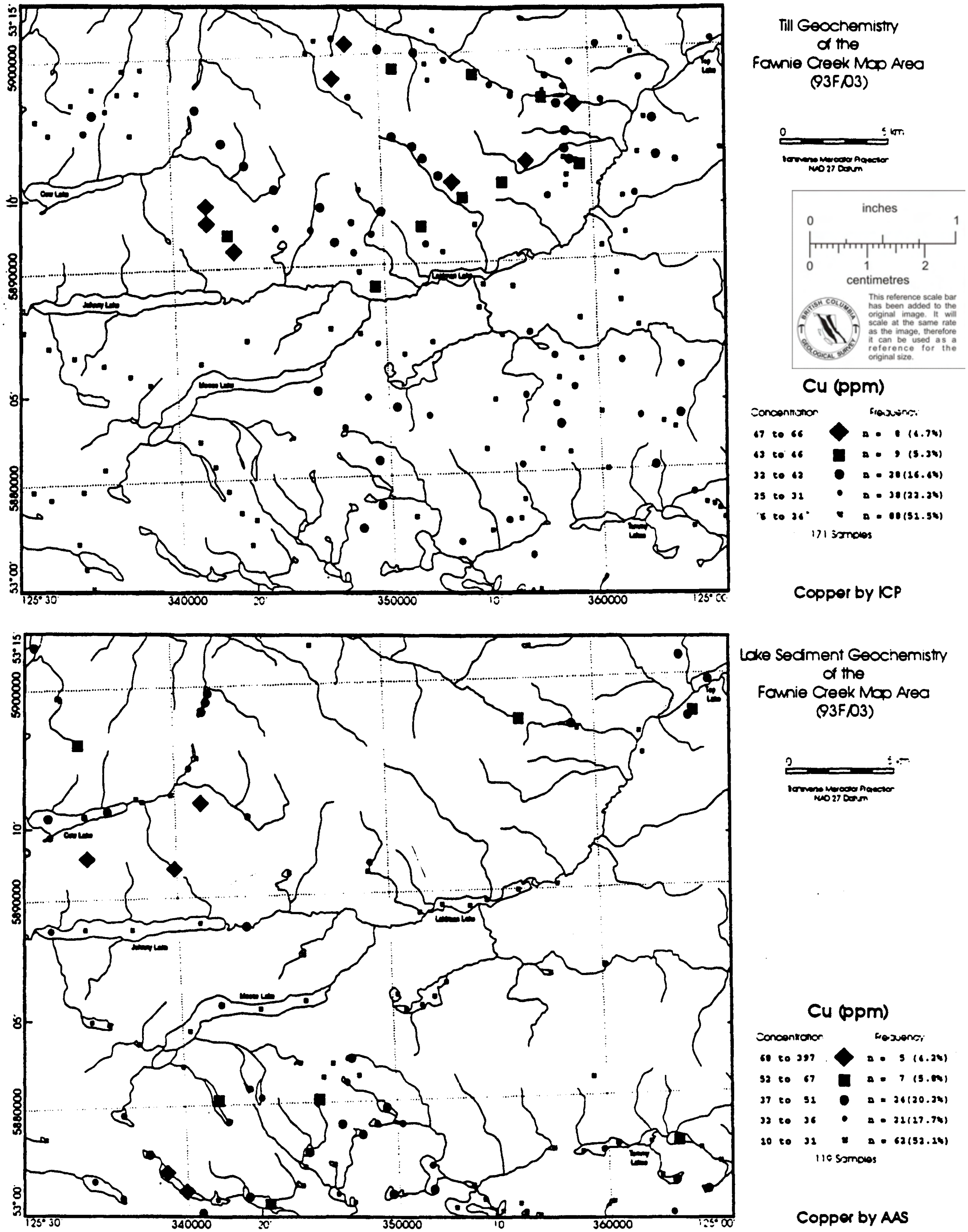


FIG. 9. Copper in lake sediments and till.

(< 10 ppm). Analytical differences were found to be more pronounced for lead, particularly at concentrations > 7 ppm, at which ICP–AES gave slightly higher values.

GOLD

Background gold concentration in lake-sediments of the Fawnie Creek area, as expressed by the median value, is 1 ppb. Median gold concentration in till (4 ppb) is considerably higher, reflecting the closer derivation (Shilts 1993) of till with bedrock. Elevated gold concentrations in lake sediments (90th percentile: 7 ppb; maximum: 256 ppb) are relatively high in this area, and 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.

Examples of how till and lake-sediment geochemical results are corroborative and useful for exploration are provided by the patterns of gold distribution in several areas (Fig. 6). Two of these areas are adjacent to known

Table 3. Anomalous elements in till and lake sediments in the vicinity of known and potential mineral prospects

Location of prospect or geochemical anomaly	Anomalous Elements[1] (>95th percentile) at geochemical sites[2]	Method of Detection[3] L - lake sediment T - till
Known Prospects		
1) Wolf	Au-Zn-Mo-As-Sb	L & T
2) Gran / Fawn	Cu-Pb-Zn-As-Sb	L & T
3) Buck	Pb-Zn-As	T & L
4) Paw	Cu-Mo	T & L
5) Tommy	Au-Pb-Zn-Sb	T & L
6) Malaput	Au-As-Sb	T
7) Fawn-5	Cu-Sb	T
Potential New Prospects		
1) NW of Laidman Lake	Au-As-Sb	T & L
2) SE of Cow Lake	Au-Cu-Pb-Zn-Mo	L & T
3) SE of Moose Lake (North Naglico Hills)	Pb-Zn-Mo-As-Sb	T & L
4) SW of Top Lake	Pb-Zn-As-Sb	T & L
5) S Naglico Hills	Pb-Zn-As-Sb	T & L
6) SE side of Entiako Spur	Cu-Pb-As-Sb	T
7) S of Cow Lake	Cu-Pb-Zn	L
8) SW Naglico Hills (SE of Trophy Lake)	Au-Pb	T & L
9) NW of Cow Lake	Au-Mo	T
10) N Entiako Spur	Cu-Au	T
11) SW corner of mapsheet	Cu-Mo	L

[1]Only 7 elements considered (Au, Cu, Pb, Zn, Mo, As, Sb)
[2]For known prospects, only sample sites within a few kilometres down-ice (for tills) or down-slope (for lake sediments) are included
[3]Geochemical method listed in order of significance for each prospect

gold mineralization in the region, and several others are interpreted to reflect evidence for potential new discoveries. In the northwest corner of the map-area, elevated gold concentrations up to 39 ppb occur in regional till samples down-ice of the Wolf prospect. Similarly, elevated gold concentrations of up to 69 ppb are present in sediment of several lakes and ponds in this area. These, varying from small ponds to large lakes such as Cow Lake, drain from the vicinity of the Wolf prospect. Similarly, in the area around the recently-discovered Tommy occurrence in the southeast corner of the map-sheet (Diakow and Webster 1994), elevated gold concentrations occur in till at three sites down-ice of the gold prospect as well as in three small lakes near the main showing. Note that one of these

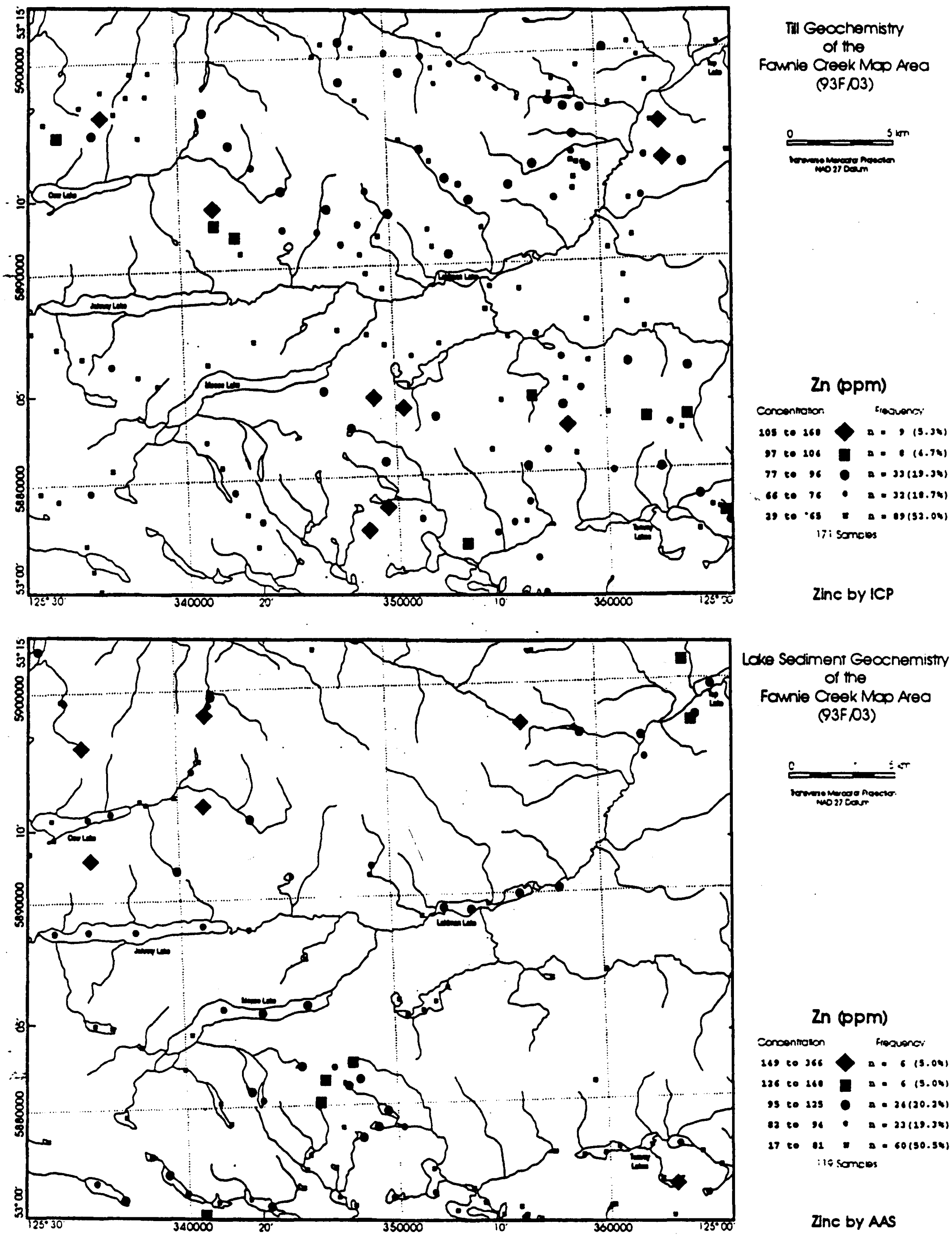


FIG. 10. Zinc in lake sediments and till.

sites (931084) is in a lake spanning the border of the Fawnie Creek and Tsacha Lake map-sheets, and does not appear here. Sediment in this lake yielded a gold concentration of 256 ppb; re-analysis of the sample returned 970 ppb. From these data it is clear that both till and lake-sediment sampling are useful for detecting gold mineralization.

Potential new gold prospects in the area are likewise indicated by corroborative till and lake-sediment geochemical data. Tills at several sample sites overlying the Capoose batholith northwest of Laidman Lake have anomalous gold concentrations ranging from 9 to 77 ppb. These sites all occur in an easterly trending zone about 1 km wide and several kilometres long; gold values in tills to the north and south of the zone decrease sharply to near-background levels (<5 ppb). The long and narrow shape of this zone, and its well-defined boundaries, are suggestive of a well-developed glacial dispersal plume, comparable or even larger than other dispersal plumes in the region (Levson and Giles 1994b), including that developed down-ice of the Wolf property (Fig. 6). This interpretation is further supported by the orientation of the anomalous zone, which is parallel to the glacial paleoflow direction in the area (Fig. 5). The till data are corroborated by elevated gold concentrations in Laidman Lake sediments, downslope of the anomalous zone, and in two ponds near its western end (Fig. 6).

Although anomalous gold concentrations (higher than 90th percentile) in tills in the area north of Cow Lake are interpreted to reflect glacial dispersal of gold mineralization from the Wolf prospect, one till sample yielding a gold concentration of 40 ppb occurs up-ice of the prospect, indicating a potential source of mineralization to the southwest. This interpretation is also supported by high gold concentrations in sediments in Cow Lake, to the south of the Wolf property, and possibly also at the west end of Johnny Lake (Fig. 6). Likewise, in the southwest corner of the map-area, elevated gold values occur at a number of lake-sediment and till sampling sites, thus indicating potential undiscovered gold mineralization in this region. Further east, numerous angular fragments of bedrock containing finely disseminated pyrite occur at a site at which gold concentrations in till are 21 ppb. The high angularity of the rocks suggests a local source, and immediately downstream moderately elevated gold concentrations of 4 ppb and 5 ppb occur in the sediments of two small lakes. These data suggest that this area has good exploration potential.

The complementary use of lake-sediment and till geochemical survey results in mineral exploration is illustrated by an analysis of high gold concentrations (256 ppb) in a small pond east of Cow Lake (Fig. 6). The gold concentration in sediment of this lake is among the highest of the 461 sites in the 1993 Interior Plateau survey areas (Cook and Jackaman 1994b). Anomalous gold concentrations are not observed in till samples down-ice of the pond or on the north side of the valley. The relatively high density of lake-sediment and till samples yielding comparatively lower gold values, immediately to the west, north, and east of the anomalous pond, strongly suggests a southern, upslope source for the gold. This interpretation is supported by the fact that the pond occurs directly at the base of a slope rising to the south. In addition, the pond is on the southern side of a large area of thick, poorly drained, glaciolacustrine sediments (Fig. 4), and it is unlikely that the high gold concentrations would be derived from these typically barren sediments. The low permeability of the glaciolacustrine sediments also suggests that the high gold concentrations in the pond do not reflect the gold content of the underlying bedrock, but instead are of hydromorphic origin from an upslope source. Without these geochemical and surficial geology data, the potential source of the anomalous gold and other elements in the pond could not have been defined.

In addition to providing complementary data of a geologic nature for exploration purposes, till and lake-sediment geochemical surveys commonly are complementary in a geographic sense. For example, in the Entiako Spur area in the north-central part of the Fawnie sheet, there are few suitable sites where lake-sediment samples could be obtained, but a high density of till samples was obtained in this region. Distribution patterns of gold in tills in this region reflect the presence of gold prospects, such as Malaput and Buck, as well as at least one new target area for gold exploration. Likewise, a high density of lake-sediment sample sites in the Naglico Hills in the south-central and southwestern part of the map area complements the poor representation of till geochemical data for these regions due to the lack of suitable basal till sampling sites (Fig. 6).

ARSENIC AND ANTIMONY

The median arsenic concentration in lake sediments in the Fawnie Creek area is 5.5 ppm (INAA). This is slightly more than half the median arsenic concentration in tills (9.2 ppm). The median concentration of antimony in lake sediments, less abundant than arsenic, is 0.8 ppm. Median antimony concentration of till, at 1.2 ppm, is

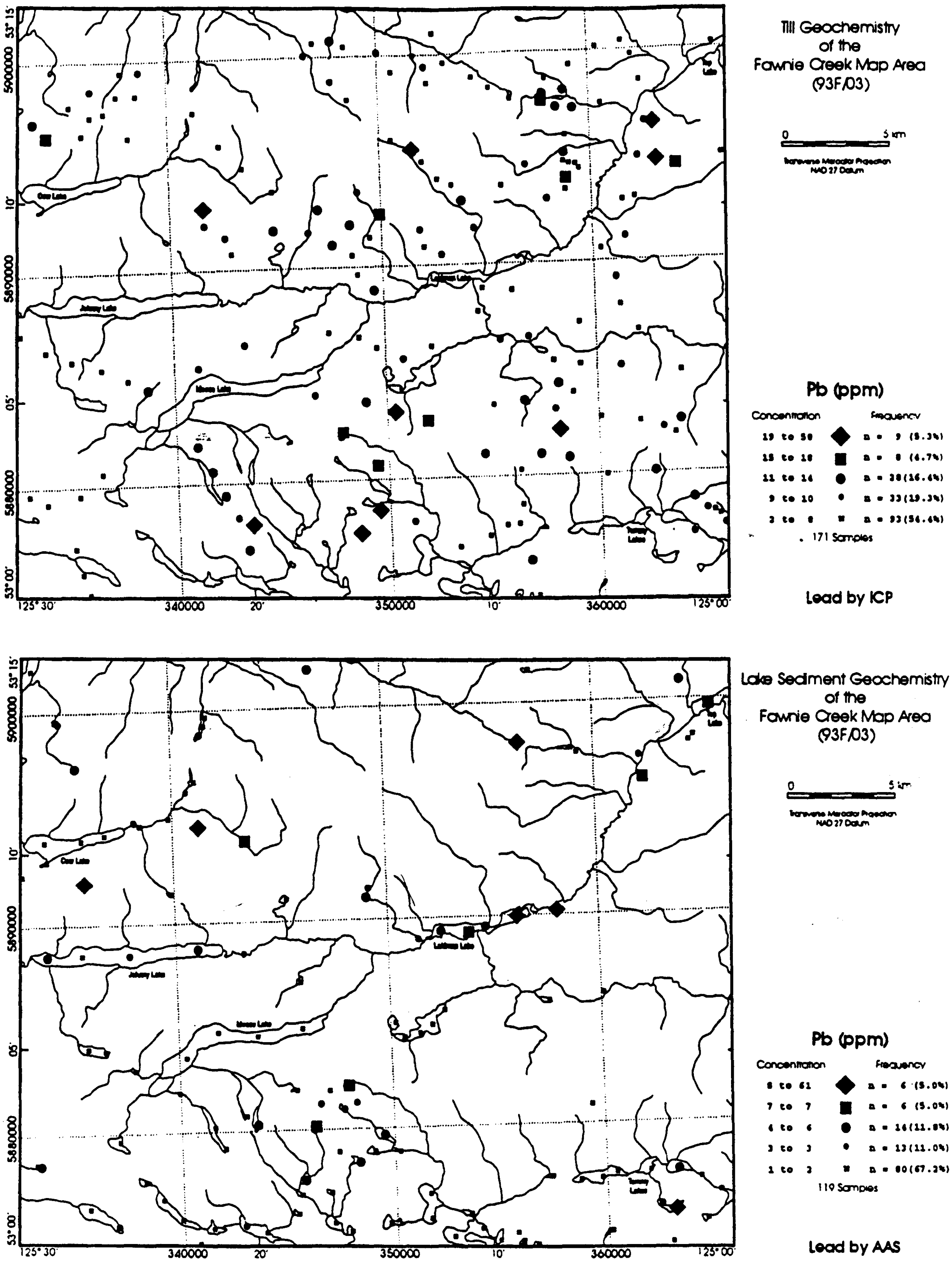
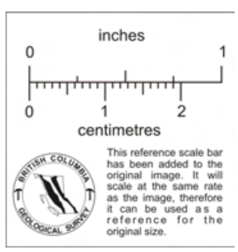


FIG. 11. Lead in lake sediments and till.



only slightly greater than that of lake sediments. Maximum arsenic and antimony concentrations in lake sediments (44 ppm and 2.5 ppm, respectively) are lower than those in till (170 ppm and 4.3 ppm, respectively).

Patterns of arsenic and antimony distribution in tills and lake sediments are corroborative in three main areas (Figs. 7, 8): northwest of Laidman Lake, in the Naglico Hills, and in the northeastern part of the map-area. A zone of elevated arsenic and antimony concentrations in till northwest of Laidman Lake, similar in extent but not entirely coincident with the up-ice end of the linear zone of anomalous gold concentrations in tills described above, is reflected by slightly elevated arsenic and antimony values in Laidman Lake sediments downslope of the zone. Two other lakes having elevated arsenic concentrations in their sediments also occur at the up-ice end of the linear gold anomaly in tills. The till and lake-sediment sampling sites are near the northwestern margin of the Capoose batholith. Altered bedrock occurring along the batholith margin just north of this area was chip-sampled and found to contain 101 ppb gold and 12730 ppm arsenic (Diakow and Webster 1994).

The second area in which till and lake-sediment data are corroborative covers a broad region of elevated arsenic and antimony values in till of the Naglico Hills southeast of Moose Lake. This area, underlain by andesites and basalts of the Naglico Formation to the south of the Capoose batholith, occurs down-ice of a region of tightly-spaced lake-sediment sites which have elevated arsenic and antimony values. Within the region, all lake-sediment and till sampling sites that show arsenic or antimony concentrations above the 95th percentile occur at the peripheries of quartz monzonite intrusions associated with the Capoose batholith. Most notably, a small intrusion in the southern most part of the area (Fig. 3) is surrounded by two lake-sediment sites and one till site which have anomlaous arsenic and antimony concentrations. The country rocks along the margin of this intrusion locally exhibit evidence of hydrothermal alteration, including sulfide mineralization and destruction of the porphyritic texture in the augite-phyric flows. The altered rocks are rusty (oxidized) and contain finely disseminated and fracture-controlled pyrite. Although the general distribution of anomalous till sites northeast (down-ice) of the anomalous lake-sediment sites may reflect the effects of glacial dispersal, the distribution may also reflect the non-coincidence of the lake-sediment and till sampling sites in this region.

The presence of known and of possible new mineral prospects in the northeastern part of the map-area is reflected by elevated antimony and arsenic concentrations in both the till and the lake sediments. The highest concentrations (greater than 95th percentile) of these elements in this region occur in lake sediments downslope of the Gran (Fawn) and Buck prospects, and in tills down-ice of these same prospects. Similarly high concentrations also occur at a few other sites in the region, indicating potential new areas of mineralization. These concentrations include the highest arsenic and antimony analyses in tills in the map-region (170 ppm arsenic and 4.3 ppm antimony) at a site (#187) about 2 km south of the Buck prospect (Fig. 7), as well as elevated antimony concentrations at two small lakes southwest of Top Lake (Fig. 8).

The complimentary use of lake-sediment and till geochemical data is also well-illustrated by the arsenic and antimony results for several other areas. Elevated arsenic and antimony in till reflect the presence of the Malaput prospect (Table 3), but no lake-sediment sample sites occur in this area. The prospect, therefore, would not have been detected by a lake-sediment survey alone, simply because of the absence of lakes. Conversely, elevated arsenic and antimony in lake sediments reflect the location of the Tommy prospect, but high concentrations of arsenic do not occur in tills at any site in the region, and high antimony occurs at only one till site down-ice of the prospect. Similarly, the Wolf prospect is highlighted mainly by the presence of elevated arsenic and antimony, among other elements, in sediment from one small pond adjacent to the prospect. Low concentrations of these elements in tills here are explained by their low concentrations in the mineralized system, as was indicated by rock geochemistry (Schroeter and Lane 1994). In the area, the one lake-sediment sample site containing high arsenic and antimony occurs adjacent to the only mineralized part of the property known to contain anomalous concentrations of these elements (the Blackfly zone). Till sampling was focused down-ice of the Ridge and Lookout zones, and probably did not intercept sediment that had been glacially dispersed from the Blackfly zone.

COPPER, ZINC, AND LEAD

Median concentrations of copper and zinc (AAS) in Fawnie Creek lake sediments are 31 ppm and 81 ppm, respectively. These values are slightly greater than, although similar to, median concentrations of copper and zinc (ICP) in till (24 ppm and 65 ppm, respectively). Maximum copper and zinc concentrations in lake sediments (397 ppm and 366 ppm, respectively) are also greater than those in till. Most elevated copper and zinc values are

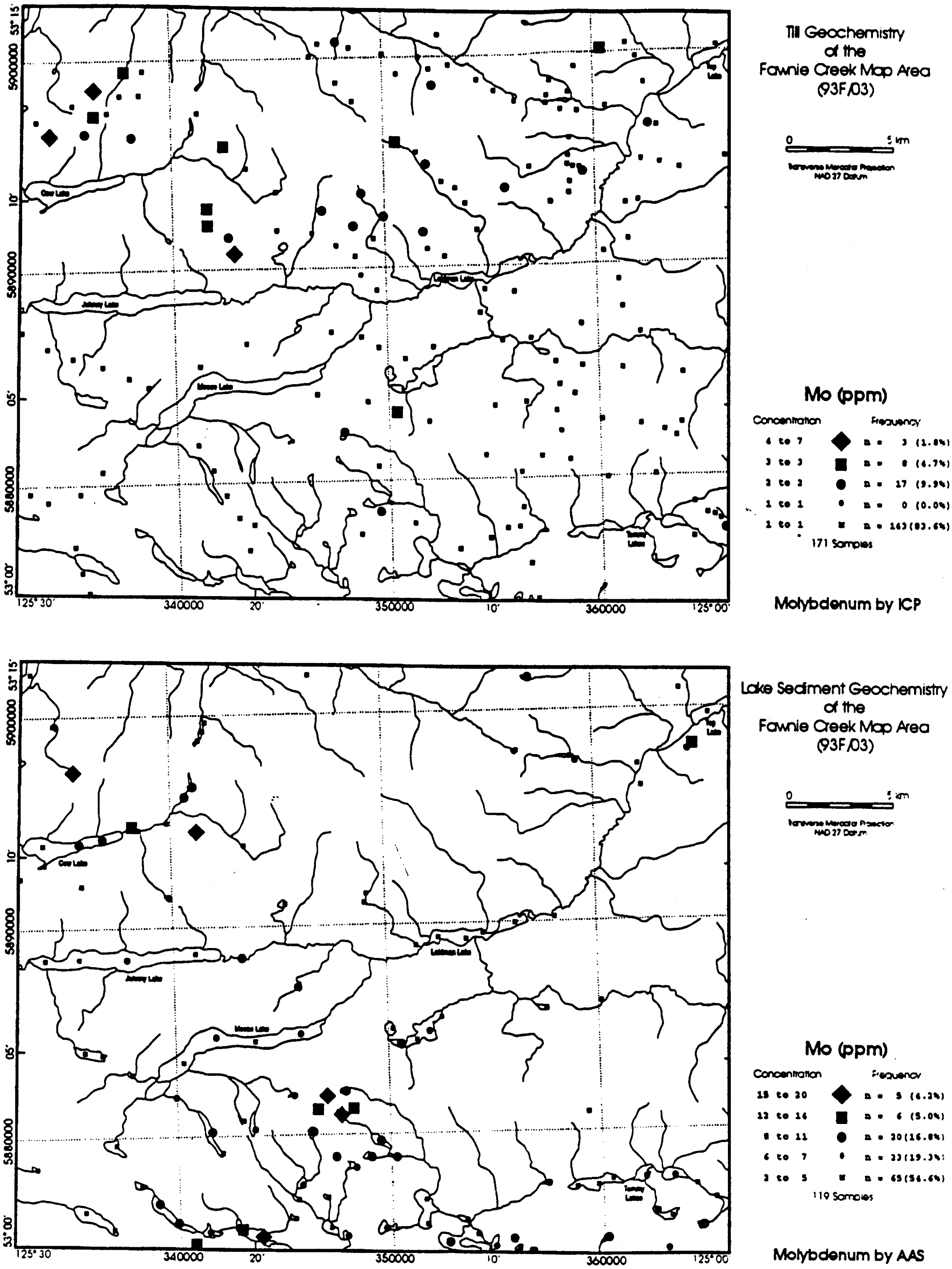


FIG. 12. Molybdenum in lake sediments and till.

associated with lakes draining units of the Middle Jurassic Naglico Formation. Conversely, elevated copper values in lake sediments are almost completely absent from the region underlain by the Capoose batholith. The median lead concentration in Fawnie Creek lake sediments is 2 ppb, considerably less than the 8 ppb median concentration of lead in tills.

Till and lake-sediment copper patterns (Fig. 9) are corroborative in the Wolf prospect – Cow Lake – Paw area, wherein elevated copper concentrations occur. The sites, to the north, south, and east of Cow Lake, drain areas underlain by both Ootsa Lake Group and Naglico Formation volcanic rocks. The highest copper concentration in the Fawnie survey area occurs in this area, and many sites exhibit coincident zinc anomalies as well. Elevated copper does not occur at all till sites here, but is prominent in several sites on a ridge near the Paw showing, corroborating downslope lake-sediment anomalies.

The copper maps (Fig. 9) best illustrate how till and lake-sediment geochemical data provide complementary geographic coverage. A zone of moderately elevated copper values in lake sediment (52-67 ppm) occurs in the southwestern part of the Naglico Hills. This area, underlain by various units of the Naglico Formation, has few corresponding till sites. Conversely, the most widespread area of anomalous copper in till occurs on the eastern part of the Entiako Spur, where there are little available lake-sediment data.

Till and lake-sediment zinc and lead patterns (Figs. 10, 11) also are corroborative in the Wolf prospect – Cow Lake – Paw area. Elevated lake-sediment zinc concentrations at several sites here roughly correspond to two zones of elevated zinc in till. The first zone is situated adjacent to, and up-ice of, the Wolf prospect. The second zone, with corresponding copper and lesser lead anomalies, is situated on a ridge above both the Paw showing and an anomalous lake-sediment site to the north. Similarly, three lakes in the Naglico Hills have moderately elevated zinc and lead concentrations, and have substantiating till geochemical data. These lakes occur within a cluster of small unnamed lakes draining Naglico Formation basalt and lesser andesite flows. A zone of elevated zinc and lead in till (105-168 ppm) is present a few kilometres to the northeast, down-ice of this area, near the southern margin of the Capoose batholith. Elevated zinc and lead in till also occur near the margin of a small intrusion to the south.

Several elevated lead concentrations in sediment in and near Laidman Lake in the Fawnie Creek valley (Fig. 11) may be related to elevated lead in upslope till sites atop the Entiako Spur, near the northern margin of the Capoose batholith, or from sources up the Fawnie Creek drainage, wherein anomalous lead in tills occurs in several areas. An elevated lead value in sediment of a small pond in the Fawnie Creek valley, located southwest of Top Lake, corresponds with a zone of anomalous lead concentrations in upslope till sites in the Fawnie Range. These sites, adjacent to and south of the Buck prospect, are situated above Naglico Formation sedimentary rocks.

MOLYBDENUM

Median molybdenum concentrations in Fawnie Creek area lake-sediments are 5 ppm (AAS), versus 1 ppm (ICP) in till. Molybdenum concentrations here are generally greater in lake sediment than in till, at all percentile levels. Elevated molybdenum concentrations greater than the 90th percentile (at least 12 ppm Mo) are predominantly associated with Naglico Formation and, to a lesser extent, Ootsa Lake Group rocks; elevated values are almost completely absent from the area underlain by the Capoose batholith.

Till and lake-sediment molybdenum patterns (Fig. 12) are corroborative in one area, the Wolf prospect – Cow Lake – Paw area. The distribution of elevated molybdenum in lake sediment north and southeast of Cow Lake is similar to that of gold, copper, and zinc. The distribution of elevated molybdenum in till is similar to that of zinc and lead, but is more widespread, particularly in the area down-ice of the Wolf prospect. Conversely, two zones of elevated molybdenum in lake sediment in the Naglico Hills complement the limited till data available for this area. The northernmost of these lakes, situated above Naglico Formation volcanics near the southern margin of the Capoose batholith, are also within a zone of elevated zinc and lead values, and are up-ice of elevated zinc and lead concentrations in tills.

SUMMARY AND CONCLUSIONS

Integrated geochemical exploration techniques are, together with surficial mapping, a useful exploration method in the drift-covered and thickly-forested regions of the Nechako Plateau in central B.C. Selected analytical results from 171 till sites and 119 lake-sediment sites in the Fawnie Creek map-area clearly demonstrate that regional till and lake-sediment surveys are useful for detecting areas of prospective epithermal mineralization. Surficial and bedrock-geology mapping and mineral-deposit studies, also conducted in the same region, are used here to help evaluate the geochemical results. Basal tills are selected as the preferred sample medium over other surficial sediment types as they typically contain dispersal plumes that are both relatively large and comparatively easy to trace to source. Organic lake-sediments obtained from every lake and pond, and from all major sub-basins in larger lakes, are most suitable for detecting buried mineralization derived from up-slope and up-drainage sources, and from its dispersed remnants within surficial deposits.

Patterns of till and lake-sediment metal distribution provide corroborating evidence for the presence of drift-covered minéralization in several areas. All existing mineral occurrences in the map-region are detected in the till geochemical data, and lake-sediment results identify all known mineral occurrences situated near lakes. Anomalous concentrations of these elements in lake sediments and tills generally occur within a few kilometres down-slope and down-ice, respectively, of mineralized areas. In addition, eleven new exploration targets with multi-element geochemical anomalies are highlighted by the two surveys. Six of these target areas are indicated both by lake-sediment and till geochemical data, three by till data alone, and two by lake-sediment data alone (Table 3). These targets include highly anomalous (greater than 95th percentile) concentrations of gold in six areas, lead and zinc in five areas, copper in five areas, and molybdenum in four areas. Highly anomalous concentrations of arsenic and antimony occur in four of the five areas that have elevated lead and zinc, and in one area with gold. Anomalous gold also occurs with copper, lead, and molybdenum.

Lake-sediment and till data are complementary in at least two ways. First, geological and geochemical interpretations from each can be integrated to constrain the location of potential mineralized source-areas. Second, helicopter-supported lake-sediment surveys and ground-based till surveys are commonly best suited for different areas because of variable access and terrain conditions in any one region. Thus, the two survey types are commonly geographically complementary, increasing the chances of detecting buried mineral prospects.

REFERENCES

BOYLE, D.R. and TROUP, A.G. (1975) Copper-molybdenum porphyry mineralization in central British Columbia, Canada: an assessment of geochemical sampling media useful in areas of glaciated terrain. *In* Prospecting in Areas of Glaciated Terrain (M.J. Jones, ed.). *The Institution of Mining and Metallurgy*, London, 6-15.

COOK, S.J. (1993) Preliminary report on lake sediment studies in the northern Interior Plateau, central British Columbia (93C, E, F, K, L). *In* Geological Fieldwork 1992 (B. Grant and J.M. Newell, eds.). *B.C. Ministry of Energy, Mines and Petroleum Resources Paper* **1993-1**, 475-481.

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. (1994a) 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 (B. Grant and J.M. Newell, eds.). *B.C. Ministry of Energy, Mines and Petroleum Resources Paper* **1994-1**, 39-44.

COOK, S.J. and JACKAMAN, W. (1994b) Regional lake sediment and water geochemistry of part of the Nechako River map area (NTS 93F/2,3; parts of 93F/6,11,12,13,14). *B.C. Ministry of Energy, Mines and Petroleum Resources Open File* **1994-19**.

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**.

DIAKOW, L.J. and WEBSTER, I.C.L. (1994) Geology of the Fawnie Creek map area. *In* Geological Fieldwork 1993. *B.C. Ministry of Energy, Mines, and Petroleum Resources Paper* **1994-1**, 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**.

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*, 69-106.

FOX, P., CAMERON, R. and HOFFMAN, S. (1987) Geology and soil geochemistry of the Quesnel River gold deposit, British Columbia. *In* Geoexpo '86 (J. Elliot and B. Smee, eds.). *The Association of Exploration Geochemists*, 61-67.

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**, 4.1-4.20.

GILES, T.R. and LEVSON, V.M. (1994a) Surficial geology and drift exploration studies in the Fawnie Creek region (93 F/3). *In* Geological Fieldwork 1993 (B. Grant and J.M. Newell, eds.). *B.C. Ministry of Energy, Mines and Petroleum Resources Paper* **1994-1**, 27-38.

GILES, T.R. and LEVSON, V.M. (1994b) Drift prospecting potential of the Fawnie Creek area (NTS 93 F/3). *B.C. Ministry of Energy, Mines and Petroleum Resources Open File Map* **1994-10**.

GLEESON, C.F., RAMPTON, V.N., THOMAS, R.D. and PARADIS, S. (1989) Effective mineral exploration for gold using geology, Quaternary geology and exploration geochemistry in ares of shallow till. *In* Drift Prospecting (R.N.W. DiLabio and W.B. Coker, eds.). *Geological Survey of Canada Paper* **89-20**.

HOFFMAN, S.J. and FLETCHER, W.K. (1976) Reconnaissance geochemistry of the Nechako Plateau, British Columbia, using lake sediments. *Journal of Geochemical Exploration* **5**, 101-114.

HOLLAND, S.S. (1976) Landforms of British Columbia – a physiographic outline. *B.C. Ministry of Energy, Mines and Petroleum Resources Bulletin* **48**.

HOWES, D.E. (1976) Fawnie Creek terrain map. *B.C. Ministry of Environment Lands and Parks* (1:50,000-scale map).

KERR, D.K. and LEVSON, V.M. (1994) Annotated bibliography of drift prospecting activities in British Columbia. *In* Drift Exploration in Glaciated and Mountainous Terrain. *B.C. Ministry of Energy, Mines and Petroleum Resources, Short Course Notes.* Cordilleran Roundup, Vancouver, 40p.

LEVSON, V.M. and GILES, T.R. (1994a) Surficial geology and Quaternary stratigraphy of the Fawnie Creek area (NTS 93 F/3). *B.C. Ministry of Energy, Mines and Petroleum Resources Open File Map* **1994-9**.

LEVSON, V.M. and GILES, T.R. (1994b) Glacial dispersal patterns of mineralized bedrock with examples from the Nechako Plateau, central British Columbia. *B.C. Ministry of Energy, Mines and Petroleum Resources, Short Course Notes*. Cordilleran Roundup, Vancouver, 13p.

LEVSON, V.M., GILES, T.R., COOK, S.J. and JACKAMAN, W. (1994) Till geochemistry of the Fawnie Creek map area (NTS 93 F/3). *B.C. Ministry of Energy, Mines and Petroleum Resources Open File* **1994-18**, 34p.

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 (B. Grant and J.M. Newell, eds.). *B.C. Ministry of Energy, Mines and Petroleum Resources Paper* **1994-1**, 45-55.

SHILTS, W. (1973a) Glacial dispersion of rocks, minerals and trace elements in Wisconsin till, southeastern Quebec, Canada. *Geological Society of America Memoir* **136**, 189-219.

SHILTS, W. (1973b) Till indicator train formed by glacial transport of nickel and other ultrabasic components: a model for drift prospecting. *Geological Survey of Canada Paper* **73-1**, 213-218.

SHILTS, W. (1976) Glacial till and mineral exploration. *In* Glacial Till, an Interdisciplinary Study (R.F. Legget, ed.). *Royal Society of Canada Special Publication* **12**, 205-224.

SHILTS, W. (1993) Geological Survey of Canada's contributions to understanding the composition of glacial sediments. *Canadian Journal of Earth Sciences* **30**, 333 - 353.

TENHOLA, M. (1989) Regional geochemical mapping based on lake sediments in eastern Finland. *In* Prospecting in Areas of Glaciated Terrain – 1988. *CIM*, Montreal, Quebec, 305-331.

TIPPER, H.W. (1963) Nechako River map-area, British Columbia. *Geological Survey of Canada Memoir* **324**.

PROCEEDINGS

OF

DISTRICT 6 CIM ANNUAL GENERAL MEETING

OCTOBER 11 - 15, 1994
VANCOUVER, BRITISH COLUMBIA

CONFERENCE ORGANIZING COMMITTEE:

Chairman:	Jed Dagenais
Honorary Chairman:	John Willson
Treasurer:	Jeff Mason
Secretary:	Nancy Dinsmore
Technical Program:	Harlan Meade
Trade Show:	Mary Paddon
Services Program:	Rick McCaffrey
Social Program:	Grig Cook
Quest Program:	Joyce Mulligan/Gloria Petrina
Donations:	Art Fraser
Publicity:	Jim Taylor
Tours:	Grant Gibson
Plenary Session:	Pete Stacey
Education Program:	John Meech

Editor:

J.L. Jambor