BRITISH COLUMBIA

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

INTERIOR PLATEAU GEOSCIENCE PROJECT: SUMMARY OF GEOLOGICAL, GEOCHEMICAL AND GEOPHYSICAL STUDIES

Edited by Larry J. Diakow, P.Geo., John M.Newell, P.Eng., and Paul Metcalfe

Mineral Development Agreement

Geological Survey of Canada
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INTRODUCTION

By L.J. Diakow, British Columbia Geological Survey,
P. van der Heyden and P. Metcalfe, Geological Survey of Canada

The Interior Plateau (Figure 1) is one of the most promising, yet least explored areas of high mineral potential in British Columbia. In 1992, the Geological Survey of Canada and British Columbia Geological Survey initiated the Interior Plateau Project, operating under the auspices of the Mineral Development Agreement (1991-1995). The objectives of the project were to improve understanding of the geology and mineral deposits, test and develop exploration techniques suited for drift-covered terrain, and provide the best possible mineral potential assessment for the Interior Plateau region. The project brought together a team of 26 scientists, some of whom provided ancillary information for core programs that included mineral deposit studies (Figure 2), bedrock and surficial mapping, till and lake sediment geochemistry, and biogeochemistry, airborne magnetic, gamma-ray spectrometric and electromagnetic surveys (Figure 3). The Interior Plateau's dense forest, blanket of glacial sediments and Neogene volcanic rocks have hidden much of the older bedrock and hitherto hindered exploration. This volume contains summary reports for these programs.

Mapping programs were carried out in areas of varied topography from low-lying plateau terrain, typical of much of the Interior Plateau, to mountainous terrain which borders the plateau in the southwest. They focused on areas with known deposits, working outwards into less well-known prospective geology. Two mapping programs, in the southern Nechako River and northeastern Anahim Lake map areas, were conducted where epithermal precious metal and porphyry copper-molybdenum prospects are exposed in windows through the younger Neogene cover. Other mapping in the vicinity of the Fish Lake deposit and further to the north in the Charlotte Lake, Junker Lake (NTS 92N), Tatla Lake and Bussel Creek (NTS 93C) map areas encompassed prospective terrain for porphyry style deposits along the eastern margin of the Coast Belt and in the structurally complex zone marking the western margin of the Intermontane Belt. The results of these programs provide an updated stratigraphic and structural framework for ongoing mineral exploration.

The Interior Plateau contains a number of present and past-producing mines, including Blackdome, Gibraltar, Endako and Equity Silver, that all lie outside the region studied. A survey of mineral occurrences in the northern part of the Interior Plateau was carried out in order to document their characteristics and to establish local geologic setting and controls. These data are integrated in a conceptual model.

A high-resolution aeromagnetic survey covering fifty-nine 1:50 000-scale map sheets in the Interior Plateau is integral to better understanding of regional trends of stratigraphy, structure and mineral deposits in areas of poor outcrop. In addition, three multiparameter airborne geo-

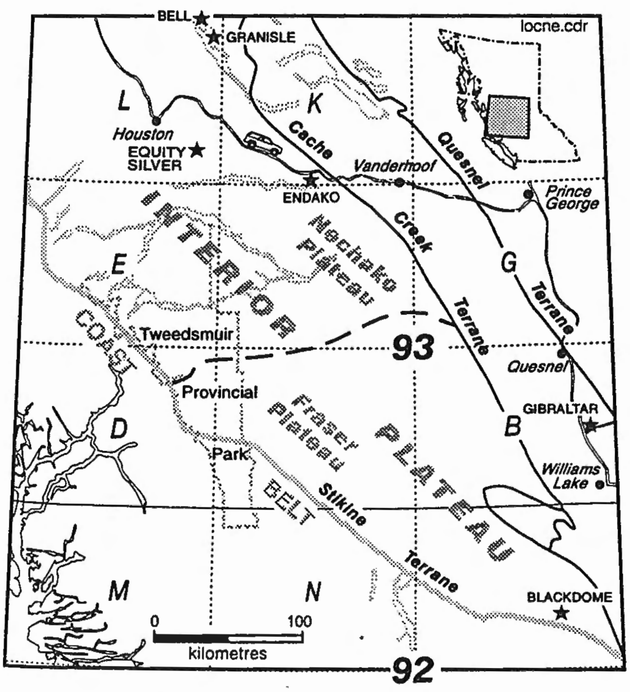

Figure 1. Location of the Interior Plateau and physiographic subdivisions and tectonostratigraphic terranes in south and central British Columbia.

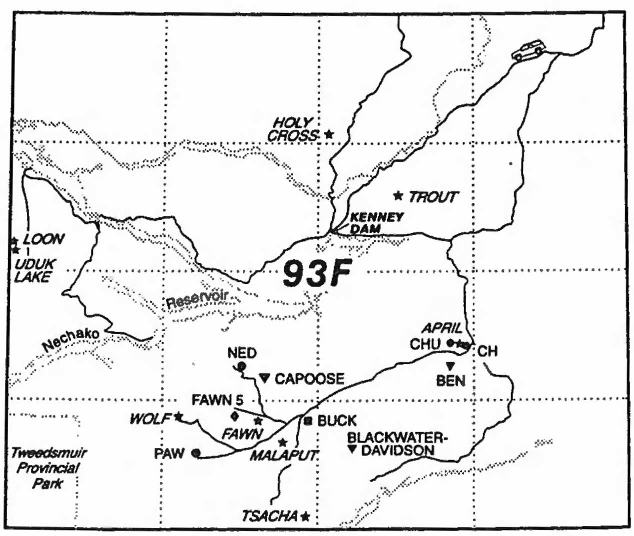

Figure 2. Location of metallic mineral occurrences studied in the southern Nechako Plateau.

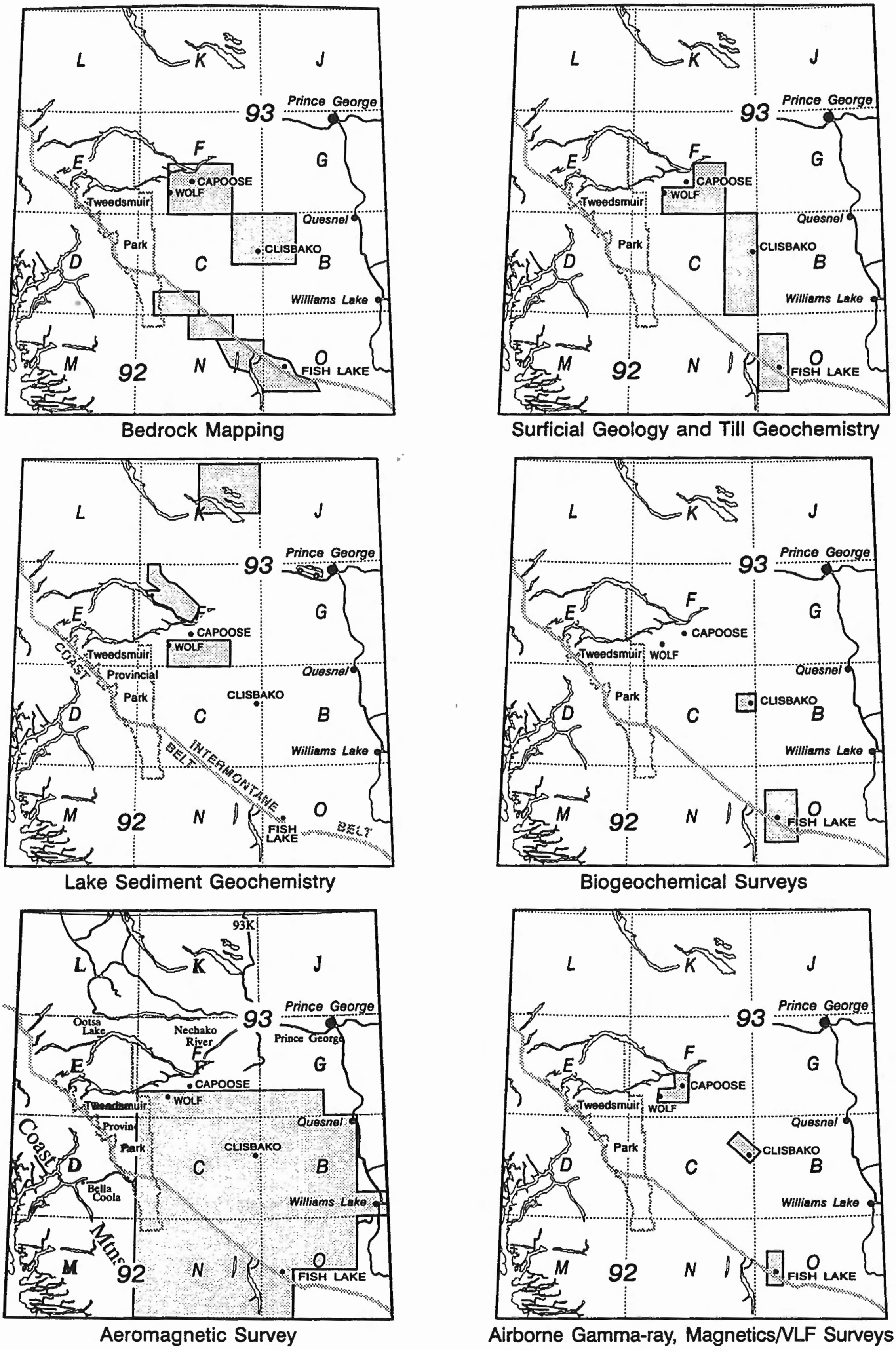

Figure 3. Location of geoscience programs in the Interior Plateau region.

geophysical surveys, centred on the Fish Lake, Clisbako and Wolf deposits, acquired gamma-ray spectrometric, magnetic and VLF-EM data at an elevation approximately one third of that of the regional aeromagnetic survey. The study was designed to test the application of these techniques in the vicinity of known prospects with differing parameters such as host lithology, mineralization and alteration. Detailed ground electromagnetic surveys were used locally to substantiate differences in till thickness and the location of buried intrusive contacts.

Studies of glacial deposits, supplemented by geochemical analysis of till samples were conducted in the Anahim Lake (NTS 93C) and Nechako River (NTS 93F) map areas and, in the Mount Tatlow and Elkin Creek map areas (NTS 92O) in the southern part of the Fraser Plateau. The main objectives of these projects were to map the distribution of Quaternary deposits, determine glacial history, identify geochemically anomalous areas, refine models of glacial dispersal and develop methods of drift exploration applicable to the Interior Plateau. Three small, regional lake sediment geochemical surveys were completed in the Nechako River and the Fort St. James (NTS 93K) map areas, where Mesozoic and Cenozoic rocks host a variety of mineral deposits. The program, based on prior orientation studies, determined background levels for pathfinder elements, corroborated previous lake sediment anomalies, and outlined new areas for further exploration. Two biogeochemical surveys were carried out over the Fish Lake porphyry and Clisbako epithermal deposits to assess the potential of plant species for detecting different types of concealed mineral deposits.

Contributions of the Interior Plateau Project have significantly improved our understanding of geology in this region. Integration of geological studies from the different disciplines has led to new mineral discoveries and identified additional exploration targets. Advances have also been made in development of exploration techniques specifically suited to this part of the Canadian Cordillera.

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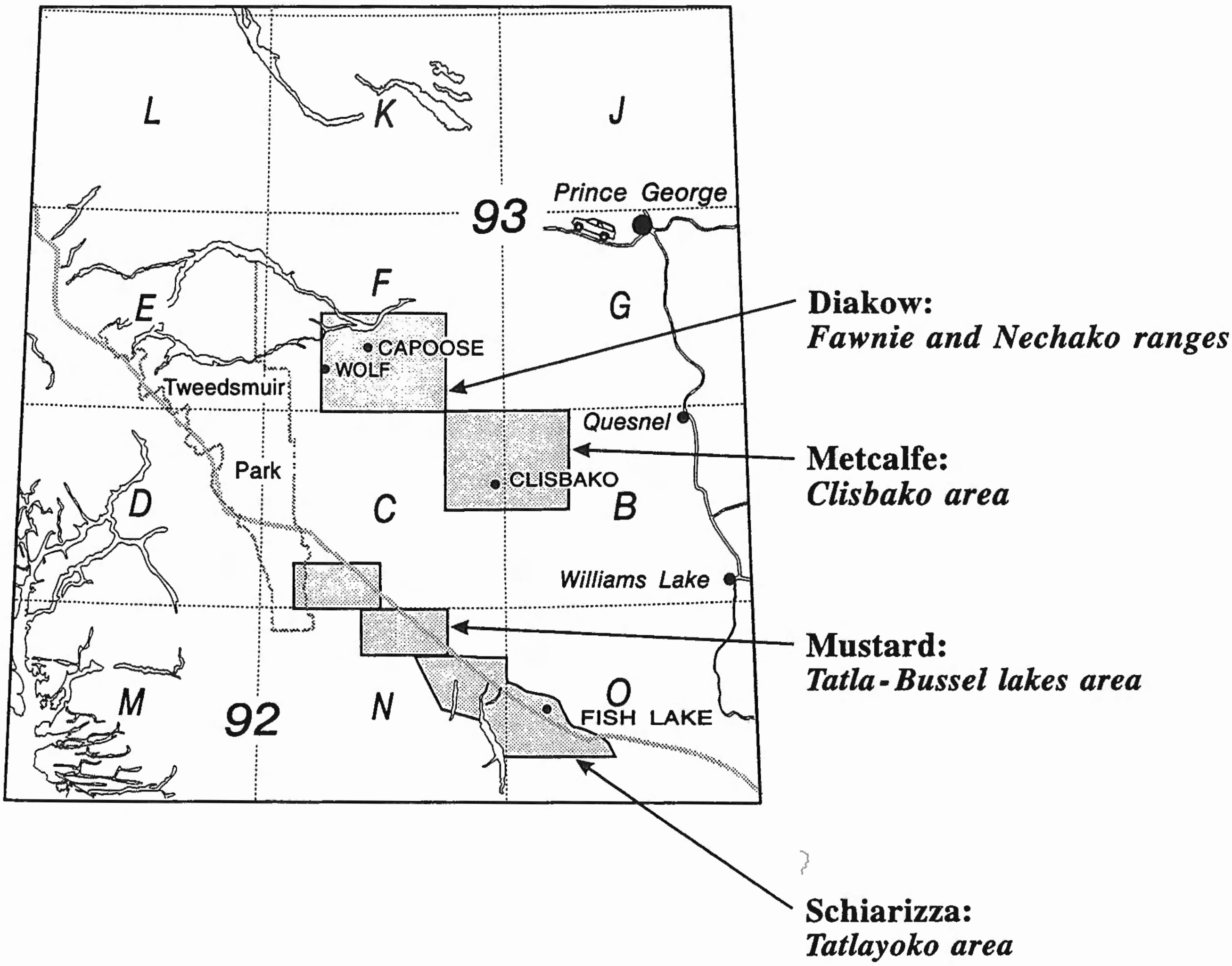
We thank Verna Vilkos for preparing figures for this paper. Production of this volume benefited greatly from the diligence of Janet Holland and Doreen Fehr, of the B.C. Geological Survey Branch, and Rachael Madsen and Tracey Feeney, of the Geological Survey of Canada.

Bedrock Mapping



GEOLOGY OF THE FAWNIE AND NECHAKO RANGES, SOUTHERN NECHAKO PLATEAU, CENTRAL BRITISH COLUMBIA (93F/2, 3, 6, 7)

By L.J. Diakow and I.C.L. Webster, British Columbia Geological Survey, T.A. Richards, Geological Consultant, Calgary and H.W. Tipper, Geological Survey of Canada

KEYWORDS: Nechako Plateau, Nechako River, Hazelton Group, Entiako formation, Naglico formation, Nechako volcanics, Capoose batholith, Nechako uplift, Ootsa Lake Group.

INTRODUCTION

The southern Nechako River map area (93F) was remapped at 1:50 000 scale to update stratigraphic, plutonic and structural relationships, building upon a regional geological base published at 1:250 000 scale (Tipper, 1963). This mapping provides a modern geological framework which better defines Jurassic and Tertiary magmatic events associated with volcanic-hosted gold-bearing epithermal veins and intrusion-related copper-molybdenum mineralization (*see* Lane and Schroeter, 1997, this volume). Advances in the geology of the southern Nechako River map area are discussed in this report and some new informal stratigraphic names introduced for the Jurassic stratigraphy in the area.

Bedrock mapping from 1992 to 1994 covered four 1:50 000 map areas, encompassing approximately 3500 square kilometres of the southern Nechako Plateau (Figure 1). During the first year of the program, mapping was completed in the Natalkuz Lake map area (93F/6; Diakow *et al.*, 1993b; Green and Diakow, 1993). The following year it was expanded southward into the Fawnie Creek area (93F/3), where surficial mapping was conducted in parallel, and the results of each program subsequently published in a combined bedrock-surficial geological map (Diakow and Webster, 1994; Diakow *et al.*, 1994). The program concluded in 1994 with expansion of bedrock and surficial mapping coverage into the Tsacha Lake (93F/2) and Chedakuz Creek (93F/7) areas (Diakow *et al.*, 1995a, b, c).

The Blackwater (West Road) River, a natural physiographic division in the central part of the Interior Plateau, separates the Nechako Plateau to the north from the Fraser Plateau to the south (Holland, 1976). The southern boundary of the study area follows the river; it comprises a series of northeast-oriented interconnected lakes which served as an ancient native trading route between the interior and the coast. G.M. Dawson (1878) followed this route to conduct the first geological reconnaissance of the Interior Plateau region. The present study area is centred on the Fawnie and Nechako ranges and the connected east-west trending ridges of the Entiako Spur and Naglico Hills. The ranges are parallel, trending northwest and rise a maximum of 950 metres above the intervening Chedakuz Creek valley with a base elevation of about 900 metres. The ranges drop abruptly to a surrounding plateau characterized by thickly forested hills. The Nechako Reservoir lies just beyond the northern terminus of the ranges, marking the northern boundary of the study area.

Access to the area from Vanderhoof, the closest major centre, is via the Kluskus-Ootsa forest service road. This all-weather gravel road branches onto secondary logging roads suitable for two-wheel drive vehicles and provides access to logged areas on the upper slopes of the Nechako Range. The Kluskus-Ootsa road transects the central part of the Nechako Range, and continues westward across the Chedakuz Creek valley into the Fawnie Range, to an important junction at the 142-kilometre marker. Here the Kluskus-Malaput forest service road leads to principal areas of bedrock exposure in the Entiako Spur in the north, and the continuation of the Kluskus-Ootsa road southward leads to a network of secondary roads in the Naglico Hills.

REGIONAL GEOLOGIC SETTING

The Nechako River map area is situated along the eastern margin of the Stikine Terrane, just west of the

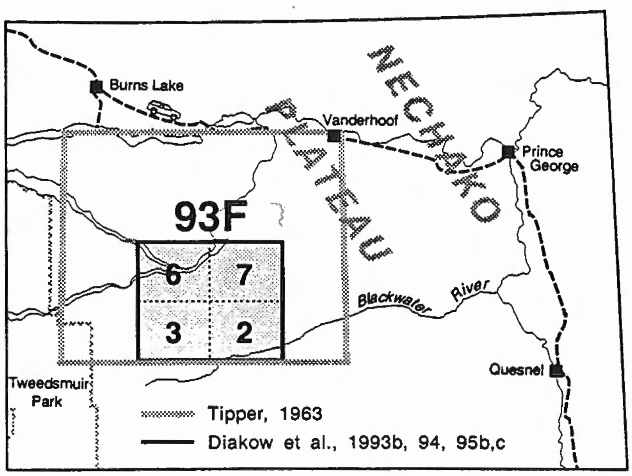


Figure 1. Location of the study area in the southern Nechako Plateau region, central British Columbia.

TABLE 1
TABLE OF FORMATIONS AND GENERALIZED LEGEND FOR FIGURE 2

	Epoch	Stage	Stratigraphy	Map Unit	Lithology
NEOGENE	Pliocene – 5		Chilcotin Group	MPc	Olivine basalt flows, vesicular texture, columnar jointed
	Miocene				
	– 23				*Unconformity*
PALEOGENE	Oligocene				
	– 35				
	Eocene		Endako Group	EE	Andesite flows, massive and amygdaloidal textures
					Disconformity
			Ootsa Lake Group	EO	Quartz-phyric rhyolite flows and air-fall tuffs; some bladed feldspar and augite-phyric andesite flows; local basal boulder conglomerate
				ECH	CH pluton: Hornblende biotite granodiorite
	– 57				*Unconformity; block faulting*
CRETACEOUS	– 65	Maastrichtian	Unnamed volcanics	uKv	Hornblende andesite tuff-breccia and flows
	L			LKf	Biotite-bearing felsite sills
				LKd	Quartz diorite stocks and plugs
		Cenomanian			
	– 97		Skeena Group	lKs	Rare black mudstone
		Albian			
	E				*Unconformity; inception of the Nechako uplift; brittle deformation*
				EKc	Capoose batholith: hornblende biotite granodiorite and quartz monzonite
		Berriasian	Unnamed volcanics	lKv	Rare biotite-phyric dacite flows
JURASSIC	– 146	Tithonian			
	L	Kimmeridgian	Bowser Lake Group – Nechako volcanics	uJBN	Pyroxene-phyric basalt flows, rhyolitic tuffs
		Oxfordian			*Paraconformity/ angular unconformity*
	– 157	Callovian	Bowser Lake Group – Ashman Fm.	muJBA	Black mudstone; chert-bearing conglomerate, sandstone and siltstone
	M	Bathonian			*Major unconformity; erosional interval*
		Bajocian	Hazelton Group – Naglico fm.	mJHN	Pyroxene-phyric basalt flows and tuffs; feldspathic sediments
		Aalenian	Hazelton Group – Entiako fm.	lmJHE	Near-shore and distal marine facies: volcanic sandstone and granule-pebble conglomerate; black laminated tuffaceous mudstone Subaerial facies: quartz-phyric rhyolite tuffs, lesser rhyolite flows; variegated maroon and green air-fall tuffs
	– 178	Toarcian			
	E				*Major unconformity*
TRIASSIC	– 208	Norian			
		Carnian	Unnamed Sediments	uTRs	Marine black, laminated siltstone

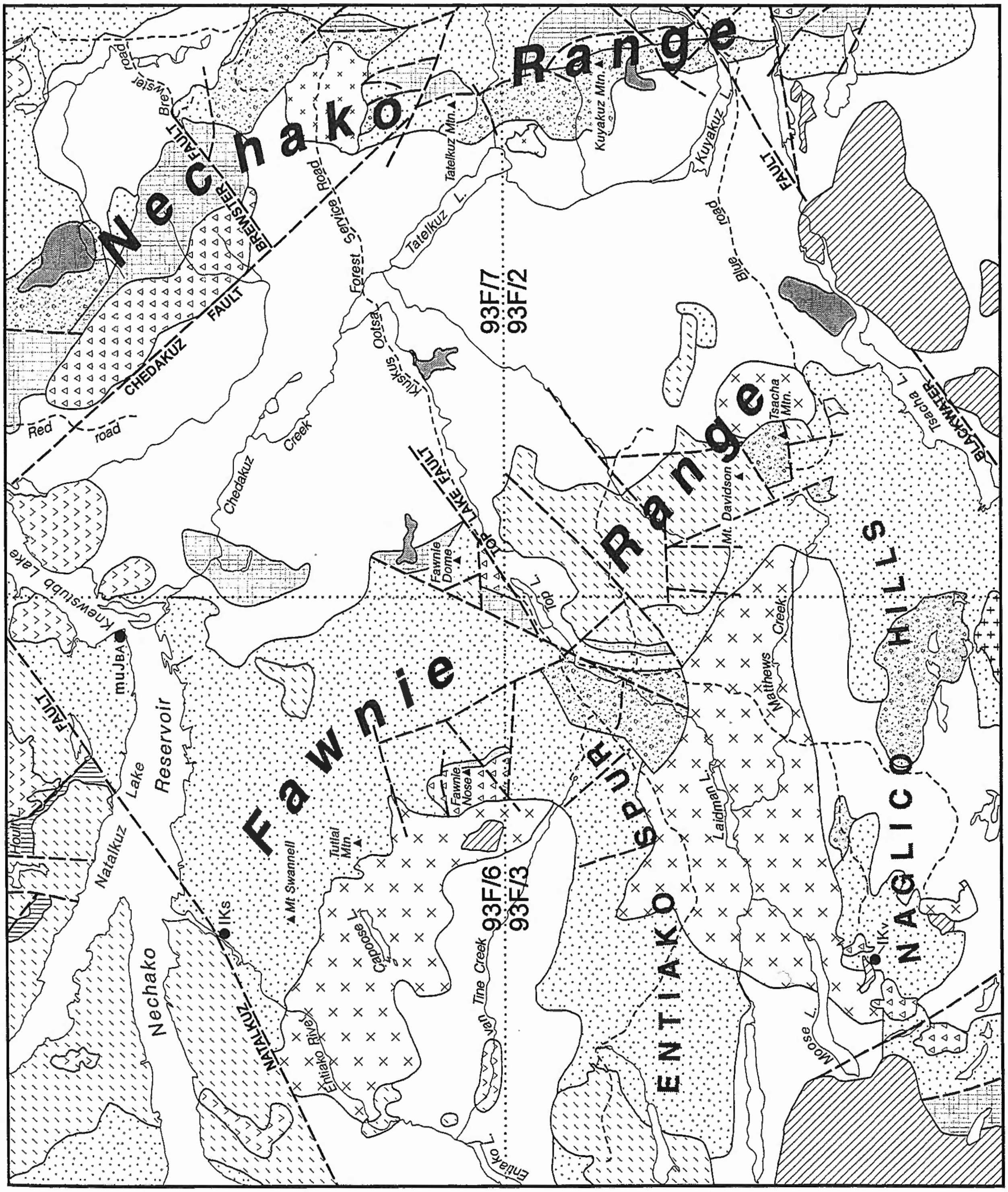


Figure 2. Generalized geology of the Fawnie and Nechako ranges.

presumed structural contact with the Cache Creek Terrane and immediately south of the Skeena Arch. Strata of the Stikine Terrane in central and east-central British Columbia comprise superposed island and continental margin arc assemblages and epicontinental sedimentary sequences.

Island arc volcanism and associated sedimentation in central Stikine Terrane spans Late Triassic to Middle Jurassic time. Elsewhere in Stikinia, remnants of Early Devonian to Permian arc volcanic rocks are known (Monger, 1977). The oldest strata exposed in east-central Stikinia are fossiliferous Upper Triassic sediments, sporadically exposed in the Smithers (Tipper and Richards, 1976b; MacIntyre *et al.*, 1996) and Nechako River (Tipper, 1963) map areas. Rare augite-plagioclase-phyric lavas, yielding a Late Triassic age (D.G. MacIntyre, personal communication, 1996), that closely resemble flows of the Stuhini Group, crop out near fine-grained marine sediments containing the Carnian to early Norian bivalve *Halobia* in the Fulton Lake map area (93L/16; MacIntyre *et al.*, 1996). These rocks are possibly coextensive with fossil-bearing Upper Triassic marine sediments mapped along the western margin of the Stikine Terrane in the Whitesail Lake (van der Heyden, 1982) and Terrace (Mihalynuk, 1987) map areas, where they crop out in close proximity to Lower Permian carbonates (van der Heyden, 1982). Early and Middle Jurassic rocks of the Hazelton Group stratigraphically overlie the Stuhini Group throughout much of Stikinia. The Hazelton Group is a lithologically varied island arc succession composed of subaerial and submarine volcanics locally interlayered with marine sediments (Tipper and Richards, 1976a).

Island arc volcanism commenced in Middle Jurassic time, broadly coincident with a protracted event of terrane accretion and the subsequent overlap of older arc strata by widespread Upper Jurassic and Lower and mid-Cretaceous flysch and molasse deposits. Terrane accretion began possibly as early as Bajocian time, resulting in structural juxtaposition of oceanic Cache Creek Terrane onto Stikinia, and led to early development of the Bowser Basin and shale deposited in a starved marine environment (Ricketts and Evenchick, 1991; Tipper and Richards, 1976a). Overlying coarser clastic rocks, consisting largely of conglomerate shed from the uplifted Cache Creek Terrane, record fluvatile transport and progradation of deltaic deposits along the periphery of the basin. The Skeena Arch became an uplifted area and sediment source for northerly flowing drainages into the southern part of the Bowser Basin from mid-Oxfordian to earliest Early Cretaceous times. During parts of the Early and Late Cretaceous, sediments sourced from the northeast and east record initial deposition of nonmarine and shallow marine sediments of the Sustut and Skeena groups. In south and south-central Stikinia, contemporaneous deposits of sandstone, siltstone and conglomerate are widespread and suggest that a number of smaller sedimentary basins may have been connected (*e.g.*, Nazko Basin; Hunt, 1992).

Regional contractional deformation, documented in widely separated areas of the Stikine Terrane in the Taseko-Pemberton (NTS 92N,O; Schiarizza and Garver, 1995), and the Spatsizi (NTS 104H; Evenchick, 1991; Evenchick and McNicoll, 1993) map areas was a middle and Late Cretaceous event. This orogenic event coincides with the transition from sedimentary deposition to continental margin arc volcanism. Definitive evidence of Cretaceous contractional deformation in the intervening region of central Stikinia, particularly in the Nechako River map area (NTS 93F), has not yet been recognized. However, a domain of cleaved rocks with local zones of mylonite in the Nechako Range may be the record of this event.

Continent margin arc volcanism began in south and central Stikine Terrane in Late Cretaceous time and continued episodically into the Eocene with eruption of the Kasalka, Ootsa Lake and Endako groups. The Upper Cretaceous Kasalka Group unconformably overlies the Skeena Group. The Kasalka Group records construction of isolated volcanic centres as the magmatic front apparently migrated from the Coast Belt eastward across the Stikine Terrane over a period of nearly 30 million years, ending in latest Cretaceous time. Robust continental arc magmatism was re-established during Middle and late Eocene time with eruption of the Ootsa Lake and Endako groups. This volcanism appears to be closely linked to regional crustal transtension in central British Columbia, manifest in upwelling of high-grade metamorphic rocks in core complexes (Ewing, 1980) and major strike-slip faults, such as the Tatla Lake Metamorphic Complex adjacent to the Yalakom fault in the Anahim Lake map area (Friedman and Armstrong, 1988).

Miocene and younger volcanism, represented by the Chilcotin Group, is dominated by transitional basalts that formed flat-lying lava fields, mainly in southern Stikinia. The Chilcotin Group is interpreted to have erupted in a back-arc setting, east of the Pemberton-Garibaldi arc (Souther, 1991, Bevier, 1983a,b). Shield volcanoes, comprising the Anahim Belt, are locally perched on the plateau-forming Chilcotin lavas. They consist of distinctive peralkaline volcanoes erupted between 8.7 and 1.1 Ma above a mantle hotspot (Bevier *et al.*, 1979; Souther, 1986; Souther and Souther, 1994).

The study area is underlain by rocks deposited between Late Triassic and Neogene time (Table 1; Figure 2). The Fawnie and Nechako ranges in the southern Nechako River map area are uplifted blocks in which Mesozoic rock units have been widely exposed. These include mainly volcanic and sedimentary strata that broadly correlate in age and lithology with the Stuhini, Hazelton, Bowser Lake, Skeena and Kasalka groups. All sequences are separated by hiatuses inferred from gaps in the stratigraphy. Strata of Cenozoic age include the Ootsa Lake, Endako and Chilcotin groups.

UPPER TRIASSIC SEDIMENTARY BASEMENT (UNIT uT_S)

The oldest rocks are exposed just outside the study area at a single locality along the Red road, which hooks around the northern end of the Nechako Range. The outcrop consists of very thinly bedded black shale and buff-weathered, ripple-laminated siltstone containing the Carnian to early Norian pelecypod *Halobia* (Collection GSC C-203473; H.W. Tipper, personal communication, 1994). Triassic rocks are rare in the Nechako River map area with one other confirmed site of Halobia-bearing siltstone mapped to the northwest of the study area at Verdun Hill (Tipper, 1963). These rocks are representative of a quiescent marine environment that probably existed throughout much of central Stikine Terrane in Late Triassic time.

JURASSIC ROCKS

Broad areas of volcanic strata underlying much of the study area were previously assigned to Upper Triassic map units (Tipper, 1963). However, through discovery of relatively thin intervals of fossiliferous sedimentary beds interlayered with the volcanic rocks, they are now known to be Jurassic and part of a much thicker, unique Mesozoic stratigraphy. Fossil identifications have played an important role in unraveling the internal stratigraphy of this succession; they indicate a general age range of the rocks that spans early Toarcian to early Bajocian time in an older sequence, which has some lithologic similarity to a younger, unconformable sequence of late Bathonian to early Callovian and possibly early Oxfordian age. Dating the volcanic rocks by isotopic methods has produced indeterminate results in the older sequence, but expands the known range of the younger sequence into the Kimmeridgian. There are many gaps in the biostratigraphy of this area; nevertheless it has been critical to the inference of depositional ages for thick volcanic intervals. These volcano-sedimentary rocks are interpreted to be an island arc deposited above an inferred sub-Toarcian unconformity on Upper Triassic sediments. The older sequence broadly correlates in age and tectonic setting with the Hazelton Group, a lithologically varied subaerial island arc succession which is well exposed in a northerly trending belt that extends for over 450 kilometres from Whitesail Lake map area in the south to the Toodoggone River map area in the north (Tipper and Richards, 1976a; Diakow *et al.*, 1993a; Diakow *et al.*, in preparation). The younger sequence is correlative with the Bowser Lake Group, widespread in the Bowser Basin north of the Skeena Arch (Tipper and Richards, 1976a).

Granodiorite and quartz monzonite of the Early Cretaceous Capoose batholith intrudes the Jurassic succession and may be genetically associated with hydrothermal alteration and a variety of exploration prospects in the study area (Lane and Schroeter, 1996). This magmatic episode may have an extrusive component, manifest in an erosional remnant of volcanic rock that yields a similar K-Ar biotite date as the batholith.

Recent nomenclature for Jurassic volcano-sedimentary strata in the study area originally comprised the Bajocian Naglico formation and an overlying, unnamed Callovian sedimentary sequence (Diakow and Webster, 1994). We now subdivide the Naglico formation into two informal formations, each dominated by lithologically distinct volcanic units and associated volcanic-derived sediments. They are the Entiako formation, in which a western, subaerial felsic volcanic facies grades into an eastern, marine volcaniclastic-epiclastic facies, and stratigraphically overlying augite-phyric mafic flows and volcanogenic sediments of the Naglico formation. The Naglico formation is unconformable with overlying fine-grained and chert-bearing clastic rocks of the late Bathonian to early Oxfordian(?) Ashman Formation. It is locally disconformable with a Kimmeridgian mafic flow member that closely resembles flows characteristic of the older Naglico formation.

HAZELTON GROUP

ENTIAKO FORMATION (UNIT $lmJH_E$)

Rocks of the Entiako formation can be grouped in two facies: a marine sedimentary facies characterized by volcanic-derived sediments, and a felsic volcanic facies containing subordinate epiclastic rocks. Ammonites collected from the sediments indicate deposition from early Toarcian to possibly early Bajocian time. Rocks of the sedimentary facies crop out intermittently for nearly 45 kilometres along the flanks of the Nechako Range. In the southern part of the range, near Kuyakuz Lake, the proportion of volcanic rock in the sections increases. The volcanic facies predominates farther west in the Fawnie Range, with the best exposures located in the eastern part of the Entiako Spur.

Marine Volcaniclastic-Epiclastic Facies

The sedimentary facies is widespread in the Nechako Range and includes varying proportions of mudstone, arkosic sandstone and sharpstone conglomerate. Detritus in these rocks includes abundant angular feldspar, quartz and potassic felsic-volcanic lithics that all appear to be volcanic derived, either laid down contemporaneously during coeval volcanism or as epiclastic debris shed from a nearby volcanic source. Because of poor exposure, lithofacies distributions are not well defined; however, the general trend mapped is towards tuffaceous mudstone-siltstone-dominated sections in the northern half and, locally, east of the central Nechako Range. The proportion of primary volcanic interbeds increases and sedimentary rocks become coarser, dominated by arkosic arenite and granule conglomerate, towards the southern part of the range, particularly in the segment between Tatelkuz Mountain and Kuyakuz Lake. This trend suggests that finer, distalmarine subfacies lay outboard, to the north and east of an intermixed, coeval, coarser grained near-shore marine and subaerial volcanic subfacies.

The distal marine subfacies comprises the oldest Jurassic strata in the study area, dominated by black, laminated argillite and subordinate feldspathic siltstone interbeds containing diagnostic early Toarcian ammonite fauna including *Dactylioceras kanense* (McLearn), *Lioceratoides* (Paciferas) *propinquum* (Whiteaves), *Liocera-toides* (Paciferas) *angionus* and *Tiltoniceras antiquum* (Collection GSC C-177435; H.W. Tipper, Report J7-HWT-1994; Jakobs *et al.*, 1994). These rocks crop out only in a small area immediately to the northeast of the CH pluton. Presumably overlying argillite and lesser feldspathic siltstone containing the small, delicate pelecypod *Bositra* (Collection GSC C-177437; H.W. Tipper, Report J7-HWT-1994) are exposed only 1.5 kilometres northwest of this site. The *Bositra*-bearing beds are exposed sporadically along the eastern lower slope of the northern Nechako Range, and extend just beyond the study area to a quarry along the 2500 road, east of the central Nechako Range. These rocks apparently continue farther east and northwest, beneath low-lying terrain, to *Bositra* sites along the Euchiniko River (Collections GSC C-90798 and GSC 23468; T.P. Poulton, Report J7-TPP-1995; Taiuk Creek (Collection GSC 23469, Tipper, 1963) and one locality now submerged by the Nechako Reservoir at Knewstubb Lake (Collection GSC 2188; Tipper, 1963). Typically, exposures consist of recessively weathered black pyritic mudstone, limy siltstone, and fewer but prominent, thick resistant beds of arkosic sandstone that in places contain angular felsic volcanic-lithic granules, broken shells of more robust fossils and wood fragments. In places the black mudstone is distinctly banded, with parallel laminae a few millimetres to 1 centimetre thick, alternating with cream to pinkish weathered ash-tuff, representing airborne felsic ash ejected from distant, contemporaneous volcanoes and filtered through quiescent marine water. Some of these ash lamellae are potash rich. Grey and brownish weathered limestone layers and concretions were sampled for microfossils but none were found. A similar section of rusty weathered, interlaminated ash and mudstone is exposed to the west in the Fawnie Range in roadcuts between 144.5 and 146.5 kilometres on the Kluskus-Ootsa forest service road. Based on similar lithologies, it is correlated with the *Bositra* beds in the Nechako Range.

These interlaminated tuff and mudstone beds are tentatively correlated with distinctive Toarcian to Bajocian Quock Formation ("pyjama beds") fringing the Bowser Basin (Jeletzky, 1976; Tipper and Richards, 1976a; Thomson *et al.*, 1986; Anderson and Thorkelson, 1990; Evenchick, 1991b; Jakobs, 1993). According to T.P. Poulton "*Bositra* has been identified from Pliensbachian through early Oxfordian collections in western Canada, but predominates in the Toarcian, so that it has come to serve as a guide for that interval. Both its total range, and abundance in the Toarcian, are characteristic of *Bositra* worldwide. Its abundant occurrence in the Toarcian coincides with the high-organic, low-oxygen, pyritic black shale facies that characterizes the Toarcian marine high-stand globally" (Report J9-TPP-1995). Elsewhere in the study area, *Bositra* is reported from a locality immediately north of Kuyakuz Lake (Collection GSC 21889, Tipper, 1963) where it is believed to occur in an interval between fossiliferous middle Toarcian volcaniclastic-epiclastic strata and probable Aalenian(?) feldspathic sediments. Correlative rocks about 200 kilometres to the west, adjacent to Morice Lake in the Whitesail Lake map area, contain *Bositra* in a thinly bedded mudstone-sandstone sequence that occupies an interval between thick basaltic flows of probable late Sinemurian to Pliensbachian age, and unconformably overlying rhyolitic fragmental rocks with a U-Pb zircon date of 184±4 Ma (Sample 83WV-1038; van der Heyden, 1989). This isotopic date is considered provisional as it is based on a single fraction, but nevertheless infers a minimum age for the underlying sediments.

A near-shore subfacies, comprising shallow-marine sediments intermixed with subaerial volcaniclastic beds, underlies a transect along the west-facing slope of the Nechako Range, between Tatelkuz Mountain and Kuyakuz Lake. These rocks, previously subdivided into the Nechako Range and overlying Kuyakuz Mountain volcanic and sedimentary assemblages (Diakow *et al.*, 1995b), form a gently east dipping homoclinal sequence estimated to be more than 600 metres thick on the west side of Kuyakuz Mountain. Neither the lower or upper contacts of the unit have been observed; but it is consistently close to a thick overlying sequence of pyroxene-bearing mafic flows and interspersed maroon tuffs assigned to the Bajocian Naglico formation and is therefore believed to be in stratigraphic contact. The lowest beds, best exposed south of Kuyakuz Lake along the Blue road near the 38 kilometre marker, consist of reworked tuffs. Tuffaceous sandstone, characterized by 15 volume percent broken volcanic quartz grains, marks the bottom of the succession. Uranium-lead dating of this rock gives an erroneous Early Cretaceous date, with a large error, from the lower intercept of a discordia line for three zircon fractions. Sharply overlying these rocks are about 30 metres of feldspathic sandstone and volcanic-lithic granule conglomerate containing *Collina*, a late-middle Toarcian ammonite, extracted from the base of the section (Collection GSC C-143706; H.W.Tipper and G.K.Jacobs, personal communication, 1994). This ammonite establishes a depositional age for the lower part of the near-shore subfacies and a biocorrelation with the distal marine subfacies to the northeast.

Stratigraphically higher sediments of the near-shore subfacies are sporadically exposed along the western slope between Kuyakuz and Tatelkuz mountains, where they are capped by a volcanic marker unit. The lower part of this sequence is dominated by interbedded arenaceous sandstones and siltstones that are rich in angular feldspar detritus, and conglomeratic interbeds dominated by volcanic-lithic and feldspar detritus. The lithics, typically subangular and granule to pebble sized, include aphanitic and fine-grained porphyritic varieties of andesite and rhyolite. Mudstone, which is present but not common, in places occurs with grey or brown weathered impure limestone lenses. Bedding is variable, ranging from laminated in the finer grained beds, to medium and thick layering in coarser grained beds. Fine ripple laminations and internal textural grading suggest facing is towards the northeast. Fossils in the sediments are generally indeterminate, thick-shelled bivalves. Several indistinct ammonite collections, containing either poorly preserved or difficult to identify forms (*i.e. Witchellia*(?); Collection GSC 21886, Frebold *et al.*, 1969, T.P. Poulton, Report J7-1994-TPP; GSC C-143705, T.P. Poulton, Report J6-TPP-1995 and GSC C-203460, H.W. Tipper, personal communication, 1994), indicate a general range of fossil ages from middle Toarcian to early Bajocian. Interestingly, the early Bajocian genus *Witchellia(?)*, sonniniid(?) and stephanoceratid(?) ammonites are tentatively identified with *Bositra* from a fossil site on the Euchiniko River (Collection GSC 23468, T.P. Poulton, Report J7-1995-TPP). If this association is valid it implies the age of *Bositra* beds comprising the distal marine subfacies might range from late Toarcian to as young as early Bajocian; evidently not all that unlike the age deduced from fossils of the shoreline subfacies in the Kuyakuz Lake area.

The uppermost section of the near-shore subfacies is marked by an abrupt change from feldspathic sediments into conformably overlying local accumulations of silica-bimodal fragmental volcanic rocks which, in turn, grade into volcaniclastic-epiclastic derivatives of the felsic member. This marker unit is most complete along the ridge through Kuyakuz Mountain where the entire succession may be as much as 250 metres thick. With the exception of a lowermost mafic member, which thickens locally to 60 metres or is missing altogether, the succession trends northerly to the lower west-facing slope of Tatelkuz Mountain and in the opposite direction to the south side of Kuyakuz Lake. In places the base of the section is dominated by superbly layered dark green tuff beds composed of andesitic to basaltic pyroclasts. The pyroclasts are commonly lapilli size or finer with aphanitic and vesicular textures. Successive texturally graded beds, some with shallow planar crossbedding, bomb sags and internal angular unconformities suggest the deposit is a product of multiple air-fall eruptive episodes that probably occurred in relatively rapid succession.

Rhyolitic volcanics and related epiclastic rocks depositionally overlie the mafic tuffs. Locally, several metres of accretionary lapilli tuff underlie the main felsic tuff beds. The tuff is composed of white aphanitic lapilli set in a dense, light green, siliceous ash charged with broken plagioclase and ubiquitous quartz grains. Potash-rich fragments, confirmed by staining, and the presence of quartz fragments in amounts between 1 and 5 volume percent, are the most diagnostic features of these rocks. These tuffs grade imperceptibly, both laterally and up-section, into scantily fossiliferous marine interbeds of reworked volcaniclastic detritus in which much of the ash component is elutriated out, resulting in layers that are exceptionally rich in angular crystals and lithics. Along trend of the Kuyakuz Mountain section, the quartz-bearing unit appears to wedge out, supplanted in the north, near Tatelkuz Mountain, by volcanogenic quartz-bearing arkosic sediments, and south of Kuyakuz Lake by quartz-deficient maroon tuffs with waxy green felsic fragments. Overall, this volcanic section records subaerial and subaqueous deposition of air-fall tephra that mark the top of the Entiako formation and presumably the end of a long period of contemporaneous marine sedimentation. The age of this late volcanic activity in the Entiako formation is unconstrained, but it is believed to be temporally equivalent and coextensive with a belt of subaerial quartz-phyric felsic volcanic rocks that are found to the west in the Fawnie Range.

Subaerial Volcanic Facies

The subaerial volcanic facies of the Entiako formation consists almost exclusively of fragmental rocks of rhyolitic composition. Exposures of these rocks are scattered over a broad area encompassing parts of the Entiako Spur, Naglico Hills and the lower west slope of the Fawnie Range. The contemporaneity of similar rocks on the northwest side of Tsacha Mountain is equivocal and inclusion of these rocks with the volcanic facies of the Entiako formation is provisional.

The reference section for the volcanic facies of the Entiako formation is situated in the eastern Entiako Spur, roughly at the 5-kilometre marker of the Kluskus-Malaput forest service road, where at least 150 metres of rhyolite flows, ash-flow tuff and lapilli tuff form a series of blocky weathered, gently inclined benches that approximate bedding. The base of the section is not exposed and the upper contact is conformable with depositionally overlying flows of the Naglico formation.

Rhyolite of the Entiako formation is typically off-white to salmon coloured and characteristically contains up to 3% rounded and resorbed quartz phenocrysts that average 2 to 3 millimetres in diameter. At the reference section, however, the rocks are grey, hardened and locally laced with epidote-garnet veinlets resulting from thermal overprinting by the Capoose batholith. The lowest exposures in this section are rhyolite flows with light coloured flow laminae in a contrasting dark grey to black aphanitic groundmass. Most of the section, however, is made up of light grey fragmental rocks in typically thick, well-indurated beds devoid of internal structure. The beds are composed of lapilli and fewer block-sized fragments supported by a plagioclase-rich matrix. The lithic fragments are mainly textural variants of plagioclase-porphyritic andesite, and some flow-laminated rhyolite. Several monzonitic accidental fragments were also observed. Scarce, thin, welded zones within the otherwise massive, unwelded tuffs have a compaction fabric defined by compressed lithic fragments. Scant exposures of the Entiako formation in the Naglico Hills consist mainly of compositionally similar rhyolitic lapilli tuff with some strongly welded zones. Some cobble-boulder conglomerate with interlayered siltstone and sandstone containing quartz and rhyolite indicate contemporaneous erosion of the fragmental rocks.

A U-Pb zircon date on rhyolite ash-flow tuff from the reference section is inconclusive, as the most concordant fraction gives a best estimate for the age of crystallization of 170±40 Ma. Despite similar quartz-bearing fragmental rocks in both the subaerial and shoreline facies of the Entiako formation, these facies can only be broadly correlated. It is clear from the high proportion of ash and juvenile felsic volcanic lithic and crystal fragments found throughout the entire stratigraphic range of the marine facies that there was contemporary felsic volcanism. However, the subaerial facies now manifest as a dissected sequence of interleaved fragmental and flow deposits, is merely a snapshot of one, perhaps two, explosive pulses that probably provided direct airborne and epiclastic input from volcanic centres bordering a long-lived marine basin.

Rhyolitic tuffs underlying the northern part of Tsacha Mountain are tentatively included in the volcanic facies of the Entiako formation. They are characterized by a preponderance of flow-laminated pyroclasts, but lack the diagnostic quartz phenocrysts so prevalent elsewhere in the unit. Rare laminated flows are also present. Sedimentary rocks overlying the volcanics consist of hornfelsed black siltstone with minor sandstone and rare quartz-bearing lapilli tuff interbeds. The age of these sediments is not known, but they are believed to be part of the Entiako formation.

The topmost beds of the felsic sequence in the reference section are conformable with lithologically different fragmental rocks. The lowest part of this section is alternating laminated, very thin beds of green ash tuff and crystal tuff. They pass upward into thicker beds containing lapilli to block-sized fragments in which coarse-grained pyroxene is dispersed in both the fragments and matrix. These tuffs record an air-fall event that preceeded comagmatic pyroxene-phyric basaltic flows of the Naglico formation, capping the section. A comparable tuffaceous section, representive of this explosive episode, is also evident immediately to the east of the Kluskus-Ootsa forest service road near the 147 kilometre marker. Here 25 metres of exposed rhyolite flows have a gradational upper contact with about 75 metres of thick, variegated green and maroon ash and crystal tuff beds. Quartz, abundant in the underlying flow and the lowest ash-crystal tuff bed above the contact, is notably absent higher in the tuff section. Near the top, the tuff interval is overlain by fossiliferous synvolcanic sharpstone conglomerate. It is dominated by angular felsic volcanic pebbles and feldspar occupying ball and pillow structures at the interface of sediments and an underlying bed of vitric and ash tuff. Beds of coarse sandstone and fine conglomerate diminish within 25 metres of the contact, passing rapidly up-section into finer grained arkosic sandstone and siltstone and lesser black mudstone. Along strike these same sediments extend northward in a belt for about 3 kilometres, and stratigraphically lower strata exposed along the Kluskus-Ootsa road between 144.5 and 146.5 kilometres consist of distinctly banded white ash and black mudstone beds. The banded beds crop out within 500 metres along strike, and probably wedge out before they reach the previously described volcanic-sediment contact.

Nondiagnostic casts of belemnites and bivalves found at the volcanic-sediment contact provide little information on the depositional age of the sediments. An attempt to obtain a U-Pb zircon date from the quartz-bearing rhyolite flows beneath the sediments was unsuccessful. The banded tuff-mudstone beds which presumably mark the gradational base of the sediments are strikingly similar to the deeper marine Toarcian *Bositra* beds in the northern Nechako Range, and the overlying feldspathic lithologies resemble those of the Toarcian and Aalenian? shoreline facies in the southern Nechako Range. In general, the sediments above the contact weather recessively, resulting in discontinuous exposures traceable up-section for nearly 1200 metres upslope and to the east to an important fossil site at the top of the sediment package that contains definitive early Callovian fauna (Collection GSC C-143396; H.W.Tipper, Report J2-1994-HWT). Because no major lithological differences were noted, the scattered outcrops appear to represent a single continuous section, but in reality a significant hiatus is suspected, spanning late Bajocian(?) and most of Bathonian time. Field evidence for this unconformity is discussed further under Ashman Formation.

NAGLICO FORMATION (UNIT mJH_N)

The Naglico formation is dominated by augite-phyric mafic flows, lesser tuffs and scarce intervolcanic marine sediments, locally, containing early and late(?) Bajocian fossils. It is the most widespread of map units in the study area, underlying much of the Fawnie Range. Extensive exposures throughout the Naglico Hills and Entiako Spur display varying intensity of propylitic alteration which is caused by the Capoose batholith that intrudes the Early and Middle Jurassic strata. In the southern to central Nechako

Range, cleaved mafic and intermediate volcanics of the Naglico formation appear to occupy two parallel belts separated by a medial belt underlain by younger Middle to Upper Jurassic coarse clastic rocks. In the northern part of the range, however, the interpretation of two lithologically identical and temporally equivalent belts of volcanics is refuted by stratigraphic relationships at several localities and a new Ar^{40}/Ar^{39} plateau age which suggests that some of these mafic volcanics are in fact younger (early Kimmeridgian). In the extreme northeast of the study area, the Naglico formation appears to rest on the Entiako formation, but immediately to the west its removal by erosion, or nondeposition of the mafic volcanic sequence, might account for its absence between differing clastic units of the Ashman and Entiako formations. Another possible explanation of the lack of Naglico volcanics is they may be locally replaced by sedimentary rocks. Some support for this possibility is scattered outcrops of compact black shale and lesser feldspathic sandstone along the Brewster road, in close proximity to but not in direct contact with unconformably(?) overlying chert-pebble conglomerates. Poorly preserved ammonite fragments, questionably resembling early Bajocian stephanoceratids(?), are found with belemnites, gastropods and various indeterminate bivalves in the shales (Collections GSC C-177438, 39, 40; J.W. Haggart, Report JWH-1995-04).

The thickness of the Naglico formation is difficult to ascertain because of rather heterogeneous physical attributes of the volcanics and absence of internal stratigraphic markers. Some apparently thicker sections underlie the easternmost Naglico Hills, south to Tsacha Lake, and the region along the eastern slope of the Fawnie Range north of Top Lake. The Capoose batholith is believed to be relatively close to the surface beneath the Entiako Spur so that the Naglico strata are thinner and more altered in this locality than those exposed in the Naglico Hills. Although a direct contact between pyroxene flows of the Naglico formation and underlying rhyolitic rocks of the Entiako formation has not been found, a consistent spatial relationship is observed at a number of localities, suggesting they are in stratigraphic contact. The top of the reference section for the Entiako formation is one of the best places in which to examine the contact zone. At this and another site in the Naglico Hills, a sequence of bedded tuffs, with or without boulder conglomerate that contains clasts derived from the underlying Entiako formation, is exposed at the base of the Naglico formation. Bedding in the tuff section is congruent with that in thin epiclastic layers and compaction foliation in the underlying Entiako formation. This relationship leads to the interpretion that these successions are disconformable, separated by a brief(?) erosional hiatus. In the Nechako Range at Kuyakuz Mountain, the felsic tuff marker at the top of the Entiako formation underlies greenstone of the Naglico formation. In the northeasternmost part of the range, pyroxene-phyric tuffs tentatively included in the Naglico formation because of lithologic similarities, may rest directly upon Toarcian sediments. Farther south along the axis of the Nechako range, a similar lower contact with Lower Jurassic strata is assumed and the upper contact is with a coarse clastic assemblage of probable early Callovian age.

Because of internal lithologic variability in rocks of the Naglico formation, no single section is representative, however, certain lithological features persist over broad areas. The primary lithologies include dark green and sometimes maroon, massive weathered flows of basalt and andesite. Augite phenocrysts are a diagnostic feature of these flows, commonly comprising 1 to 3 volume percent as vitreous prisms averaging between 1 and 2 millimetres long (in rare instances, 5 to 15 millimetres in length). Despite partial to complete replacement of augite by chlorite, epidote, carbonate and opaque granules, they generally retain their prismatic habit. Plagioclase is the primary constituent in all flows that include a number of textural varieties such as sparsely porphyritic, fine-grained crowded plagioclase porphyry to coarse-grained porphyry. Plagioclase is slender, less than 2 millimetres long, in amounts up to 35 volume percent in the crowded varieties. Elsewhere, it typically occurs as subhedral to idiomorphic equant and tabular phenocrysts between 2 and 4 millimetres in diameter, and rarely as large as 1 centimetre, in volumes between 15 and 20%. Amygdaloidal lavas are comparatively minor and contain rounded to irregular, quartz, epidote and chlorite-filled cavities. They locally grade into hematite-rich breccia in discontinuous layers and lenses less than 1 metre thick. Dense aphanitic basalts are commonly interlayered with the more voluminous porphyritic flow varieties. They are lava flows with a fine granular aphanitic texture that sometimes display millimetre-thick resistant laminae protruding from smooth weathered surfaces. Thin sections of these rocks reveal olivine and augite grains occupying interstices between plagioclase microlites. A representative suite, comprised of both pyroxene-bearing and aphanitic lavas, has a compositional range of basalt to basaltic andesite. Major and trace elements indicate they are subalkaline with a low-potassium tholeiitic to calcalkaline trend of island arc affinity.

Various pyroclastic rocks interlayered with the flows comprise a significant proportion of the Naglico formation, but an estimate of their relative proportion is difficult to determine due to highly variable conditions of preservation and exposure. In general, pyroclastic rocks predominate over flows in the central and eastern Entiako Spur and to the north-northeast across the headwaters of van Tine Creek, in the Fawnie Range. Maroon and green pyroclastic rocks are intercalated with flows in the central part of the Entiako Spur. They are composed predominantly of lapilli tuff in which the lithic fragments and the matrix contain abundant plagioclase and subordinate chloritized mafic minerals. A somewhat different succession of fragmental rocks is found intimately layered with the augite porphyry flows in the central and eastern parts of the spur. They consist of lapilli and lesser block-tuffs dominated by plagioclase-rich pyroclasts with a fine-grained, crowded texture. This distinctive texture is due to minute plagioclase up to 2 millimetres long in amounts up to 35 volume percent. Interbeds of ash-tuff and rare accretionary tuff are also present. Tuffs in shades of red and maroon and containing diagnostic quartz phenocrysts are widespread, with scattered exposures along the shoreline of Natalkuz Lake, and in parts of the western Entiako Spur, central and southern Fawnie Range and southern Nechako Range. Although these tuffs cover a wide area and look similiar, they are unlikely to be products of a single eruptive event, as they recur at different stratigraphic levels, typically in layers several metres to tens of metres thick, between aphanitic and pyroxene-phyric flows. Dark red, aphanitic lapilli rarely exceed 1.5 centimetres in diameter and occur in a matrix of plagioclase and ash. In many beds where the ash and crystals dominate over lithic fragments, layering is thinner and small-scale textural grading is noted. Quartz fragments are generally present, but because of their small size, typically about 1 to 2 millimetres in diameter, and low abundance (less than 2% and rarely to 5%) they are easily overlooked. The red coloration is due to finely comminuted hematite dispersed throughout the fragments and matrix. Oxidation of these rocks probably reflects their subaerial environment of deposition.

Fossiliferous sediments are only rarely in direct contact with volcanic rocks of the Naglico formation. Generally, these sedimentary rocks tend to comprise thin recessive beds that rarely crop out and are commonly found as angular sedimentary debris churned up in roadcuts and logging cutblocks, near more diagnostic lithologies of the Naglico formation. The main feature of these intervolcanic sediments is their immaturity, characterized by the high proportion of angular plagioclase and volcanic-lithic detritus. The dominant lithologies include feldspathic sandstone and siltstone, tuffaceous argillite, locally prominent volcanic conglomerate and scarce limestone. Fossils are nearly always present, varying in abundance from a few indeterminate belemnites and bivalves to zones containing a rich and varied fauna. A solitary sonninid ammonite extracted from limestone suggests a probable early Bajocian age for the Naglico formation underlying much of the Entiako Spur (Collection GSC C-143394; H.W. Tipper, Report J2-1994-HWT).

Presumably higher stratigraphy of the Naglico formation is exposed along the banks of the Blackwater River, beneath the waterfall located about 4.5 kilometres due west of the inflow to Tsacha Lake. Here medium and thick-bedded siltstone and arkosic sandstone predominate, with lenses of pebble conglomerate and minor limy interbeds. Fossils are abundant, including mainly thick-shelled bivalves and a few ammonites that suggest the section was deposited in a relatively high-energy marine environment, probably during latest early Bajocian or early late Bajocian time (Collection GSC C-203458; T.P. Poulton, Report J6-TPP-1995). Exposures above the waterfall pass into overlying younger rocks assumed to be Callovian; however, they unfortunately were not examined. Similar rocks about 1 kilometre to the northwest of the waterfall are poorly exposed in a section 20 metres thick at the base of a prominent east-trending ridge. The lowest beds consist of siltstone and fine-grained feldspathic sandstone, transitional into about 5 metres of fine volcanic conglomerate and coarse sandstone in the uppermost exposures. The lithic component is typically angular and of volcanic origin. Farther west, along strike, these rock pass into about 40 metres of lapilli and block-lapilli tuffs that alternate with thinner interbeds containing ash, crystals and fine lithic fragments.

The Naglico formation represents early constructional events of low-potassium tholeiitic and calcalkaline volcanics in an island arc setting. It is difficult to decipher from the volcanic units whether some represent submarine deposits. With the exception of one locality where hyaloclastite breccia was observed, scattered accretionary lapilli tuff layers, oxidized tuff beds and the paucity of pillow lavas in apparently thick massive lava sections, points to subaerial deposition. Scarce marine sediments comprised of a large proportion of angular feldspar and some volcanic-lithic fragments probably represent comparatively short-lived marine incursions onto the volcanic pile. However, there is no obvious explanation for the absence of pyroxene grains, if these sediments have an intrabasinal provenance.

AUGITE PORPHYRY PLUGS (UNIT mJap)

Augite porphyry plugs, typically less than 1.5 square kilometres in area, are exposed in the eastern part of Entiako Spur and south of Tommy Lakes. These plutons apparently intrude and bleach rocks of the Entiako formation. Their main feature is subhedral augite phenocrysts, which comprise as much as 25% of the rock, and plagioclase microphenocrysts arranged in a felty texture. The similar texture, mineralogy and spatial relationship of these plutons to volcanic rocks of the Naglico formation, lead to the conclusion that they may be cogenetic and possible feeder intrusions. Lithologically similar augite-phyric dikes and sills intrude sediments of the Entiako formation east of Fawnie Creek. However, without field evidence of an intrusive relationship, it would be impossible to distinguish these hypabyssal rocks from mafic extrusive flows of the Naglico formation or younger Nechako volcanics.

BOWSER LAKE GROUP

ASHMAN FORMATION (UNIT muJBA)

The Ashman Formation in the study area consists of possibly late Bathonian, early Callovian and possibly early Oxfordian clastic rocks that succeed the Naglico formation. It is subdivided into two interfingering clastic successions that represent contrasting depositional environments. The earliest deposits comprise a deeper water succession composed mainly of mudstone and siltstone with limy lenses and layers that are generally transitional, up-section and laterally, into an eastward thickened wedge of conglomerate interlayered with sandstone and siltstone. The coarser facies crops out mainly in the Nechako Range, occupying a belt that widens significantly to the north. It is thickest (possibly as much as 1500 m) along the axis of the northern Nechako Range and thins rapidly to the west where, across the Chedakuz Creek valley and farther west into the Fawnie Range, conglomerate diminishes to only a few rare lenses and beds within a predominantly finer siltstone and shale facies. The fine-grained facies is best exposed in the Fawnie Range where sections estimated at more than 150 metres thick occur intermittantly in a belt that extends along the lower east slope for about 9 kilometres, truncated in the south by an east-trending fault.

The Ashman Formation contrasts markedly in lithology and depositional environment with that of the underlying Naglico formation, suggesting the two units may be separated by a major unconformity. This contention is further supported by the lack of definitive upper Bajocian and Bathonian strata throughout the study area in the interval between a lower Callovian and possibly upper Bathonian fine-grained marine facies that comprises the base of the Ashman Formation, and the older, early Bajocian Naglico formation. Locally in the Fawnie Range there is a sharp conformable contact with overlying volcanic rocks that are tentatively considered to be Late Jurassic (*see* Nechako volcanics). The contact relationship in not as obvious in the Nechako Range where the upper contact is obscured by vegetation, but there is a similar general relationship of sediments succeeded by volcanics. The actual contact with underlying rocks has not been observed, although in the southern part of the Nechako Range volcanic rocks of the Naglico formation are always nearby, apparently beneath the sediments.

The finer clastic facies is mainly a sequence of black mudstone and some feldspathic sandstone beds. They weather recessively, resulting in poor exposures, most of which are found at widely spaced localities west of the Chedakuz Creek valley. The facies in the Fawnie Range is particularly well exposed in one bedded section exposed about 1 kilometre at 110° azimuth from Fawnie Nose. Here a section 75 metres thick consists mainly of rusty weathered, black siliceous mudstone with limy lenses and a few more resistant thick beds that include a lens of chert-pebble conglomerate, 2 to 5 metre-thick, and grey, fine-grained sandstone. The upper contact, which is exposed at several localities, is an abrupt change into stratigraphically overlying rhyolitic dust and welded ash-flow tuffs that, in turn, are overlain by dark green, andesitic crowded feldspar porphyry flows. Light coloured ash-tuff laminae in some of the uppermost mudstone beds may represent the initial pulse of explosive felsic volcanism near the end of mudstone deposition. Relatively sparse fossils are scattered throughout the mudstone, although the friable nature of these rocks makes collecting difficult. Fossils collected from along the belt of sediments in the Fawnie Range include the early Callovian ammonite, *Kepplerites* (Collection GSC 91762, H.W. Tipper), and perhaps *Iniskinites*(?) (Collection GSC C-143383; T.P. Poulton, Report J7-1992-TPP), which would indicate the presence of upper Bathonian strata. Mudstone several metres below the volcanic contact contains the bivalve *Anditrigonia* sp. aff. *plumasensis* (Hyatt) which probably indicates a range of Callovian or early Oxfordian (Collection GSC C-143726, T.P. Poulton, Report J9-TPP-1995).

Farther to the east, broadly coeval strata crop out discontinuously from the Kluskus-Ootsa road in the south, northward along the western side of the Chedakuz Creek valley bottom to a prominent point that marks the narrows between Knewstubb and Natalkuz lakes. The shoreline exposure at this locality consists of a section of lower sandstone with scarce chert pebbles, overlain by black mudstone containing large, differentially weathered calcareous concretions, which in turn is overlain by feldspathic sandstone. Above the sediments is an abrupt stratigraphic contact with basaltic flows and some tuffs characterized by coarse, vitreous pyroxene phenocrysts. The contact lacks evidence of erosion and is thought to be depositional, similar to that observed with volcanic rocks in the Fawnie Range. Corresponding sedimentary strata were previously mapped along the Nechako River to the north, but are now submerged beneath Knewstubb Lake. Mudstone exposed at this site is reported to contain abundant calcareous concretions, each containing an ammonite identified as the early Callovian species *Lilloettia tipperi* (Collection GSC 21885; H.W. Tipper, 1963). Coextensive lithologic units continue south of the Nechako Reservoir, indicated by the presence and probable identification of the ammonite *Lilloettia* (Collection GSC C-143712, H.W. Tipper, personal communication, 1994). These sediments display some fundamental differences from those exposed to the north, including general coarsening, evidenced by an increased proportion of coarse feldspathic sandstone and the rare occurrence of chert granule and pebble interbeds; mudstone is a comparatively lesser component generally occurring as only minor thin interbeds. Abundant fossils, including thick-shelled bivalves, belemnites, gastropods, worm burrows and wood debris suggest a shallow-marine, high-energy environment (Collection GSC C-143712, T.P.

Poulton, Report J6-TPP-1995). The sandstones are typically dark green and contain angular grains of pyroxene, some delicate resorbed volcanic quartz, plagioclase and lithic clasts of very fine feldspar porphyries. The provenance is suspected to be local, perhaps from the underlying Naglico and Entiako formations. Grains of potassic detritus, confirmed by staining, are also present in the matrix of chert-pebble conglomerate and it may reveal local downcutting through the Naglico formation and erosion of felsic rocks from the older Entiako formation. Excluding the chert beds, these strata extend westward to a small creek north of Top Lake where friable black mudstone with limy concretions and some resistant feldspathic sandstone layers up to 2 metres thick are exposed. Diverse fauna at this site include at least four species of early Callovian ammonites and numerous other less diagnostic fossils (Collection GSC C-143395; H. W. Tipper, Report J2-1994-HWT and T.P. Poulton, Report J7-1995-TPP).

Ashman strata that comprise meagre exposures along the lower eastern slope of the northern Fawnie Range, described above, are possibly between 900 and 1500 metres thick in the northern Nechako Range, only 15 kilometres to the east across the Chedakuz Creek valley. For this reason the Ashman Formation is thought to perhaps underlie the entire Chedakuz Creek valley, although this is difficult to prove because a thick mantle of till obscures bedrock beneath the valley. In the Nechako Range, the northwest-trending belt of Ashman strata is segmented by faults trending both parallel and transverse to the belt. The thickest continuous exposures underlie the northernmost segment which is bounded on the south by the Brewster fault. The nature of the contacts is conjectural because of poor exposure, however, here the Ashman Formation is thought to be unconformable on sediments of the Entiako formation and possibly the Naglico formation, and it is overlain by the Nechako volcanics.

Chert-bearing conglomerates are very abundant in the Nechako Range, locally accounting for as much as 40% of the Ashman Formation. Siltstone, sandstone and mudstone predominate, generally forming the better layered intervals between more massive, thick conglomerate interbeds and lenses. The conglomerates are typically a clast-supported aggregate of well rounded spherical pebbles and small cobbles that commonly fine upwards into tops with isolated clasts supported in sandstone and siltstone. The matrix is composed of a finer mixture of granules and coarse sandstone compositionally consanguineous with the framework clasts. The framework clasts are characterized by chert which is found in translucent shades of grey, green, off-white and black. Black, oblate mudstone clasts are also common. The proportion of siltstone, sandstone and mudstone varies from place to place, but the latter is least abundant, generally evident as thin beds with shaly partings. The sandstones are characteristically light grey, with a salt and pepper appearance imparted by tightly packed subangular grains typically between 0.5 and 1 millimetre in diameter. In thin section the grains appear to be chert(?) and mudstone varieties with some apparently containing microfossils. Siltstone may weather light green, contrasting with the general grey coloration of the sandstone and conglomeratic beds. Locally the siltstone may have a distinctive differentially weathered surface characterized by randomly distributed voids and indentations. Bedding is typically planar, the contacts are sharp and lack evidence of scours or channels and internal traction bedforms are rarely seen; where present they constitute shallow planar crosslaminations in some of the sandstone and finer layers. Thin coal beds are found in the chert unit exposed along the Red road (Kennecott Canada Inc., personal communication, 1995); these deposits are just outside the study area.

Rare, indeterminate shelly fauna and a single ammonite impression (Collection GSC C-56989; H.W. Tipper, Report J7-1994-HWT) provide little information on the age of the clastic assemblage in the Nechako Range. However, because of the similarity to fossiliferous strata farther west, they are believed to be at least of Early Callovian age, and pre-Kimmeridgian based on the isotopic age from the immediately overlying Nechako volcanics. The coarse clastic deposits in the Nechako Range are interpreted to represent deposition in a moderately deep marine-delta slope environment.

Unlike the strata along the western side of the Chedakuz Creek valley, systematic staining of a large suite of conglomerates and sandstones from the Nechako Range did not reveal the presence of any potassic detritus. This suggests that the Nechako Range area received a high influx of compositionally uniform chert detritus from an extrabasinal source throughout its history. In the vicinity of the Fawnie Range some of this chert detritus was at times carried farther west into deeper water, forming sparse, discrete layers in mudstone. In the intervening area of the Chedakuz valley, shoaling resulted in periodic mixing of sorted chert with immature detritus shed from a local volcanic source. Paleocurrent directions could not be determined from outcrops in the study area, hampering attempts to infer transport direction. The most probable source of the chert is the Cache Creek Terrane, now exposed only 70 kilometres to the northeast. However, because of the absence of mafic volcanic or carbonate clasts in deposits in the study area, a short, direct drainage corridor connecting the source region with a basin, situated in part over the study area, is questionable. Chert clasts are characteristically well sorted and spherical implying considerable transport or perhaps extensive and prolonged reworking.

Basalt dikes and a few sills(?), characterized by fresh pyroxene phenocrysts, cut and alter sediments of the Ashman Formation at several localities in the northern Nechako Range. These rocks are intrepreted as feeder dikes for lavas of the stratigraphically overlying Nechako volcanics.

NECHAKO VOLCANICS (UNIT uJB$_N$)

The informally named Nechako volcanics are a sequence of silica bimodal flows and pyroclastic deposits that abruptly overlie sedimentary rocks of the Ashman Formation. The lower contact of the Nechako volcanics rests directly on the Ashman Formation in the Fawnie Range. At the reference section in the northern Nechako Range, the Nechako volcanics are separated from the Ashman Formation to the east by an apparent angular unconformity. Bedding in the lowest exposed volcanic members dips steeply at about 70° to the west, whereas the topographically lower sediments face west, dipping at about 40°. Because the overlying volcanic package has many lithologic features in common with rocks of the Naglico formation, it was originally assigned to it and the contact interpreted as a thrust fault that appeared to place a panel dominated by mafic volcanic rocks structurally above the younger Ashman Formation (Diakow *et al.*, 1995c). A new Late Jurassic $^{40}Ar/^{39}Ar$ plateau age on very coarse hornblende from a flow at the base of the volcanic succession is 152±2 Ma (Kimmeridgian), indicating general stratigraphic continuity with the underlying Ashman Formation, which may be as young as early Oxfordian(?). In addition to the localities mentioned above, other exposures considered to represent the Nechako volcanics include roadcuts along the Kluskus-Ootsa forest service road immediately north of Top Lake and, several remote areas of outcrop in the western Naglico Hills and southern Nechako Range, south of Kuyakuz Lake.

The reference section for the Nechako volcanics is a thick succession of mafic flows and tuffs exposed along the west-facing slope of the northern Nechako Range. The hallmark of the mafic package is the presence of commonly coarse (5 to 7 mm) vitreous pyroxene in flows that are more voluminous than associated ash and lapilli tuffs. A hornblende-bearing flow at the base of the section is the only occurrence known anywhere in the study area. Glassy black hornblende and pyroxene commonly range from 0.3 to 1 centimetre long, with some as long as 2.5 centimetres. This flow is interlayered with block tuff containing pyroxene-phyric pyroclasts. Furthest west and presumably up section, the mafic unit passes into rhyolitic lapilli tuff and some flows. Although a contact was nowhere observed, brittle shearing and mylonitized felsic tuffs in several outcrops indicate the units may be juxtaposed against the mafic package across the Chedakuz fault which follows the base of the range. The felsic unit contains bone white, flow-laminated and aphanitic rhyolite pyroclasts in a matrix with 1 to 2% volcanic quartz and potassium feldspar phenocrysts.

Rocks tentatively assigned to the Nechako volcanics succeed the belt of Ashman sediments in the Fawnie Range. At the top of the Ashman Formation east of Fawnie Nose, the bottom of the volcanic sequence is locally marked either by off-white rhyolite ash-flow tuff and ash tuff or andesite porphyry flow members in depositional contact with underlying late Bathonian or early Callovian black mudstone. Above this contact exposure is discontinuous and largely unmapped, passing farther west and up-section into cliffs, bounding the ridge on the east, that exhibit a continuous, crudely bedded west-southwest-inclined volcanic sequence that persists to the ridge axis. This sequence, which is more than 350 metres thick, consists of mafic flows, some containing vitreous pyroxene, interlayered with dacitic to rhyolitic volcanics and thin intervals of variegated maroon and green ash-tuffs. Somewhat different rhyolite is exposed along the ridge axis, capping the previously described volcanic section. It is considered to be an erosional remnant of an Upper Cretaceous volcanic member that is stratigraphically above probable Nechako volcanics (*see* Unnamed Volcanic Rocks at Hoult Lake and in the Northern Fawnie Range).

The most southerly extent of the Nechako volcanics is in the Naglico Hills where they overlie rocks of the Naglico formation. The main lithologies are felsic tuffs composed of aphanitic off-white lapilli in a light green matrix. The fragmental rocks are interlayered with augite-bearing basalt flows and locally with welded dacite. In the central part of the study area, immediately north of Top Lake, the Naglico formation is confined to a fault block lodged against Eocene strata to the south across the Top Lake fault. Early Callovian fossiliferous sediments crop out about 2 kilometres southwest of an area underlain by volcanic rocks, believed to be up-section and representative of the Nechako volcanics. These rocks are mainly basaltic flows with coarse, fresh pyroxene, some up to 1.5 centimetres long. A bedded section along the main access road at Top Lake consists of interlayered volcanic conglomerate and some epiclastic sandstone interbeds with pyroxene detritus, pyroxene-bearing mafic flows and lesser ash-tuff with accretionary lapilli horizons. Locally, interbeds of pyroxene-rich sandstone contain abundant bivalves.

It is difficult to distinguish between mafic volcanic units of the Naglico formation and those of the Nechako volcanics. The problem is critical, particularly in the Nechako Range where two belts with similar lithologic characteristics and alteration are exposed. In the absence of a distinctive recognizable lithologic datum below the units, such as the Ashman Formation, they are inseparable. Outcrop at several of the localities described above is discontinuous and Ashman sediments are absent or some distance away from the first exposures of mafic rocks. At these sites the presence of rhyolitic volcanics, either tuffs or flows, with the ubiquitous pyroxene-phyric mafic volcanics serves to distinguish the Nechako volcanics. Geochemistry might prove useful discriminating these units, but this possibility was not systematically tested.

CRETACEOUS ROCKS

UNNAMED VOLCANIC ROCKS IN THE WESTERN NAGLICO HILLS (UNIT lK_v)

Map unit lK_v comprises rare biotite-phyric dacitic lava flows exposed at two sites 700 metres apart in the western Naglico Hills. The contacts with bounding strata are covered, however, dacitic flows about 30 metres thick presumably cap mafic volcanics assigned to the Naglico formation on a prominent knoll and, at another nearby locality, they also crop out between tuffs of the Nechako volcanics, and immediately down slope from overlying basaltic flows of the Chilcotin Group. The rocks contain biotite (1-2%) and plagioclase (25%) phenocrysts arranged in trachytic texture in black, variably devitrified fluidal-banded glass. A K-Ar date on biotite from the dacite is 144±4 Ma.

CAPOOSE BATHOLITH (UNIT EKc)

The Capoose batholith underlies a broad region in the southwestern half of the study area. At its northwestern extremity, it is juxtaposed against Paleogene volcanic rocks across the Natalkuz fault. The main mass of the batholith lies to the southeast, outcropping extensively between the Entiako River and van Tine Creek. It continues at depth to the south, beneath a thin roof of altered volcanic rocks that comprise the backbone of the Entiako Spur, cropping out again along the south-facing slope down to Laidman and Moose lakes, and beyond to its southern contact in the Naglico Hills. Thick glacial drift mantles the batholith in the valley between the Entiako Spur and the Naglico Hills, however, farther east exposure improves locally with increasing elevation up the west-facing slope of the Fawnie Range. The Capoose batholith has a strong magnetic response identified in a recent regional aeromagnetic survey covering part of the study area (GSC Open File 2785). Beyond the main exposures of the batholith, strong magnetic anomalies extend to the south beyond the study area, and also to the east where they coincide with widespread propylitically altered country rocks and rare exposure of granitic rocks in the region east of Tsacha Mountain and the eastern Naglico Hills. These features undoubtedly indicate the presence of larger, near-surface plutons that may be extensions of the Capoose batholith. A time-domain electromagnetic survey has proved useful for mapping the margin of the batholith in areas of thick drift cover (Best *et al.*, 1996).

The main phase of the batholith is homogeneous medium to coarse-grained equigranular quartz monzonite. The rock is typically light pink and has a hypiodomorphic-granular texture imparted by 35% quartz, roughly equal proportions of alkali feldspar and plagioclase, about 10 to 15% combined fresh hornblende and biotite, and trace amounts of microscopic idiomorphic titanite. Xenoliths are abundant in the pluton and composed of fine-grained porphyry with randomly oriented plagioclase laths less than 1 millimetre long and an interstitial anhedral mafic mineral, possibly hornblende. Quartz monzonite is gradational into a porphyritic monzonite phase that is most common south of Moose Lake. Plagioclase phenocrysts in this rock are subhedral and approximately 5 millimetres long, forming an interlocking aggregate with anhedral potassium feldspar, approximately 10% quartz and 5% hornblende and biotite. A small isolated stock, south of the main body in the Naglico Hills, may represent yet another phase of the batholith. It consists for the most part of white, equigranular granodiorite with up to 15% chloritized mafic minerals. Coarse potassium feldspar phenocrysts, and chloritized plagioclase and biotite, occur locally along the northern margin this satellite pluton.

The contact zone of the Capoose batholith is locally marked by thermally altered rocks. Between Mount Swannell and Fawnie Nose the contact between the batholith and country rocks appears to be a relatively planar surface gently inclined toward the east beneath the Fawnie Range. Alteration associated with the intrusion varies from intense silicification immediately adjacent to the contact, outward to a zone of hornfels alteration up to 1 kilometre wide, that is characterized by destruction of primary volcanic textures and the local development of patchy secondary biotite. Intensely altered rocks, localized below Tutiai Mountain and nearest the intrusion, are characterized by pervasive replacement of the primary minerals in mafic to intermediate volcanic rocks by fine-grained silica. These rocks commonly grade imperceptibly, over just a few metres, into an assemblage of silica and pyrite, with or without clay minerals. Disseminated pyrite is particularly abundant (up to 15% by volume) in rocks around Green Lake where it is oxidized and forms an extensive gossan. Minor sericite accompanies the quartz-pyrite assemblage in this area. On the southwest side of Tutiai Mountain the silicified zone is at least 100 metres wide and probably wider, as exposure continues down slope where it is obscured by cover. This silicified zone passes abruptly outward into a broad zone of dense, baked country rocks that are typically dark grey-green and recrystallized. Alteration is also extensive throughout the Entiako Spur where volcanic strata of the Naglico and Entiako formations comprise a relatively thin cover above the batholith. The altered rocks consist of an epidote-quartz-calcite±garnet assemblage. These minerals are most evident lining fractures, as veins and incipient replacement of groundmass and primary minerals.

The age of the Capoose batholith is equivocal as available K-Ar dates derived during this study are contradictory, and another date from a previous study (Andrew, 1988) indicate the presence of a much younger, Late Cretaceous pluton. Uranium-lead geochronology of the batholith is in progress at the University of British Columbia, but age determinations were not yet available at the time of writing. Coexisting biotite and hornblende from quartz monzonite exposed along the southern slope of the Entiako Spur give

K-Ar ages of 141±4 Ma and 201±6 Ma, respectively. The biotite date is interpreted as a cooling age and, the considerably older date derived from hornblende is attributed to excess radiogenic argon. Nearby, similar quartz monzonite dikes intrude diorite that yields a congruent K-Ar biotite date of 142±4 Ma and an erroneous K-Ar hornblende date of 105±4 Ma. The older diorite possibly records resetting of biotite during cooling of crosscutting quartz monzonite, and simultaneous argon diffusion from coexisting hornblende to account for the substantially younger date. Field relationships indicate the batholith is younger than fossiliferous early Bajocian strata that it thermally alters near where the intrusion is dated. If the Early Cretaceous age (*ca.* 141 Ma) for the Capoose batholith is correct, it indicates a temporal equivalence with rare exposures of possibly cogenetic dacite flows described above (*i.e.*, lK_V).

SEDIMENTARY ROCKS ALONG THE ENTIAKO RIVER (UNIT lKs)

Lower Cretaceous sediments crop out at a single site adjacent to the Natalkuz fault where it cuts across the mouth of the Entiako River. This small exposure consists of about 6 metres of interlayered black mudstone and dark green siltstone. The sediments are faulted against probable Eocene volcanic rocks. Palynomorphs recovered from a thin layer of carbonaceous plant debris are tentatively identified as late Albian to early Cenomanian species (Collection GSC 143390; G. Rouse, 1993, internal report). Near Hoult Lake, a small, isolated exposure of grey siltstone, and 20 metres of bedded chert sandstone to coaly mudstone in another nearby outcrop may represent Lower Cretaceous strata north of the Natalkuz fault. A sample was barren of palynomorphs, making a definitive stratigraphic determination of these rocks difficult. The lithology and inferred age of these sediments implies they are correlative with the Skeena Group which is widespread throughout much of the northern Interior Plateau (Hunt, 1992).

UNNAMED VOLCANICS AT HOULT LAKE AND IN THE NORTHERN FAWNIE RANGE (UNIT uKv)

Upper Cretaceous volcanic rocks of differing lithology and composition are exposed in two widely separated areas, at substantially different elevations, on opposite sides of the Natalkuz fault. North of the Nechako Reservoir, scattered exposures of Upper Cretaceous rocks occupy a belt trending towards Hoult Lake. They may unconformably overlie recessive grey and black siltstone resembling strata of the Skeena Group, but because exposure is poor and the contact zone is covered, this relationship cannot be proven. Eocene volcanic rocks of the Ootsa Lake Group, exposed nearby, presumably are unconformable on the Upper Cretaceous volcanics. These Cretaceous volcanics are generally everywhere the same, composed of block-lapilli tuff and volcanic breccia in which the pyroclasts are characteristically monolithic, grey-green or purple hornblende-phyric andesite that are up to 15 centimetres in diameter. Plagioclase crystals between 1 and 3 millimetres long comprise up to 35% of the rock, accompanied by 5% hornblende as long as 4 millimetres. Pristine vitreous common hornblende, dated by the K-Ar method, indicate they crystallized around 64.5±1.8 Ma. This latest Cretaceous volcanic episode is represented elsewhere in the Nechako River map area by compositionally similar hornblende-phyric andesite flows, near Holy Cross Mountain, that yield a preliminary K-Ar date of 70.3±3 Ma (R.M. Friedman, personal communication, 1996).

In the northern Fawnie Range probable Upper Cretaceous rhyolitic rocks form a series of isolated exposures that cap the ridge crest above 1700 metres elevation. They are apparently conformable with underlying rocks of either the Nechako volcanics or the Ashman Formation. The rhyolitic rocks consist of lava flows, welded ash-flow tuff and some interbedded ash and crystal tuffs. Subtle flow laminae are locally evident, but most flows are massive and typically grey or off-white, dense siliceous rocks. These flows may be coeval and perhaps genetically related to a variety of garnet-bearing rhyolitic hypabyssal rocks that have demonstrable intrusive relationships with volcanics stratigraphically down-section from the capping rhyolites.

Maastrichtian rhyolitic and andestic volcanics in the study area correlate with nearly identical strata mapped locally in the Whitesail Range and at Mount Ney (NTS 93E/14 and 11), respectively; at the latter locality Maastrichtian rhyolite conformably overlies hornblende-phyric andesitic rocks more typical of the Kasalka Group (Diakow, unpublished data). If Maastrichtian rocks in the study area are in fact part of the Kasalka Group, they represent a discrete felsic event that terminates a protracted interval of episodic continental arc magmatism spanning roughly 30 million years, which, in its youngest eruptive phase, extended across the breadth of Stikinia.

RHYOLITIC SILLS AND DIKES (UNITS LKr AND LKf)

On the Capoose property in the the northern Fawnie Range, Andrew (1988) distinguished several varieties of dikes and sills which commonly vary from 2 to 20 metres thick, generally trending northwest and moderately inclined (<30°) southwest. Features common to most of these intrusions include their rhyolitic composition, the ubiquitous presence of garnets as aggregates of small brown crystals, and resorbed quartz phenocrysts (unit LKr). Some intrusions actually resemble flows with finely laminated and spherulitic textures. Within some very thick rhyolitic sills(?) round spherulite-like balls, between 2 and 25 centimetres in diameter, occupy crude layers within otherwise massive, aphanitic rocks.

Potassium-argon age determinations on whole rocks from the sills range from 68.4 to 70.3 Ma, with the youngest sill dated at 64.3 Ma (Andrew, 1988). Uranium-lead zircon geochronometry on identical garnetiferous rhyolite sills in the Fawnie Range suggests two distinct magmatic episodes (R.M. Friedman, personal communication, 1996). A younger Maastrichtian (*ca.* 70 Ma) U-Pb date was obtained from massive aphanitic rhyolite that underlies the upper part of a prominent rusty knoll on the Capoose property. These data corroborate K-Ar geochronometry on the same rock reported by Andrew (1988). Andrew also obtained a K-Ar biotite date of 67.1±2.3 Ma on quartz monzonite near Capoose Lake, which she interpreted to be comagmatic with coeval garnet-bearing sills on the nearby Capoose property. An older U-Pb zircon date (*ca.* 140 Ma.) obtained from a sill that intrudes early Callovian fossiliferous sediments, lower on the east side of the knoll, is coeval with Early Cretaceous K-Ar dates obtained from the Capoose batholith in the Entiako Spur area. Although our mapping failed to discriminate the separate plutons, together these age determinations suggest the possibility of two similar quartz monzonite bodies, each associated with age-equivalent subvolcanic felsic sills.

Greyish green fine-grained crystalline felsite sills (unit LKf), that characteristically contain up to 5% minute biotite grains, are confined to the area around Tommy Lake in the southeast corner of map sheet 93F/3. These rocks crop out sporadically over a broad area, and are locally concordant with gently south dipping sediments and volcanics of the Naglico formation. One isolated remnant rests directly on a probable Middle Jurassic augite porphyry plug (unit MJap). These sills also cut across mineralized quartz veins at the Tsacha prospect, where a U-Pb zircon date indicates latest Cretaceous emplacement (R.M. Friedman, personal communication, 1996). The sills weather to porcellaneous, conchoidally fractured fragments. Sparse plagioclase phenocrysts, up to 4 millimetres long, are observed on the fine-granular weathered surface.

LATE CRETACEOUS (?) DIORITIC PLUTONS (UNIT LKd)

Unit LKd includes widely distributed dioritic stocks in the central and southern Chedakuz Creek valley and throughout the Nechako Range. Dioritic rocks in the Nechako Range consist of numerous small dikes and clusters of small, poor exposures that have been portrayed on the map as larger cohesive stocks. They consist of dull mottled dark greenish white fine to medium-grained pyroxene and plagioclase with a hypidiomorphic-granular texture. These plutons are undeformed but intrude the penetratively cleaved Upper Jurassic and older strata underlying the range. The age of these plutons is unknown; an attempt to date rocks from the largest body in the northern Nechako Range by U-Pb zircon geochonometry was thwarted by the absence of zircon.

The plutons exposed in the Chedakuz valley are grouped with those in the Nechako Range only on the basis of similar bulk composition. They are exposed through thick till and Neogene lavas that occupy the valley. The plutons in the central part of the valley appear to cut pyritized rocks of the Middle Jurassic Ashman Formation and are composed, for the most part, of fresh medium-grained equigranular diorite, and a local coarse-grained pyroxene-rich phase. The main dioritic phase of these plutons is very similar to the stock just north of Tsacha Lake.

PALEOGENE ROCKS

Paleogene rocks in the study area include the mid-Eocene Ootsa Lake Group and younger Endako Group. The Ootsa Lake Group forms a semicontinuous volcanic field in the central Nechako River (Tipper, 1963) and eastern Anahim Lake areas (Tipper, 1969, Metcalfe *et al.*, 1996). Their continuity is interrupted in the study area by a medial zone of widely exposed Jurassic rocks that delineate the Nechako uplift. Rocks of the Ootsa Lake Group thin dramatically over the uplifted region, forming scattered remnants that unconformably overlie Mesozoic rocks. The Nechako uplift evidently restricted the distribution of the Endako Group largely to the topographically subdued region to the north, where gently inclined flows are unconformable on the Ootsa Lake Group and, farther south, onlap Mesozoic rocks.

OOTSA LAKE GROUP (UNIT EO)

The type area for the Ootsa Lake Group is in the Whitesail Lake map area (Duffell, 1959). Here detailed studies on the Whitesail Volcanic Complex and other outliers indicate a brief eruptive history of continental volcanism, inferred from eleven K-Ar dates between 47 and 53 Ma, producing high-potassium calcalkaline rhyolite and lesser andesite flows and associated fragmental rocks (Drobe, 1991; Diakow *et al.*, in preparation). Remarkably similar mid-Eocene volcanic strata extend to the east into the study area, where they are most widespread immediately north of the Natalkuz fault. The fault roughly demarcates the southern margin of the extensive Ootsa volcanic field in central Nechako River map area against older basement of the Nechako uplift. South of the fault, Ootsa Lake volcanic strata form outliers that cap high-standing Jurassic rocks along the Fawnie Range and Entiako Spur. Except for a small area of rhyolites exposed low down along the eastern slope of the southern Nechako Range the Ootsa Lake Group was not found elsewhere in the uplifted region east of the Fawnie Range.

North of the Natalkuz fault, crudely layered Ootsa Lake strata unconformably overlie Upper Cretaceous volcanics and have an estimated minimum composite thickness of 450 metres. The lowermost unit consists of dark grey, massive and amygdaloidal andesite flows with amygdules infilled by silica, calcite and epidote. These flows are minor members within a gradationally overlying bladed-feldspar porphyritic andesite section that is locally up to 100 metres thick. Typically these rocks are dark grey-green and contain diagnostic plagioclase laths between 5 and 15 millimetres long (20-40% by volume) and pyroxene (5-10% by volume). These units generally appear beneath an upper, conformable section of felsic rocks made up of volumetrically minor dacite flows and more prevalent rhyolite flows and tuffs. The dacitic rocks, which commonly weather to flaggy porcellaneous fragments, are light green or grey and contain tabular feldspar phenocrysts 2 to 3 millimetres long (5-10% by volume) and slender hornblende phenocrysts 1 to 3 millimetres long. Rhyolitic rocks occupy the stratigraphic top of the Eocene sequence north of the Natalkuz fault. They consist primarily of flows, and occasionally recessive air-fall tuffs are preserved. The flows are typically chalky white and pink coloured and display a variety of textures that includes porphyritic and thinly laminated flows, massive flows and flow breccias, and rare interlayered pitchstones. Spherulites are common in rocks that have undergone varying degrees of devitrification. Phenocrysts up to 3 millimetres in diameter comprise up to 20% of the rhyolite flows and include, in order of abundance, plagioclase, potassium feldspar, quartz (<3%) and biotite (1-2%). Air-fall tuffs, sometimes interlayered with the rhyolite flows, consist of white and light green, massive to well bedded ash, crystal, crystal-lapilli and lapilli-block tuffs. A section of graded crystal-lapilli tuffs more than 200 metres thick crops out along the north side of Natalkuz Lake, almost directly north of Jim Smith Point. The tuffs contain a phenocryst assemblage of feldspar, quartz and biotite. Lithic fragments are fine grained, subangular to angular and predominantly felsic volcanic rocks. Carbonized wood fragments and rare upright tree trunks observed in the rhyolitic tuff unit attest to subaerial deposition. A massive aphanitic rhyolite, with conspicuous parallel joints, is exposed in the canyon walls along the Entiako River near its confluence with the Nechako Reservoir. This rhyolite is interpreted as a possible subvolcanic dome that has intruded along the Natalkuz fault and warped the peripheral Eocene flows, tuffs and Cretaceous sediments into a broad antiformal structure.

South of the Natalkuz fault rocks of the Ootsa Lake Group form three widely separated outliers.The largest covers more than 100 square kilometres between the Top Lake valley and a narrower valley separating Mount Davidson and Tsacha Mountain. Northeast-trending, steeply dipping normal faults trace through these valleys, placing Eocene rocks against fault blocks underlain by Jurassic formations. Other northerly and northeasterly trending faults locally disrupt the Eocene strata. Movement on some of these structures is synchronous with and postdates deposition of the Eocene rocks.

Stratigraphy in the Mount Davidson outlier consists of two lithologically distinct rhyolite flow and pyroclastic members that bound an intervening andesite flow member. The lower rhyolite bears a close lithologic resemblance to rocks forming the top of the Eocene sequence north of the Natalkuz fault. It consists of off-white, mauve and pale green flows, interflow breccia, and scarce lapilli tuff. Typically these rhyolitic rocks have thinly laminated and aphyric textures, however, some are sparsely porphyritic and contain plagioclase, quartz and biotite phenocrysts. Fine laminae in the flows are commonly overgrown in part by spherulites, which coalesce and form discontinuous layers that obscure the primary textures. Scarce lithophysae are also present. The middle andesite member is mainly composed of massive flows, with lesser flow breccia and some laharic deposits that conformably overlie rhyolitic rocks. The flows contain slender plagioclase phenocrysts up to 6 millimetres long and sometimes rounded amygdules, filled with chlorite and opalescent and crystalline silica, set in a dark green groundmass. The lithologic similarity of these rocks to those of the Naglico formation and Nechako volcanics makes separating the successions difficult. In general, Eocene andesites in the area are relatively unaltered and vitreous pyroxene, although present, is more abundant in the Jurassic rocks. Nevertheless these andesite flows are very difficult to distinguish from the older andesites unless found in close proximity to each other. The upper rhyolite member consists of pyroclastic flows and related tuffs that thicken locally to 250 metres within a small volcanic subsidence structure centred on Mount Davidson. The rocks thin outward from the main area of subsidence, with the farthest outcrops north of Top Lake and south of Tsacha Mountain forming isolated exposures that rest directly on Jurassic rocks. The main lithology is massive, blocky weathered, uniformly welded ash-flow tuff that forms resistant benches, some dominated by cooling features resembling columnal joints. The ash-flows typically contain up to 35% broken crystals, usually less than 3 millimetres in diameter, and lithic fragments within a grey indurated matrix. Quartz is very diagnostic (3-10%), commonly occurring as clear euhedra between 1 and 4 millimetres in diameter. The lithic fragments are mainly porphyritic lapilli and fewer blocks of andesitic composition. Thin discontinuous volcaniclastic-epiclastic deposits locally cap the upper rhyolitic member along the Mount Davidson ridge. These deposits are only a few to 10 metres thick and consist of poorly sorted blocks and lapilli beds, and less common mudstone and siltstone interbeds. The fragments are subangular to subrounded and consist of coarse-grained plagioclase and pyroxene that resemble andesitic flows characteristic of the Naglico formation. Quartz and some biotite grains are found with plagioclase in the matrix of the coarse deposit and some of the finer grained beds. These remnants are interpreted as post-subsidence fill, derived in part from high-standing Jurassic rocks and deposited with thin lacustrine mudstone and siltstone over locally subsided ash-flow tuff.

A variety of small hypabyssal intrusions are found in the Davidson outlier, but none are particularily prominent. Rhyolite, thought to represent a high-level intrusive dome, is exposed immediately southwest of Top Lake. It is similar to the dome that intrudes the Natalkuz fault at the mouth of the Entiako River. It consists exclusively of monolithic, aphanitic rhyolite breccia fragments loosely packed in a finer grained rhyolitic matrix. This deposit may represent the breccia carapace of a near-surface pluton or talus breccia of a small plug dome. Biotite-plagioclase porphyry sills and dikes of dacitic composition intrude the upper rhyolite member. Typically they weather to a light green or grey rock containing up to 10% chloritized euhedral biotite between 1 and 3 millimetres in diameter, up to 20% subhedral plagioclase up to 5 millimetres in diameter and, in places, trace quartz phenocrysts.

Eocene outliers elsewhere in the uplifted region are mainly dominated by quartz-bearing rhyolitic flows and associated fragmental rocks. A cluster of exposures sporadically caps Jurassic rocks along the northeast side of the northern Fawnie Range. Eocene rocks north of Entiako Lake are dominated by thinly laminated andesite and quartz-phyric rhyolite flows that nonconfomably overlie the Capoose batholith. Farther south, near Cow Lake, discontinuous Eocene rocks cover about 20 square kilometres with the best exposures occurring on three isolated hills north of the lake. The sequence is relatively thin, about 150 to 175 metres thick, dipping gently westward above an unconformable contact with underlying Jurassic sedimentary and volcanic rocks. The base is locally marked by an oligomictic orthoconglomerate about 20 metres thick composed of well rounded hornblende-biotite quartz monzonite and aplite clasts up to 1.3 metres in diameter. The texture and mineralogic features of the clasts suggest local derivation from the Capoose batholith. Quartz-phyric rhyolite flows are the predominant lithology and are interlayered with some welded tuffs and unwelded ash and lithic-rich beds. Tuffaceous siltstone and sandstone of probable lacustrine origin locally comprise a bedded section 3 metres thick beneath conformably overlying rhyolite. A sill-like body and rhyolitic dikes, interpreted as synvolcanic hypabyssal rocks, intrude the lavas. They have a medium to coarse-grained porphyritic texture imparted by plagioclase, potassium feldspar megacrysts and quartz.

The ages of the volcanic rocks assigned to the Ootsa Lake Group in the study area are established by K-Ar radiometric dates. North of the Natalkuz fault, on an island approximately 1 kilometre east of Jim Smith Point, a rhyodacite flow member contains vitreous biotite dated at 49.2±1 Ma. It is one of the fresher members of a laterally extensive, incipiently altered rhyolitic member that comprises the top of the Ootsa Lake Group north of the fault. Nearby, leaves and palynomorphs identified as mid-Eocene forms (Collection C-143387; G. Rouse, internal report, 1993) were recovered from an interval of laminated tuffaceous siltstone and lithic wacke that locally overlies rhyolite breccia, and is sharply overlain by lavas of the Endako Group. At the Cow Lake outlier, rhyolitic volcanic rocks and the subvolcanic intrusion into the upper part of the flow succession yield three whole-rock K-Ar dates varying from 47.6±1.7 to 49.9±1.7 Ma (Andrew, 1988).

EOCENE INTRUSIVE ROCKS (UNITS ECH AND Eqfp)

The CH stock (unit ECH) is the largest dated Eocene intrusion in the study area. It is a circular body that intrudes and thermally alters strongly sheared Middle Jurassic sedimentary and volcanic rocks in the central Nechako Range. The pluton itself is undeformed, composed of equigranular to slightly porphyritic biotite-hornblende granodiorite in which the mafic minerals are fresh and locally comprise 15% of the rock. The stock has returned K-Ar dates of 51.8±1.8 Ma and 48.8±1.3 Ma on coexisting hornblende and biotite, respectively. These dates are similar to an unpublished crystallization age determined from the pluton by U-Pb zircon geochronology (R.M. Friedman, personal communication, 1996). Pervasively altered rocks, locally forming a narrow envelope along the northeast margin of the intrusion, are bleached and rusty, containing an assemblage of pyrite, clay minerals, quartz and sericite, with or without garnet and secondary biotite. The sharp eastern contact of the CH pluton appears to dip steeply under altered country rocks. Molybdenum mineralization on the CH property to the east is associated with granitic rocks, but their relationship with the dated intrusion remains conjectural.

Elsewhere in the Nechako Range, granodiorite similar to the CH stock contains quartz-molybdenite veins and disseminated chalcopyrite. Scattered outcrops of coarse equigranular granite are mapped on the heavily forested western slope of Nechako Range, south of Tatelkuz Lake. A strong aeromagnetic signature, corresponding with this intrusion, is comparable to another magnetic anomaly farther south (GSC Open File 2785). Sparse basalt outcroppings of the Chilcotin Group in this area evidently do not account for this anomalous magnetism.

Small stocks and dikes composed of quartz feldspar porphyry (unit Eqfp) crop out intermittantly east of the Capoose batholith between Mount Swannell and Matthews Creek, and also north of the Natalkuz fault. Locally they cut Middle Jurassic rocks. They commonly occur in close proximity to Eocene rocks. Because of this spatial association and their similar bulk composition, particularly with rhyolitic strata that predominate in the Ootsa Lake Group within the study area, they are thought to represent subvolcanic roots of the Eocene felsic extrusives. These plutons vary in size and shape, ranging from oval, 1 by 2-kilometre plugs to elongate bodies hundreds of metres wide to narrow dikes a few metres thick. Diagnostic features include medium to coarse-grained quartz phenocrysts (1-5%; rarely to

10%), subhedral plagioclase up to 5 millimetres in diameter (<20%), biotite (1-2%) and, on occasion, hornblende phenocrysts. The matrix is typically pink or light grey and aphanitic. Rare mariolitic cavities locally suggest high-level emplacement.

ENDAKO GROUP (UNIT EE)

The Endako Group, as originally defined by Armstrong (1949), included Oligocene or younger flat-lying lava flows up to 600 metres thick that underlie the Endako River drainage basin between Babine and Francois lakes. These rocks extend beyond the type area, westward into the Whitesail Lake and southward into the Nechako River map areas, where they comprise scattered erosional remnants unconformably resting on volcanic rocks of the Ootsa Lake Group. In the Nechako River area, Endako volcanics mapped along the northern part of the study area apparently mark the southern edge of this extensive belt of lavas, onlapping Jurassic rocks along the north side of the Nechako uplift. The sharp disconformable contact between massive and columnar jointed lavas of the Endako Group and underlying subaerial air-fall rhyolite tuff of the Ootsa Lake Group is exposed locally along the shoreline of Knewstubb Lake. In the study area exposures of these lavas are less than 100 metres thick. They form a series of isolated knolls and fill channels and undulations on the upper surface of the Ootsa Lake Group.

The Endako Group is dominated by gently inclined lava flows which typically display massive, crudely layered, thick beds and uncommon columnar jointing. Individual flows are rarely discernible in the low-relief exposures; however, in a superb section exposed in a quarry on the southside of the Kenney Dam, they vary from several metres to over 15 metres thick. Hematized breccia is locally present between individual flows. They weather tan or grey and produce brown soil. The lava flows are characteristically dense, black and aphanitic to sparsely porphyritic, but commonly include vesicular or amygdaloidal varieties. Amygdules are commonly filled with creamy opalescent silica and calcite. Despite the appearance of basalts, chemical data indicate the majority are andesite and lesser basaltic andesite with high-potassium calcalkaline compositions. In thin section they contain plagioclase microlites, augite, and rarer hypersthene and olivine grains. Clay minerals and chlorite occur as alteration products of both phenocrysts and groundmass phases.

The Endako Group has not been dated in the study area. However, whole-rock K-Ar dates from identical aphanitic basaltic andesite flows about 120 kilometres to the west in the Whitesail Lake map area range from 31 to 42 Ma (Diakow and Koyanagi, 1988). Similar rocks described in the southeast quadrant of the Smithers map area are assigned to the Swan Lake member of the Buck Creek formation (Church and Barakso, 1990). The lowest member of the Buck Creek formation yielded a whole-rock K-Ar date of 48.2±1.6 Ma, which indicates a maximum age for conformably overlying rocks of the Swan Lake member.

NEOGENE ROCKS

CHILCOTIN GROUP (UNIT MpC)

Basalt lava flows of the Chilcotin Group are the youngest rocks mapped in the study area. Chilcotin lavas exposed in the southern Nechako River map area mark the northern margin of the extensive Neogene volcanic field that underlies much of the southern Interior Plateau (Mathews, 1989). The Blackwater River coincides with a profound physiographic change from a highland underlain by Mesozoic rocks of the Nechako uplift in the north, to a plateau comprised of thick, flat-lying basaltic lavas of the Chilcotin Group to the south (Bevier, 1983a, Mathews, 1989), on which late-Miocene and younger shield volcanoes of the Anahim volcanic belt (Souther and Souther, 1994) are perched. South of Tsacha Lake and the Blackwater River, the plateau is rimmed by an escarpment that exposes more than 150 metres of basaltic flows. North of the Blackwater River, the Chilcotin Group crops out between 1000 and 1400 metres elevation. However Chilcotin basalts also generally underlie low-lying areas, below 1150 metres elevation, where exposure is commonly obscured by glacial deposits, but there presence is inferred from abundant large boulders and diagnostic brown soil. Isolated lava exposures, typically no more than 50 metres thick and rarely covering more than 2 square kilometres, rest unconformably on Jurassic and Upper Cretaceous volcanic rocks and, in a few outcrops, nonconformably on the Capoose batholith and probable Eocene granite. Lavas of the Chilcotin and Endako groups overlap geographically in only one locality around van Tine Creek, but nowhere is the contact observed. Lavas of these groups also crop out at the opposite ends of the broad Chedakuz Creek valley. Although the Chilcotin lavas are exposed south of Tatelkuz Lake at 1350 metres elevation, well above the valley bottom, they are not recognized farther north within the valley, where they may be covered by till or are mistakenly mapped as part of the Endako Group.

Basalt of the Chilcotin Group is massive and commonly columnar jointed. Individual flows commonly grade through massive into vesicular and oxidized scoriacous and brecciated flow tops. They weather light brown and fresh surfaces are black with a dense aphanitic texture. Unaltered olivine phenocrysts are conspicuous in a dark black aphanitic groundmass; plagioclase laths between 1 and 1.5 centimetres long are present, only rarely. Chilcotin basalts were not dated in the study area, but numerous dates on the Chilcotin Group to the south indicate a broad Miocene-Pliocene range (Mathews, 1989).

STRUCTURE OF THE NECHAKO UPLIFT

The Nechako uplift is specifically applied to the broad region of uplifted Mesozoic rocks that underlie the Fawnie and Nechako ranges. Several northeast-trending faults bound the uplifted region, they include the Natakuz fault in the north and the Blackwater fault in the south. These structures are not well understood because they are largely concealed by thick till and Tertiary volcanic rocks. The faults approximate terminal points of the ranges, where they pass into lower terrain. Internally the Nechako uplift comprises two distinct domains, separated by a probable northwest structure(s) beneath the Chedakuz Creek valley. The western domain comprises a coherent block in the Fawnie Range and connected ridges in the west, broken by a rectilinear pattern of faults. The eastern domain encompasses the Nechako Range where a regional penetrative foliation is locally transitional into steep zones of mylonite striking northwest.

Uplift has been relatively uniform across the Fawnie Range and connected ridges as inferred from the widespread distribution of a relatively narrow stratigraphic interval of Middle Jurassic rocks, comprised mainly of the Naglico formation. Commonly these strata underlie broad areas and display relatively consistent bedding which deviates across high-angle faults that trend either northwest or northeast. Movement on these faults is difficult to document, but it is considered minor as many appear to displace only one stratigraphic unit. In some cases the cumulative displacement along poorly defined networks of steep faults may be significant, as in the case of early Callovian sediments in the northern Fawnie Range that are dropped more than 500 metres, almost to the level of the valley occupied by Top Lake.

The Top Lake fault, which strikes northeast along this valley, juxtaposes early Callovian sediments and overlying Kimmeridgian(?) volcanics exposed locally north of the fault against a thick sequence of Eocene volcanic rocks south of the fault. The latest movement on the Top Lake fault is mid-Eocene, evidently closely timed with explosive ash-flow tuff eruptions and synvolcanic subsidence that mark the last event of Ootsa Lake volcanism in the study area. The main area of subsidence near Mount Davidson is controlled by a system of steep northeast and northerly striking faults that delimit blocks underlain by thick quartz-phyric ash-flow tuff, placing them against older Jurassic units. To the west, the Top Lake fault intersects a structure that trends southwest along a straight valley occupied by Fawnie Creek and to the northeast appears colinear with a topographic break. Strata of the Entiako formation dip in opposite directions across the southern part of this fault, suggesting they may be broadly warped or occupy rotated blocks.

High-level emplacement of the Early Cretaceous Capoose batholith into Middle Jurassic rocks beneath the Entiako Spur generated numerous small-scale faults and fractures. Fracturing, accompanied by widespread propylitic alteration, is most intense in the central part of the spur where the batholith is closest to the surface. Adjacent to the batholith, particularly in the Naglico Hills, country rocks appear to be gently bowed radially outwards from the intrusion, inferring relatively passive emplacement.

At the Eocene outlier near Cow Lake, granite boulder conglomerate found locally at the base of the sequence is dominated by clasts resembling the Capoose batholith. This suggests that the batholith was unroofed prior to deposition of dated mid-Eocene rhyolites that overlie the conglomerate. Faults postdating rhyolite deposition are indicated by the incremental displacement of the basal unconformity separating Eocene rhyolite from underlying Middle Jurassic rocks. This contact is disrupted by several steeply dipping north-trending structures that coincide with two valleys that separate three prominent knolls capped by rhyolite. The apparent movement is extensional; the unconformable surface steps down progressively toward the west, resulting in thicker Eocene strata towards the west.

Stuctural geology of the Nechako Range is characterized by a weak to intense penetrative foliation and zones of mylonite. The deformed rocks are confined to belt over 50 kilometres long that tapers from 8 kilometres wide in the north to about 1.5 kilometres wide in the south. The intensity of foliation development varies along the length of the belt, independent of lithological contrasts and unaffected by a system of steep northerly and northeast-striking faults. The attitude of the foliation generally maintains a consistent northwest strike and moderate southwest to locally vertical dip.

Early and Middle Jurassic volcanic and sedimentary rocks underlying the Nechako Range are separated into three structural blocks by the northeast-striking Brewster and Blackwater faults which trace along prominent valleys traversing the range. The block north of the Brewster fault is mostly underlain by the youngest Jurassic units, the Ashman Formation and Nechako volcanics, which are also significantly thicker here than elsewhere in the study area. The extent of deformed rocks is also greatest within this block, about 8 kilometres wide. Strain is most prevalent in some of the finer grained clastic units in which phyllitic cleavage is locally prominent. Conglomerate beds commonly exhibit stretched and flattened clasts. An incipient foliation is developed in the overlying mafic volcanics that rapidly grades into localized zones of strongly cleaved greenschist. The Chedakuz fault, at the western edge of the block, traces along the eastern edge of the Chedakuz Creek valley and is marked by mylonite exposed locally through thick till. The fault dips steeply west, and trends southwest where it apparently converges or is represented by a broad zone of vertically dipping mylonitized sediments and volcanic rocks, extensively exposed along the southern perimeter of the CH pluton in the middle structural block.

The middle block, between the Brewster and Blackwater faults, is dominated by the oldest Jurassic strata of the Entiako formation. Overlying mafic flows of the Naglico formation are divided into two parallel belts by a series of disconnected fault segments that are interpreted as the probable southward continuation of the Chedakuz fault. These faults trend northerly, roughly parallel to the axis of the range. In the south they are cut by the northeast-trending Blackwater fault that passes through the valley occupied by Kuyakuz Lake. Across this structure the southern extension of the Chedakuz fault system is manifest again in mylonitized volcanic rocks exposed in a roadside outcrop south of the east end of Kuyakuz Lake. This structure extends to the south, mainly juxtaposing different units of the Entiako formation, where it is truncated by a splay off the Blackwater fault that follows the east-trending valley occupied by the Euchiniko Lakes.

In the middle block between Tatelkuz Mountain and Euchiniko Lakes, the broad region west of the Chedakuz fault system has undergone varying amounts of uplift relative to the eastern region. Block rotation is inferred from opposing bedding attitudes across the fault. East of the fault younger sediments of the Ashman Formation apparently face and dip west, overlying a thick sequence of mafic flows assigned to the Naglico formation. On the uplifted side, volcaniclastic sediments of the Entiako formation are widely exposed in bedded sections dipping east. Overlying, or possibly in sharp fault contact, are mafic rocks of the Naglico formation. They appear as a thick, locally foliated greenstone unit underlying Tatelkuz Mountain, but farther south, between Kuyakuz Mountain and Kuyakuz Lake the section is considerably thinner and rotated to a vertical, moderately to strongly foliated greenstone-greenschist section along the Chedakuz fault. Clastic rocks of the Ashman Formation are absent above the Naglico formation west of the fault. North of Tatelkuz Mountain, the Chedakuz fault intersects another steep fault trending southeast. North of this structure the relatively straightforward stratigraphic relationships observed to the south are complicated by a number of smaller northerly trending faults in a broad zone marked by moderately foliated to locally mylonitized rocks of Lower to Upper Jurassic units that are truncated by undeformed granodiorite of the CH pluton.

Rocks of the Naglico formation predominate in the southern structural block. They dip to the east and are locally overlain by sediments of the Ashman Formation and possibly the Nechako volcanics. Foliation, confined to the Naglico formation, is present but less pronounced and more randomly oriented than elsewhere in the range.

The timing and nature of movement on these major structures are difficult to determine because of poor exposure. The presence of thin Eocene strata above uplifted Mesozoic rocks between the Natalkuz and Blackwater faults may suggest the region was already partly elevated in Eocene time and perhaps formed a low buttress that impeded broader distribution of the Oosta Lake Group. However, small volcanic centres in the Mount Davidson area and Eocene plutons in the Nechako Range also suggest the uplifted region was the locus for some Eocene magmatism. In the Nechako Range, the CH pluton truncates the regional penetrative foliation and three age determinations on the granodiorite of *circa* 51 Ma establish a minimum age for deformation. A possible lower bracketing age is provided by sericite from mylonitic rocks along the Chedakuz fault zone south of Kuyakuz Lake, which yields a "tentative" mid-Cretaceous $^{40}Ar/^{39}Ar$ plateau date. The extent of deformed rocks beyond the study area to the north is not known. Structures in the northern Nechako Range may extend through low terrain towards the northern end of Knewstubb Lake and terminate against the northeast-trending Natalkuz fault.

SUMMARY AND CONCLUSIONS

Extensive Tertiary volcanic deposits and Quaternary glacial debris cover much of the Interior Plateau region. They are interrupted in the southern Nechako River map area by the Nechako uplift, a structurally uplifted region centred on the Fawnie and Nechako ranges. Regional mapping, supported by paleontologic and geochronologic work by outside agencies has provided new insights into stratigraphic, magmatic and structural development of the Nechako uplift. It provides a window through comparatively young cover into an underlying Mesozoic substrate that is lithologically distinct and perhaps indicative of the broader makeup of the central Stikine Terrane near its eastern contact with the Cache Creek Terrane at 53°N latitude.

Prior to this study, broad tracts of pre-Tertiary rocks in the southern Nechako River map area were assigned to the Upper Triassic Takla Group. Triassic rocks are in fact, represented by a single exposure of Carnian to early Norian siltstone. Lower and Middle Jurassic volcanic and sedimentary rocks predominate in the Nechako uplift where they are subdivided into two informal formations correlative with the Hazelton Group. The Entiako formation is an early Toarcian and possibly Aalenian sequence comprised of a subaerial rhyolitic volcanic facies that is replaced to the east by near-shore and deeper marine facies dominated by volcanogenic-epiclastic rocks. The conformably overlying Naglico formation is a sequence of subaerial pyroxene-phyric basaltic flows and tuffs containing interbeds of early Bajocian shallow-marine volcanic-derived sediments. Together these strata record island arc volcanism and associated intra-arc clastic sedimentation. Lower Callovian marine siltstone and shale are sporadically exposed, but widespread in the study area. They feature chert-bearing conglomerate interbeds that become thicker eastward from the Fawnie Range towards the Nechako Range. These deposits, correlative with the Bowser Lake Group, are interpreted to record intial transport of chert-rich detritus shed into the Nechako basin from a probable source region underlain by high-standing rocks of Cache Creek Terrane.

Extrusive products of Late Jurassic and earliest Cretaceous magmatism are rare in the Stikine Terrane; however, based on several new age determinations a few are preserved in the Nechako River map area. An assemblage of pyroxene-phyric flows, indistinguishable in the field from those of the Naglico formation, occurs with rhyolitic fragmental rocks in both the Nechako and Fawnie ranges above a sharp conformable contact with clastic rocks of the Ashman Formation. This volcanic succession, called the Nechako volcanics, yields an $^{40}Ar/^{39}Ar$ date of 152 Ma. Even more areally restricted are dacitic volcanic rocks of Jura-Cretaceous age (*ca.* 144 Ma). These rare volcanics are coeval with the Capoose batholith (*ca.* 142 Ma) and together they may represent the southern extension of Jura-Cretaceous magmatism related to the Francois Lake intrusive suite. Late Cretaceous (*ca.* 65-70 Ma) hornblende andesite and rhyolitic extrusives and subvolcanic dikes and sills, and contemporaneous quartz monzonite sporadically exposed in the area, may represent the easternmost and youngest continental arc magmatic event corresponding with the Kasalka Group in central Stikinia.

Uplift of the Fawnie and Nechako ranges in the southern Nechako River area is related to several inferred northeast-striking faults that truncate the ranges to the north and south. They intersect a major structural zone trending northeast beneath the Nechako Range, evidenced by the development of a persistent foliation and zones of mylonite. Deformation in the Nechako Range is thought to have coincided with regional uplift. The timing of this event is bracketed by a provisional mid-Cretaceous $^{40}Ar/^{39}Ar$ date on sericite from mylonite and the undeformed Eocene CH stock which locally trucates the penetrative fabric.

Uplift of the ranges preceeded widespread Paleogene and Neogene volcanism, influencing the distribution of Tertiary volcanic rocks repetitions. Subaerial high-potassium calcalkaline volcanic rocks of the Ootsa Lake Group cap a small area in the uplifted region, resting unconformably on Mesozoic rocks, but are widespread in topographically lower regions to the north and south. The Endako Group is a sequence of andesitic flows that have compositional continuity with volcanic rocks of the Ootsa Lake Group. Their source is believed to be volcanic centres to the north of the uplifted region as they thin dramatically southward, overlying progressively older rocks along the northern flank of the ranges. The youngest magmatic event in the study area is represented by Neogene plateau-forming alkali olivine basalts that flooded the region from sources south of the Nechako uplift. The uplift apparently served as a partial barrier to northward advance of these flows as they have not been observed overlapping older Endako lavas along the northern slope of the uplifted region.

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Working ties were forged with mining companies and prospectors active in the region - we wish them success with their exploration programs. Finally, it has been a pleasure collaborating with our colleagues at the Geological Survey of Canada and the British Columbia Geological Survey who were engaged in various other studies as part of the Interior Plateau Project. Verna Vilkos is thanked for preparing the figures in this report.

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PHYSICAL AND CHEMICAL VOLCANOLOGY OF THE EOCENE MOUNT CLISBAKO VOLCANO, CENTRAL BRITISH COLUMBIA

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KEYWORDS: Interior Plateau, British Columbia, epithermal mineralization, clisbako, eocene, volcanic centre, calc-alkaline, potassic, pyroxene-phyric, intermediate, felsic, biotite-phyric, pyroclastic eruption, caldera, flow-domes, ^{40}Ar/^{39}Ar Isotopic ages, palynology, geochemistry, trace elements, chemical models.

INTRODUCTION

This paper summarizes current results of reconnaissance geological mapping, sampling and petrologic analysis of Tertiary volcanic rocks in the Clisbako River area of central British Columbia, carried out as part of the (1991-1995) Canada - British Columbia Agreement on Mineral Development (van der Heyden *et al.*, 1993, 1995). This work complements other studies in this area such as drift mapping (Proudfoot, 1993), a lake sediment geochemical survey (Cook, 1993, 1995) and a multiparameter geophysical survey (Shives and Carson, 1994).

A preliminary study of Tertiary volcanic stratigraphy in the Clisbako area of central British Columbia (Figure 1) began in September 1993. The purpose was to determine the stratigraphic succession and petrologic relationships of the Early Tertiary felsic volcanic rocks which host epithermal mineralization discovered on the Baez and Clisbako claim groups (MINFILE 093C 015 and 093C 016, respectively), near the headwaters of the Clisbako River. Results are compared with information from Tertiary volcanic rocks exposed to the north in the Nechako River area (93F; Green and Diakow, 1993; Diakow *et al.*, 1993; Diakow and Webster, 1994) and to the south in the Taseko Lakes area (92O; Hickson *et al.*, 1991; Hickson, 1992, 1993; Hickson and Higman, 1993).

The study area is part of the Chilcotin Plateau and comprises four 1:50 000 map sheets (93B/12, B/13, C/9, C/16), bounded by latitudes 52°30"N and 53°00"N and by longitudes 123°30"W and 124°30"W (Figure 2). Relief is gentle and the area is forested. Outcrop is not abundant. The area is accessible by means of numerous logging roads, west from Quesnel and northwest from Alexis Creek.

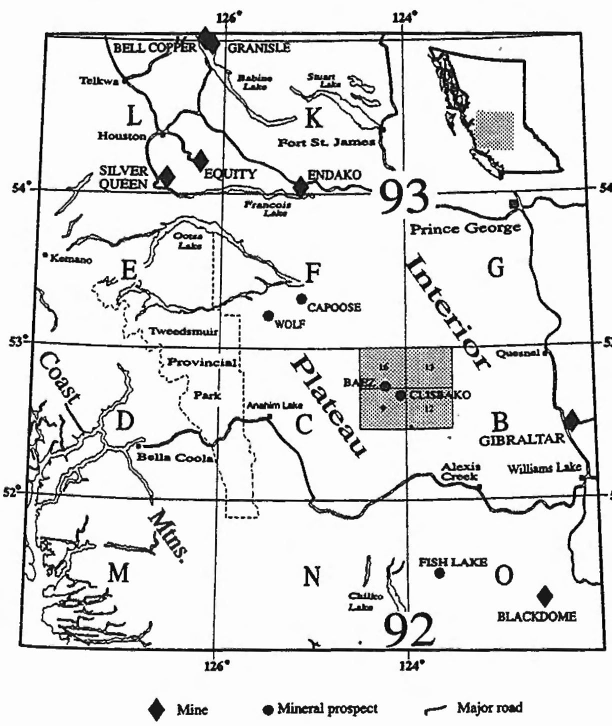


Figure 1. Location of the study area.

GEOLOGY OF THE CLISBAKO AREA

The pre-Eocene basement rocks in the Clisbako area are exposed as discrete inliers, usually as ancient ridges, more resistant to erosion than the younger rocks which overlie them (Figure 2). The Eocene volcanic rocks are the focus of the present study and therefore only a few outcrops exposing the older assemblages were visited during the course of fieldwork.

FOSSILLIFEROUS LIMESTONE (TRIASSIC)

This unit is exposed in only one location in the study area, which was not visited. Tipper (1959) described a small area in the McFarland Creek valley underlain by rocks which he tentatively identified as Cache Creek Group. The unit is exposed over a larger area than originally described and forms a low ridge, surrounded by the younger Eocene and Chilcotin lavas (Figure 2). Tipper (personal communication, 1996) described the unit as a grey-weathering fossilliferous limestone of Triassic age, based on paleontological evidence.

JURASSIC VOLCANIC AND SEDIMENTARY ROCKS

Two parts of the study area are underlain by an assemblage of intermediate fragmental rocks. Tipper (1959;

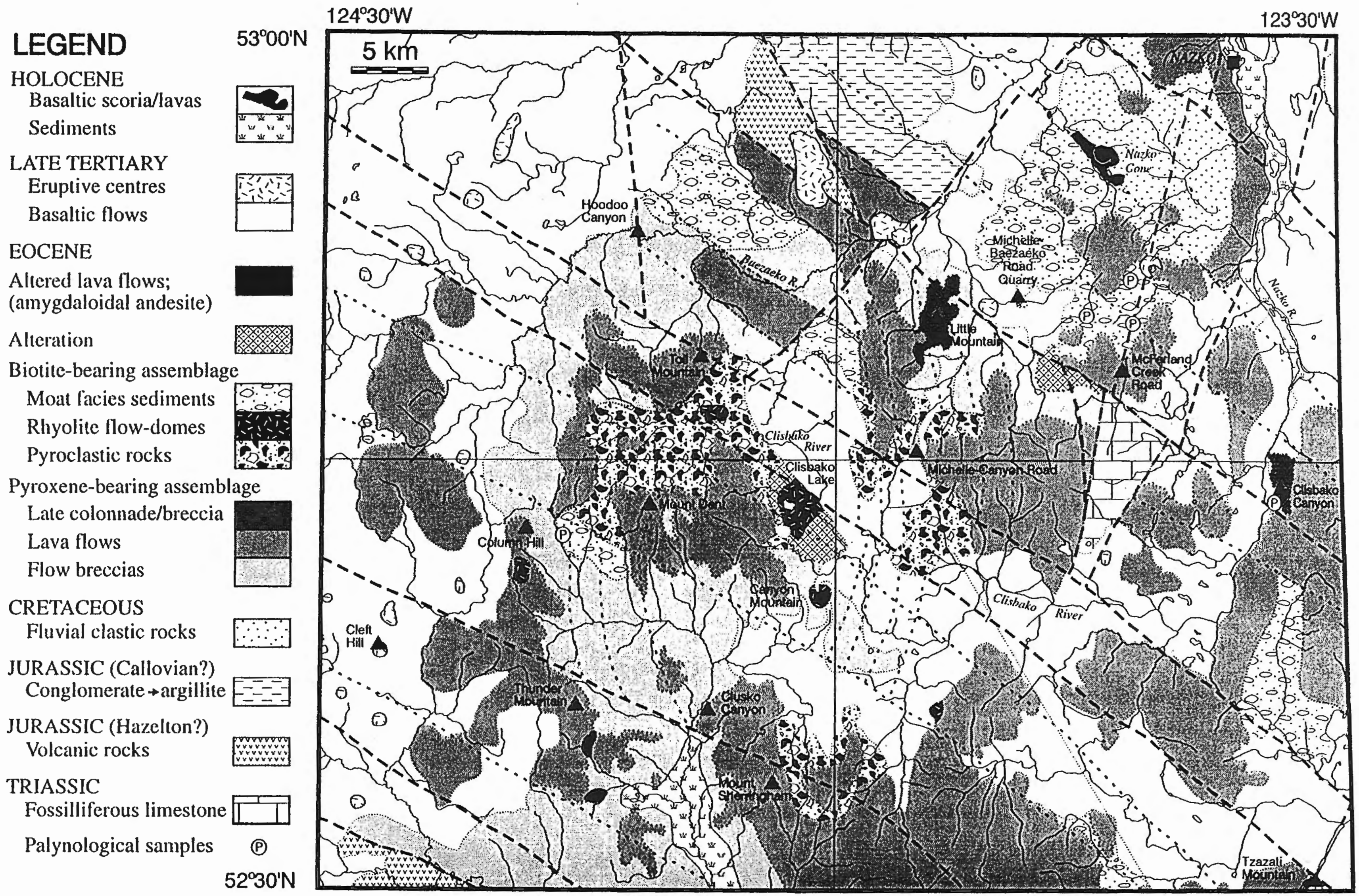
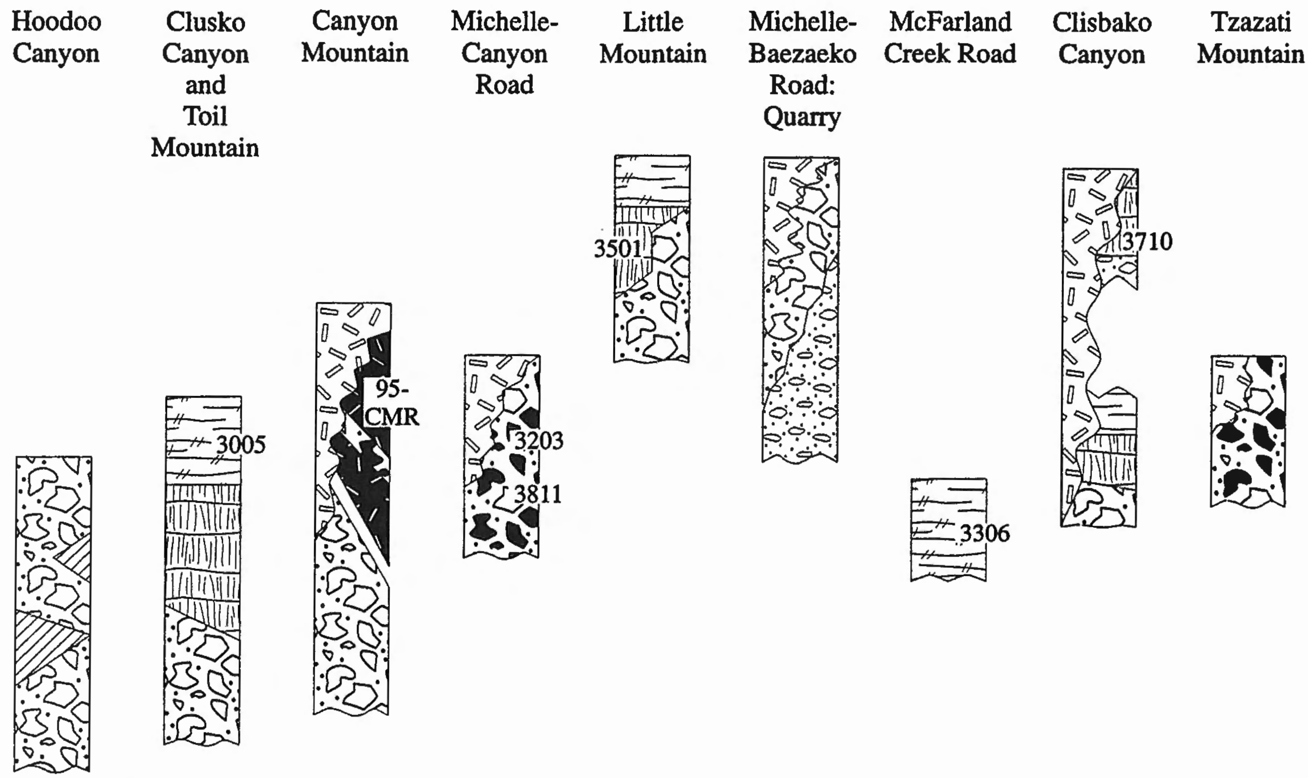


Figure 2. Geological map of the Clisbako area (this study; Tipper, 1959, 1969; Richards and others, unpublished data). Eocene volcanic rocks rest on a deformed basement of presumed Mesozoic age and are partially covered by valley-filling Chilcotin Group basalts. The area was glaciated and outcrop is not abundant. Probable and possible faults (heavy and light dashed lines) are inferred from juxtaposition of rock units, magnetic discontinuities (G.S.C., 1994) and topographic lows.



CHILCOTIN GROUP (MIOCENE)

Plagioclase-olivine phyric basalts, overlying Eocene volcanic rocks with erosional unconformity and filling paleovalleys

CLISBAKO VOLCANICS (EOCENE)

Plagioclase+augite-bearing assemblage

Pyroxene and/or plagioclase-phyric dacite flows, often flow laminated or flow banded and as much as 100 m thick.

Plagioclase-phyric dacite colonnades, grading laterally/down section to flow-breccia. Variable thickness, as much as 100 m.

Flow breccias with pyroxene-bearing dacite boulders and rare coherent flow lobes. Some units may be related to biotite-bearing moat facies.

Biotite-bearing assemblage

Moat facies; biotite-bearing clastic sedimentary or epiclastic rocks containing plant remains. This facies may include dacite flow breccias.

Biotite-bearing pyroclastic/epiclastic rocks, containing blocks of biotite rhyolite and accidental blocks of pyroxene-bearing dacite.

Biotite, quartz and feldspar-phyric rhyolite flow domes, intercalated with or grading laterally into flow breccias.

Figure 3. Stratigraphic sections through Eocene volcanic assemblages in the study area; locations of sections are shown on Figure 2. Samples analysed for $^{40}Ar/^{39}Ar$ are shown by number. The biotite-bearing assemblage is recessive, but includes a large number of accidental fragments of pyroxene-phyric dacite. In some sections it is overlain by dacite colonnades which are clearly younger. The biotite rhyolites are interpreted as the product of a large pyroclastic eruption, or eruptions which interrupted a long (>6 Ma) period of dacitic volcanism.

1969) assigned this assemblage to the Lower Jurassic Hazelton Group, based on lithological similarity. These rocks differ from the more recent volcanic rocks (Eocene and younger) in containing a schistose foliation. This foliation is regional only in a north-south belt, approximately 10 kilometres wide, which can be traced from the Baezaeko River northward. To the west of this belt the older rocks (Mesozoic) do not contain this strong foliation.

Scarcity of outcrop precluded comprehensive structural mapping. The limited number of outcrops examined are volcanogenic and fragmental. The rocks are brown or green, weathering to green or maroon. Lithologies vary from lapilli tuff to volcanic breccia (Fisher, 1961) and angularity varies from angular to subangular, less commonly to subrounded. The rocks include both heterolithic and homolithic types.

Fragments are most commonly weakly feldspar phyric, containing as much as 10% subhedral feldspar phenocrysts, usually less than 1 millimetre in length. Other fragments are aphanitic, some possibly with relict pumiceous texture. They are commonly matrix supported in a dark green or purple aphanitic matrix.

Immediately to the north of the Baezaeko River, at the northern edge of the study area, the Mesozoic strata comprise argillite, chert-pebble conglomerate and sandstone, all strongly cleaved. These rocks do not show the same pervasive foliation and are interpreted as possibly Callovian in age. This foliation is present only in a zone 10 kilometres-wide which can be traced northward from the study area; west of this zone the Mesozoic rocks are not cleaved (Richards and others, unpublished data).

CLASTIC SEDIMENTARY ROCKS (CRETACEOUS)

Small, discrete exposures of clastic sedimentary rock are exposed at several locations in the northeast of the study area, towards the Nazko River valley. This poorly exposed assemblage comprises dark grey to brown argillite and lithic sandstone; Tipper (1959) and Hunt (1992) recorded conglomerate, not observed in this study. These conglomerates were intersected by exploration diamond drilling carried out on the Bob claims. The sedimentary rocks observed are thickly laminated to thinly bedded. Scarcity of outcrop precluded detailed mapping, but the rocks lack the distinctive foliation of the older volcanic rocks to the west. Tipper (1959) assigned these to the Cretaceous on the basis of lithological similarity to equivalent rocks. Hunt (1992) obtained palynological data giving ages ranging from Albian to Maastrichtian for Cretaceous sedimentary rocks in the Clisbako area.

EOCENE CLISBAKO VOLCANICS

The Mesozoic basement rocks are overlain by a succession of intermediate to felsic volcanic rocks which are the subject of the present study (Figure 2). The Eocene rocks underlie all higher ground in the study area and were identified by Tipper (1959, 1969) as part of the Ootsa Lake Group. The outcrop area is elevated, roughly circular, identifiable from satellite imagery and measures approximately 50 kilometres in diameter. To the north, the Eocene strata abut against a paleotopographic ridge underlain by the older volcanic rocks. Eastward, the Eocene outcrop area becomes progressively more dissected towards the valley of the Nazko River, where erosional level extends below the Eocene paleotopography. To the west and south the contacts are more abrupt, in both cases with the younger olivine-bearing basaltic lavas of the Chilcotin Group, which fill paleotopographic lows.

Hydraulic brecciation, epithermal alteration and mineralization are locally abundant in this assemblage. For this reason, the Eocene felsic and intermediate volcanic units outcropping in the study area are assigned a moderate to high exploration potential. The Eocene volcanic rocks comprise three lithologic assemblages, identified on the basis of fieldwork and petrography. Contacts between the assemblages are not exposed and stratigraphic relationships are inferred from the relative positions of the assemblages and, where available, their $^{40}Ar/^{39}Ar$ isotopic ages. Relationships observed at nine sections in the study area are shown in Figure 3.

PYROXENE-BEARING ASSEMBLAGE

The most commonly exposed assemblage comprises weakly to moderately porphyritic intermediate lavas and related breccias, containing plagioclase and/or pyroxene phenocrysts. The preliminary name "augite-bearing assemblage" (Metcalfe and Hickson, 1994, 1995) is here replaced by "pyroxene-bearing assemblage" after the discovery of

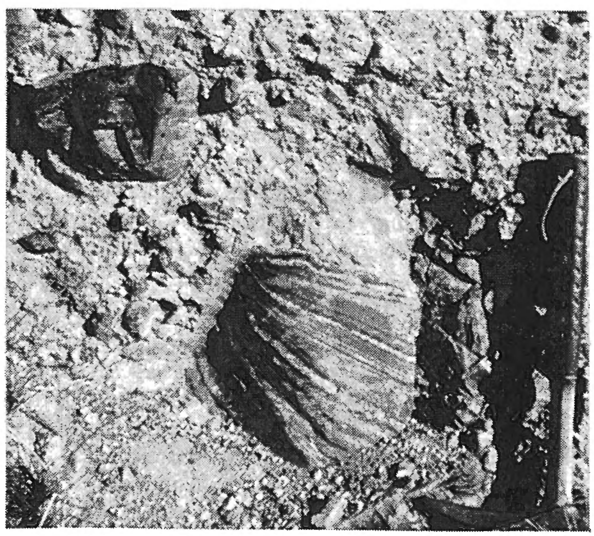


Photo 1. Dacite flow-breccia, showing black glassy appearance of fresh dacite and brown to white weathering surfaces. The largest block exhibits flow banding while the black glassy block at upper left has a perlitic texture.

small but significant numbers of orthopyroxene phenocrysts in many of the samples.

Phenocrysts are usually less than 3 millimetres in length and comprise, at most, 15% of the rock. The groundmass is distinctive, being black and glassy in the freshest specimens and dark grey, weathering to cream or brown, in devitrified or slightly altered samples (Photo 1). The glassy or aphanitic nature of the groundmass distinguishes this suite of rocks from the overlying Chilcotin Group basaltic lavas.

The part of the pyroxene-bearing assemblage inferred to be the lowest stratigraphic unit is exposed mainly in the west of the study area (Figure 2). The basal, or distal, units form a thick sequence of flow breccias, containing glassy aphanitic, aphyric and plagioclase and plagioclase-pyroxene-phyric blocks, as much as 2 metres across, in a red, yellow or cream-weathering matrix. The flow breccias are intercalated with discontinuous lobes of coherent dacite, interpreted as unbrecciated flow lobes within the breccia on the basis of near-identical textures and chemical com-

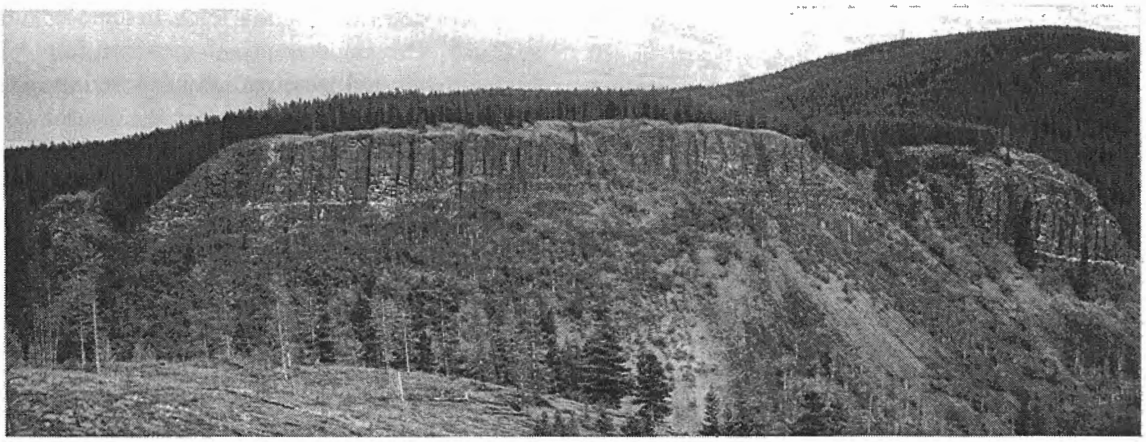


Photo 2. Section of the pyroxene-bearing assemblage exposed in Clusko Canyon. A dacite colonnade overlies and passes laterally into equivalent flow breccias and is overlain by flow-laminated dacite of identical composition, probably a zoned flow.

Photo 3. Radiating colonnade in later dacite flow dome at Column Hill, in the west of the area.

positions. Both blocks and lobes commonly contain spectacular examples of flow banding, flow folding and perlitic cracking.

Areas underlain by the flow breccias have moderate topography; outcrop is sparse and usually occurs near contacts with the more resistant overlying units, which form a protective cap (Photo 2). The flow-breccia sequence is at least 100 metres in total thickness and is probably repeated many times; isotopic data for this assemblage are too few to construct a detailed stratigraphic sequence.

The flow-breccia units pass laterally into and are overlain by black glassy flows very similar in lithology to the blocks and flow lobes in the breccias. These flows are mainly dacitic, although their distribution in the field suggests a more fluid and mafic composition (Metcalfe and Hickson, 1994). The dacites contain between trace and 15% plagioclase, with or without pyroxene phenocrysts. They are interpreted as proximal, unbrecciated equivalents of the flow breccias.

The lava flows locally exhibit flow banding and flow folding. Many may be dry flow domes, as the flow foliation is commonly steep. This lithology is resistant to erosion and forms rare cliff exposures with spectacular colonnades as much as 30 metres high. The total thickness of this part of the succession could not be measured, due to lack of continuous outcrop; it probably varies greatly throughout the area. Significant exposures occur at Little Mountain, Clisbako Canyon, Clusko Canyon, Thunder Mountain and 8 kilometres west of Mount Dent, at Column Hill (Figure 2, Photo 3). In the central part of the area, near Clisbako Lake, the flows grade up-section from relatively high pyroxene-plagioclase phenocryst contents to weakly pyroxene-phyric flows.

Exposures of colonnade-forming lavas are overlain by strongly flow- laminated lavas. These lavas are also mainly of dacitic composition. The rocks are weakly vesicular; the vesicles are usually less than 2 millimetres in diameter and irregular in shape. Flow banding is rare; instead, flow layers (Photo 4) are defined by smearing of vesicles in planes parallel to the basal contact. This fabric is deformed in some lava flows to form flow folds. In some locations, such as Clusko Canyon, the upward transition from colonnade to flow-laminated lava, partially exposed on a cliff face (Photo 2) appears to be part of the flow morphology. Certainly the chemical compositions of the colonnade and flow-laminated lava are closely similar. In this location and in several others, flow-laminated lava may represent the upper part of thick (100 metres) dacite flows, while the colonnades represent parts of the flow base and centre.

Elsewhere, flow-laminated dacite occurs as discrete flows or as lobes within the volcanic breccias. Several ridges, particularly near the periphery of the Eocene outcrop area, are cored or capped by flow-laminated lavas, possibly lateral equivalents of the colonnade-forming flows. No flow tops were observed in the course of the present study.

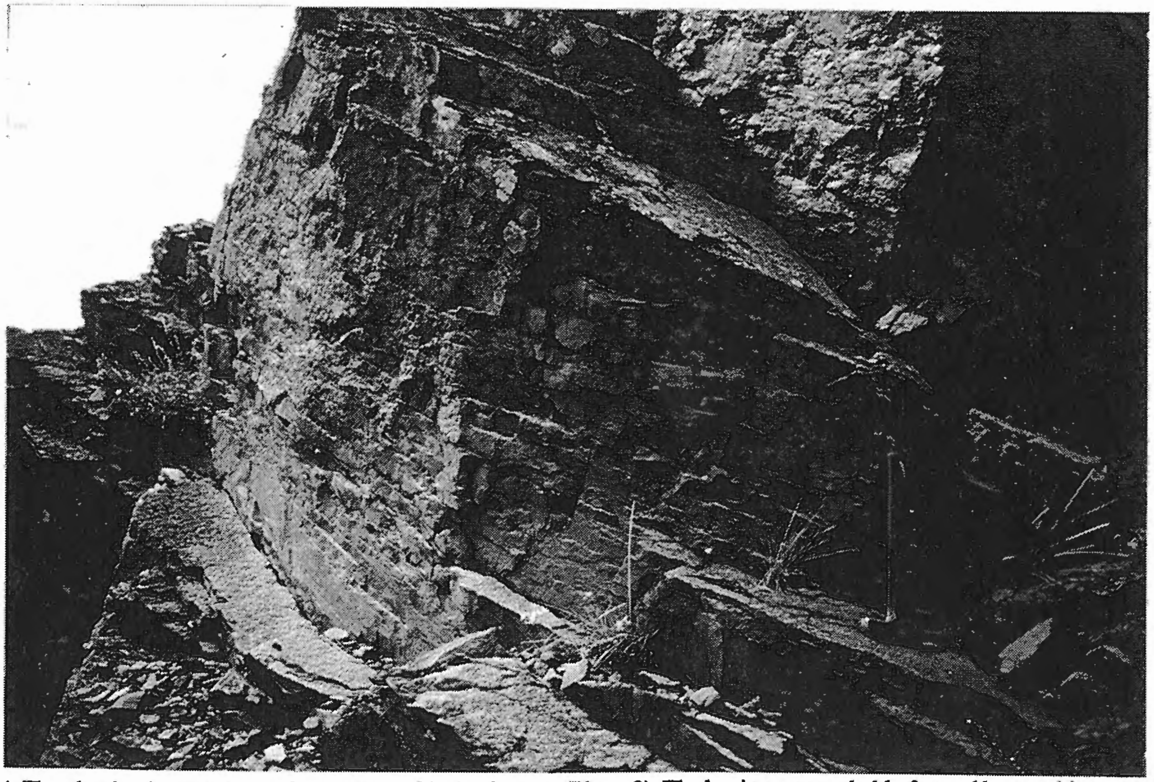


Photo 4. Flow laminations near top of exposure at Clusko Canyon (Photo 2). The laminae are probably formed by streaking out of vesicles in viscous lava, in a manner analogous to the development of "platy" colonnades in basalt.

BIOTITE-BEARING ASSEMBLAGE

The second assemblage exposed in the study area is identified by the presence of abundant phenocrysts of primary biotite, in addition to plagioclase and, less commonly, hornblende. Lavas of this assemblage are typically rhyolitic. Fresh surfaces are light grey in colour with a characteristic greasy vitreous lustre, in which subhedral to euhedral phenocrysts of the diagnostic biotite are easily visible. The lava weathers to a dull grey or brownish grey; where altered, weathered surfaces are white to cream. Locally, flow breccias may occur, grading laterally into flows (Photo 5).

The rhyolitic lavas are restricted to small flow domes near the centre of the area. At least four such eruptive centres are located, on a roughly northwest trend, in the central and west-central part of the area. Typical of these is Canyon Mountain (Figures 2 and 3). This distinctive mountain comprises a flow-dome complex (Photo 6) consisting of biotite-porphyritic rhyolite flows and flow breccias intercalated with pyroclastic and epiclastic fragmental units of similar composition (Photo 7). Southwest of Canyon Mountain is a 10 metres-wide porphry dike of quartz-hornblende-feldspar and a second knoll of hornblende-biotite-quartz phyric rhyolite, also interpreted as a flow dome. To the northwest of Clisbako Lake, on the south side of the Clisbako River valley, is a brecciated and flow-banded biotite-quartz-phyric rhyolite, with broken quartz phenocrysts, interpreted as an autobrecciated flow-dome.

Photo 5. Homolithic flow-breccia, grading laterally into biotite rhyolite lava in the flow-dome at Canyon Mountain.

South of Clisbako Lake are small exposures of a white to buff-weathering felsic rock; contacts are obscured at all localities examined. The unit may therefore be intrusive or extrusive in origin, but studies of the unit T.A. Richards and others, unpublished data noted abundant broken crystals and a lack of flow textures, suggestive of a pyroclastic origin. The unaltered rock contains subhedral biotite phenocrysts (1-2 mm) and 20-25% euhedral to subhedral quartz phenocrysts (2-5 mm) in an extremely fine grained groundmass. This abundance of modal quartz is unusual in the Eocene volcanic rocks. Quartz phenocrysts enclose relict biotite and the occurrence of altered biotite phenocrysts indicates that the unit is part of the biotite-bearing assemblage. Minor hornblende phenocrysts are also present. Quartz porphyries are exposed in several localities throughout the area, often close to mineralization, including that discovered at Clisbako and also on the Bob mineral claims in the northeast of the area (T.A. Richards and others, unpublished data). As noted above, quartz phenocrysts are ubiquitous in this biotite-bearing assemblage. The quartz porphyries appear to postdate most, if not all the other biotite-bearing volcanic rocks and overlie lacustrine sedimentary rocks of the moat facies, described below.

A more widespread biotite-bearing lithology comprises massive breccias, lapilli tuffs and tuff-breccias (Photo 8), intercalated with volcanic sedimentary rocks. The massive units include blocks and lapilli of rhyolite, very similar in composition to the lavas, matrix supported in an altered tuff. All units observed in outcrop are heterolithic and contain lapilli and blocks of pyroxene-bearing dacite. Phenocrysts comprise biotite, hornblende and feldspar; broken crystals are abundant. This part of the assemblage is interpreted as the product of pyroclastic flows.

The pyroclastic units are very poorly lithified and weather recessively. On the lower slopes of Toil Mountain are exposures of a thick (50 m) massively bedded unit identified as a welded heterolithic pyroclastic deposit containing abundant blocks of pyroxene-bearing and aphyric dacite, fiammé, and crystals of biotite, plagioclase and quartz in a vitrophyric groundmass. Similar fragmental units crop out 11 kilometres northeast of Canyon Mountain, south of the Michelle-Canyon road (Figures 2 and 3). Here they exhibit well developed reverse grading, interpreted as the result of pyroclastic flow. Here and at Canyon Mountain, the fragmental units include blocks of plagioclase-pyroxene-phyric dacite.

Stratigraphic relations between the biotite-bearing and pyroxene-bearing assemblages are poorly known. Blocks of pyroxene-bearing dacite occur in the biotite-bearing fragmental rocks. However, northeast of Canyon Mountain, in a quarry near the junction of the Michelle-Canyon and Michelle-Baezaeko forest service roads (Figures 2 and

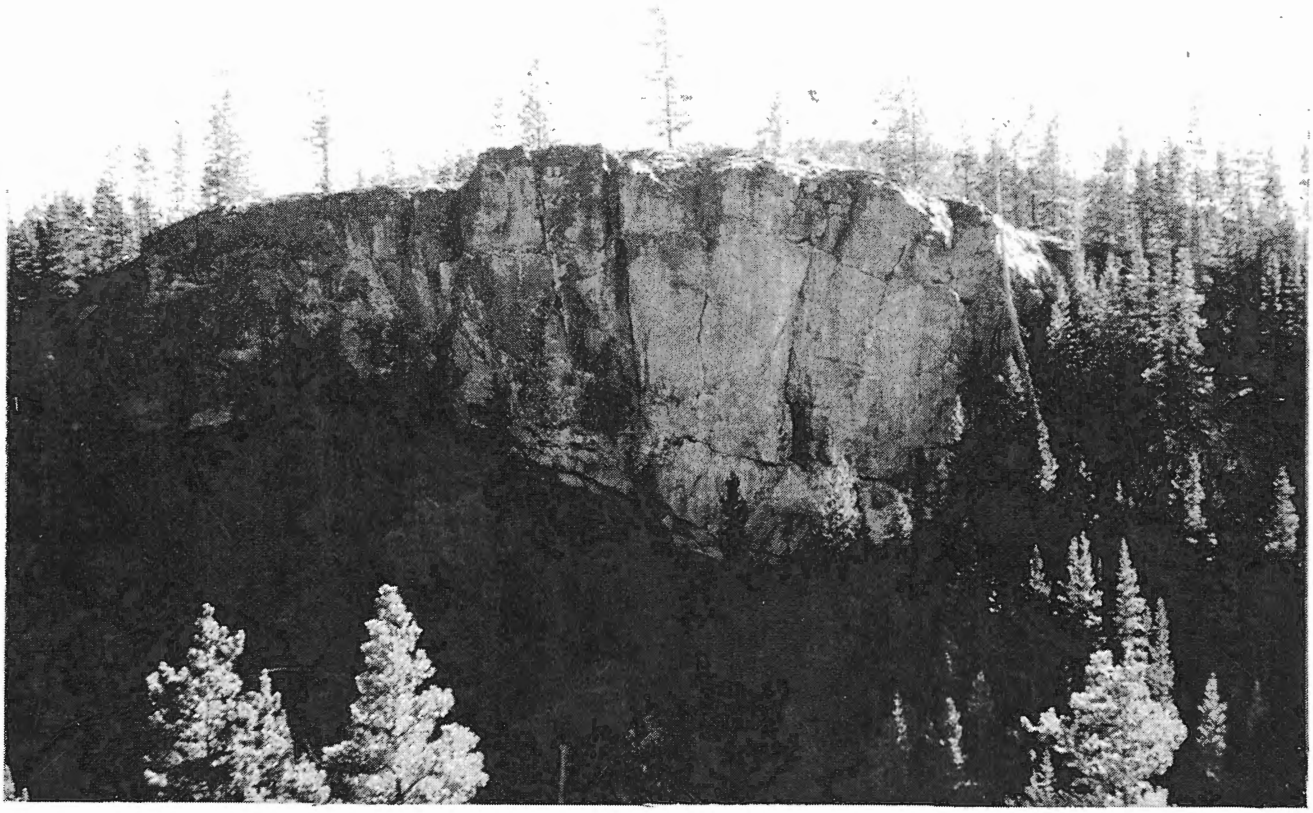


Photo 6. Dissected flow dome of biotite rhyolite on the west side of Canyon Mountain in the centre of the Clisbako area. The flow dome comprises lava flows and related flow breccias, intercalated with pyroclastic flow deposits.

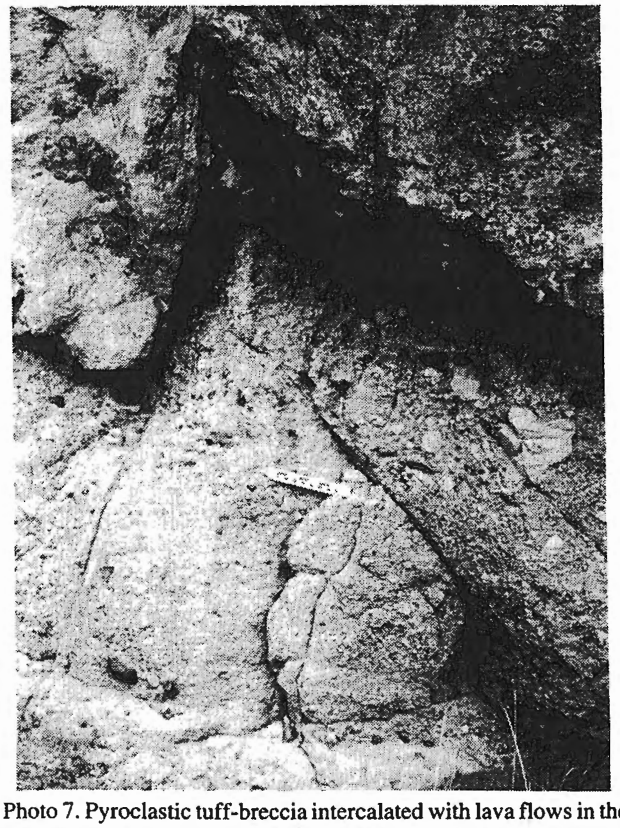


Photo 7. Pyroclastic tuff-breccia intercalated with lava flows in the flow dome at Canyon Mountain. Note the presence of blocks of biotite rhyolite (white) and accidental blocks of pyroxene-bearing dacite (black).

3), pyroxene-bearing dacite flow breccias overlie at least one unit of tuffaceous conglomerates associated with the biotite-bearing volcanic rocks. In the Michelle-Canyon roadside exposure east of Canyon Mountain (Figures 2 and 3), the biotite-bearing pyroclastic strata dip moderately to the east, apparently beneath dacite flows and flow breccias. The biotite-bearing fragmental rocks therefore occupy paleotopographic depressions in the older pyroxene-bearing volcanic products and are overlain by younger pyroxene-bearing lavas.

The biotite-bearing assemblage was noted at two other locations, one of which is on Tzazati Mountain, in the extreme southeast of the area. The outcrop is separated from those in the centre of the area by a topographic low, interpreted here as having formed by erosion of the less resistant fragmental rocks and subsequently filled with basalts of the younger Chilcotin Group. A well, drilled by Canadian Hunter Ltd. in this depression during the course of hydrocarbon exploration, intersected the base of the Chilcotin Group lavas at a depth of approximately 230 metres and the base of the Eocene volcanic sequence at approximately 600 metres. A synopsis of the drill log (Chilcotin B-22-K well) is given by Hunt (1992). At 542 metres depth, the hole intersected a horizon of white felsic rock with hornblende crystals, biotite and quartz. This is almost certainly an intersection of the biotite-bearing assemblage capped by later lava flows, including basalts of

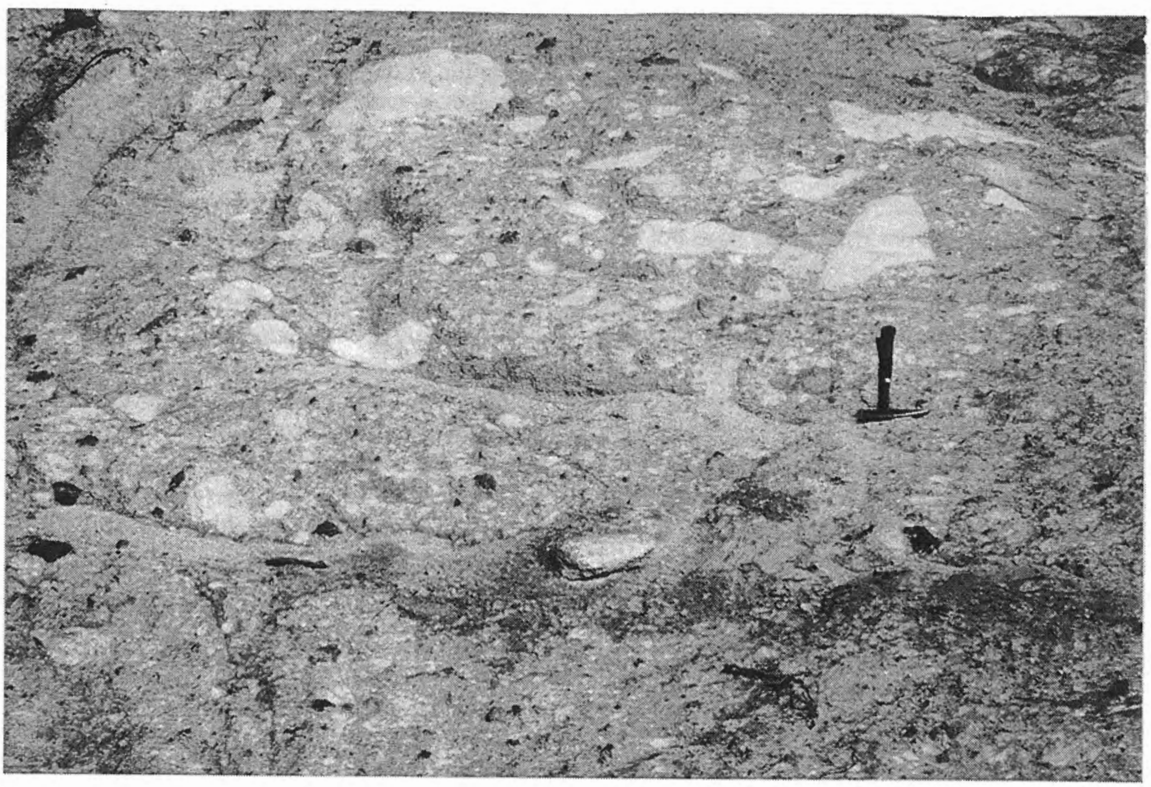


Photo 8. Pyroclastic tuff-breccia exposed near the centre of the Clisbako area. Clasts of quartz-feldspar-biotite-phyric rhyolite are subangular to subrounded and matrix supported. Accidental clasts include plagioclase-augite dacite.

the Chilcotin Group. It is apparent from the log that, in addition to the Chilcotin Group lavas, a considerable thickness of Eocene dacite lava overlies the biotite-bearing unit.

MOAT FACIES OF THE BIOTITE-BEARING ASSEMBLAGE

Epiclastic sedimentary rocks are exposed in several locations in the central part of the study area. They are as poorly consolidated as the pyroclastic rocks, invariably white to bleached in colour and are extremely recessive; exposure is almost entirely man-made disturbances (roads and logging slashes).

The rocks are thickly laminated to thinly bedded and commonly show normal grading, bed perturbation and rip-up clasts, characteristic of a high-energy environment. The facies includes a wide variety of rock units and includes chaotic breccia, lahar-fanglomerate, conglomerate, poorly to well sorted lithic sandstone, laminated siltstone, claystone and minor gritty argillite; this last is locally highly carbonaceous.

The clastic sedimentary rocks are polymictic and are dominated by white, clay (kaolinite) altered lithic clasts of rhyolite with phenocrysts of biotite, quartz and feldspar; also subordinate (20-40%) clasts of unaltered, massive to flow-banded rhyolite and dacite. Fresh, unaltered biotite, quartz and feldspar crystals, with numerous angular grains of volcanic glass, occur as detritus in members that range in grain size from boulder conglomerate/lahar to fine sandstones. These unaltered detrital mineral clasts serve to correlate the lahar/breccia members with the fine-grained, finely laminated lacustrine members of the same facies. The detrital biotite, quartz and feldspar appear identical to the phenocrysts in the biotite-bearing assemblage

The facies is distributed in a number of areas peripheral to the main area of outcrop of the biotite-bearing assemblage and is included in it partly because of this spatial association. More importantly, the facies contains detrital biotite which is absent in the rare epiclastic deposits associated with the pyroxene-bearing assemblage. The biotite-bearing sedimentary rocks are therefore interpreted to have formed as a moat facies in a topographic depression, possibly a caldera, during a period of volcanic quiescence. The disjointed occurrence of this facies is interpreted as indicating the presence of separate depositional basins, peripheral to a central rhyolite complex.

In a number of locations, particularly southeast of Fishpot Lake, the moat facies includes beds of siliceous sinter deposits, associated with the lacustrine members and suggesting deposition from a paleogeothermal spring into a lake. This is interpreted as further evidence for the existence of a major volcanic centre and suggests an age for the Eocene epithermal mineralization; all the known occurrences of widespread epithermal alteration and associated quartz and precious metal mineralization in the area are associated with the biotite-bearing assemblage. Local hydrothermal bleaching of the younger dacites spatially associated with the biotite-bearing assemblage suggests that the hydrothermal alteration that affected the older facies was still active, but weaker during their eruption.

The chemical sedimentary and fine-grained clastic rocks contain locally abundant plant fossils, described below and, less commonly, fossil fish, which have not been studied in detail. This indicates the existence of an environment in which immature clastic and chemical sediments accumulated and supported plant and animal life during the period of volcanic activity.

AMYGDALOIDAL LAVA

Minor exposures of amygdaloidal lava occur south of Thunder Mountain, east of Clisbako Canyon and in several other parts of the study area. These were not examined in detail nor subjected to chemical or isotopic analysis because of ubiquitous alteration. The lavas are green as a result of pervasive chlorite-epidote alteration and contain as much as 10% amygdules, 0.5 to 3 centimetres across. The amygdules contain fine-grained silica and, rarely, carbonate. The flows appear to overlie the other Eocene lithologies in the Clisbako area and probably represent the latest stages of volcanic activity in this period. No evidence of epithermal-style mineralization associated with these flows was observed during the course of fieldwork.

^{40}AR/^{39}AR ISOTOPIC AGE DETERMINATIONS

Four samples from the pyroxene-bearing assemblage and three samples from the biotite-bearing assemblage were analysed for argon isotopic composition, to determine their age. The analyses were carried out at the Geological Survey of Canada's isotope laboratory in Ottawa. Due to the fresh nature of the samples and the absence of potassium-bearing phases in the dacites, a whole-rock fraction was analysed for each of the pyroxene-bearing samples. Biotite fractions from the three biotite-bearing samples were used to make the determinations, owing to the ubiquity of fresh phenocrysts of this mineral.

Analytical procedures for all samples in the pyroxene-bearing assemblage and for 95-CMR, from the flow dome at Canyon Mountain, follows that outlined in Appendix 1 of Roddick (1990). Whole-rock samples weighing 32 to 34 milligrams were loaded into aluminum foil packets, arranged in an aluminum can 40 by 19 millimetres , together with evenly distributed packets of FCT-3 biotite as flux monitors. The can was sent to the research reactor at McMaster University for 8-hour neutron irradiation in an approximate fast neutron fluence of $3x10^{16}$ neutrons/square centimetre. An age of 27.68±0.03 Ma was ascribed to FCT-3 (M.J. Kunk, personal communication, as quoted in Roddick, 1990) resulting in a calculated J factor of 0.00185 to 0.00187, although variation along the can, as measured with FCT-3, allowed interpolation of J factor for samples that fell between monitors. Analytical procedure for 95-CMR was very similar to that described above for whole-rock samples from the pyroxene-bearing assemblage, with the difference that only 3 milligrams of hand-picked biotite from this sample were prepared, with an irradiation time of 2 hours resulting in a calculated J factor of 0.000485.

Mass spectrometry was carried out on a modified MS-10 mass spectrometer and data corrections were applied as described in Roddick (1990). A shortened step-heating analysis was carried out on these samples, with three to four steps ranging between 500°C to 1550°C. Comparison of the ages derived from the last two or three steps helps in the assessment of the internal consistency of the age and provides a cross-check on the concordancy of the results. Errors in isotopic ratios were propagated and evaluated as outlined in Roddick (1988).

Samples HHB93-3203 and HHB93-3811, from rhyolite blocks in pyroclastic units of the biotite-bearing assemblage at localities east of Canyon Mountain, were prepared in a similar manner as a separate irradiation, with a resulting J factor of approximately 0.00185. Mass spectrometry of these samples was carried out on a VG3600 mass spectrometer, a magnetic sector mass spectrometer with 60° extended geometry equipped with a Faraday collector and electron multiplier. The signal on the latter is measured across a $1x10^{9}$ ohm resistor with a resulting gain, relative to Faraday, of approximately 50. Mass spectrometer sensitivity while using the electron multiplier is gain dependent, but is approximately at $1.900x10^{-9}$ cubic centimetres STP/V. Samples were loaded into foil packets and irradiated as described above, except that the corresponding monitor was Fish Canyon Tuff sanidine, with an age of 28.03±0.1 Ma (Renne *et al.*, 1995).

Upon return from the reactor, samples were split into two aliquots, loaded into separate 1.5 millimetre diameter x 4 millimetre deep holes in a copper planchet and placed under vacuum in a chamber topped with a Zn-Se window. This window is transparent to the beam of a Weck CO_2, 45-watt surgical laser, which was stepped incrementally from 2 to 45 power watts before being optically attenuated by 1/20. Power density in the beam forms a Gaussian distribution, and thus the edges are clipped by a metal mask restricting the beam to approximately 150 millimetre diameter at the sample with roughly constant power distribution. The beam is manually "panned" for 1 minute around the hole to provide roughly even heating of the sample. Cross-checking of gas release spectra on standards step-heated in the MS-10/double vacuum furnace shows that the increasing CO_2 laser power mimics an increase in furnace temperature. Quantitative temperature calibration is not possible because sample geometry, size, opacity of sample to laser and other factors shift the heating spectrum to higher or lower absolute temperatures within any one hole.

TABLE 1
ARGON STEP HEATING DATA FOR SAMPLES RUN ON MS-10/FURNACE AT GEOLOGICAL SURVEY OF CANADA

Temp (°C)	$^{36}Ar_{tr}$	$^{37}Ar_{Ca}$	$^{38}Ar_{Cl}$	$^{39}Ar_K$	^{40}Ar	%Atmos ^{40}Ar	Apparent Age Ma±2 [b]	^{39}Ar (%)
	x10^{-9} cm^3 STP[a]							
HHB93-3710 (21.54 mg) J = .001874 ± 0.50 %, 1								
500°	0.006	0.139	0.100	1.085	16.660	10.8%	45.7±0.4	11.2%
750°	0.024	1.175	0.452	5.383	80.190	9.0%	45.3±0.1	55.4%
1050°	0.005	0.923	0.140	1.811	25.690	6.1%	44.5±0.5	18.6%
1550°	0.016	0.906	0.125	1.433	23.980	19.9%	44.8±0.2	14.8%
Total[c]	0.050	3.140	0.820	9.710	146.500	10.5%	45.1±0.5	
Conc.(/g)	2.410	145.900	37.900	450.900	6803.0			
HHB93-3306 (19.71 mg) J = .001868 ± 0.50 %, 1								
500°	0.010	0.140	0.011	0.481	5.750	49.2%	20.4±0.6	5.7%
850°	0.021	1.561	0.047	5.146	83.710	7.5%	50.0±0.1	61.3%
1050°	0.004	0.594	0.088	1.922	29.330	4.4%	48.5±0.1	22.9%
1550°	0.010	0.429	0.049	0.843	14.960	19.4%	47.6±0.2	10.0%
Total[c]	0.040	2.720	0.200	8.390	133.700	9.9%	47.7±0.5	
Conc.(/g)	2.280	138.200	9.900	425.700	6786.0			
HHB93-3501 (21.05 mg) J = .001861 ± 0.50 %, 1								
500°	0.011	0.230	0.193	2.002	30.270	10.8%	44.7±0.2	21.4%
850°	0.018	2.246	0.522	5.975	84.890	6.2%	44.2±0.1	63.8%
1050°	0.003	0.881	0.056	0.660	8.980	8.7%	41.2±0.4	7.0%
1550°	0.009	1.287	0.075	0.724	12.050	21.3%	43.4±0.2	7.7%
Total[c]	0.040	4.640	0.850	9.360	136.200	8.7%	44.0±0.4	
Conc.(/g)	1.910	220.600	40.210	444.700	6470.0			
HHB93-3005 (26.11 mg) J = .001851 ± 0.50 %, 1								
500°	0.013	0.172	0.008	0.569	6.180	61.8%	13.8±0.5	6.3%
850°	0.016	2.407	0.024	6.966	113.060	4.3%	51.1±0.1	76.7%
1050°	0.003	0.728	0.048	1.151	17.680	5.3%	48.0±0.3	12.7%
1550°	0.008	1.434	0.042	0.401	8.270	30.0%	47.6±0.5	4.4%
Total[c]	0.040	4.740	0.120	9.090	145.200	8.3%	48.3±0.5	
Conc.(/g)	1.570	181.500	4.700	348.000	5561.0			
95-CMR (3.1 mg) J = .000485 ± 0.50 %, 1								
600°	0.005	0.023	0.000	0.005	1.660	85.2%	42.6±57.2	0.9%
970°	0.013	0.023	0.009	0.132	11.920	33.5%	52.0±0.7	23.7%
1550°	0.007	0.022	0.025	0.420	26.740	7.4%	50.9±0.6	75.4%
Total[c]	0.020	0.070	0.030	0.560	40.300	18.3%	51.1±0.9	
Conc.(/g)	8.060	21.780	11.010	179.400	13010.0			

[a]All gas quantities have been corrected for decay, isotopes derived from minor interfering neutron reactions and blanks. tr denotes trapped Ar. Ca, Cl, K denote Ar derived from these elements. ^{40}Ar denotes trapped plus radiogenic Ar. ^{40}Ar assumes a trapped argon component of atmospheric composition.

[b]Errors from individual steps are analytical only anddo not include the error in irradiation parameter J.

[c]Includes the integrated age. The uncertainty in J is included in the error

TABLE 2
ARGON STEP HEATING DATA FOR SAMPLES RUN ON VG3600/LASER AT GEOLOGICAL SURVEY

Power[a] (W)	$^{36}Ar_{tr}$	$^{37}Ar_{Ca}$	$^{38}Ar_{Cl}$	$^{39}Ar_K$	^{40}Ar	%Atmos ^{40}Ar	Apparent Age Ma±2 [c]	^{39}Ar (%)
	x10-11 cm3 STP[b]							
HHB93-3203 Biotite, J = .0018188 ± 0.50 %, 1								
Aliquot A								
3W	0.436	0.055	0.051	0.682	130.420	98.7%	7.9±12.8	0.4%
5W	0.212	0.064	0.132	1.998	76.170	82.3%	22.0±1.9	1.2%
8W	0.165	0.055	0.116	1.682	65.830	74.2%	32.8±2.1	1.0%
10W	0.165	0.062	0.210	2.940	79.370	61.3%	34.0±1.1	1.8%
11W	0.376	0.136	0.695	9.513	235.310	47.2%	42.4±0.4	5.7%
15W	0.442	0.335	1.125	15.157	355.950	36.7%	48.1±0.4	9.1%
18W	0.491	0.676	2.247	30.317	618.570	23.5%	50.5±0.2	18.1%
20W	0.275	0.607	1.674	22.884	443.430	18.3%	51.2±0.2	13.7%
22W	0.113	0.330	0.677	8.897	172.850	19.3%	50.7±0.2	5.3%
25W	0.105	0.410	0.701	9.072	175.080	17.8%	51.3±0.3	5.4%
30W	0.136	0.962	0.915	11.277	218.130	18.4%	51.1±0.3	6.7%
35W	0.090	0.671	0.557	6.655	130.890	20.4%	50.7±0.5	4.0%
45W	0.103	0.970	0.919	10.966	202.440	15.0%	50.7±0.2	6.5%
Subtotal[d]	3.110	5.330	10.020	132.040	2904.400	31.6%	48.7±0.5	79.0%
Aliquot B								
3W	0.129	0.042	0.048	0.646	42.530	89.4%	22.7±8.0	0.4%
5W	0.108	0.069	0.205	2.899	67.160	47.4%	39.5±0.8	1.7%
8W	0.070	0.080	0.237	3.204	68.480	30.3%	48.2±0.7	1.9%
10W	0.043	0.079	0.180	2.370	49.640	25.6%	50.4±0.4	1.4%
11W	0.058	0.120	0.318	4.194	83.190	20.5%	51.0±0.3	2.5%
12W	0.028	0.101	0.162	2.070	40.630	20.4%	50.5±0.5	1.2%
15W	0.054	0.189	0.261	3.346	69.200	23.2%	51.3±0.4	2.0%
20W	0.063	0.396	0.524	6.887	127.810	14.7%	51.2±0.3	4.1%
25W	0.025	0.262	0.203	2.563	47.930	15.2%	51.3±1.1	1.5%
30W	0.039	0.331	0.392	5.235	94.810	12.2%	51.4±0.6	3.1%
45W	0.013	0.257	0.155	2.013	35.460	10.9%	50.8±0.6	1.2%
Subtotal[d]	0.630	1.930	2.680	35.430	726.800	25.6%	49.4±0.5	21.0%
Total[d]	**3.740**	**7.100**	**12.700**	**167.470**	**3631.300**	**30.4%**	**48.8±0.5**	

[a]Laser power in watts, prior to 20x optical attenuation of beam

[b]All gas quantities have been corrected for decay, isotopes derived from minor interfering neutron reactions and blanks. tr denotes trapped Ar. Ca, Cl, K denote Ar derived from these elements. ^{40}Ar denotes trapped plus radiogenic Ar. ^{40}Ar assumes a trapped argon component of atmospheric composition. [a]All gas quantities have been corrected for decay, isotopes derived from minor interfering neutron reactions and blanks. tr denotes trapped Ar. Ca, Cl, K denote Ar derived from these elements. ^{40}Ar denotes trapped plus radiogenic Ar. ^{40}Ar assumes a trapped argon component of atmospheric composition.

[c]Errors from individual steps are analytical only and do not include the error in irradiation parameter J.

[d]Includes the integrated age. The uncertainty in J is included in the error

TABLE 2 Continued

Power[a] (W)	$^{36}Ar_{tr}$	$^{37}Ar_{Ca}$	$^{38}Ar_{Cl}$ x10^{-11} cm^3 STP[b]	$^{39}Ar_K$	^{40}Ar	%Atmos ^{40}Ar	Apparent Age Ma±2 [c]	^{39}Ar (%)
HHB93-3811 Biotite, J = .0018424 ± 0.50 %, 1 S.E.								
				Aliquot A				
3W	0.746	0.079	0.097	1.676	231.010	95.5%	20.7±5.1	1.9%
5W	0.172	0.075	0.166	2.526	85.570	59.4%	45.1±1.5	2.9%
8W	0.130	0.093	0.280	4.165	105.210	36.6%	52.5±0.7	4.7%
10W	0.096	0.110	0.280	4.068	93.930	30.3%	52.7±0.8	4.6%
11W	0.140	0.273	0.512	7.144	157.290	26.3%	53.2±0.6	8.1%
12W	0.043	0.113	0.185	2.556	54.240	23.6%	53.1±0.6	2.9%
15W	0.045	0.167	0.202	2.777	58.460	22.8%	53.2±0.7	3.2%
20W	0.064	0.376	0.351	4.697	94.530	20.0%	52.8±0.4	5.3%
30W	0.018	0.157	0.030	1.102	22.850	23.4%	52.0±0.6	1.3%
45W	0.014	0.359	0.108	0.974	19.380	20.6%	51.8±1.2	1.1%
Subtotal[d]	1.470	1.800	2.210	31.690	922.500	47.0%	50.5±0.6	36.0%
				Aliquot B				
3W	0.754	0.071	0.071	1.285	232.400	95.8%	25.0±8.8	1.5%
5W	0.141	0.096	0.245	3.577	97.080	42.8%	50.9±0.9	4.1%
8W	0.079	0.116	0.242	3.236	75.940	30.6%	53.4±0.8	3.7%
10W	0.061	0.131	0.192	2.473	58.160	31.0%	53.1±1.2	2.8%
11W	0.050	0.171	0.167	2.238	51.510	28.7%	53.8±1.1	2.5%
12W	0.020	0.119	0.071	0.892	20.630	29.0%	53.8±1.6	1.0%
15W	0.022	0.097	0.075	1.021	23.330	27.9%	53.9±1.0	1.2%
20W	0.027	0.079	0.057	0.860	21.880	36.2%	53.2±1.4	1.0%
45W	0.478	0.499	0.728	10.197	299.190	47.2%	50.8±0.5	11.6%
Subtotal[d]	1.630	1.460	1.850	25.780	880.100	54.8%	50.6±0.7	29.4%
				Aliquot C				
3W	0.924	0.072	0.103	1.941	287.900	94.9%	25.0±7.0	2.2%
5W	0.242	0.109	0.291	4.516	138.630	51.6%	48.8±1.0	5.1%
8W	0.114	0.123	0.323	4.623	109.810	30.6%	54.0±0.5	5.3%
10W	0.073	0.130	0.264	3.644	81.590	26.4%	54.0±0.7	4.1%
11W	0.120	0.345	0.479	6.571	144.070	24.7%	54.1±0.5	7.5%
12W	0.029	0.112	0.130	1.805	38.650	22.5%	54.4±0.4	2.1%
15W	0.036	0.229	0.163	2.216	46.570	22.8%	53.2±0.5	2.5%
20W	0.050	0.231	0.227	3.162	66.470	22.3%	53.5±0.4	3.6%
30W	0.015	0.106	0.077	1.130	22.620	19.9%	52.5±1.1	1.3%
45W	0.013	0.106	0.060	0.829	16.870	22.3%	51.8±1.0	0.9%
Subtotal[d]	1.620	1.680	2.120	30.440	953.200	50.1%	51.2±0.7	34.6%
Total[d]	**4.720**	**4.740**	**6.180**	**87.900**	**2755.800**	**50.5%**	**50.8±0.6**	

[a]Laser power in watts, prior to 20x optical attenuation of beam.
[b]All gas quantities have been corrected for decay, isotopes derived from minor interfering neutron reactions and blanks. tr denotes trapped Ar. Ca, Cl, K denote Ar derived from these elements. ^{40}Ar denotes trapped plus radiogenic Ar. ^{40}Ar assumes a trapped argon component of atmospheric composition.
[c]Errors from individual steps are analytical only and do not include the error in irradiation parameter J.
[d]Includes the integrated age. The uncertainty in J is included in the error

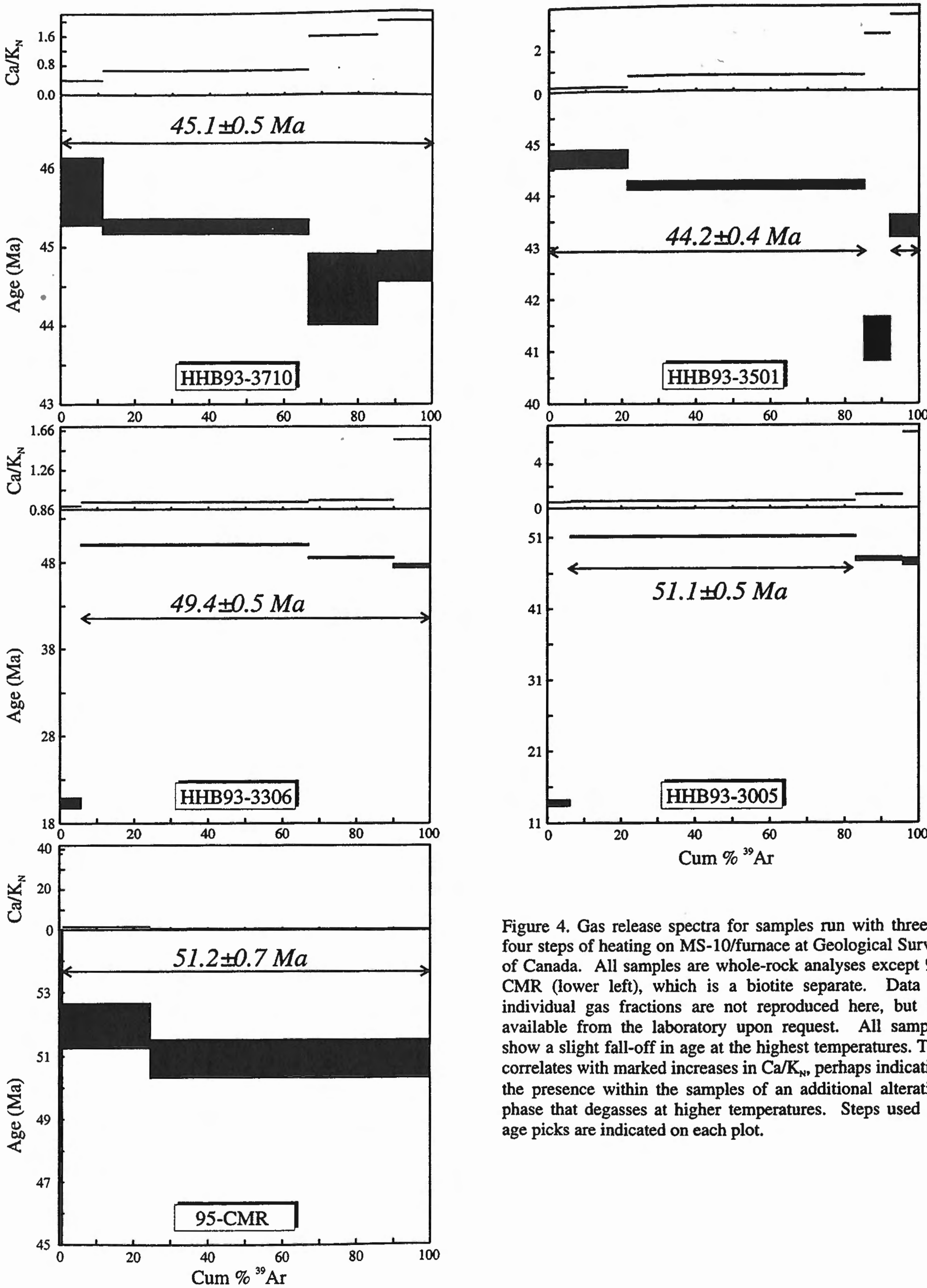
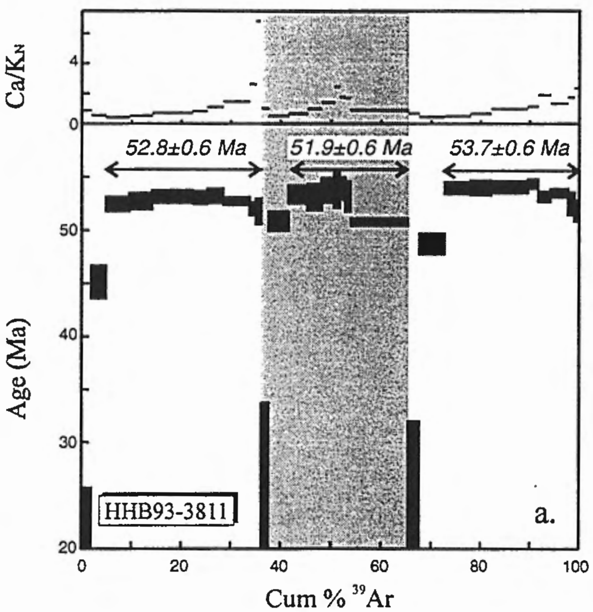
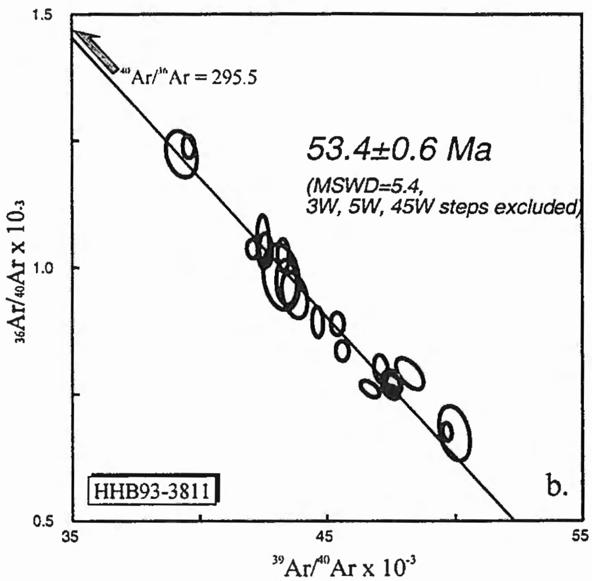


Figure 4. Gas release spectra for samples run with three to four steps of heating on MS-10/furnace at Geological Survey of Canada. All samples are whole-rock analyses except 95-CMR (lower left), which is a biotite separate. Data on individual gas fractions are not reproduced here, but are available from the laboratory upon request. All samples show a slight fall-off in age at the highest temperatures. This correlates with marked increases in Ca/K$_N$, perhaps indicating the presence within the samples of an additional alteration phase that degasses at higher temperatures. Steps used for age picks are indicated on each plot.

The gas released is cleaned by passive equilibration of the gas with a getter filled with three SAES™ NP-10 getters of ST707 alloy held at 400°C, as well as a cold getter of SAES™ alloy 201 pellets for 2 to 5 minutes. Total extraction blank is approximately 8×10^{-12} cubic centimetres STP ^{40}Ar for all steps. Argon peaks are sequentially scanned by computer-controlled switching of magnetic field, as monitored by a calibrated Hall probe (see Roddick, 1995 for details). Twelve scans of each mass were measured together with baselines taken 0.4 masses away from the ^{36}Ar peak. Corrections to the measured peak intensities were carried out as described in Roddick (1990). Data reduction procedures for each aliquot follows Roddick (1988). Upon completion of each of the two aliquots of the sample, data were combined and treated as a single data set for analysis by the inverse isochron method (Roddick *et al.*, 1980; error analysis follows Roddick, 1988) and integration of plateau portions of a gas release spectrum. Because data from the two samples presented in this paper are highly radiogenic and point towards an initial $^{40}Ar/^{36}Ar$ value of 295.5, the data are presented as a single gas-release spectrum (consisting of two aliquots) for each sample. For reasons outlined in Roddick (1988), error in J factor measurement of ±0.5% is only included in the final age determination.

Analytical data are presented in Tables 1 and 2. Analytical results are summarized in Figures 4 (MS-10 mass spectrometer/furnace) and 5 (VG3600 mass spectrometer/laser). The interpreted ages are similar to the age range of 47.6 Ma to 49.9 Ma obtained for the Wolf property (Andrew, 1988).





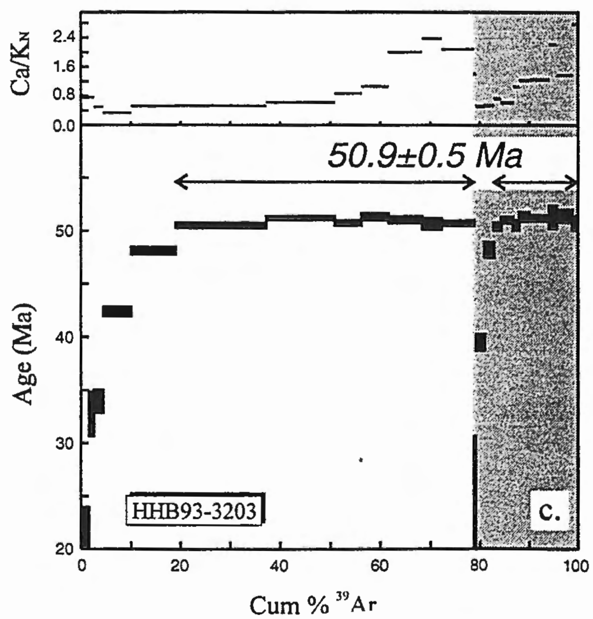


Figure 5. Results from samples run on VG3600/laser system at Geological Survey of Canada.
a. Gas release spectra for aliquots A, B and C from sample HHB93-3811 biotite. 300-500 μm, strongly altered, mottled gold biotite was analysed, with each aliquot giving a different plateau age. Isotope systematics indicate argon loss in the first two low-temperature steps, while the highest temperature step of each aliquot appears to contain gas from an alteration phase (as indicated by increased Ca/K_N).
b. An inverse isochron diagram of all aliquots with low and high-temperature steps removed results in an age of 53.4± 0.6 Ma, the interpreted age of the sample.
c. Gas release spectra for aliquots A and B from sample HHB93-3203 biotite. Both aliquot plateau ages agree and the combined results give an age of 50.9±0.5 Ma.

The four samples taken from the pyroxene-bearing assemblage yielded ages ranging from 51.1±0.5 Ma to 44.2±0.4 Ma. Pyroxene-bearing volcanism in the Clisbako area was therefore active for at least 6 million years during Middle Eocene (Lutetian) time. The considerable range in ages for this assemblage, and their relatively silicic and viscous compositions, suggest that the lavas are reasonably close to a source vent. The presence of a circular highland which marks their outcrop area, and the associated magnetic high in the west-central part of the area (Teskey *et al.*, 1996; Shives and Carson, 1994), strongly suggest that the area was occupied by a large volcanic complex in Eocene time.

The number of samples analysed from this assemblage is insufficient to document the volcanic history of the area, but their individual ages and locations are of interest. Samples HHB93-3005 and HHB93-3306 are flow-laminated dacite taken from Toil Mountain and from an outcrop on the McFarland Creek road in the eastern-central part of the area. Both samples have suffered some surface alteration along flow laminae and their ages are less well constrained, but lie in the 48 to 52 Ma range. Sample HHB93-3710, from a colonnade at the extreme eastern edge of the Eocene outcrop area, returned a well constrained age of 45.1±0.3 Ma, consistent with the layered stratigraphy of a stratovolcano.

Sample HHB93-3501 was taken from Little Mountain, near the centre of the Eocene outcrop area and returned an age of 44.2±0.4 Ma, the youngest of the four ages and within error of the colonnade sample on the eastern margin (the age grouping may be due to the small number of samples analysed). The age and position of the Little Mountain sample suggest either that the volcano was not a true stratovolcano, or that there has been substantial subsidence of the central part of the edifice since formation.

The sample from Canyon Mountain (95-CMR) returned an age of 51.2±0.7 Ma and one sample of biotite rhyolite from a pyroclastic flow has an interpreted age of 50.9±0.5 Ma that lies within error of this date. This age distribution strongly suggests a single large pyroclastic phase of activity. However, the other pyroclastic sample, HHB93-3811, yielded mottled gold biotite which, despite a disparity in plateau ages (Figure 5), returned an age of 53.4±0.6 Ma. The sample does show some geological contamination by augite-bearing dacite, which significantly affects its chemical composition, but should have had little effect on the isotopic systematics of biotite. The age is interpreted as real; the phase of pyroclastic biotite-bearing volcanism was therefore at least 1.4 Ma in duration, or there was more than one period of such activity. It is also noteworthy that the intensely quartz-phyric units appear to postdate the other units of this assemblage (Richards and others, unpublished data).

Data obtained in this study are in agreement with data obtained for the eastern part of the study area by Rouse and Mathews (1988) and with data obtained for the Quesnel area (Rouse and Mathews, 1979). Both areas returned ages of 48.8±1.5 Ma to 49.8±1.7 Ma for a biotite-bearing assemblage, which is within error of the two youngest rhyolite samples analysed in this study. Dacite samples from the Nazko area returned ages of 48.7±1.7 Ma and 45.7±1.6 Ma and dacites in the Quesnel area returned an age range of 42.9±2.9 Ma to 41.6±2.9 Ma. It should be noted that, in all three studies, the dacite ages while within error of those returned from biotite-bearing rocks, are younger. This is inconsistent with the great volume of dacitic accidental material in the rhyolitic pyroclastic rocks.

Metcalfe and Hickson (1995) interpreted the Clisbako area as the erosional remnant of a large volcanic edifice, on the basis of its subdued relief. However, this hypothesis of deep erosion is inconsistent with the presence of uneroded Eocene sedimentary rocks which formed after deposition of a large volume of volcanic material. A substantial thickness of Eocene volcanic rock probably underlies the central and western part of the area. The relatively subdued topography is either the result of considerable subsidence in the central part of the edifice or its inundation by an equivalent thickness of Chilcotin basalts.

Isotopic and field evidence indicate the occurrence of one, possibly two episodes of silicic pyroclastic volcanism with the associated extrusion of rhyolitic flow domes, preceded by a major phase of constructive dacitic volcanism and followed by 6 to 7 million years of intermittent dacitic eruptions. This history is consistent with the younger ages of two of the pyroxene-bearing assemblage, the roughly coeval ages (within error) of the two remaining pyroxene-bearing samples and the occurrence of large quantities of dacitic accidental fragments in the biotite-bearing pyroclastic rocks.

PALYNOLOGICAL AGE OF MOAT FACIES

Seven samples from within the study area were submitted for palynological analysis to the Institute of Sedimentary and Petroleum Geology, Geological Survey of Canada, Calgary. Table 3 lists the pollen and spore flora found in each sample with their abundance (rare, few, common and abundant). Microscope slide co-ordinates for specimens are in an unpublished fossil report (White, 1993).

The flora assemblages are derived from epiclastic and related rocks from the moat facies of the Mount Clisbako volcano, all of which contain detrital biotite. The only local source of biotite is the Eocene biotite-bearing volcanic assemblage, therefore the floral assemblages are contemporaneous with or postdate the biotite-bearing volcanic rocks. The biotite-bearing assemblage has been constrained at 51.4±0.7 Ma by $^{40}Ar/^{39}Ar$ analysis (*see* above).

TABLE 3

PALYNOLOGY OF SELECTED MICROFLORA IN THE CLISBAKO MOAT FACIES

Sample number (Richards)	93/B/17-A	93/B/13-13	93/B/13-13	22/6/92/15a	22/6/92/15b	16/6/92RR	04/7/92 A	04/7/92 B
Sample number (White)	C-310131	C-310132	C-310132	C-310133	C-310134	C-310135	C-310137	C-310138
UTM N	5856400	5853600	5853600	5854100	5854100	5842400	5840200	5840200
UTM E	452000	452200	452200	449200	449200	461500	414500	414500
fraction	unscreened	unscreened	+20 µm	+20 µm	+20 µm	unscreened	+20 µm	+20 µm
Acer		(?) rare						
cf. *Aesculus*		few		few				
Alnus sp., 4 and 5 pore	few						common	
cf. *Betula*	rare							
cf. *Boisduvalia clavatites* Piel	rare, eroded							
Bombacaceae							rare	
Carya juxtaporipites (Wodehouse) Rouse		few		common	few	few		
Carya sp.					few			few
cf. *Cedrus* sp.						rare		
Cercidiphyllum sp.	rare				rare		*cf*; rare	rare
Corylus-type		rare						
Cupuliferoidaepollenites liblarensis (Thompson) Potonie		(?) few						
Cupuliferoipollenites sp. of Rouse and Mathews (1988, Plate 2, Fig. 6)	(?) rare			rare[1]				
Ericales								few
Hyphomycetes, hyphae		common[2]						
Laevigatosporites sp.		few		v. abundant				
Liliaceae	rare	few		rare				
Liquidambar sp.								rare
Osmunda sp.		few						rare
Pachysandra/Sarcococca	(?) rare	rare					(?) rare	
Paraalnipollenites cf. *P. alterniporus* (Simpson) Srivastava					rare			
Picea sp.				rare			few	common
Pinaceae (undifferentiated)		few		rare		common	common	

TABLE 3 Continued

Sample number (White)	C-310131	C-310132	C-310132	C-310133	C-310134	C-310135	C-310137	C-310138
Pinus sp.	few	abundant						common
Pistillipollenites mcgregorii Rouse					common	few	rare	
Podocarpus-type		*cf*;.few					rare	rare
Polyadosporites sp.				few				
Pterocarya sp.				abundant			rare	
Quercus sp.		rare						
cf. *Rhoiipites latus* of Mathews and Rouse (1984 Plate 1, Fig. 6)				rare				
Sciadopitys sp.		few					rare	*cf*, few
Staphylosporonites sp.		few						
Syncolporites? sp.			rare					
Taxodiaceae		common						
Taxodiaceae-Cupressaceae-Taxaceae (T-C-T)	common	abundant		common	common	common	common	abundant
Tilia crassipites Wodehouse		rare						
Tilia sp.					rare		few	
Tricolpate, new, of Rouse and Mathews (1988, Plate 2, Fig. 16)	rare							
Tricolporate A of Piel (1971)		fragment						
Tricolporopollenites sp.		few						
Triporate B of Piel (1971, Plate XVII, Fig. 150)		gemmate fragment[3]	rare					
Tsuga canadensis-type	few	few			rare			
Tsuga sp.				rare				rare
Ulmus-type				few			few	
fungal hyphae	common							

? denotes tentative identification
cf. denotes identification by close comparison
[1] Tricolporate, slight equatorial elongation 20/14 µm, psilate
[2] Many with microechinate or microverrucate ornamentation
[3] Fragment may be of *Boisduvalia clavatites* (Piel 1971)

Samples C-130134, -135, and -137 are inseparable in age based on the palynomorph assemblage. C-310138 has a non-diagnostic flora but is from the same locality as C-130137 and is of the same age. C-130134, -135 and -137 contain *Pistillipollenites mcgregorii*, a Late Paleocene to early Middle Eocene indicator (Mathews and Rouse, 1984). The value of *P. mcgregorii* as an indicator is emphasized by the fact that it was not observed in 200 palynological samples of Late Eocene to Oligocene age from the Amphitheatre Formation, Yukon Territory (Ridgeway *et al.*, 1995). The presence of *Tilia* pollen in C-130134 and -137 limits the maximum age of those samples to Eocene (Mathews and Rouse, 1984).The presence of *Paraalnipollenites alterniporus* in C-130134 is consistent with an Early to early Middle Eocene age range. The age of these four samples is in agreement with the $^{40}Ar/^{39}Ar$ age of 51 Ma on the biotite-bearing lithological assemblage.

C-130132 lacks *P. mcgregorii.* It contains cf. *Aesculus* pollen, found in late Eocene beds at Cheslatta Falls (Rouse and Mathews, 1988). Tricolporate A and Triporate B of Piel (1971) were described in a palynomorph assemblage from the Australian Creek Fm. (Piel, 1971; Rouse and Mathews, 1979). The Australian Creek Formation assemblage, formerly considered to be of early Oligocene age (Piel, 1971; Rouse and Mathews, 1979), is now correlated to the Late Eocene (Ridgeway *et al.*, 1995), with the possibility that the assemblage extends into the Oligocene. Thus, C-130132 is younger than the samples described above, and is of Late Eocene or possibly Early Oligocene age. C-130131 has a very sparse assemblage, but contains *Boisduvalia clavatites*, an element of the Australian Creek Formation assemblage from central British Columbia described by Piel (1971). It is probably contemporaneous with C-130132. The significantly younger age of these samples may indicate a late phase of volcanism, but there is no isotopic or field evidence for such an event taking place. More probably, the provenance of biotite in these later rocks is the result of its recycling in an epiclastic environment, close to the source.

CHILCOTIN GROUP BASALTIC ROCKS

Relatively well exposed basaltic lava flows occur in most of the valleys in the study area. These lavas are distinctively fresh in appearance and commonly show well developed colonnades and flow tops. Phenocrysts are most commonly olivine; less commonly plagioclase and rarely augite. They were assigned by Tipper (1959, 1969) to the Chilcotin Group and were also described by Mathews (1989). The ages of all the basaltic flows have not been documented, but Hunt (1992) described plant fossils in terrestrial sedimentary layers within the basaltic pile which are consistent with an Early Miocene age. No isotopic ages are available for flows within the area and some may be considerably younger. The basalts do not mask paleotopography, as they do in the plateau area to the west and south of the Clisbako highland; rather they fill paleovalleys, in places to depths of 200 metres or more (Hunt 1992), frequently covering eroded areas of less resistant Eocene rock and forming a protective cap. It should be noted that these

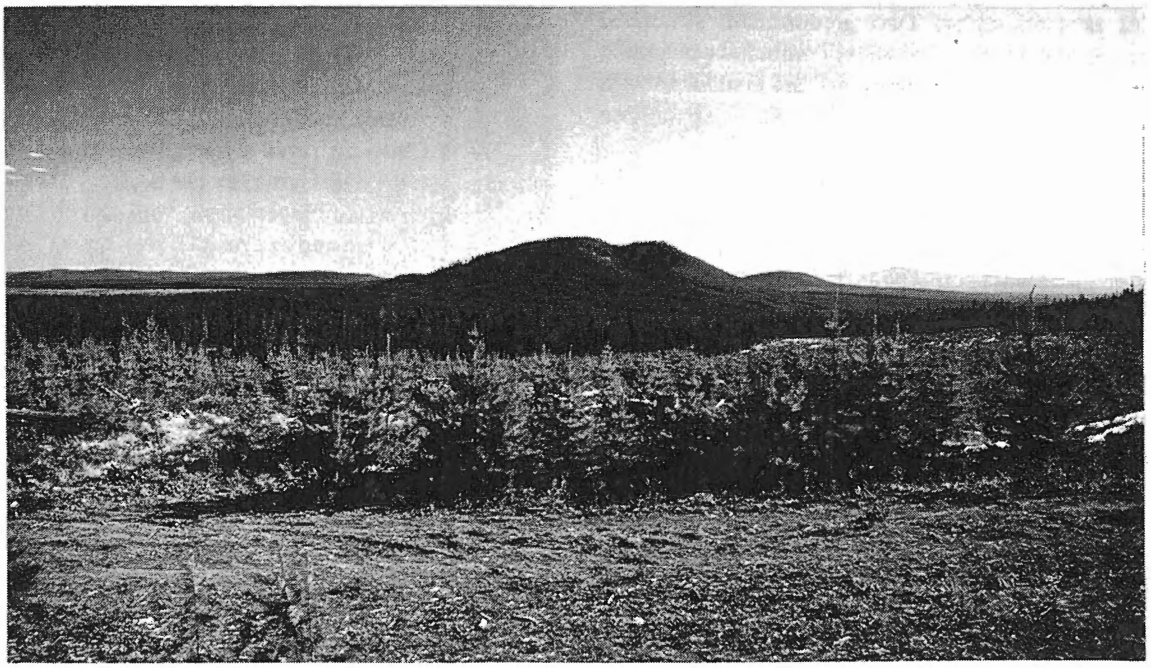


Photo 9. Relict cinder cones break the flat topography of the Chilcotin plateau lavas. In the foreground is Cleft Hill, one of the cones interpreted as a source for the lavas. The Chilcotin basalts overlie the two Eocene assemblages, filling ancient valleys and swamping the Eocene volcanic edifice.

lavas may mask significant epithermal exploration targets in the area.

Tipper (1959, 1969) noted the presence of a number of small cinder cones, which are probable source vents for the lavas. Several such structures were discovered during the course of fieldwork and may be more abundant than suggested by Tipper's mapping. Sharp, discrete magnetic anomalies over the Chilcotin Plateau to the southwest are coincident with small hills and may mark the locations of numerous Chilcotin vents. Tipper (personal communication to T.A. Richards) noted that some of the cinder cones present in the area and elsewhere on the Chilcotin Plateau may be considerably younger than their assumed age and represent part of the volcanism associated with the Anahim Belt.

One such cone (Cleft Hill) lies southwest of the Eocene outcrop area (Figure 2; Photo 9) and was examined in 1994. It has a central crater which is open to the north. Rocks exposed on the crater wall comprise interlayered agglutinate and vesicular basalt blocks. The cone appears to have a very low proportion of scoriaceous material, compared to the 7200-year-old Nazko cone, in the northeast of the area. The latter was described by Souther *et al.* (1987) and is outside the scope of the present study.

INFERRED STRUCTURES

The Clisbako area is a glaciated area of low relief and poor outcrop; recessively weathering units and structures are very rarely exposed. The structural trends are therefore inferred from magnetic anomalies (Geological Survey of Canada, 1994; Shives and Carson, 1994) and by subtle variations in topography. Two predominant structural trends occur in the area. The most continuous magnetic lineaments have a northwest trend and are associated with a topographic "grain" which can be traced through the area and for a significant distance along strike.

A second set of strong magnetic anomalies trend north-northeasterly to northerly across the study area and also occur on the Chilcotin Plateau to the west and south. This set of anomalies is less continuous, but many of them cross the northwest-trending set without apparent displacement. Neither of the sets were observed in outcrop and neither their absolute and relative ages nor their senses of movement are known. The north-northeast structures are interpreted as extensional faults, analogous to basins and range and possibly hosting feeders either to the Eocene volcanic rocks or to the Chilcotin Group basalts. Extensional movement on these inferred structures could have taken place with associated strike slip reactivation of a northwest-trending fault set.

A third inferred structural trend is represented by two west-northwest-trending magnetic discontinuities north and south of the Toil Mountain anomaly. The more northerly is an extension of a persistent magnetic discontinuity along the trend of the Anahim volcanic belt, the other is poorly defined and discontinuous. Both anomalies may represent westerly trending splays from the northwest-trending structures; their age is also unknown. The lack of age data for all potential structures in the area, precludes assessment of their relative potential as exploration targets, but if epithermal mineralization in the area is structurally controlled, the intersections of structures, particularly northwest trending and west trending, would be high-potential exploration targets.

Some non-linear anomalies in the study area are interpreted as edge effects of the more strongly magnetized Chilcotin Group flows. Spot anomalies coincident with small hills on the Chilcotin Plateau to the southwest are interpreted as eruptive centres for the Chilcotin Group basalts. These anomalies will mask geophysical exploration targets in the underlying Eocene rocks.

CHEMICAL AND PETROGRAPHIC ANALYSIS OF THE CLISBAKO VOLCANIC COMPLEX

PETROGRAPHY

Sixty-six samples from the area were examined in thin section. Of these samples, eleven were of Chilcotin Group basalts, the remainder from Eocene intermediate flows, flow breccias and related tuffaceous sedimentary rocks.

The Chilcotin basalts, although not the focus of the study, are described briefly here. The lavas are weakly to moderately porphyritic. Phenocryst assemblages comprise olivine, titaniferous augite and plagioclase. Where proximal to a vent, the basalts are often strongly porphyritic and/or xenophyric. On the western slopes of Canyon Mountain, they contain many xenoliths of chromian lherzolite, probably with trace chrome spinel; associated olivine and pyroxene xenocrysts are also abundant.

Distal Chilcotin lavas are less easy to distinguish in outcrop from the underlying Eocene dacitic volcanic rocks; lavas of both assemblages show well developed colonnades, are glaciated and as a result do not have flow surface features. Olivine, which occurs in the basaltic lavas, is often not visible in hand specimen and epidote alteration after plagioclase can be mistaken for olivine in a cursory examination of a dacite outcrop. The only consistent difference in appearance between the two lithologies is the ubiquitous dictytaxitic groundmass of the Chilcotin basalts, in contrast with the microcrystalline to glassy groundmass of Eocene dacites. Even where the basalt groundmass is finer grained, or microcrystalline, it is usually felted, while the dacites exhibit a moderate to strong trachytic crystal alignment, flow banding or flow folding.

PYROXENE-BEARING ASSEMBLAGE

Samples of the pyroxene-bearing assemblage are weakly porphyritic to aphyric and monotonous in their phenocryst mineralogy. Phenocrysts rarely exceed 1 millimetre. The most abundant phenocryst phase is subhedral to euhedral plagioclase, commonly with strong oscillatory zoning, forming as much as 10% of any sample. Epidote alteration is common, but rarely pervasive. Larger plagioclase crystals contain intensely corroded cores (Photo 10). Core compositions, determined optically by the albite-Carlsbad method, range from An_{50} to An_{55}, with rare occurrences of cores as sodic as An_{30}. Non-corroded rims exhibit pronounced oscillatory zoning and range in composition from An_{67} to An_{62}, the latter value at the rims. Microphenocrysts and groundmass plagioclase are in apparent equilibrium with these rims.

Pyroxene phenocrysts rarely comprise more than 5% of the whole rock and never more than 10%. Augite phenocrysts are usually more common, often with exsolution lamellae of orthopyroxene, but the latter phase also occurs as discrete phenocrysts. Phenocrysts of both pyroxene phases are euhedral to subhedral, with unaltered cores; both exhibit oscillatory zoning, faint in the orthopyroxene, often strong in the clinopyroxene and indicative of a significant titanium content (Photo 11). Pyroxene phenocrysts are rarely in contact with plagioclase, but the two phases are mutually interpenetrant, indicating cotectic crystallization.

Hornblende phenocrysts occur rarely in the pyroxene-bearing rocks, in some cases as equant, possibly uralitic phenocrysts after clinopyroxene or orthopyroxene and rimmed with iron-titanium oxide. A few samples from the eastern edge of the Eocene outcrop contain prismatic phenocrysts of euhedral to subhedral oxyhornblende, with

Photo 10. Corroded core of plagioclase phenocryst, with a fresh rim showing strong oscillatory zoning. Crossed polars.

Photo 11. Euhedral titaniferous clinopyroxene with oscillatory zoning. Crossed polars.

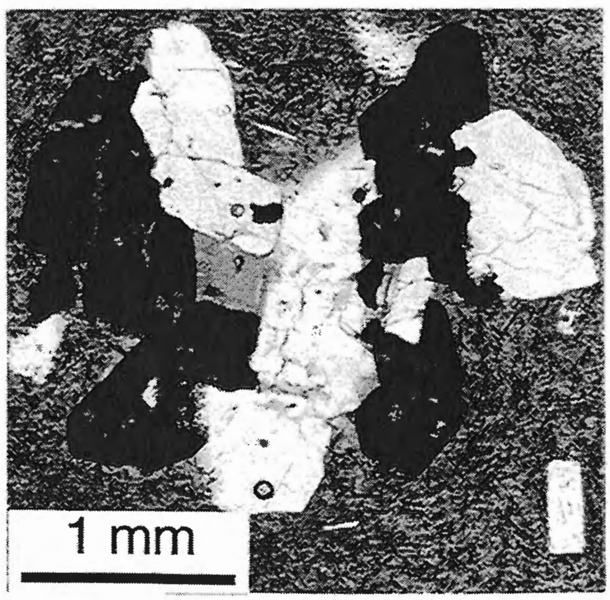


Photo 12. Glomerocryst in pyroxene-bearing lava, comprising corroded plagioclase phenocrysts and pseudomorphs after hornblende. Plane polarised light.

strongly oxidized rims. Most commonly, discrete crystals of hornblende are peripherally or pervasively replaced by a fine-grained intergrowth of alteration products or, rarely, by pyroxene.

Glomerocrysts, cored by anhedral clinopyroxene and orthopyroxene and rimmed with corroded plagioclase, are common in samples of the pyroxene-bearing assemblage. Relict outlines of pervasively altered euhedral to subhedral hornblende crystals were seen in a few sections (Photo 12). Relict phenocrysts of olivine, usually partially or completely replaced by pyroxene, are present in more mafic samples.

Apatite and zircon are rarely present in the phenocryst assemblage, although microphenocrysts of both phases are included in clinopyroxene. Apatite phenocrysts are as much as 0.1 millimetre in length, while microphenocrysts of zircon are volumetrically insignificant.

BIOTITE-BEARING ASSEMBLAGE

Eight of the Eocene samples examined in thin section were taken from outcrops of the biotite-bearing assemblage. The assemblage is defined by the presence of magmatic biotite, either fresh or exhibiting replacement due to hydrothermal alteration. In all but one sample, the biotite occurs as phenocrysts, euhedral to subhedral and as large as 2 millimetres across (Photo 13). In rare cases, biotite and plagioclase coexist as microphenocrysts.

Hornblende phenocrysts are common in the biotite-bearing rocks and are often peripherally replaced by magmatic biotite (Photo 14). Hornblende is infrequently intergrown with plagioclase of intermediate composition; the two phases are probably coeval and are certainly older than the biotite. The latest phenocryst phases are rare, subhedral potassium feldspar (orthoclase, possibly after sanidine; Photo 15) and rare rounded quartz with well developed magmatic embayments (Photo 16). Both phases enclose one or more of the earlier phenocrysts. Apatite and zircon occur as rare microphenocrysts, with an undetermined position in the crystallization sequence.

Larger plagioclase crystals in rocks of the biotite-bearing assemblage contain intensely corroded cores (Photo 17), as do those in the pyroxene-bearing assemblage. Core

Photo 14. Euhedral hornblende phenocryst in rhyolite, peripherally replaced by biotite (bi). Biotite also occurs as discrete phenocrysts. At lower left is a large plagioclase crystal with corroded core and strongly zoned rim. Crossed polars.

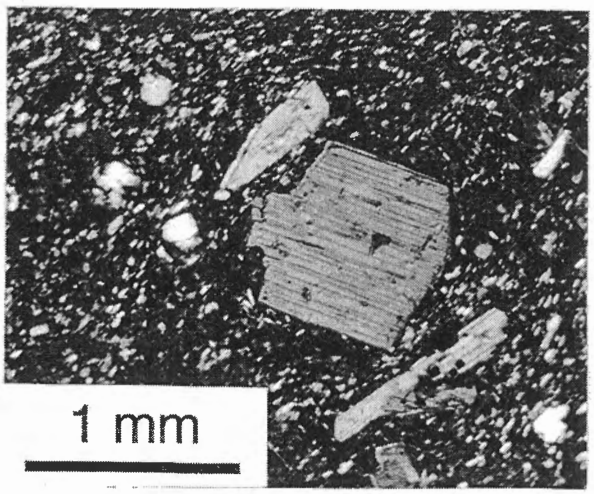


Photo 13. Euhedral biotite phenocryst, with two elongate hornblende phenocrysts, in lava of biotite-bearing assemblage. Crossed polars.

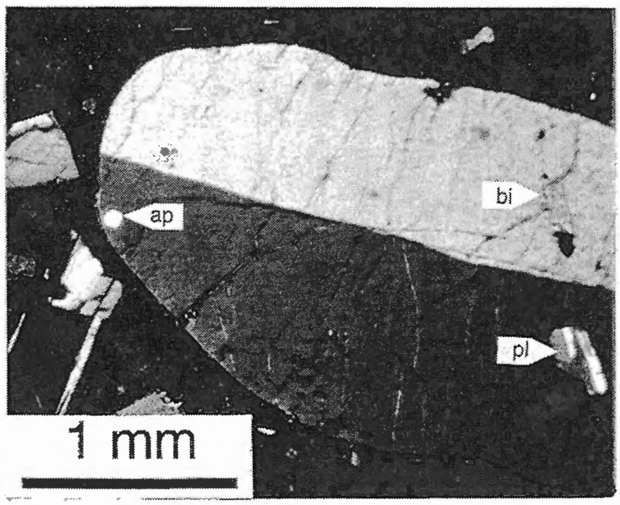


Photo 15. Potassium feldspar phenocryst, enclosing phenocrysts of plagioclase (pl), biotite (bi) and apatite (ap). Plagioclase also includes biotite. Crossed polars.

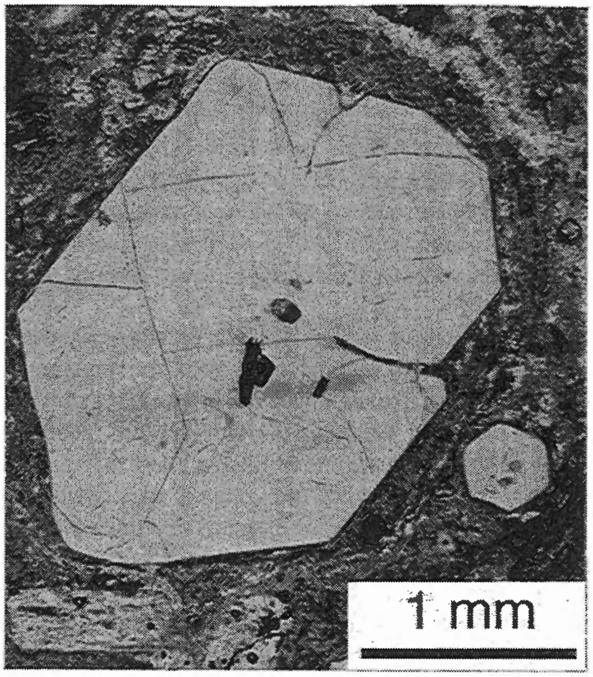


Photo 16. Quartz phenocryst with magmatic embayment and including a biotite phenocryst. Plane polarised light.

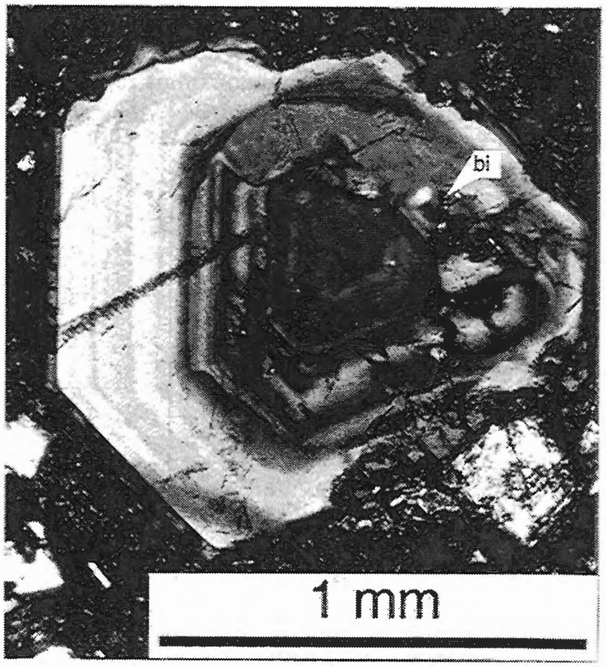


Photo 17. Corroded core of plagioclase phenocryst in biotite-bearing assemblage, with a fresh rim showing strong oscillatory zoning. A small crystal of biotite (bi) is included in the core. Crossed polars.

and rim compositions, determined optically, are more variable than in the pyroxene-bearing assemblage; cores range from An_{65} to An_{35} and non-corróded rims (with strong, oscillatory zoning) range from An_{55} to An_{48} at the rims. Microphenocrysts and groundmass plagioclase are in apparent equilibrium with these rims.

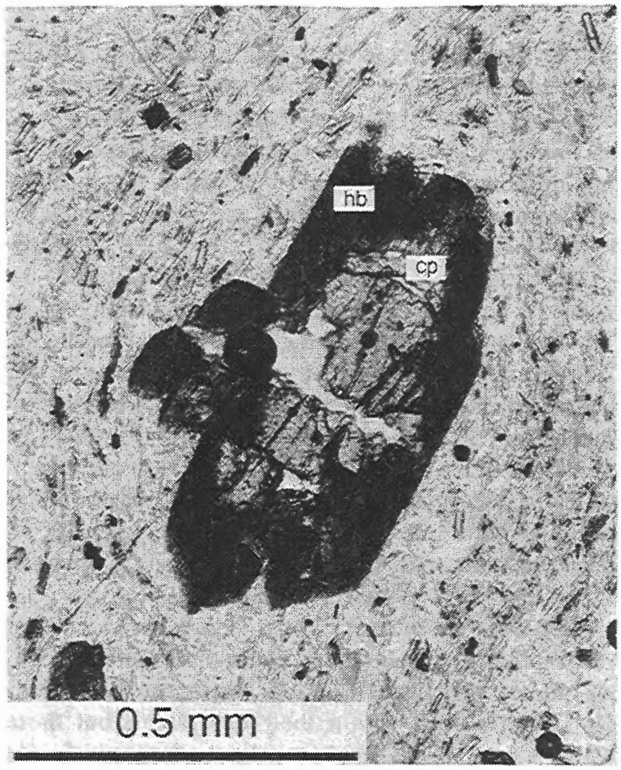


Photo 18. Clinopyroxene xenocryst with overgrowth of hornblende, possible evidence of magma mixing or, more probably, contamination. Plane polarised light.

One sample (HHB94-5117) contains subhedral clinopyroxene crystals, with overgrowths of hornblende (Photo 18). This sample is somewhat more mafic than others of this assemblage and of atypical chemical composition. Nearly all the other samples examined contain small (2-5 mm) aggregates of corroded plagioclase and anhedral amphibole, identical in texture and size to those found in samples of the pyroxene-bearing assemblage. The sample may be the product of magma mixing, but the viscosities of potential parent magmas are probably too high to allow for efficient mixing (J.A. Roddick, personal communication, 1996). More probably, the sample is a product of contamination or assimilation of solid material (including previous intrusions) during ascent.

CHEMISTRY

Sixty-seven samples were selected for chemical analysis, eleven from the Chilcotin Group basalts and the remainder from the Eocene Clisbako volcanic rocks. Chemical variations in the Chilcotin Group lavas are outside the scope of this study. Seven of the Eocene samples were biotite-bearing; the remaining 49 were from the pyroxene-bearing assemblage. The presence of alteration and occurrence of incognate xenocrysts were also used to group samples. Analyses were carried out by Chemex Labs, using x-ray fluorescence spectrometry. Analytical results for the

Clisbako volcanic rocks analysed in this study are not presented here but are available upon request from the Geological Survey of Canada. Data for 31 additional samples from the Clisbako area, made available by courtesy of Inmet Mining Corporation, are included in the chemical variation diagrams for comparison, but are not included in the petrologic discussion.

The Clisbako volcanic rocks are fairly typical of the Eocene Ootsa Lake Group in major element composition. They are subalkaline on a standard alkali-silica plot (Figure 6). The majority of samples in the pyroxene-bearing assemblage are dacites and nearly all of the biotite-bearing assemblage are rhyolites. On an AFM diagram (Figure 7) the samples lie in the calcalkaline field and with one exception, in the high-potassium field a SiO_2-K_2O diagram (Figure 8). In these respects, the samples are typical of all Eocene volcanic rocks in the Interior Plateau (*cf.* Andrew, 1988; Drobe, 1991; Green, 1990; Smith, 1986).

Studies in the Interior Plateau to date have identified stratigraphic units such as the Ootsa Lake Group, Kamloops Group and Endako Group. These are valid stratigraphic definitions within their type areas, but these roughly coeval volcanic rocks overlie an area equivalent to that covered by the Cascades volcanoes. It is extremely unlikely that intermediate or silicic volcanic rocks from a single source would cover such a large area and far more probable that volcanic activity took place at a number of discrete centres (volcanoes). In the latter case, volcanic stratigraphy would vary greatly between type sections (Alldrick, 1989). The location of volcanic paleocentres *within* a stratigraphic division must therefore be a priority in any study of the Eocene volcanic rocks of the Interior Plateau. The presence or absence of paleocentres also affects the economic potential of an area; epithermal mineral deposits such as that at Blackdome require a heat source.

Circumstantial evidence for the presence of a volcanic centre in the Clisbako area comprises the topographic expression of the Eocene units, the pronounced magnetic signature over Toil Mountain (Geological Survey of Canada, 1994; Teskey *et al.*, 1996; Shives and Carson, 1994) and the proximal nature of the volcanic deposits of both biotite-bearing and pyroxene-bearing assemblages. Evidence of a discrete chemical evolution for the Clisbako volcanic rocks would be conclusive evidence for their production from a discrete volcanic centre. A further test of the hypothesis of an Eocene volcanic centre would be the observed variations in trace element chemistry consistent with fractionation of phases with distinctive chemical compositions. If the chemical variation in unaltered rocks were predictable, lithochemical studies for areas of high exploration potential would be feasible.

Chemical evidence for a common origin for a discrete suite of volcanic rocks is provided by constant ratios of

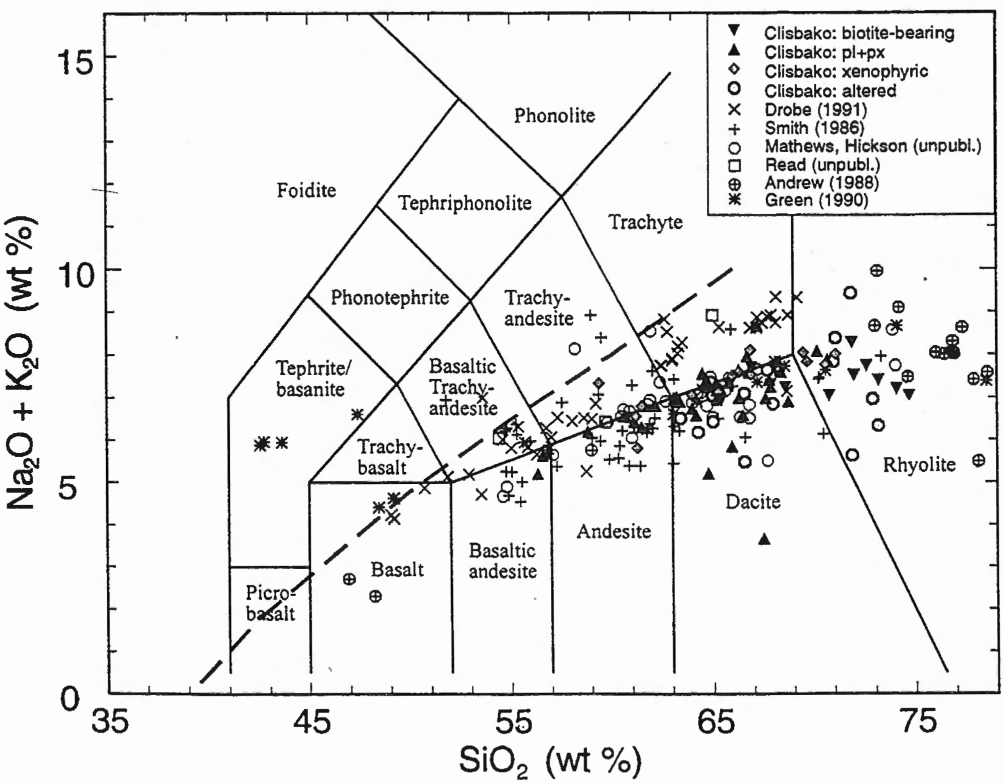


Figure 6. Weight percent silica against weight percent total alkalis after Irvine and Baragar (1971) and LeMaitre (1989). The Eocene rocks from the Interior Plateau lie in the oversaturated and saturated parts of the subalkaline field; those from Clisbako all lie reasonably close to the boundary, except for altered samples.

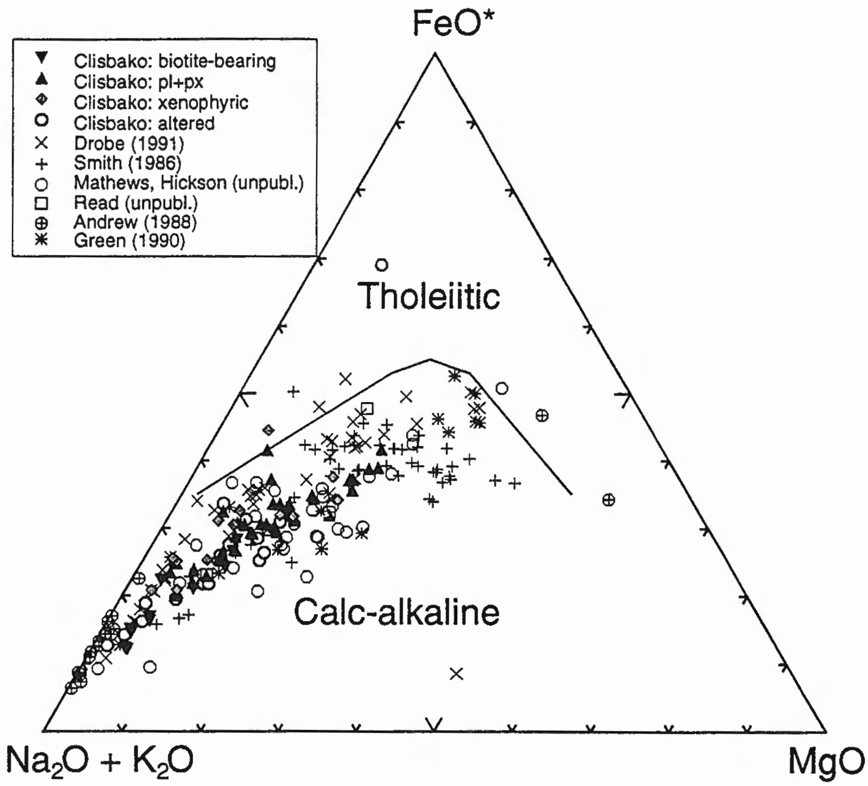


Figure 7. AFM diagram after Irvine and Baragar (1971). Nearly all samples from the Interior Plateau lie in the calcalkaline field.

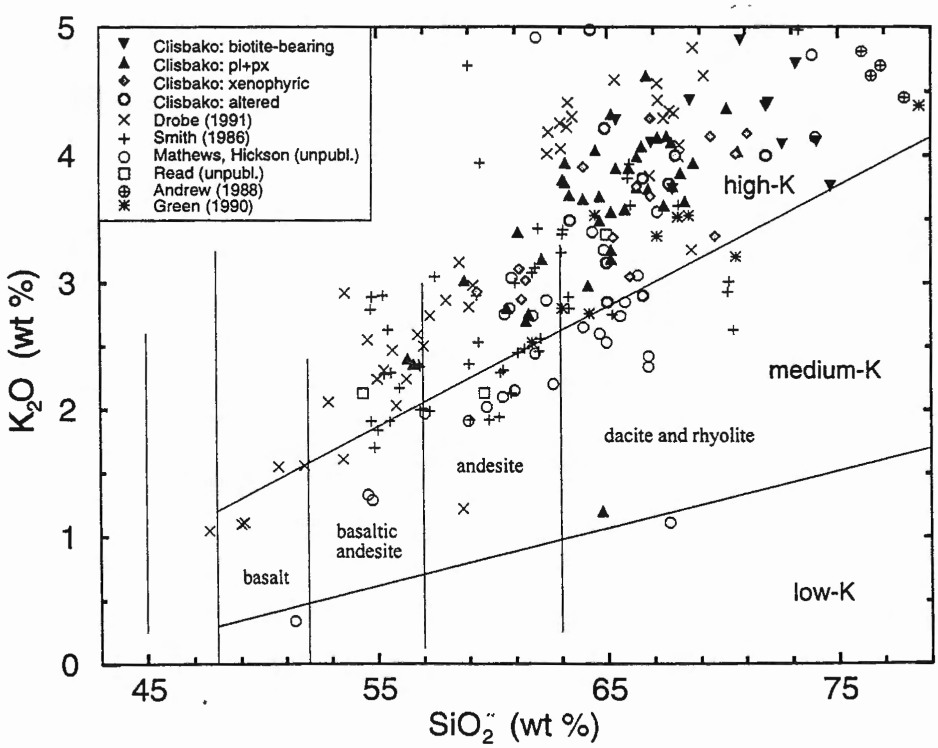


Figure 8. Weight percent SiO_2 against K_2O after leMaitre (1989). With few exceptions, the Eocene lavas of the Interior Plateau lie in the high-potassium field

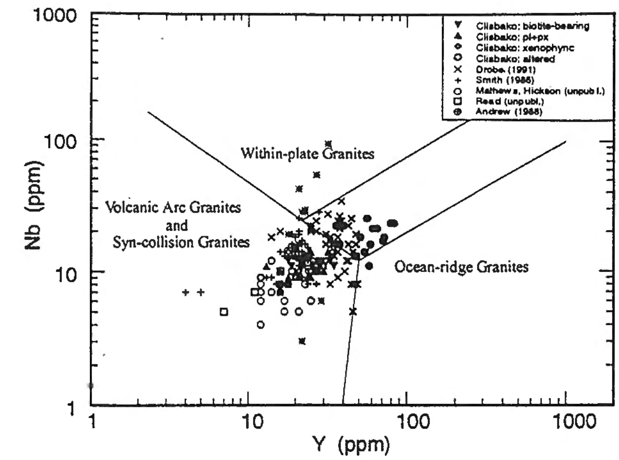


Figure 9. Yttrium *vs.* niobium after Pearce *et al.* (1984), for granitoid rocks. The majority of the intermediate and felsic volcanic rocks in the Interior Plateau lie in the same field as volcanic arc or syn-collision granites.

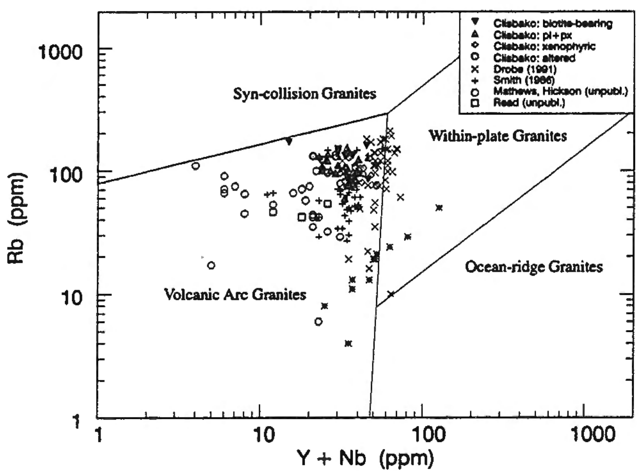


Figure 10. Yttrium+niobium against rubidium after Pearce *et al.* (1984), for granitoid rocks. The majority of the intermediate and felsic volcanic rocks in the Interior Plateau lie in the same field as volcanic arc granites.

conserved elements, that is, elements which are not involved in the formation of phenocryst or xenocryst phases (Russell and Nicholls, 1988). In the Interior Plateau, the available major element data (Figures 6-8) indicate that the volcanic assemblages are of similar composition. Moreover, the occurrence of potassium feldspar, apatite and titaniferous mafic phases in the Clisbako volcanic rocks suggests that no suitable candidates for a conserved constituent exist among the major elements.

Trace element abundances in Eocene rocks have only been determined in a few cases (Andrew, 1988; Drobe, 1991; Smith, 1986; Hickson and Mathews, unpublished data; Read, unpublished data) and for different groups of trace elements. Two slightly differing data sets (no Rb data exist for Andrew's samples), plotted after Pearce *et al.* (1984) on granitoid discrimination diagrams (Figures 9 and 10), indicate that trace element compositions of the Interior Plateau lavas lie within the field of volcanic arc granites. Exceptions are the majority of Andrew's (1988) samples from close to the Wolf deposit. Only three of these samples lie within the field covered by the majority of the Eocene volcanic rocks. Most of the unaltered samples from the Clisbako area are similar in trace element composition to other samples from the Interior Plateau.

Ratios of incompatible large-ion lithophile and high field strength elements in the two Clisbako volcanic assemblages are relatively constant (Figures 11 and 12). By contrast, samples taken from a wide area of the Interior Plateau show a correspondingly wide distribution of incompatible element concentrations. Both assemblages of the Clisbako Volcanic rocks lie in fields discrete from other Eocene samples and reasonably closely constrained, interpreted as evidence for a discrete origin for both these assemblages and therefore the existence of a volcanic centre in the Clisbako area. The ratios of the high field strength elements yttrium, niobium and zirconium are most closely constrained and suggest that these elements are conserved in the Clisbako magmas.

A conserved constituent in any system is a constituent that is not removed or augmented by any of the processes affecting that system. The effect of closure (the summing of chemical compositions in that system to 100%) results in non-linear chemical variation diagrams (Russell and Nicholls, 1988). Normalization of the chemical components of any system to a conserved component allows for treatment of chemical or isotopic variation in the system using a linear model. The method is identical to that used for any isotopic system which generates an isochron, such as Rb-Sr, ^{87}Rb and ^{87}Sr being the variable constituents and ^{86}Sr being the conserved constituent, for any given suite of samples.

Phenocryst phases present in the Clisbako volcanic rocks have distinct ranges of chemical variation. In the case of the pyroxene-bearing assemblage, chemical variation in the rocks may be expressed by the removal of plagioclase ($CaAl_2Si_2O_8$-$NaAlSi_3O_8$), orthopyroxene ($Mg_2Si_2O_6$-$Fe_2Si_2O_6$) and clinopyroxene ($CaMgSi_2O_6$-$CaFeSi_2O_6$).

Using phase composition matrices (Russell and Stanley, 1990), axis coefficients were determined for an x-y graph of cation proportions upon which all chemical variations due to addition or subtraction of any or all of these phases will produce a chemical trend with a slope of 1. The axis coefficients to test for all species of feldspar are, for the x-axis, (Al)/Zr and for the y-axis, (2Ca+Na+K)/Zr. Similarly, the axis coefficients to test for plagioclase and pyroxene are, for the x-axis, (Si)/Zr and, for the y-axis, (Ca+Fe+Mg+Mn+2.5Na+0.5Al)/Zr.

On the plagioclase-pyroxene graph, for example, the slope dy/dx produced by separation of albite ($NaAlSi_3O_8$)

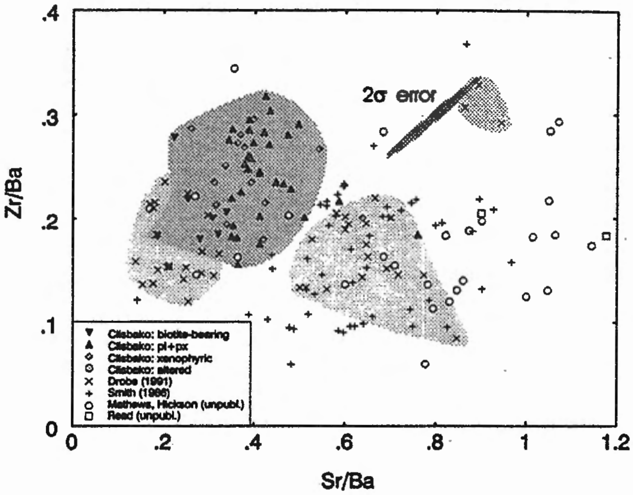


Figure 11. Sr/Ba *vs.* Zr/Ba plot (molecular proportions) for Eocene volcanic rocks of the Interior Plateau. Both assemblages of the Clisbako volcanics lie in fields distinct from the wide range of ratios in other suites.

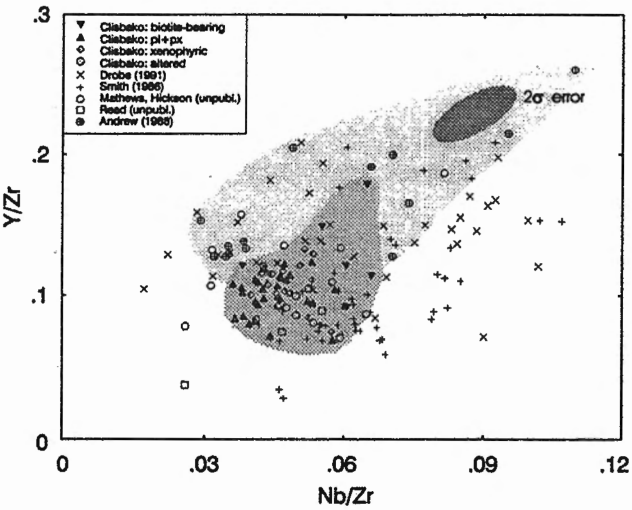


Figure 12. Ratios of high field strength incompatible elements for Eocene volcanic rocks of the Interior Plateau.

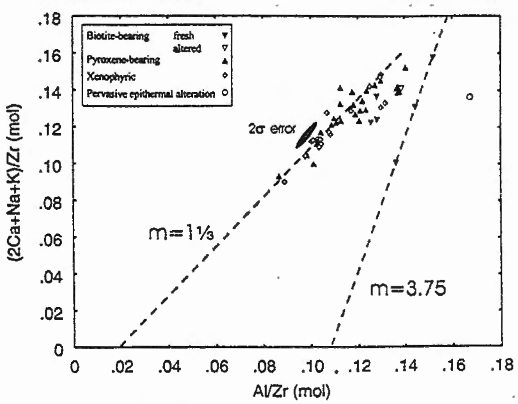


Figure 13. Pearce element ratio test diagram for feldspar for the Clisbako volcanics. Both assemblages fail this test, indicating that fractionation of plagioclase cannot account for the chemical variation in either assemblage.

would be (2.5x1xNa+0.5x1xAl)/(3xSi) =1. The hypothesis that the compositional range of the pyroxene-bearing assemblage is derived from fractionation (or assimilation) of feldspar, or of plagioclase and pyroxene, can be tested by plotting the compositions of the Eocene rocks on such graphs. Note that these graphs use cation proportions rather than weight percentages.

The test diagram for feldspar fractionation is shown in Figure 13. The Eocene pyroxene-bearing assemblage lies along a very poor trend which is nowhere close to unity and most of the samples lie considerably further from the line than the width of the correlated 2σ error envelope. The biotite-bearing assemblage shows an even worse correlation. Even assuming that either suite is comagmatic, the chemical variation cannot be accounted for by fractionation or assimilation of feldspar alone. A similar diagram, testing for pyroxene fractionation alone, shows an absence of trends.

A better correlation is seen in Figure 14, the test diagram for fractionation of plagioclase and/or pyroxene and in the test diagram for pyroxene and feldspar (Figure 15). Samples of the pyroxene-bearing assemblage lie along recognizable trends close to a median line with a slope of 1. This suggests that chemistry in magmas of this composition is controlled dominantly by removal (or addition) of plagioclase (or feldspar) and pyroxene. The concern (J.A. Roddick, personal communication, 1996) that much of the "phenocryst" assemblage is incognate material, may be valid, but will not cause departure from the trends on this diagram.

Despite the demonstrated correlation, almost half the samples in the pyroxene-bearing assemblage lie outside the 2σ error envelope, indicating that the suite is not related by a single chemical process. This is reasonable, considering the 5 to 8 Ma span of eruption ages. However, samples with a close spatial relationship usually lie within error of lines with a slope of 1, suggesting that this model of chemical variation can be used for specific eruptive phases or for restricted areas. Certainly, the sample containing pervasive epithermal alteration (on the far right in Figures 14 and 15) can be readily identified as the recipient of a substantial quantity of silica. This method can therefore be used in exploration, to outline areas of alteration.

One group of pyroxene-bearing samples, from the southern part of the study area, clearly lies in a field between the bulk of the pyroxene-bearing assemblage and the samples of the biotite-bearing assemblage. These lavas were either from a discrete source or have suffered contamination since generation, either by magma mixing with the biotite-bearing assemblage (unlikely given the high viscosity of silicic magmas) or by inclusion of wallrock.

Four samples from the biotite-bearing assemblage lie in a discrete trend, well within the 2σ error envelope of a line with a slope of 2. Three samples from the suite lie off the line, one a pervasively altered sample, the second

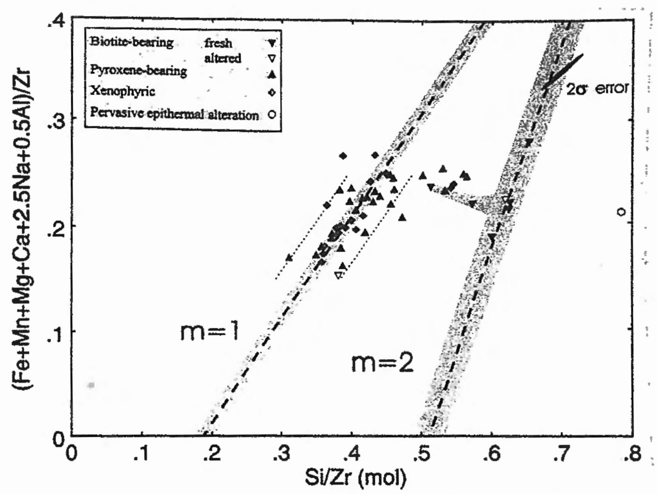


Figure 14. Pearce element ratio test diagram for plagioclase+orthopyroxene+clinopyroxene for the Clisbako volcanics. The majority of samples from the pyroxene-bearing assemblage lie within error of the unit gradient line, even those bearing xenocrysts. The 5 Ma history of the pyroxene-bearing assemblage precludes a comagmatic origin for the entire suite, but the envelope of samples lies along a slope of 1, suggesting that much of the chemical variation in the assemblage can be accounted for by fractionation of pyroxene and plagioclase. If potassium is added to the constituents (Figure 15), the grouping is tighter still. Samples from the biotite-bearing assemblage lie along a line with a slope of 2; this can be accounted for by separation of biotite and, possibly, sodic hornblende, both observed phenocryst phases in the biotite-bearing assemblage.

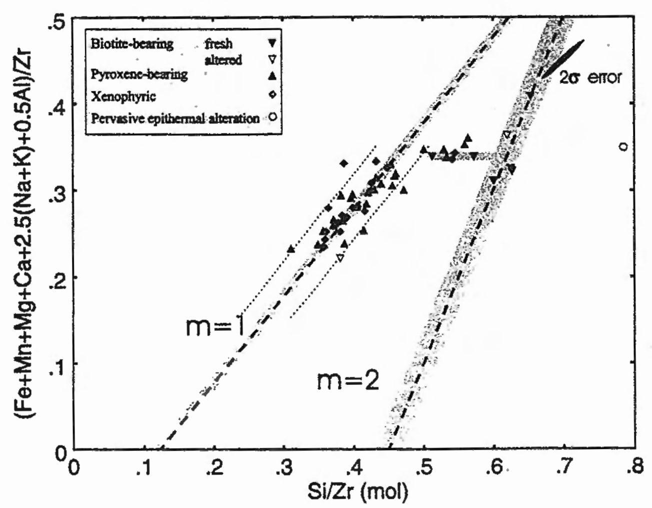


Figure 15. Pearce element ratio test diagram for feldspar+pyroxene for the Clisbako volcanics. The grouping is tighter for the pyroxene-bearing assemblage than in Figure 14, along the same trend.

(HHB94-5117) a sample with textures interpreted as the possible product of magma mixing or strong contamination. The last, from a rhyolite block in a pyroclastic flow, lies closest to the line and may have suffered minor physical contamination by pyroxene-bearing material during deposition. The slope of the line indicates that the biotite-bearing assemblage, while probably comagmatic, fails the test of pyroxene-plagioclase fractionation. The approximate slope of 2 may be coincidental; phases which would cause this trend are olivine (including fayalite), and possibly sodic biotite or hornblende. Iron titanium oxide fractionation, in conjunction with a silicate phase, could also cause this trend.

SUMMARY

The Clisbako area is a highland area within the Chilcotin Plateau, part of the Interior Plateau of central British Columbia. This highland area is constructed from Eocene rocks, resting on a basement of Mesozoic rocks comprising Triassic fossilliferous limestone, intermediate foliated volcanic rocks of presumed Jurassic age, younger sedimentary rocks (also presumed to be Jurassic) and a clastic sedimentary sequence of Albian to Maastrichtian age. With the exception of a Triassic inlier in the east-central part of the area, faulting with centerly downthrow in the north of the area exposes younger basement to the east.

The Eocene rocks are relatively undeformed and rest on a Late Cretaceous to Paleocene erosional surface. The base of the Eocene succession is not well exposed. The erosional surface is overlain by Chilcotin Group basaltic lava flows containing olivine, plagioclase and augite phenocrysts. The flows till paleovalleys to a depth of at least 250 metres in places..

The Eocene outcrop forms a circular highland area approximately 50 kilometres across. Most of this area is underlain by a sequence of pyroxene-plagioclase-porphyritic dacite lava flows and related flowbreccias. The large volume of volcanic material and the proximal nature of the dacitic flows strongly suggest that the area is a remnant of a large volcano.

A recessive but widespread volcanic assemblage, comprising flowdomes and pyroclastic flows of biotite-bearing rhyolite, is exposed in the centre and southeastern parts of the area. This unit returned ages of 53.4 Ma to 50.9 Ma and is interpreted as the product of one or two large, caldera-forming phases of activity which destroyed the main part of the volcano. The isotopic ages are the oldest returned from the area, but the abundance of accidental fragments of pyroxene-bearing dacite in the biotite-bearing pyroclastic rocks indicates that a great volume of dacitic volcanic rock predates the rhyolitic eruption.

The biotite-bearing pyroclastic rocks are associated with a discontinuous sequence of clastic sedimentary and chemical sedimentary rocks, containing detrital biotite and also fossil flora consistent with a Middle Eocene age. These deposits are interpreted as a caldera-filling moat facies, including deposits from hotsprings. During or after this time, local hydraulic brecciation and locally intense epithermal alteration and mineralization took place, localized along northwesterly and westerly structural lineaments in the underlying basement.

A return to dacitic volcanism occurred after the pyroclastic phase and continued until at least 44 Ma; there is no field evidence for the persistence or recurrence of the pyroclastic phase of eruption. A sample from a small dome in the centre of the area returned the youngest age of all (44.2 Ma). The presence of such late domes and the moat facies is inconsistent with previous interpretations of deep erosion of the edifice. The subdued topography is probably due to a combination of central subsidence during the Eocene and inundation by basaltic lavas during and after the Miocene.

The biotite rhyolites and pyroxene-bearing lava flows are high-potassium calcalkaline lavas typical of the Ootsa Lake Group, with affinities to volcanic arc granites. Both assemblages contain plagioclase with intensely corroded cores and relict amphibole-plagioclase glomerocrysts, interpreted as incognate material, possibly from incomplete melting of the source. The major element compositions are similar to other Eocene volcanic rocks from the Interior Plateau but are distinct in their concentrations of incompatible trace elements, interpreted as further evidence for their origin from a discrete volcanic centre. The pyroxene-bearing assemblage, however, fails a Pearce element ratio test for pyroxene and plagioclase fractionation or assimilation; the duration of this type of volcanism precludes derivation from a single batch of magma. The biotite-bearing assemblage also fails this test, but both assemblages lie along discrete linear trends, which are predictable base compositions for local lithochemical exploration.

Locally intense epithermal alteration and mineralization affects rocks of the Eocene Clisbako volcanic assemblage, close to areas underlain by biotite-bearing rocks. A distinctive and similar lithological sequence is also associated with mineralization at Blackdome mine (Church, 1980, 1982), and rocks of similar age and composition host the epithermal mineralization at the nearby Wolf property (Andrew, 1988; Diakow and Webster, 1994). Biotite-bearing granitoid rocks are prospective for porphyry-related mineralization throughout the Babine and Nanika porphyry belts (Carter, 1976; Carson *et al.*, 1976; Carson and Jambor, 1976). The rocks formed from Eocene biotite-bearing magmas in the Interior Plateau, whether extrusive or intrusive, have proved highly prospective in the past and should be assigned a concomitant high potential in future exploration.

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GEOLOGY OF THE TATLAYOKO LAKE - BEECE CREEK AREA (92N/8, 9, 10; 92O/5, 6, 12)

By Paul Schiarizza and Janet Riddell

KEYWORDS: Eastern Coast Belt, Bridge River Complex, Cadwallader Terrane, Stikine Terrane, Mount Moore formation, Methow Terrane, Mount Skinner Igneous Complex, Huckleberry formation, Tyaughton - Methow basin, Relay Mountain Group, Jackass Mountain Group, Taylor Creek Group, Powell Creek formation, Yalakom fault, Fish Lake porphyry Cu-Au deposit, Skinner gold-quartz vein.

INTRODUCTION

The Tatlayoko bedrock mapping program was designed to update the geological database for the eastern Coast Belt in parts of the Mount Waddington and Taseko Lakes map areas, and to integrate the structural and stratigraphic relationships established within this area with rapidly evolving concepts regarding the tectonic and stratigraphic framework of the region. This will provide an improved geological framework for understanding the settings and controls of known mineral occurrences in the area (*e.g.*, Fish Lake, Skinner) and for evaluating the potential for additional discoveries. The project ties in with earlier mapping by the Geological Survey Branch to the southeast, and with concurrent mapping directed by P. van der Heyden and P. Mustard of the Geological Survey of Canada to the northwest (*see* Mustard and van der Heyden, 1997, this volume), thus completing a continuous belt of recent mapping that extends for 350 kilometres along the northeast margin of the southern Coast Belt (Figure 1).

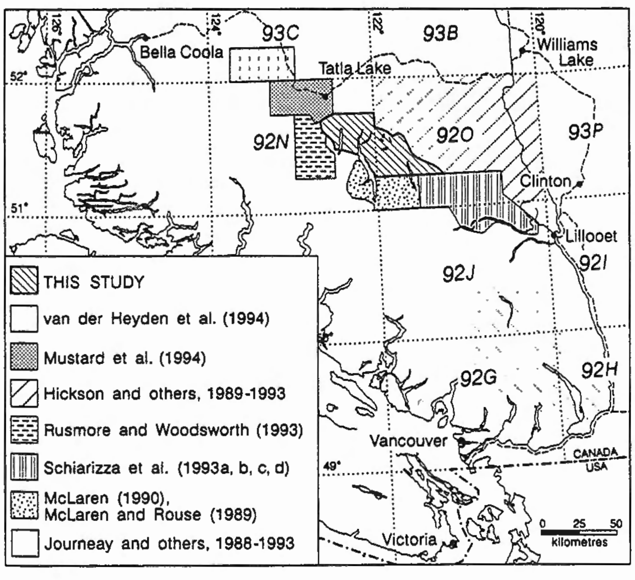

Figure 1. Location of the Tatlayoko project area, and index to recent geological mapping by the British Columbia Geological Survey Branch and Geological Survey of Canada in adjacent parts of the southeastern Coast Belt and Intermontane Belt.

The Tatlayoko project was initiated in 1992 with geological mapping of the Mount Tatlow map area (Riddell *et al.*, 1993a, b). No fieldwork was done in 1993, but the project was continued in 1994 with geological mapping of the Tatlayoko Lake map area (Schiarizza *et al.*, 1995a, b). Fieldwork was completed in July of 1995, when two and a half weeks were spent mapping in the Niut Range in the northwestern corner of the project area, and two days were spent revisiting the geology near Fish Lake (Schiarizza, 1996). This report presents an overview of the geology of the study area, and summarizes the major findings of the project. More detailed discussion of several aspects of the geology will be presented in papers that will be submitted to external scientific journals. In addition, updated 1:50 000-scale geology maps will be published (B.C. Geoscience map series) after radiometric dates and fossil identifications have been finalized.

The Tatlayoko project area covers the transition from the rugged Coast Mountains in the southwest, to gently rolling topography of the Fraser Plateau to the northeast. Mount Nemaia, in the central part of the area, is 250 kilometres north-northwest of Vancouver and 155 kilometres southwest of Williams Lake. The eastern part of the area is accessed by an all-season road that extends southwestward from Highway 20 at Hanceville to the Nemaia valley. A seasonal road branches off it at the Taseko River and continues southward to the Taseko Lakes. Tatlayoko Lake, in the western part of the area, is accessed by an all-season road that extends south from Highway 20 at Tatla Lake. A branch from this road extends eastward to the north end of Chilko Lake, and a seasonal road crosses the Chilko River and continues southward to Tsuniah Lake and the Nemaia valley.

REGIONAL GEOLOGIC SETTING

The geologic setting of the Tatlayoko project area is summarized in Figure 2. It encompasses the boundary between the Coast and Intermontane morphogeologic belts. Within the Tatlayoko project area this boundary corresponds to the Yalakom fault, a major linear feature that extends for about 300 kilometres and was the locus of more than 100 kilometres of Late Cretaceous(?) to early Tertiary dextral displacement (Riddell *et al.*, 1993a).

The eastern Coast Belt in the region of the Tatlayoko project area can be subdivided into the South Chilcotin, Methow and Niut domains, each with contrasting

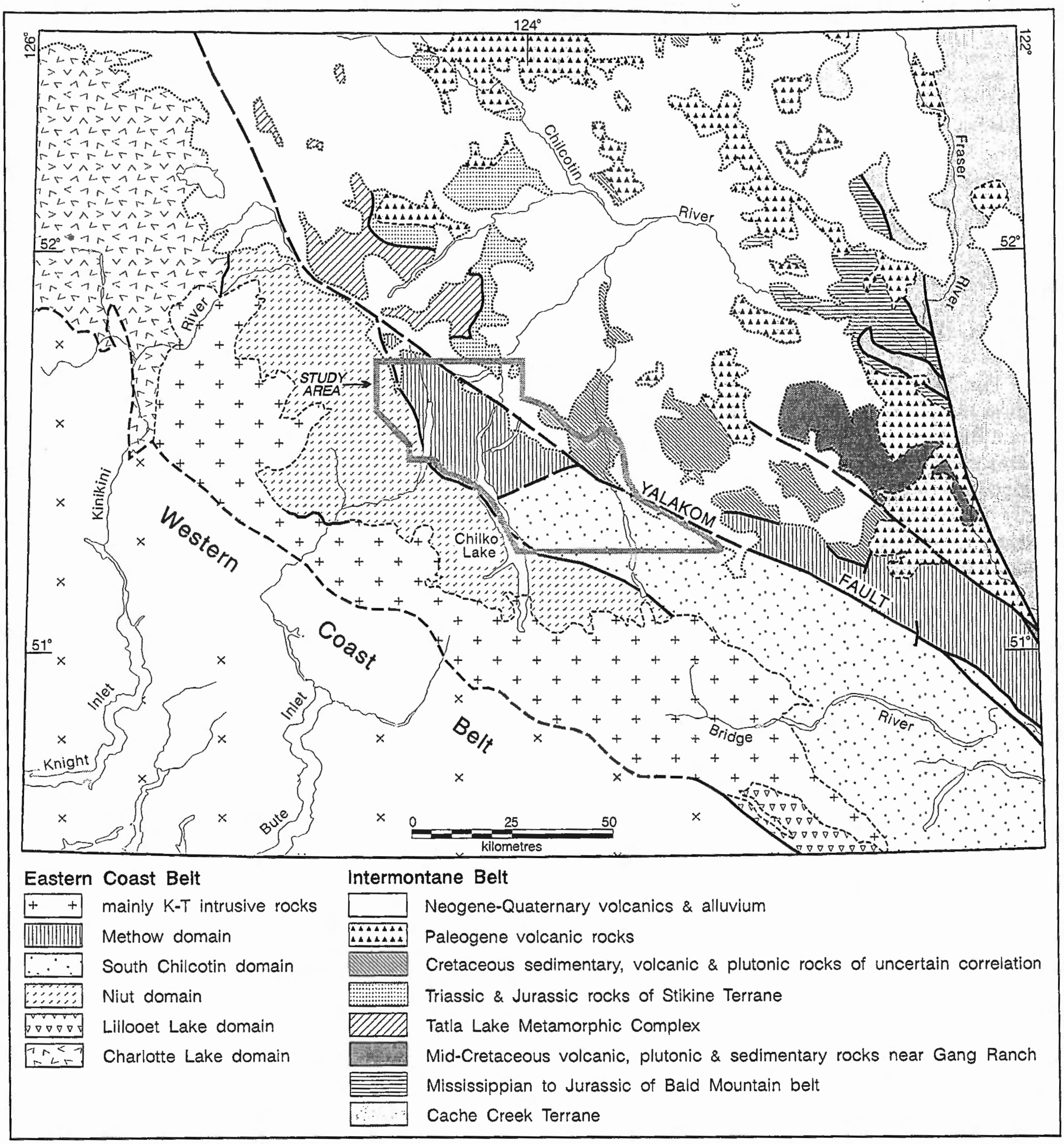

Figure 2. Geologic setting of the Tatlayoko project area.

stratigraphy and structural style (Figure 2). The South Chilcotin domain includes Mississippian to Jurassic oceanic rocks of the Bridge River accretion-subduction complex, Upper Triassic to Middle Jurassic arc-derived volcanic and clastic sedimentary rocks of Cadwallader Terrane, Permian ophiolitic rocks of the Shulaps and Bralorne - East Liza complexes, Upper Jurassic to mid-Cretaceous clastic sedimentary rocks of the Tyaughton - Methow basin, and Upper Cretaceous subaerial volcanic rocks of the Powell Creek formation. These partially coeval lithotectonic assemblages are juxtaposed across a complex network of structures that is dominated by middle to Late Cretaceous southwest-directed contractional faults, and Late Cretaceous to early Tertiary dextral strike-slip faults.

The Methow domain occurs to the north and northeast of the South Chilcotin domain, and is distinguished by a less complex structural style dominated by widely spaced faults and broad folds. The two domains are separated in part by the Yalakom fault, and in part by an earlier structure that is offset by the Yalakom fault. This earlier structure is referred to as the Camelsfoot fault in the south (Schiarizza *et al.*, 1993b; Schiarizza and Garver, 1995) and the Konni Lake fault in the north (Riddell *et al.*, 1993a). Methow domain is underlain mainly by Lower to Middle Jurassic sedimentary and volcanic rocks of the Methow Terrane, and overlying Upper Jurassic to mid-Cretaceous clastic sedimentary rocks of the Tyaughton - Methow basin. Older rocks are exposed locally and include Middle to Late Triassic quartz dioritic intrusions and overlying Upper Triassic sedimentary rocks that outcrop near Tatlayoko Lake. The Jurassic rocks of Methow Terrane are lithologically distinct from age-equivalent rocks found within the Cadwallader and Bridge River terranes of the South Chilcotin domain. The upper part of the Tyaughton-Methow basin, within the Methow domain (the Jackass Mountain Group), is also distinct from coeval rocks comprising the upper part of the basin in the South Chilcotin domain (the Taylor Creek Group). The lower part of the Tyaughton - Methow basin, represented by the Jura-Cretaceous Relay Mountain Group, is, however, common to both domains (Figure 3).

The Niut domain is underlain largely by Upper Triassic volcanic and sedimentary rocks of the Mount Moore and Mosley formations, associated Late Triassic plutons, and Lower Cretaceous volcanic and sedimentary rocks assigned to the Ottarasko and Cloud Drifter formations (Rusmore and Woodsworth, 1991a; Mustard and van der Heyden, 1994). Both the Triassic rocks, which have been correlated with those of the Stikine Terrane, and the Lower Cretaceous rocks are distinct from age-equivalent rocks to the east, but the Niut domain also includes Middle to Upper Cretaceous rocks that correlate with the upper Tyaughton basin and Powell Creek formation of the South Chilcotin domain. The stratigraphic elements of the Niut domain are deformed by early Late Cretaceous faults of the northeast-vergent eastern Waddington thrust belt (Rusmore and Woodsworth, 1991b; van der Heyden *et al.*, 1994a). The northeast boundary of the domain is a system of faults, including the Tchaikazan and West Niut faults, that juxtaposes it against the South Chilcotin and Methow domains to the northeast (Figure 2).

The Intermontane Belt is characterized by subdued topography and sparse bedrock exposure. Pre-Neogene strata north of Chilko Lake comprise volcanic and volcaniclastic rocks that have been correlated with the Lower to Middle Jurassic Hazelton Group of the Stikine Terrane (Tipper, 1969a, b). To the west, these rocks are juxtaposed against penetratively deformed metasedimentary, metavolcanic and metaplutonic rocks of the Tatla Lake Metamorphic Complex across an east to northeast-dipping normal fault. This fault formed late in the structural history of the complex, which was ductilely sheared and exhumed in Eocene time (Friedman and Armstrong, 1988), possibly in a structural regime linked to dextral movement along the Yalakom fault (Schiarizza *et al.*, 1995a).

To the southeast is a belt of mainly Cretaceous sedimentary, volcanic and plutonic rocks that extends from the Taseko River to the Fraser River. Exposures near the Taseko River include Hauterivian sedimentary and volcanic rocks that may correlate with those of Niut domain, as well as younger Aptian-Albian conglomerates that resemble the Jackass Mountain Group of the Methow domain (Fish Lake area of Figure 3). Farther to the southeast, near the Fraser River, this belt comprises Lower Cretaceous volcanic rocks of the Spences Bridge Group and an overlying succession of middle to Upper Cretaceous sedimentary and volcanic rocks (Green, 1990; Hickson, 1992; Gang Ranch area of Figure 2). Underlying rocks are not exposed, but correlative rocks to the east of the Fraser fault overlap Quesnel and Cache Creek terranes (Monger and McMillan, 1989).

LITHOLOGIC UNITS

The main tectonostratigraphic assemblages exposed in the Tatlayoko project area are summarized on Figure 3. They include late Paleozoic to Middle Jurassic volcanic, sedimentary and plutonic rocks that are assigned to Bridge River, Cadwallader, Methow and Stikine terranes, as well as Jura-Cretaceous clastic sedimentary rocks of the Tyaughton - Methow basin and Upper Cretaceous volcanic and volcaniclastic rocks of the Powell Creek formation. These assemblages are intruded by a wide variety of late Mesozoic and Tertiary dikes and plutons, and are locally overlain by Miocene-Pliocene plateau basalts of the Chilcotin Group.

BRIDGE RIVER COMPLEX

The Bridge River Complex is best exposed in the Bridge River drainage basin, 60 kilometres southeast of the

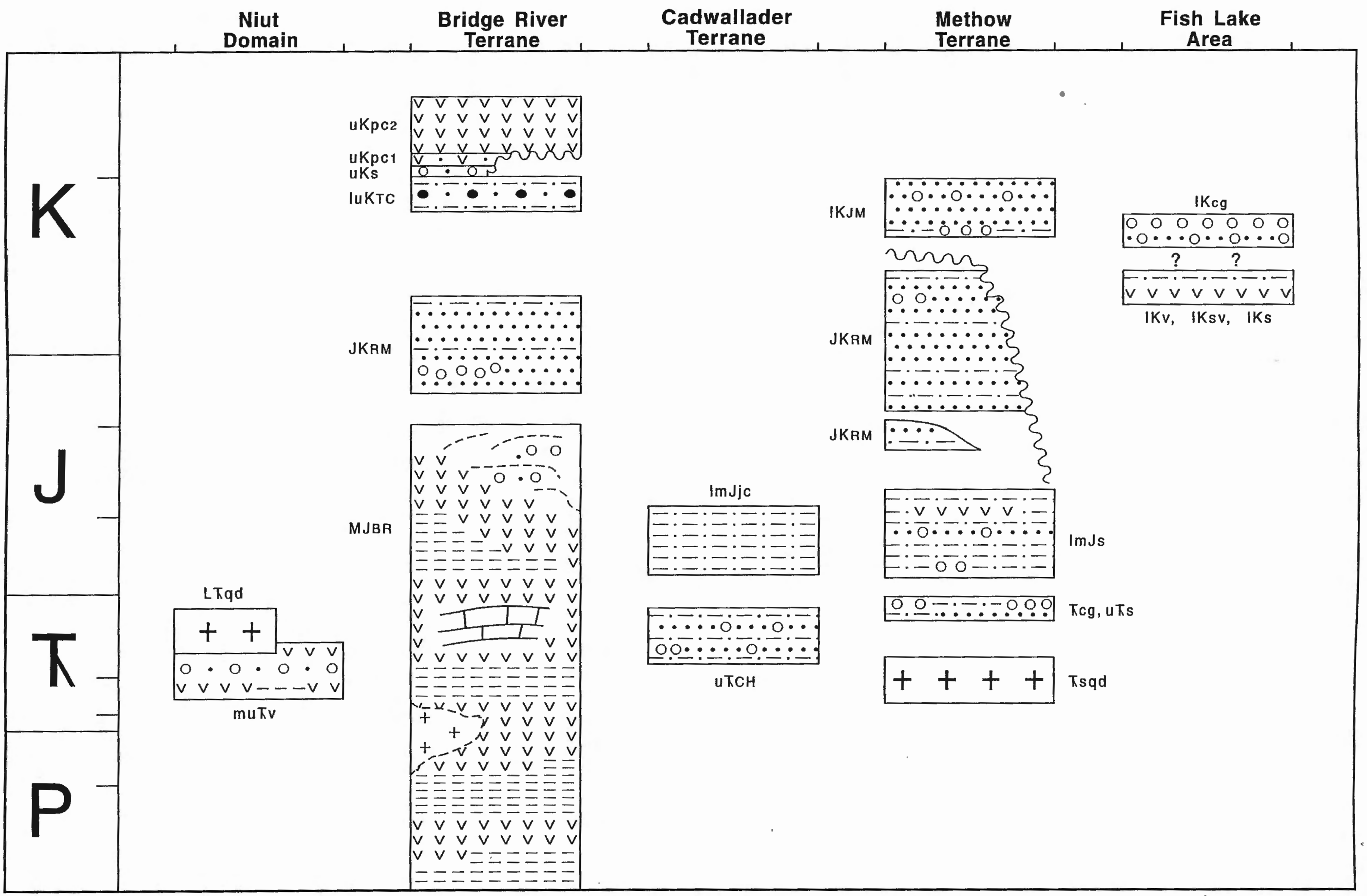

Figure 3. Main tectonostratigraphic assemblages exposed in the Tatlayoko project area. Not shown are Lower to Middle Jurassic(?) volcanic rocks of Stikine Terrane that occur northeast of the Yalakom fault in the northern part of the study area.

Tatlayoko project area. There it comprises an imbricated assemblage of chert, argillite, greenstone, gabbro, blueschist, limestone and clastic sedimentary rocks (Potter, 1986; Schiarizza *et al.*, 1989, 1990) that are thought to have accumulated as an accretion-subduction complex. Cherts range from Mississippian to late Middle Jurassic in age (Cordey and Schiarizza, 1993), and blueschist-facies metamorphism occurred in the Triassic (Archibald *et al.*, 1991). In its type area, the Bridge River Complex is structurally interleaved with Cadwallader Terrane, and is inferred to be stratigraphically overlain by Jura-Cretaceous clastic sedimentary rocks of the Tyaughton-Methow basin (Schiarizza and Garver, 1995).

The Bridge River Complex is represented in the Tatlayoko project area by a narrow east to southeast-trending belt that was traced through the forested slopes northeast of Mount Tatlow (Figure 4). It consists mainly of grey and black bedded cherts structurally interleaved with amygdaloidal greenstones, chert-rich sandstones, serpentinite and sheared muddy breccias containing boulders of greenstone, chert and marble. Foliations and mesoscopic shear surfaces in all of these rocks strike parallel to the trend of the belt and dip steeply. One sample of chert has yielded radiolarians of Permian age (GSC Loc. C-207823; F. Cordey, report FC93-4).

The Bridge River Complex apparently comprises a fault-bounded lens that separates Cadwallader Terrane to the north from the Relay Mountain and Taylor Creek groups to the south. Prior to the present study, the northernmost known occurrences of Bridge River Complex were in the Noaxe Creek map area 70 kilometres to the southeast. The intervening area is underlain by Jura-Cretaceous clastic sedimentary rocks of the Tyaughton-Methow basin. Recognition of Bridge River Complex at the northwest end of this belt lends credence to the interpretation that it forms the basement to that portion of the Tyaughton-Methow basin exposed in the south Chilcotin domain (Figure 3; Schiarizza and Garver, 1995).

CADWALLADER TERRANE

The Cadwallader Terrane, as defined in representative sections 40 kilometres southeast of the Tatlayoko project area, consists of Upper Triassic volcanic and sedimentary rocks of the Cadwallader and Tyaughton groups, and Lower to Middle Jurassic clastic sedimentary rocks of the informally named Last Creek formation and Junction Creek unit (Rusmore, 1987; Umhoefer, 1990; Schiarizza and Garver, 1995). Trace element geochemistry of volcanic rocks and the composition of the clastic sedimentary rocks suggest that the rocks of Cadwallader Terrane accumulated on or near a volcanic arc (Rusmore *et al.*, 1988).

Rocks assigned to the Cadwallader Terrane in the Tatlayoko project area outcrop within and south of the Nemaia valley, where they comprise an easterly trending belt that has been traced for 35 kilometres between Chilko Lake and the Yalakom fault (Figure 4). This belt includes siltstone, sandstone, conglomerate and limestone assigned to the Upper Triassic Hurley Formation (Cadwallader Group), together with overlying siltstone and cherty argillite correlated with the Lower to Middle Jurassic Junction Creek unit.

HURLEY FORMATION (UNIT uTCH)

The Hurley Formation in the Tatlayoko project area consists mainly of thinly bedded black and tan siltstone and shale with thin to medium interbeds of brown-weathering calcareous argillite, siltstone, sandstone and argillaceous limestone. These predominantly thin-bedded intervals are punctuated by thick, commonly graded beds of calcareous sandstone, and locally by limestone-bearing pebble to cobble conglomerates. The conglomerates have a limy sand or mud matrix and also contain clasts of granitoid and volcanic rock, chert and calcarenite. Small carbonaceous fragments derived from plant material were found in brown calcarenites that outcrop along Tsoloss and Elkin creeks. The Hurley Formation also includes massive, white-weathering limestone, which forms a lens several tens of metres thick within clastic rocks on the low slopes southeast of Konni Lake.

The belt of rocks assigned to the Hurley Formation was in large part mapped as Lower Cretaceous Taylor Creek Group by Tipper (1978), although he included the exposures of massive white limestone southeast of Konni Lake in the Upper Triassic Tyaughton Group. These rocks were assigned to the Hurley Formation by Riddell *et al.* (1993a, b) on the basis of their lithologic similarity to the formation in its type area near the Bridge River. This correlation has been confirmed by Late Triassic (early or middle Norian) conodont collections from three separate localities in the belt, including the limestone body southeast of Konni Lake (GSC Locs. C-207802, C-207805 and C-207811; M.J. Orchard, report OF-1993-41).

JUNCTION CREEK UNIT (lmJjc)

The Hurley Formation is stratigraphically overlain to the south by a belt of Jurassic rocks that is correlated with the informally named Junction Creek unit, which likewise overlies the Hurley Formation on the slopes northeast of the Yalakom and Bridge rivers, more than 100 kilometres to the southeast (Schiarizza *et al.*, 1993b; Schiarizza and Garver, 1995). These rocks consist mainly of dark grey to black, thin-bedded siliceous siltstone, cherty argillite and shale, with scattered thin interbeds of brown-weathering micritic limestone and crosslaminated silty limestone. Thin to medium beds of fine to medium-grained sandstone occur locally, and conglomerate containing argillite and less common volcanic clasts in a calcareous matrix was seen at one place southwest of Konni Lake. Belemnite guards were observed in several localities, and fragments of the Early Jurassic (Sinemurian to Toarcian) pelecypod *Weyla* were

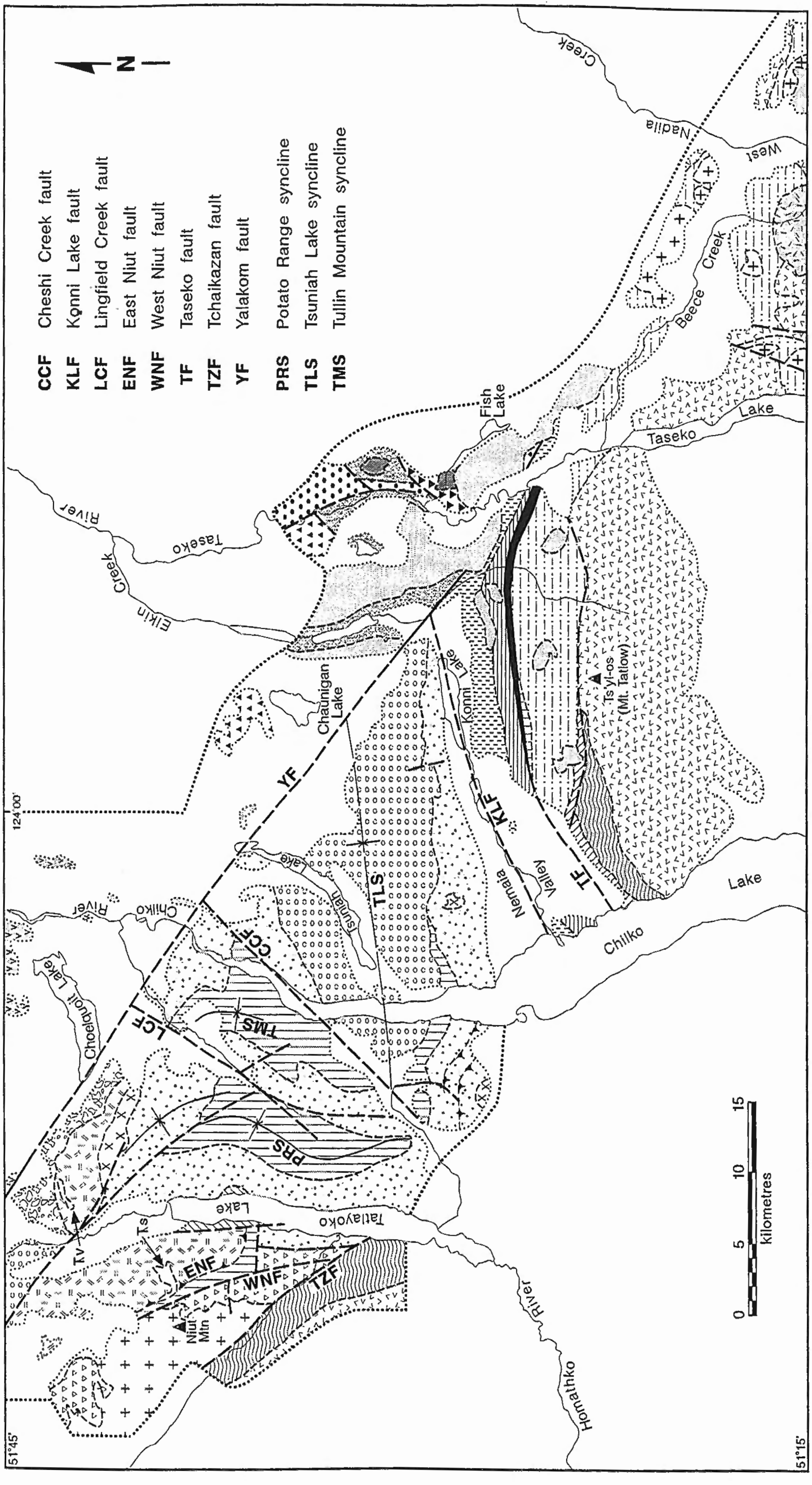

Figure 4. Generalized geology of the Tatlayoko project area.

MIOCENE AND PLIOCENE
CHILCOTIN GROUP
- MPc — *Olivine basalt flows*

Tyaughton - Methow Basin
UPPER CRETACEOUS
POWELL CREEK FORMATION (uKpc2 and uKpc1)
- uKpc2 — *Andesitic volcanic breccia, lapilli tuff, ash tuff, laharic breccia, mafic to intermediate volcanic flows; volcanic conglomerate & sandstone*
- uKpc1 — *Well stratified volcanic breccia and conglomerate; minor amounts of volcanic sandstone and siltstone*
- uKs — *Robertson Creek unit: lithic sandstone, shale, arkosic sandstone, chert-pebble conglomerate*

LOWER AND/OR UPPER CRETACEOUS
Albian and/or Cenomanian
TAYLOR CREEK GROUP
- luKTC — *Shale, siltstone, sandstone, chert-pebble conglomerate*

LOWER CRETACEOUS
Albian
JACKASS MOUNTAIN GROUP
- lKJM — *Conglomerate, arkosic sandstone, gritty sandstone*

MIDDLE JURASSIC TO LOWER CRETACEOUS
RELAY MOUNTAIN GROUP
- JKRM — *Lithic & arkosic sandstone, siltstone, mudstone, conglomerate, Buchia coquina*

CRETACEOUS ROCKS NORTHEAST OF YALAKOM FAULT
Aptian - Albian
- lKcg — *Vick Lake unit: conglomerate; minor amounts of sandstone and shale*

Hauterivian and(?) younger
- lKv — *Chaunigan Lake unit: andesitic to dacitic breccias, tuffs and flows*
- lKsv — *Fish Creek succession: sandstone, shale, conglomerate, tuffaceous sandstone, andesite, dacite*
- lKs — *Elkin Creek unit: sandstone, siltstone, shale, conglomerate*

Niut Domain
LATE TRIASSIC
- LŦqd — *Quartz diorite, diorite*

MIDDLE AND UPPER TRIASSIC
- muŦv — *Andesite, pillowed basalt, volcanic breccia, tuff, agglomerate; conglomerate, sandstone, shale*

Methow Terrane
LOWER TO MIDDLE JURASSIC
- lmJs — *Huckleberry Formation: siltstone, shale, sandstone, gritty sandstone, pebble conglomerate; minor amounts of silty limestone; locally includes andesitic tuff, volcanic breccia & rare intermediate flows or sills*

UPPER TRIASSIC
- uŦs — *Lithic sandstone, calcarenite, pebbly calcarenite, fossil hash, siltstone, micritic limestone, arkosic sandstone, pebble conglomerate*

TRIASSIC (?)
- Ŧcg — *Pebble to cobble conglomerate; sandstone, siltstone, argillite; micritic limestone*

MIDDLE TO LATE TRIASSIC
- Ŧsqd — *Mount Skinner Igneous Complex: quartz diorite, diorite & tonalite intruded by dikes of basalt, diabase, hornblende feldspar porphyry, quartz feldspar porphyry & aplite; also includes masses of fine-grained greenstone that may be dike swarms &/or screens of older volcanic rock; Ŧv-tuff & welded tuff; Ŧs-hornfelsed sandstone & siltstone*

Cadwallader Terrane
LOWER TO MIDDLE JURASSIC
- lmJjc — *Argillite, cherty argillite, siltstone; minor sandstone*

UPPER TRIASSIC
CADWALLADER GROUP
- uŦCH — *Hurley Formation: siltstone, shale, sandstone, calcareous sandstone, conglomerate, limestone*

Bridge River Terrane
MISSISSIPPIAN TO JURASSIC
BRIDGE RIVER COMPLEX
- MJBR — *Chert, greenstone, argillite, sandstone, conglomerate, serpentinite*

Jurassic Rocks Northeast of Yalakom Fault
LOWER TO MIDDLE JURASSIC
- Jv — *Andesite, volcanic breccia, tuff; local sandstone, conglomerate, diorite, gabbro*

Cretaceous and Tertiary Intrusive Rocks
EOCENE
- Egd — *Granodiorite, quartz monzonite*

LATE CRETACEOUS
- LKp — *Hornblende-feldspar-quartz porphyry*
- LKd — *Diorite, quartz diorite, hornblende feldspar porphyry*

CRETACEOUS AND/OR TERTIARY (?)
- KŦqd — *Quartz diorite, granodiorite*

LEGEND to accompany Figure 4.

collected from the unit south of the west end of Konni Lake (GSC Loc. C-207833; H.W. Tipper, report J9-1992-HWT). An earlier fossil collection reported by Tipper (1969a) included the Sinemurian ammonite *Arniotites* cf. *kwakiutlanus* Crickmay.

The rocks here assigned to the Junction Creek unit were mapped by Tipper (1978) as the Lower to Middle Jurassic portion of the Tyaughton Group, which is equivalent to the Last Creek formation in the revised nomenclature of Umhoefer (1990). In its type area, the Last Creek formation is dominated by siltstone and shale, but includes a coarser grained facies of near-shore conglomerate and sandstone in its basal (upper Hettangian to Sinemurian) part. It overlies the Tyaughton Group, which comprises uppermost Triassic nonmarine to shallow-marine clastic sedimentary rocks and limestone that are probably a facies equivalent of the upper part of the Hurley Formation. The Junction Creek unit is clearly correlative with the Last Creek formation, as both assemblages are dominated by shale and siltstone and overlie Upper Triassic rocks that are included within Cadwallader Terrane. However, the Junction Creek unit overlies the Hurley Formation (rather than the Tyaughton Group), does not apparently contain the basal coarse-grained facies of the Last Creek formation, and generally has a more siliceous or cherty aspect.

NIUT DOMAIN

The Niut domain is underlain by Middle to Upper Triassic volcanic and sedimentary rocks intruded by Late Triassic quartz diorite of the Niut Mountain pluton. The supracrustal rocks within this belt were assigned to the Lower Cretaceous by Tipper (1969a), and the associated intrusive rocks were consequently thought to be Cretaceous or early Tertiary. Recently, however, sedimentary intervals within volcanic rocks just to the northwest of the present study area were found to contain Triassic fossils (Mustard and van der Heyden, 1994; Mustard *et al.*, 1994), and crosscutting intrusive rocks within and northwest of the study area have yielded Late Triassic U-Pb zircon dates (van der Heyden *et al.*, 1994a; Schiarizza, 1996). The volcanic and sedimentary rocks correlate mainly with the informally named Middle to Upper Triassic Mount Moore formation (Rusmore and Woodsworth, 1991a; Mustard and van der Heyden, 1994; Mustard *et al.*, 1994), which has been interpreted as a part of the Stikine Terrane.

VOLCANIC AND SEDIMENTARY ROCKS (Unit muTv)

Volcanic and sedimentary rocks occur as two separate pendants within the Niut Mountain pluton (Figure 4). The

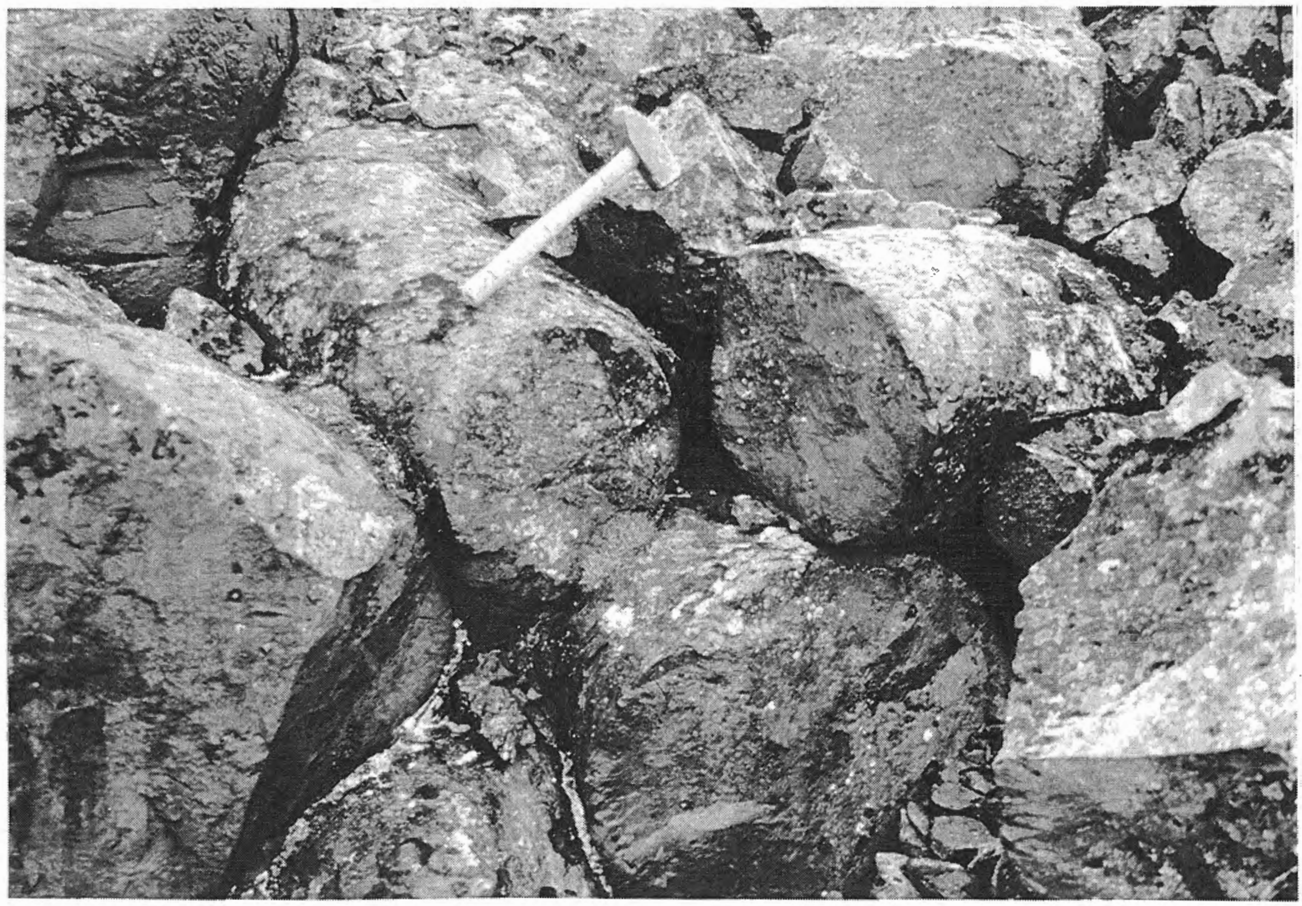

Photo 1. Pillowed basalt of unit muTv, northwest of Niut Mountain.

southeastern body consists mainly of massive green, greenish brown to rusty brown weathered andesitic flows, tuffs and breccias. The andesites commonly contain hornblende and feldspar phenocrysts, 1 to 2 millimetres in size, and locally are pyroxene phyric. Associated fragmental rocks typically comprise angular clasts of green to purple hornblende-feldspar and pyroxene-feldspar-phyric andesite within a matrix of smaller lithic grains and feldspar, hornblende and pyroxene crystals. Volcanic rock fragments are typically 1 to 3 centimetres or less in size, but range up to 10 centimetres in some coarse-grained units. Sedimentary intervals associated with the volcanic rocks are dominated by poorly stratified polymictic conglomerates, but also include intercalations of fine to coarse-grained lithic sandstone and shale. The conglomerates contain a variety of felsic to mafic volcanic rock fragments, including abundant quartz and quartz feldspar porphyries. They also include recessive weathering fine-grained sedimentary(?) clasts and uncommon medium-grained granitoid fragments. The clasts are typically angular and poorly sorted. They range up to 20 centimetres in size, and grade into a gritty sandstone matrix that includes quartz, feldspar and volcanic-lithic grains.

Schiarizza *et al.* (1995a, b) assigned the rocks of the southeastern pendant a Triassic or Cretaceous age, based on correlation with either the Mount Moore formation (Triassic) or the Ottarasko and Cloud Drifter formations (Early Cretaceous). They are now known to be Triassic, at least in part, because the Niut Mountain pluton has yielded a Late Triassic radiometric date where it intrudes the western margin of the succession (Schiarizza, 1996).

The northwestern pendant is continuous with Middle to Upper Triassic rocks mapped as Mount Moore formation to the northwest (Mustard *et al.*, 1994), and is intruded by Late Triassic quartz diorite to the west, south and northeast (Figure 4). Within the Tatlayoko project area this pendant consists mainly of fine-grained, medium to dark green, massive to pillowed mafic volcanic rocks that weather to a grey-brown or rusty brown colour (Photo 1). Feldspar and pyroxene phenocrysts are common, and the phenocryst assemblage hornblende-feldspar occurs locally. Fragmental volcanic rocks appear to be less common, although textures are obscure in many places due to extensive chlorite-epidote alteration. Where observed, they comprise feldspar and mafic crystals, together with lithic fragments to several centimetres in size, within a very fine grained, commonly well indurated groundmass. The lithic fragments are mafic to intermediate volcanic rocks which range from aphyric to porphyritic, the latter containing various combinations of feldspar, pyroxene and hornblende phenocrysts. Light grey felsite, feldspar porphyry and quartz feldspar porphyry occur locally within the mafic volcanic succession. In part they occur as dikes and small irregular intrusive bodies, but some may be extrusive. Sedimentary rocks are a relatively minor component of the northwestern pendant, but narrow intervals of thin-bedded volcaniclastic sandstone and siltstone, or of interbedded chert and siliceous siltstone, were observed locally.

The volcanic and minor sedimentary rocks of the northwestern pendant have not been dated within the present study area, but are clearly intruded by the Late Triassic Niut Mountain pluton. They are continuous with Triassic volcanic and sedimentary rocks to the northwest which have been assigned to the Mount Moore formation (Mustard and van der Heyden, 1994). Corals from thin limestone beds within this succession have been tentatively assigned to the Upper Triassic (van der Heyden *et al.*, 1994a), and chert intercalated with mafic volcanic rocks only 1 kilometre northwest of the present study area has yielded Middle Triassic (Ladinian) radiolarians (F. Cordey and P.S. Mustard, personal communication, 1994). In its type area, about 12 kilometres south of Tatlayoko Lake, a limestone lens intercalated with basaltic breccias of the Mount Moore formation has yielded conodonts of latest Carnian to earliest Norian age (Rusmore and Woodsworth, 1991a).

NIUT MOUNTAIN PLUTON (UNIT LTqd)

The Niut Mountain pluton is a large body of predominantly quartz diorite that underlies most of the Niut domain within the Tatlayoko project area, and clearly intrudes the volcanic and sedimentary rocks within the domain. It consists mainly of massive, equigranular, medium to coarse-grained hornblende±biotite quartz diorite, locally grading to medium-grained hornblende diorite. The pluton locally includes small bodies of mafic-poor medium-grained granitic rock, and it, together with the volcanic and sedimentary rocks of the domain, is cut by a suite of dikes and small plugs that includes fine-grained diorite, hornblende feldspar porphyry, pyroxene feldspar porphyry and lamprophyre. Most dikes strike northeast and dip steeply, although east, north and northwest strikes are locally predominant.

A sample of quartz diorite collected from the eastern margin of the pluton, 4.25 kilometres south-southeast of Niut Mountain, has yielded a preliminary U-Pb zircon age of 219.5±7.3 Ma (R. Friedman, personal communication, 1995). This compares closely with a U-Pb zircon date of 212.2±0.6 Ma from less than 1 kilometre west of the present study area (Mustard and van der Heyden, 1996), and confirms that the plutonic rocks within Niut domain are a single Late Triassic unit.

METHOW TERRANE

Methow Terrane is represented in the Tatlayoko map area mainly by Lower to Middle Jurassic sedimentary and local volcanic rocks of the Huckleberry formation. These rocks are assigned to Methow Terrane on the basis of their correlation with the Ladner Group and, in particular, their lithologic similarity to volcanic-derived clastic rocks and associated volcanics of the Dewdney Creek Formation, which comprises the upper part of the group near its type area (O'Brien, 1986, 1987; Mahoney, 1993). Upper Triassic sandstones and calcarenites of unit uTs apparently underlie the Huckleberry formation along Tatlayoko Lake and are also tentatively included in Methow Terrane, as are conglomerates of probable Triassic age (unit Tcg) that outcrop in the northwest corner of Methow domain. These Triassic rocks were apparently deposited nonconformably above Middle to Late Triassic plutonic rocks of the Mount Skinner Igneous Complex and correlative(?) Crazy Creek pluton, which form the basement to Methow Terrane within the Tatlayoko project area.

MOUNT SKINNER IGNEOUS COMPLEX AND CRAZY CREEK PLUTON (UNIT Tsqd)

The Mount Skinner Igneous Complex is an assemblage of intermediate plutonic rocks and associated mafic to felsic dikes that crops out in an east-west belt centred near Mount Skinner, east of the Homathko River valley. It is dominated by medium to coarse-grained diorite, quartz diorite and tonalite that seem to comprise at least two distinct phases. The more mafic phase is a coarse-grained diorite to quartz diorite containing zero to 15% quartz, and characterized by strongly chlorite-epidote-altered mafic clots, and epidote-altered feldspars which give the rock a distinctive mottled appearance. The other common phase is a medium to coarse-grained hornblende tonalite that contains 20 to 35% quartz and is generally less altered. Associated with these plutonic rocks are abundant finer grained mafic rocks that include discrete dikes and dike swarms of aphanitic basaltic rock, diabase and hornblende±feldspar porphyry, as well as irregular masses, to many tens of metres thick, of fine-grained dark greenstone that may be dike complexes or screens of older volcanic rock within the pluton. Aplite dikes cut most of the aforementioned rock types. They range from 1 to 60 centimetres wide and contain tiny rounded quartz phenocrysts in a pinkish white, very fine grained sugary groundmass. Quartz feldspar porphyry, comprising 1 to 3-millimetre phenocrysts in a grey siliceous aphanitic matrix, was noted at one place within the complex, where it occurs as a number of metre-scale patches that are apparently intrusive into a surrounding zone of greenstone.

Samples of quartz diorite and tonalite from the Mount Skinner Complex have yielded Late to Middle Triassic U-Pb zircon dates of 226.7+8.1/-0.5 and 230±6.0 Ma respectively (R.M. Friedman, written communication, 1995). Purple welded tuff that outcrops 2.8 kilometres west-northwest of Mount Skinner (unit Tv on Figure 4) appears to be a screen within these plutonic rocks, and is therefore inferred to represent part of a Middle Triassic or older volcanic succession into which plutonic rocks of the Mount Skinner Complex were intruded. The southern margin of the complex is in part a northwest-striking fault, and in part a body of biotite hornblende tonalite to granodiorite that is mapped as a separate unit, although it may actually be a part of the complex. This igneous body is in contact with the Huckleberry formation to the south, but the contact was not observed. To the northeast, the Mount Skinner Complex is in contact with conglomerates and sandstones of the Skinner Creek unit of probable Late Triassic age. This contact was not observed, but is suspected to be a nonconformity above which the sedimentary rocks were deposited on top of the igneous complex (Figure 3).

A small outcrop of quartz-pyrite-altered granitoid rock exposed along the east shore of Tatlayoko Lake, but too small to be shown on Figure 4, is inferred to correlate with the Mount Skinner Complex because it is nonconformably overlain by Upper Triassic rocks of unit us (Schiarizza *et al.*, 1995a). The preliminary results from U-Pb dating of zircons from this body support this correlation, as they suggest an age of 234 or 235 Ma (R.M. Friedman, personal communication, 1995).

The geology west of the Homathko River and northern Tatlayoko Lake is dominated by a large, fault-bounded plutonic body that is informally referred to as the Crazy Creek pluton (Schiarizza, 1996). It consists mainly of massive, medium to coarse-grained hornblende-biotite quartz diorite and tonalite, although easternmost exposures include abundant diorite and tabular to irregular bodies of fine-grained greenstone that may be dike complexes and/or screens of older volcanic or dike rock. Schiarizza *et al.* (1995a, b) correlated these eastern exposures with the Mount Skinner Complex, but suggested that most of the pluton was Cretaceous or Tertiary in age, whereas Schiarizza (1996) suggested that the entire pluton may be Triassic. The latter interpretation is presently preferred, as a preliminary U-Pb date on zircons from a sample of quartz diorite collected from the south-central part of the pluton suggests an age of 220+7/-1 Ma (R.M. Friedman, personal communication, 1995). A pendant of hornfelsed sandstone and siltstone that occurs within quartz diorite along the southwestern margin of the Crazy Creek pluton (unit Ts of Figure 4) was therefore derived from an unknown unit of Triassic or older age, rather than from the Relay Mountain Group as suggested by Schiarizza *et al.* (1995a, b).

SKINNER CREEK CONGLOMERATE (UNIT Tcg)

A distinctive assemblage of maroon conglomerates, interlayered with lesser amounts of finer grained sedimentary rock, crops out in an east to southeast-trending belt between the Homathko River and Choelquoit Lake (Figure 4). The main belt is bounded by the Yalakom fault to the northeast, plutonic rocks of the Mount Skinner Complex to the south, and an inferred north-striking fault to the west that separates it from exposures of Jackass Mountain Group in the Homathko River valley. Similar conglomerates are also exposed in a thin sliver west of the Mount Skinner Complex, near the Skinner mine; where they are in strati-

Photo 2. Conglomerate of unit TRcg, north of Skinner Creek.

graphic or fault contact with the Huckleberry formation to the southeast.

The dominant rock type in unit uTRcg is maroon, locally green, poorly stratified pebble to cobble conglomerate containing mainly intermediate to felsic volcanic clasts (Photo 2). These include common porphyritic varieties containing feldspar or feldspar and quartz phenocrysts. Fine to medium-grained granitoid clasts are commonly present, but typically comprise only a few percent of the clast population. Some are similar to quartz diorite and tonalite of the Mount Skinner Complex and may have been derived from it. Clasts of fine-grained clastic sedimentary rock and limestone occur locally. Clasts are typically angular, poorly sorted and either supported by, or gradational into a sandy to gritty matrix containing feldspar, quartz and lithic grains. The conglomerates are generally coarser in the northern part of the belt, where clasts locally range up to 40 centimetres across.

Sandstone and siltstone are intercalated with conglomerate throughout the belt, but are most common in the southeast. Green, brown or purple sandstones to pebbly sandstones occur mainly as poorly stratified lenses or layers that grade into conglomerate, whereas grey to purple siltstone and argillite commonly occur as distinct thin-bedded intervals, up to several metres thick, between conglomerate units. Locally, fine-grained sandstone to siltstone occurs as thin graded beds with argillite tops. Dark grey to purplish brown micritic limestone is seen rarely as medium to thick beds intercalated with argillite, or as lenses to a few metres thick within conglomerate. Purple tuff or tuffaceous sandstone, composed of feldspar crystals and angular volcanic fragments in a fine-grained matrix, was observed in one outcrop at the west end of the belt.

The age of the Skinner Creek conglomerate unit is not known, as samples of limestone collected in 1994 were barren of microfossils. The unit is provisionally assigned to the Triassic following Tipper (1969a), as it is lithologically more similar to Upper Triassic rocks of the region than to younger rocks. This inferred age suggests that the conglomerates may have been deposited nonconformably above the adjacent Middle to Late Triassic Mount Skinner Igneous Complex, although the contact was not observed. This interpretation is consistent with the proximal nature of many of the conglomerates and the presence of granitoid clasts within them, and is corroborated by the nonconformable contact observed between potentially correlative rocks of unit uTRs and underlying quartz diorite to the south (*see* following section).

UPPER TRIASSIC ROCKS ALONG TATLAYOKO LAKE (UNIT uTRs)

An isolated exposure of Upper Triassic sedimentary rocks occurs on a low knoll along the east shore of Tatlayoko Lake, 4.5 kilometres south of the north end of the lake. Small exposures of sandstone on the opposite side of the lake are also tentatively included in this unit (Figure 4). The eastern exposure is dominated by thin to medium-bedded, locally crossbedded calcarenite and fossil hash, intercalated with brownish weathered, fine to coarse-grained green lithic sandstone. Calcarenite units are locally pebbly, with rounded intermediate to felsic volcanic clasts and rare subangular to subrounded granitoid pebbles. Thin beds of grey siltstone are intercalated with the lithic sandstone, and medium beds of dark grey, light grey weathering micritic limestone are intercalated with sandstone and siltstone over several metres in the lower part of the unit. The base of the unit consists of about 10 metres of light grey, coarse-grained quartzofeldspathic sandstone and granule conglomerate passing downwards into pebble conglomerate comprising angular granitoid clasts in an arkosic matrix. This basal interval is underlain by a quartz-pyrite-altered granitoid rock that is exposed along the shoreline in the southwestern part of the outcrop. The contact was observed over only a short interval, where it appears to be a nonconformity above which the sedimentary interval was deposited on top of the altered intrusive rock. As noted above, preliminary U-Pb dating of zircons from the intrusive unit suggest that it is of late Middle Triassic age, and probably correlative with the Mount Skinner Complex.

Tipper (1969a) reports that fossils collected from unit uTRs on the east side of Tatlayoko Lake were examined by E.T. Tozer and assigned a Late Triassic, probably late Norian age. The present study has not supplied any additional age data, as a sample of micrite collected in 1994 was barren of microfossils, and a collection of small bivalves did not yield any precise age determination (GSC Loc. C-207897; T.P. Poulton, report J8-TPP-1995).

HUCKLEBERRY FORMATION (UNIT lmJs)

Lower to Middle Jurassic clastic sedimentary and local volcanic rocks of the Huckleberry formation (informal) are widespread in the vicinity of Chilko and Tatlayoko lakes (Figure 4). This succession includes most of Tipper's (1969a) unit 8, although Callovian strata that were included in unit 8 are excluded from the formation following Umhoefer and Tipper (1991).

The Huckleberry formation is typically very well stratified, and consists mainly of fine-grained clastic rocks

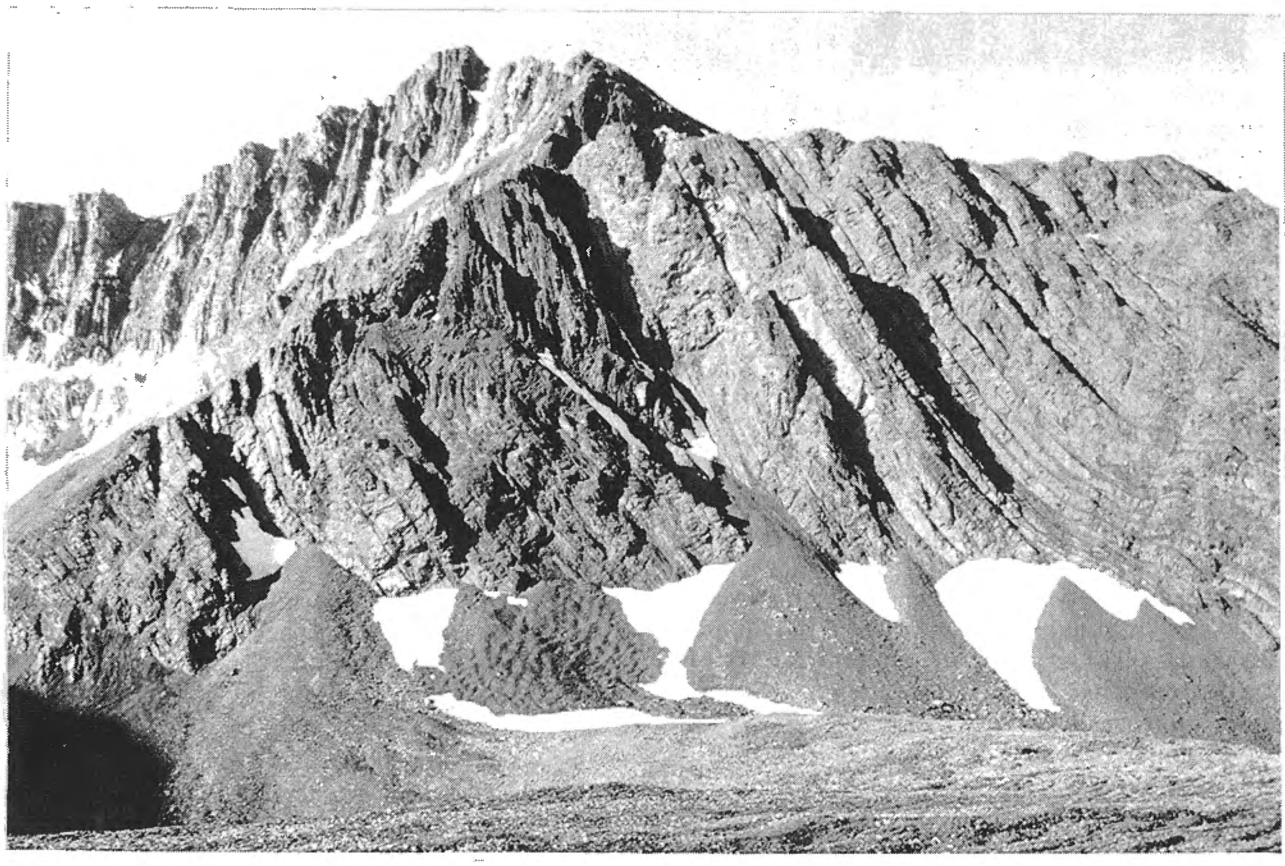

Photo 3. Looking southwest at well stratified sandstones and shales of the Huckleberry formation, west of Mount Nemaia.

intercalated with varying proportions of well indurated coarse-grained sandstone, gritty to pebbly sandstone, and granule to small-pebble conglomerate (Photo 3). Finer grained intervals are typically thin-bedded, laminated to crosslaminated siltstone and fine-grained sandstone, with scattered thin to thick beds of grey shale and fine to medium-grained lithic sandstone. Medium beds of laminated to crosslaminated calcareous siltstone or silty limestone occur locally. Coarser grained units are dominated by well indurated coarse-grained sandstone to gritty sandstone that occurs as medium to very thick, locally graded beds. The coarse sandstones consist mainly of volcanic lithic fragments and feldspar, although quartz is locally an important component. Granule to small-pebble conglomerate occurs locally as very thick, massive or weakly graded beds that are most commonly associated with intervals of coarse-grained sandstone, but also occur as isolated layers within siltstone-dominated sections. Conglomerate beds are typically dominated by intermediate to felsic volcanic clasts, and commonly include abundant shaly rip-up clasts. Limestone clasts and belemnite fragments are important constituents of some conglomerates, and rarely are the dominant clast types.

Volcanic rocks are not common in the Huckleberry formation, but were observed in several widely scattered localities. The most extensive exposures are within the isolated set of outcrops along the west side of the north end of Tsuniah Lake (Figure 4). There, several tens of metres of volcaniclastic and volcanic rock occur within an interval dominated by massive to thick-bedded sandstones and gritty sandstones typical of the unit. The base of the volcanic section is marked by about 10 metres of poorly sorted breccia or conglomerate containing angular to subrounded clasts up to 40 centimetres in size. The clasts are almost exclusively intermediate to felsic volcanic rocks, some with irregular jagged shapes indicating very little transport, and some with red cores and green rims. This coarse-grained unit is overlain by a thicker section of poorly stratified tuffs consisting of intermediate, commonly feldspar-phyric volcanic fragments up to 3 centimetres across, together with feldspar and mafic crystals. Near the top of the tuff unit is a flow or sill consisting of feldspar and mafic phenocrysts, 1 to 2 millimetres in size, within a medium green aphanitic groundmass. The lower part of the tuff unit is a distinctive muddy tuff that consists of feldspar crystals with or without volcanic rock fragments floating in a fine-grained matrix. Similar matrix-supported tuff occurs as a layer 2 to 3 metres thick within intercalated sandstone and siltstone on the opposite side of the Tsuniah Lake syncline, directly south of Mount Nemaia. Farther east within this same belt, but apparently higher in the section, is an interval, less than 10 metres thick, of blue-green andesitic lapilli tuff and breccia (Riddell *et al.* 1993a). An interval of similar tuffs and breccias was mapped about 1.5 kilometres east of the north end of Tatlayoko Lake, and again 8.5 kilometres farther to the east, west of Lingfield Creek. These occurrences may be at about the same stratigraphic level, on opposite limbs of the Potato Range syncline.

Most of the dated rocks in the Huckleberry formation are Middle Jurassic. An Aalenian fossil collection came from the vicinity of Huckleberry Mountain, and Bajocian fossils are known from several locations east of Tatlayoko Lake and the south limb of the Tsuniah Lake syncline (Tipper, 1969a; Umhoefer and Tipper, 1991). Only some of the fossils collected during the present study have so far been identified, and most of these confirm the distribution of Bajocian strata known previously. In addition, an ammonite resembling *Dactylioceras* or *Tmetoceras*, and therefore of possible Toarcian or Aalenian age, was collected 5 kilometres east-northeast of the north end of Tatlayoko Lake (GSC Loc. C-207866; T.P. Poulton, report J5-TPP-1995). This locality is stratigraphically above the only occurrence of Lower Jurassic rocks documented within the formation, which are near the north end of Tatlayoko Lake. There, early Pliensbachian fossils are reported from an interval of siltstones, sandstones and granule conglomerates (Umhoefer and Tipper, 1991).

The base of the Huckleberry formation is not exposed, but the oldest known rocks from the formation are in the same area as known and inferred Triassic rocks of units uTRs and uTRcg, suggesting that the Triassic rocks may be stratigraphically beneath the Jurassic section. However, as the closest outcrops of the respective units are separated by more than a kilometre of Quaternary cover, a stratigraphic relationship is not proven.

CALLOVIAN SHALE UNIT (mJs)

Fossiliferous Callovian rocks were identified on the south limb of the Tsuniah Lake syncline by Tipper (1969a), who included them in his Lower to Middle Jurassic unit 8. However, they were not included in the derivative Lower to Middle Jurassic Huckleberry formation of Umhoefer and Tipper (1991) because they were inferred to be separated from underlying Bajocian strata of the formation by a major disconformity. These Callovian rocks are here considered a separate unit (mJs on Figure 3), following Umhoefer and Tipper. However, they do not constitute a mappable unit on the scale of Figure 4, where they are included in the Huckleberry formation.

The Callovian unit is best defined on a northern spur at the west end of the Mount Nemaia ridge system, 1.5 kilometres east of Chilko Lake. There, it comprises about 100 metres of cleaved black shale containing rusty weathering calcareous concretions and local thin interbeds of fine-grained sandstone and calcareous sandstone. This shale interval is assigned an early Callovian age on the basis of a fossil collection which includes the ammonites *Xenocephalites vicarius* Imlay, *Lilloettia*(?) sp. and *Phylloceras*(?) sp. (GSC Loc. C-207889; T.P. Poulton, report J5-TPP-1995). Underlying rocks, comprising the upper part of the Huckleberry formation, consist of fine to coarse-grained sandstone that occurs as thin to medium beds intercalated with shale and siltstone. The contact is inferred to be a disconformity, as an ammonite collected from the upper part of the Huckleberry formation on an adjacent spur, 2 kilometres to the northeast, has been identified as *Stephanoceras(?)* sp. of probable early Bajocian age (GSC Loc. C-207883; T.P. Poulton, report J5-TPP-1995). The upper boundary of the Callovian shale unit is a sharp erosive disconformity at the base of the Relay Mountain Group. It is marked by 35 centimetres of sandstone packed with belemnite guards. Overlying massive fine-grained sandstone contains several shell-rich layers that contain belemnites and *Buchia* pelecypods, including *Buchia concentrica* (Sowerby) of late Oxfordian to early Kimmeridgian age (Tipper, 1969a, Section JA-F67-7). The Callovian shale unit thins eastward and is missing on the spur 2 kilometres to the northeast, where massive sandstones at the base of the Relay Mountain Group are in stratigraphic contact with the upper part of the Huckleberry formation.

The Callovian unit apparently extends westward, across Chilko Lake, to the ridges north of Huckleberry Mountain, where Tipper (1969a; GSC Loc. 79021) reports a fossil collection containing *Kepplerites*(?) sp. indet. of early Callovian(?) age. The unit is not well defined in this area, however, in part because of structural complications and in part because the fossil locality is apparently within a succession of interbedded shales and sandstones, with local limestone beds, that is not lithologically distinct from the upper part of the Huckleberry formation.

Callovian rocks are not documented elsewhere in the Methow Terrane. However, at the south end of the Potato Range, the Relay Mountain Group rests disconformably above an undated unit of crumbly shale containing calcareous concretions and micrite layers. This calcareous shale unit, which occurs above well bedded sandstones and shales typical of the Huckleberry formation, may correlate with the Callovian shale unit. Elsewhere in the area, the contact between the Relay Mountain Group and the Huckleberry formation is commonly obscured by a covered interval that may also be underlain by the recessive shale unit.

TYAUGHTON - METHOW BASIN

The Tyaughton - Methow basin is a belt of Jura-Cretaceous clastic sedimentary rocks that occurs along the northeast side of the southeastern Coast Belt and contiguous north Cascade orogen in southwestern British Columbia and northern Washington State (Jeletzky and Tipper, 1968; Kleinspehn, 1985). The northeastern or Methow part of the basin was deposited above Methow Terrane, whereas the Tyaughton basin to the southwest was deposited largely above Bridge River Terrane. The basin developed in two distinct time intervals. The older part records a relatively long period of predominantly shallow-water marine deposition in latest Middle Jurassic to Early Cretaceous time. This period is represented mainly by the Relay Mountain Group, which occurs in both the Methow and Tyaughton parts of the basin. The upper part of the basin comprises mid-Cretaceous synorogenic clastic sedimentary rocks that were deposited during a major period of contractional deformation within the southeastern Coast - north Cascade orogen. Rocks deposited in the Tyaughton part of the basin during this time period (mainly the Taylor Creek Group) are lithologically and stratigraphically distinct from age-equivalent rocks deposited in the Methow part of the basin (mainly the Jackass Mountain Group), in part because the two successions were separated by an intervening landmass that was uplifted during mid-Cretaceous contractional deformation (Garver, 1989, 1992).

RELAY MOUNTAIN GROUP (UNIT JKRM)

The Relay Mountain Group occurs in three separate areas within the Tatlayoko project area, each with different stratigraphic and structural contexts. The most extensive exposures are within Methow domain east of Tatlayoko Lake, where the group occurs above the Huckleberry formation and Callovian shale unit and beneath the Jackass Mountain Group. Lower Cretaceous sandstones assigned to the group also outcrop in a narrow belt north of Mount Tatlow, within the South Chilcotin domain. These rocks were probably deposited above the Bridge River Complex and then overlain by the Taylor Creek Group. The third outcrop belt is in the eastern Niut Range west of Tatlayoko Lake. It includes Upper Jurassic and Lower Cretaceous rocks that are preserved within a narrow fault block enclosed by rocks of Methow and Niut domains. Fault slivers of chert-pebble conglomerate, probably derived from the Taylor Creek Group, occur locally within this block, suggesting that it was derived from the south Chilcotin domain.

Methow Domain

Upper Jurassic to Lower Cretaceous marine and nonmarine clastic sedimentary rocks that outcrop between Tatlayoko Lake and the Nemaia valley were assigned to the Relay Mountain Group by Tipper (1969a). They are best exposed in the core of the Potato Range syncline, but also outcrop along northern Chilko Lake, where they are bounded by the Lingfield Creek and Cheshi Creek faults, and as a narrow belt that extends from the western Nemaia Range westward across Chilko Lake to Cheshi Creek (Figure 4). In these areas the Relay Mountain Group overlies the Callovian shale unit or, where Callovian rocks are missing, the Huckleberry formation. The upper part of the group is missing in the western part of the southern limb of the Tsuniah Lake syncline, where it has apparently been eroded beneath an unconformity at the base of the Jackass Mountain Group. Farther east, and on the north limb of the Tsuniah Lake syncline, the entire Relay Mountain Group

Photo 4. Lower Cretaceous *Buchia* coquina, Relay Mountain Group, western Potato Range.

is missing and the Jackass Mountain Group rests directly on the Huckleberry formation. Presumably the Jackass Mountain Group once overlaid the Lower Cretaceous Relay Mountain Group farther west, but nowhere in the Potato Range are strata exposed above the youngest Relay Mountain Group.

The Relay Mountain Group is on the order of 2400 metres thick in the Potato Range. The Upper Jurassic (upper Oxfordian - Tithonian) part of the group consists of about 900 metres of brown to green lithic sandstone and brown to black siltstone and mudstone. *Buchia* pelecypods and belemnites are common in parts of the interval and ammonites occur locally. Arkoses are present in the upper part of this sequence, which is interpreted to be offshore marine and generally becomes shallower marine upward. It is gradationally overlain by 150 to 200 metres of interlayered lithic and arkosic sandstones that are unfossiliferous and were deposited in near-shore to marginal marine environments. The Jurassic-Cretaceous boundary is within this interval.

The Lower Cretaceous part of the Relay Mountain Group, about 1300 metres thick, consists mainly of dark green to black volcanic-lithic sandstones up to a few hundred metres thick with local planar laminae and low-angle crosslaminae. In the lower part of the interval these sandstones are intercalated with sandy *Buchia* coquina sequences up to 140 metres thick (Photo 4). The coquinas are shell supported and consist of subequal amounts of fragmented, disarticulated, and whole articulated *Buchia*, with local beds of shell hash and fine-cobble volcanic and plutonic conglomerate. Both the volcanic-lithic sandstones and coquinas have rare belemnites, ammonites and inoceramid fossils and are interpreted to be shallow marine. Another common lithofacies in the Lower Cretaceous section is beige to green (commonly alternating) arkosic sandstone, tens of metres thick, most of which is interpreted to be fluvial deposits. The arkose locally has moderate to high-angle crossbeds and trough crossbeds, is commonly plant rich and has rare root casts. Arkoses are commonly interbedded with fissile black siltstones 1 to 5 metres thick, with plant fossils and wavy laminae. There are sparse beds of clast-supported, mostly massive pebble to cobble conglomerate, 5 to 20 metres thick, with local imbrication and rare plant fossils, that are interpreted to be fluvial channel deposits. The lower half of the Lower Cretaceous Relay Mountain Group in the Potato Range has been dated with *Buchia* and mixed inoceramid and ammonite assemblages to be Berriasian to late Hauterivian, with early to middle

Hauterivian strata missing across a disconformity (Tipper, 1969a). The upper half of the Lower Cretaceous consists of unfossiliferous shallow-marine and nonmarine strata, which are inferred to be mainly Barremian, because they lie conformably over the latest Hauterivian marine section.

The basal contact of the Relay Mountain Group was observed at the south end of the Potato Range and at the west end of the Mount Nemaia ridge system, 2 kilometres east of Chilko Lake. In each of these areas the contact is an erosional disconformity marked by a thin layer of belemnite coquina, and sandstones in the lower part of the group contain the pelecypod *Buchia concentrica* (Sowerby), indicating a late Oxfordian or early Kimmeridgian age (GSC Loc. C-207884, T.P. Poulton, report J8-TPP-1995; Tipper, 1969a, Section JA-F67-7). However, the basal part of the Relay Mountain Group in the Nemaia Range section appears to trace eastward into similar sandstones that, 2 kilometres farther east, contain the fossils *Camptonectes* sp., *Pleuromya* sp. and *Gryphaea*(?) sp., suggesting a Bathonian or Callovian age (GSC Loc. C-207899; T.P. Poulton, report J8-TPP-1995). Furthermore, an isolated exposure of sandstone at about the same stratigraphic level, 5 kilometres farther east, contains the fossils *Meleagrinella*(?) sp., *Entolium* sp., *Grammatodon*(?) sp. and *Myophorella*(?) sp., suggesting a probable middle Toarcian through early Oxfordian age (GSC Loc. C-207881, T.P. Poulton, report J8-TPP-1995).These latter two fossil localities suggest that either the basal Relay Mountain Group locally extends down into the early Oxfordian and Callovian, or the Callovian shale unit undergoes an abrupt facies change eastward on the Mount Nemaia ridge system, into sandstones that are not readily distinguished from those of the Relay Mountain Group.

South Chilcotin Domain

The Relay Mountain Group in the South Chilcotin domain is represented by a narrow interval of poorly exposed shales, siltstones and sandstones 5 to 6 kilometres north of Mount Tatlow. The sequence also includes minor amounts of pebble conglomerate containing rounded sedimentary, volcanic and plutonic clasts, as well as a layer of coquina about 3 metres thick. H.W. Tipper reports that fossils collected from this coquina include *Buchia* sp. resembling *B. pacifica* that has been squashed, suggesting an Early Cretaceous? (Valanginian) age (GSC Loc. C-207831; report J9-1992-HWT).

The exposures of Relay Mountain Group north of Mount Tatlow are bounded to the north by an interval of sheared serpentinite, about 50 metres thick, that is inferred to mark the trace of the Taseko fault. Chert, greenstone, serpentinite and clastic sedimentary rocks of the Bridge River Complex occur along this same fault zone farther to the east. Shale and chert-pebble conglomerate of the Taylor Creek Group outcrop south of the Relay Mountain Group, but the contact is obscured by Quaternary alluvium.

The lens of Relay Mountain rocks north of Mount Tatlow represents only a part of the group, and is bounded on one or both sides by faults. However, it is juxtaposed against the same units which stratigraphically underlie it (Bridge River Complex) and overlie it (Taylor Creek Group) in its type area to the southeast (Schiarizza and Garver, 1995). These relationships suggest that the Bridge River Complex probably underlies the Relay Mountain Group throughout the South Chilcotin domain. The exposures of Relay Mountain Group in Methow domain, just 20 kilometres to the northeast, were deposited above a completely different basement consisting of arc-derived clastic sedimentary and volcanic rocks of Methow Terrane. The initial juxtaposition of these two contrasting basement terranes may have been at an early to mid-Mesozoic plate boundary where the Bridge River ocean subducted beneath an adjacent plate that developed the Cadwallader and Methow arcs. This boundary has been subsequently telescoped across important late Mesozoic and early Tertiary structures such as the Taseko and Konni Lake faults.

Niut Range

West of Tatlayoko Lake, the Relay Mountain Group occurs as a narrow northwest-trending belt that is in fault contact with volcanic and plutonic rocks of Niut domain to the southwest, and with the Crazy Creek pluton to the northeast. This belt includes conglomerates, sandstones and shales that are cut by numerous faults and intruded by abundant sills and plugs of quartz diorite. Where best exposed, about 3.5 kilometres west of Tatlayoko Lake, the relatively wide southern part of the belt comprises two main fault panels. The northeastern panel is a coherent, northeast-dipping section that includes two distinct units. The lower unit is about 300 metres thick and consists mainly of arkosic lithic sandstone. Conglomerate dominates about 100 metres in the central part of the unit, and contains rounded pebbles and cobbles of felsic to mafic volcanic rocks together with a smaller proportion of granitoid rock (Photo 5). *Buchia* fossils collected from near the base of the unit, as well as from the upper part of the conglomeratic interval, have been identified as Upper Jurassic (Tithonian) forms (GSC Locs. C-207896 and C-208756; T.P. Poulton, report J8-TPP-1995), confirming an earlier fossil report by Tipper (1969a). The base of the upper unit comprises several tens of metres of dark grey shale containing *Inoceramus* and belemnite fragments. These rocks abruptly overlie sandstones of the lower unit and pass up-section into about 100 metres of thin to medium-bedded, locally crossbedded arkosic sandstone intercalated with siltstone and friable shale. The upper unit is assumed to be Hauterivian in age, based on the presence of *Inoceramus* fossils and its strong lithologic similarity to the Hauterivian and(?) Barremian rocks of the upper part of the Relay Mountain Group where it is well exposed and dated in the adjacent Potato Range (Tipper, 1969a; Schiarizza *et al.*, 1995a).

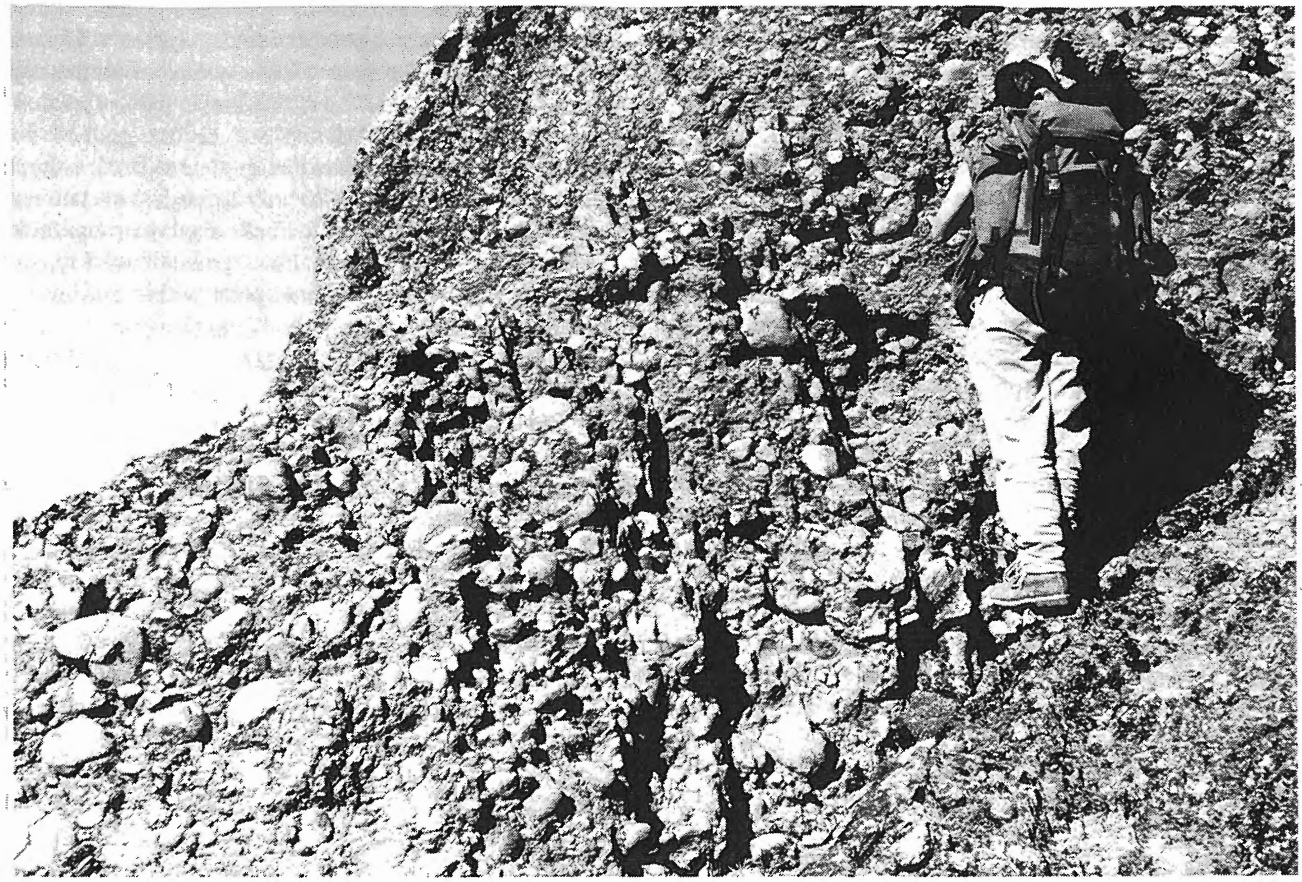

Photo 5. Upper Jurassic conglomerate, Relay Mountain Group, northeastern Niut Range.

The coherent section described above rests structurally above a southwestern fault panel that consists of faulted and folded shale containing intercalations of arkosic and lithic sandstones. These rocks are, for the most part, lithologically similar to the Hauterivian strata of the Relay Mountain Group, and this correlation is confirmed by fossil pelecypods and belemnites collected from the central part of the belt. The collection includes *Inoceramus* sp. and *Acroteuthis* sp., and was assigned a Hauterivian age by T.P. Poulton (GSC Loc. C-207893; report J8-TPP-1995). Local fault slivers of chert-pebble conglomerate occur within the upper part of the panel, however, and were probably derived from the mid-Cretaceous Taylor Creek Group, which overlies the Relay Mountain Group south of the Nemaia valley (Figure 4).

The belt of Relay Mountain Group rocks narrows to the northwest, where it becomes a series of fault-bounded slivers of sedimentary rock interleaved with quartz diorite. The sedimentary rocks include conglomerates and sandstones similar to those of the Jurassic section to the south, as well as local shale-dominated lenses that resemble the Hauterivian interval to the south. A single fossil collection from shales in the northern part of the belt was assigned a Hauterivian age based on the presence of *Inoceramus* sp. and the belemnite *Acroteuthis* sp. (GSC Loc. C-207892; T.P. Poulton, report J8-TPP-1995).

The intact section of Relay Mountain rocks exposed in the upper fault panel in the southern part of the belt differs from sections in the Potato Range, directly east of Tatlayoko Lake, in two main aspects. First of all, the thick interval of Jurassic conglomerates found in this belt does not occur to the east. Secondly, the apparent absence of Berriasian and Valanginian rocks in the Niut Range belt suggests that, here, the disconformity beneath the Hauterivian section represents much more missing stratigraphy than the disconformity beneath Hauterivian rocks in the Potato Range, where there is a thick interval of Berriasian and Valanginian strata (Tipper, 1969a). These relationships suggest that the Niut Range section originated near the margin of the Relay Mountain basin, as proposed by Jeletzky and Tipper (1968). A further difference relates to the rocks that overlie the Relay Mountain Group. In the Methow domain, east of Tatlayoko Lake, the Relay Mountain Group is stratigraphically overlain by arkosic sandstone and granitoid-bearing conglomerate of the Albian Jackass Mountain Group (Figure 3). The fault-bounded slivers of chert-pebble conglomerate imbricated with Hauterivian rocks of the Relay Mountain Group in the Niut

Range, however, suggest that the Relay Mountain Group here was overlain by the Albian Taylor Creek Group. This suggests that the Relay Mountain Group in the Niut Range relates more closely to that part of the group exposed in the South Chilcotin domain, and occurs within the Tyaughton, rather than the Methow sub-basin, as defined by Garver (1989, 1992).

JACKASS MOUNTAIN GROUP (UNIT lKJM)

Clastic sedimentary rocks of the Lower Cretaceous Jackass Mountain Group are well exposed in the core of the Tsuniah Lake syncline, in the central part of the Tatlayoko project area (Tipper, 1969a; Kleinspehn, 1985). They also outcrop near the northwestern corner of the map area, within and adjacent to the Homathko River valley. Stratigraphic relationships are well displayed only in the former area, where the group is stratigraphically above the Huckleberry formation and, locally, an intervening sliver of Relay Mountain Group (Figure 4).

The Jackass Mountain Group comprises a thick succession of sandstones, with subordinate finer and coarser grained rocks (Photo 6). The sandstones are medium green to bluish green in colour, and typically weather light brown to brownish grey. They are predominantly medium to coarse grained, rich in feldspar, and commonly contain scattered granules and small pebbles of volcanic, sedimentary and less common granitoid rock fragments. The sandstones form massive intervals many tens of metres thick, or medium to very thick beds that are, in part, separated by interbeds of thin-bedded siltstone or fine-grained sandstone-shale couplets. Individual sandstone beds within the well bedded intervals are locally graded, with laminated tops and thin shaly caps; some beds display rip-ups, scours and load casts at their bases. Finer grained facies typically occur as relatively minor interbeds within coarse sandstone, but intervals of thin-bedded, planar to crosslaminated siltstone to fine-grained sandstone are locally more than 100 metres thick.

The basal part of the Jackass Mountain Group in the Tsuniah Lake syncline includes an interval of dark grey, grey to brownish grey weathered splintery siltstone, which was assigned to the Taylor Creek Group by Tipper (1969a). It is underlain by fine to coarse-grained sandstone containing thin layers and lenses of pebble to cobble conglomerate. The siltstone unit is best exposed on the south limb of the syncline, where it is more than 500 metres thick, and contains fossils of early and middle Albian age (Jeletzky, 1968). The underlying sandstone-conglomerate unit is only a few tens of metres thick, and comprises massive to thick-bedded sandstones that enclose two or more lenses of

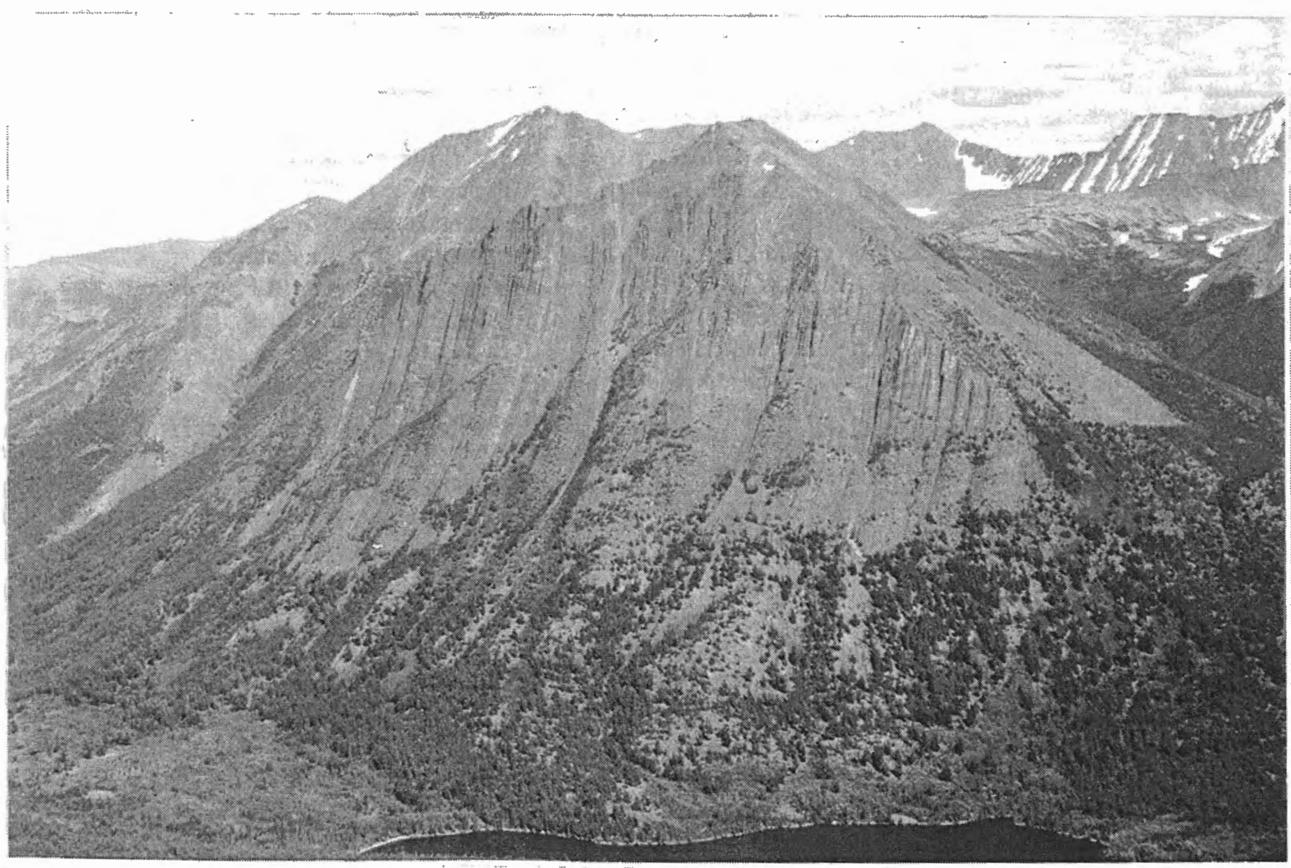

Photo 6. Looking east at Lower Cretaceous Jackasss Mountain Group, south limb of the Tsuniah Lake syncline, east of Chilko Lake

conglomerate. The conglomerate units range up to 1 metre in thickness and contain rounded clasts of mainly intermediate volcanic rocks and massive to foliated granitoid rocks. This same twofold division occurs on the north limb of the syncline, but there the siltstone unit is less than 200 metres thick and may pinch out to the east. The underlying sandstone-conglomerate unit is correspondingly much thicker than to the south; individual conglomerate units are rarely more than a metre thick, but they occur through more than 500 metres of section.

The contact between the Jackass Mountain Group and underlying rocks of the Huckleberry formation was observed at one place and is tightly constrained at three others over a 6-kilometre strike length on the north limb of the Tsuniah Lake syncline. Although mapped as a fault by Tipper (1969a), it appears to be a stratigraphic contact throughout this length. There is no angular discordance with underlying Jurassic rocks in the western part of this belt, but to the east the Jurassic rocks are locally folded and very gently dipping directly beneath the contact, whereas the overlying Cretaceous rocks maintain their moderate southward dips. On the south limb of the syncline, the basal contact of the Jackass Mountain Group was observed at one place north of Konni Lake (Riddell *et al.*, 1993a, b), and is constrained to within a few metres on the ridge system to the north-northwest of Mount Nemaia (Schiarizza *et al.*, 1995a, b). This contact is also depositional, at least in part, although it was mapped as a fault by Tipper (1969a). The Jackass Mountain Group is essentially concordant with underlying Jurassic rocks in this area. However, it rests directly above the Huckleberry formation in the east, but above an intervening, westward-thickening wedge of Upper Jurassic rocks of the lower part of the Relay Mountain Group in the vicinity of Chilko Lake (Figure 4). Furthermore, in exposures farther to the west, the Huckleberry formation is overlain by a thick section of both Jurassic and Lower Cretaceous rocks of the Relay Mountain Group. These relationships indicate that there has been an abrupt eastward bevelling of the Relay Mountain Group beneath a sub-Jackass Mountain unconformity.

The Jackass Mountain Group in the core of the Tsuniah Lake syncline is the offset counterpart of Jackass Mountain exposures on the northeast side of the Yalakom fault in the Camelsfoot Range, more than 100 kilometres to the southeast (Kleinspehn, 1985; Riddell *et al.*, 1993a). The fossiliferous shale interval and underlying conglomerates and sandstones at the base of the group in the Tsuniah Lake syncline are equivalent to Jeletzky's (1971) grey siltstone - shale division in the Camelsfoot Range, which contains the same early lower Albian *Brewericeras (Leconteites) lecontei* fauna. Overlying sandstones, which constitute most of the group in the Tsuniah Lake syncline, are equivalent to Jeletzky's massive greywacke division in the Camelsfoot Range. A major difference between the two sections, however, is that the distinctive Albian rocks are underlain by an interval of Barremian-Aptian rocks in the Camelsfoot Range that are also included in the Jackass Mountain Group (variegated clastic division of Jeletzky, 1971; unit lKJMy1 of Schiarizza *et al.*, 1993b,c). These Barremian-Aptian rocks comprise volcanic-lithic sandstones and shales that are lithologically similar to underlying Middle Jurassic rocks (unit lmJys of Schiarizza *et al.*, 1993b,c), that are equivalent to the Huckleberry formation of the Tatlayoko project area. This lower part of the Jackass Mountain group is apparently not represented in the Tsuniah Lake area, where the group appears to be entirely Albian in age, and rests unconformably or disconformably above Jurassic rocks.

TAYLOR CREEK GROUP (UNIT luKTC)

Mid-Cretaceous clastic sedimentary rocks here assigned to the Taylor Creek Group include those that were assigned to the group by Tipper (1978) as well as rocks that he included in the sedimentary unit of the Kingsvale Group. They underlie much of the southeastern corner of the map area, east of Taseko Lake, and also outcrop as an east-trending belt north of the Mount Tatlow ridge system. The group is characterized by black shale and siltstone, together with chert-rich sandstone and pebble conglomerate. Olive-green muscovite-bearing sandstones, brown limy sandstone, and green ash and crystal tuffs also occur locally within the Taylor Creek sequence.

Black to dark grey shale is the dominant lithology in the Taylor Creek Group. It typically erodes into irregular splinters, but may be cleaved into paper-thin sheets near intrusions. The shale intervals locally include lighter coloured silty and sandy interbeds, resistant carbonate-cemented interlayers, thin micrite beds and limestone concretions. Small plant fragments and cone fragments are rare.

Chert-rich pebble conglomerate to pebbly sandstone is the most distinctive lithology within the Taylor Creek Group. The conglomerates typically occur as layers or lenses, from less than 1 metre to more than 20 metres thick, enclosed within shale. Their basal contacts are locally channeled into the underlying shale. The clast population is dominated by white, grey, green, black and red chert. Other common lithologies include white and grey quartz, and felsic to intermediate volcanic rocks; clasts of calcarenite, black shale and siliceous argillite occur locally. Most of the conglomerates are clast supported, but sandy matrix-supported beds also occur. Pebbles are angular to rounded. They are commonly 1 to 2 centimetres across, and rarely larger than 4 centimetres.

The Taylor Creek Group in the Tatlayoko project area is lithologically similar to, and in part continuous with, Taylor Creek rocks in the northwestern corner of the Warner Pass map area which are assigned to the Beece Creek succession by Schiarizza *et al.* (1993d). The Beece Creek succession occurs in the upper part of the Taylor

Creek Group and is, at least in part, equivalent to the Silverquick formation (Garver, 1989, 1992) farther to the southeast. The Beece Creek succession is not dated, but is assigned a late Albian to Cenomanian age because it locally rests above the middle to upper Albian Lizard formation, and occurs beneath the Cenomanian and younger Powell Creek formation. However, as its stratigraphy is not well defined, rocks assigned to the Beece Creek succession (including the Taylor Creek Group in the Tatlayoko project area) may also include older parts of the group, correlative with the Lizard formation and the mid-Albian Dash formation (Garver, 1989).

The base of the Taylor Creek Group is not exposed in the Tatlayoko project area, although it may rest stratigraphically above the thin sliver of Relay Mountain Group on the south side of the Taseko fault (Figure 4). In its type area, 50 to 90 kilometres to the southeast, the Taylor Creek Group either rests unconformably above the Bridge River Complex, or disconformably above the Relay Mountain Group (Garver, 1989; Schiarizza *et al.*, 1993a,c,d). East of Taseko Lake, it is overlain by unit uKpc2 of the Powell Creek formation across an angular unconformity that is well exposed in several places along the southern boundary of the project area, where it was described by Glover and Schiarizza (1987). West of Mount Tatlow, however, the Taylor Creek Group grades upwards into a relatively sandstone-rich interval (unit uKs), which in turn grades upward into unit uKpc1 of the Powell Creek formation (Figure 4).

UPPER CRETACEOUS ROCKS NEAR ROBERTSON CREEK (UNIT uKs)

Unit uKs consists of clastic sedimentary rocks that form a transitional interval between the Taylor Creek Group and Powell Creek formation west of Mount Tatlow (Figure 4). The unit is dominated by intercalated dark grey to purple shale and brownish weathered, grey to green lithic sandstone (Photo 7). The sandstone is fine to coarse grained, and occurs as thin to very thick beds that are locally laminated or crosslaminated; woody debris is common in some beds. The interval also includes medium beds of light grey, commonly crossbedded arkosic sandstone, and medium to thick beds of chert-rich pebble conglomerate.

The Robertson Creek unit lies above the Taylor Creek Group across a poorly defined gradational contact marked by an increase in the amount of sandstone relative to shale, and the introduction of crossbedded arkosic sandstone that

Photo 7. Sandstone and shale of unit uKs, 13 kilometres west of Mount Tatlow.

is not common in underlying rocks. This transition is shown in Figure 13 of Kleinspehn (1985), where the lower 600 metres of section are here included in the Taylor Creek Group and the upper 200 metres are assigned to unit uKs. The contact with the overlying Powell Creek formation (unit uKpc2) is also gradational, but is more sharply defined. Where observed 13 kilometres west of Mount Tatlow, this abrupt transition occurs over a 30-metre interval of green sandstone intercalated with friable dark grey silty shale. Sandstone at the base of this unit is predominantly feldspar-lithic wacke, and encloses an interval of chert pebble conglomerate 2 metres thick. Higher in the section, sandstone beds also contain conspicuous hornblende and pyroxene crystals and are intercalated with beds of pebbly sandstone and pebble conglomerate that include clasts of pyroxene-feldspar and hornblende-feldspar-phyric volcanic rocks typical of those found in the overlying volcanic breccias of the Powell Creek formation.

POWELL CREEK FORMATION (UNITS uKpc1 and uKpc2)

The Powell Creek formation (informal) is a thick succession of Upper Cretaceous nonmarine volcanic and volcaniclastic rocks. These rocks were assigned to the Kingsvale Group by Jeletzky and Tipper (1968) and Tipper (1969a, 1978). The name Powell Creek was introduced by Glover *et al.* (1988a, b) following the work of Thorkelson (1985), who suggested that the term Kingsvale Group be abandoned as it is not a valid stratigraphic entity where originally defined by Rice (1947), and has not been used consistently by subsequent workers. The Powell Creek formation is well exposed in the southern part of the Tatlayoko project area, east of Chilko Lake (Figure 4). There it rests stratigraphically above either the Taylor Creek Group or the intervening Robertson Creek unit. The formation is also exposed west of Tatlayoko Lake, where it is separated from Triassic rocks of the Niut domain by the Tchaikazan fault.

The Powell Creek formation in the Tatlayoko map area includes two mappable divisions. The lower division (unit uKpc1) only occurs in the western part of the map area, and consists of well stratified coarse volcanic breccias and conglomerates separated by thin interbeds of siltstone and sandstone. Overlying rocks, which make up most of the formation, comprise a heterogeneous succession of andesitic flow breccias, crystal and ash tuffs, laharic breccias, flows, and volcaniclastic sandstones and conglomerates. These rocks are assigned to unit uKpc2 (Figure 4).

The lower division of the Powell Creek formation crops out in a westward-thickening wedge northwest of

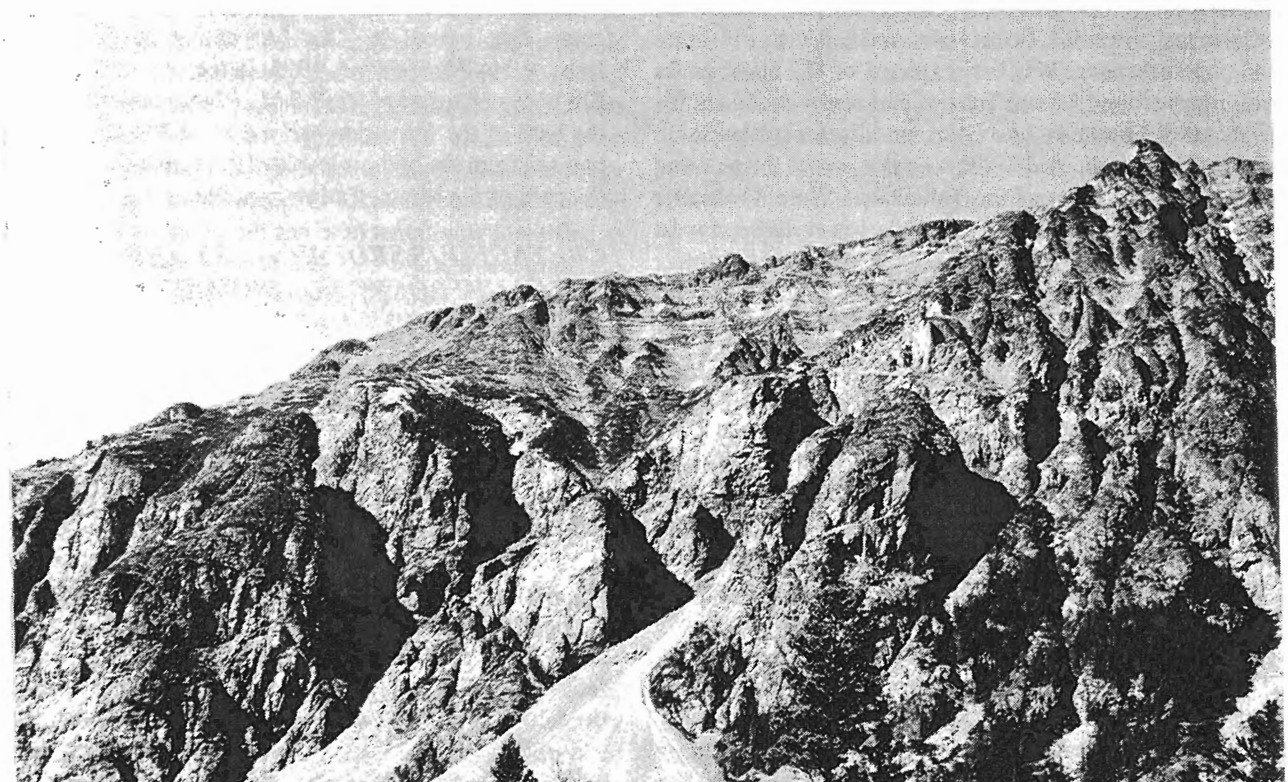

Photo 8. Massive volcanic breccia overlain by bedded crystal tuff, Powell Creek formation (unit uKpc2), west of Taseko Lake.

Mount Tatlow, and also on the northeast side of the belt that is southwest of the Tchaikazan fault. The pronounced stratification of this division readily distinguishes it from the more massive and resistant flows and flow breccias of the upper division. It consists mainly of volcanic conglomerates and breccias in beds ranging from tens of centimetres to more than 10 metres thick. Andesitic clasts are poorly sorted, angular to subrounded and generally vary in size from less than a centimetre to 30 centimetres; coarse conglomerates in the lower part of the unit, however, contain clasts more than 1 metre in size. The matrix is commonly sandy and rich in feldspar and hornblende crystals. Stratification is accented by local interlayers, from a few centimetres to more than 1 metre thick, of purplish siltstone, sandstone and pebbly sandstone. The stratigraphic base of the lower division was observed east of Chilko Lake, where it is an abrupt gradation from sandstones and shales of the underlying Robertson Creek unit, as described previously. The base of the lower division is not seen farther east, as it is bounded to the north by an east-striking fault. The east-tapering outcrop geometry of the unit in part reflects truncation along this fault, but a primary depositional pinch-out is also inferred as this unit does not occur anywhere east of Mount Tatlow, where the upper division rests directly above the Taylor Creek Group.

The upper division of the Powell Creek formation is a thick succession of andesitic flow breccias, crystal and ash tuffs, laharic breccias, flows and volcaniclastic sandstones and conglomerates. It is best exposed on the steep peaks and ridges around Mount Tatlow, and also outcrops in the hills east of Lower Taseko Lake, on ridges east and south of Anvil Mountain, and in the western part of the belt that is exposed southwest of the Tchaikazan fault. The upper division rests conformably above the lower division west of Mount Tatlow. To the east however, where the lower division is missing, it occurs directly above the Taylor Creek Group across a pronounced angular unconformity (Glover and Schiarizza, 1987; Riddell *et al.*, 1993a).

Fragmental rocks are much more abundant than flows within the upper division of the Powell Creek formation. They consist mainly of massive, unsorted breccias comprising angular to subrounded fragments within a finer matrix of lithic and crystal grains. The clasts are mainly feldspar and hornblende-feldspar-phyric andesitic volcanics in shades of purple, green and grey. They are commonly 1 to 8 centimetres across; but locally are more than half a metre in size. Most breccias have a matrix rich in plagioclase crystals; many are also rich in hornblende and some contain pyroxene.

Laharic breccias are a significant part of the upper division on the ridges south of Mount Tatlow peak. The lahars have a muddy matrix and are unsorted, with rounded cobbles and boulders of all sizes up to over a metre across. Muddy and sandy layers, centimetres to tens of metres thick, are intercalated with the coarse beds and delineate the bedding. On a gross scale, the bedded intervals are remarkably planar; individual layers can be traced without disruption for more than a kilometre. Muddy layers weather brown and maroon, and are brick-red in some sections.

Ash and crystal tuffs typically form relatively thin sections (less than 10 m) within sequences dominated by coarse breccias or lahars. An exception to this is at the Vick property on the mountain directly west of the narrows at the foot of Lower Taseko Lake. There, the top 300 or 400 metres of section on the mountaintop is dominated by crystal tuffs, with lesser intercalated flow breccia (Photo 8). The tuffs are markedly less resistant than other rock types in the Powell Creek formation and the transition to tuffs from flow breccia is marked by an abrupt break in slope. Tuff matrix is commonly calcareous and in some places the rock is friable.

Most flows within the upper division of the Powell Creek formation are andesitic, but dacites also occur, and thin bands of rhyolite are intercalated in the section at the Vick property. The andesite flows are green and feldspar-hornblende or feldspar-pyroxene phyric. In the coarsest flows crowded feldspar crystals are up to 5 millimetres across. Sills and dikes of hornblende feldspar porphyry, compositionally similar to the andesitic flows, are common in both divisions of the formation and may be comagmatic with the volcanics.

The Powell Creek formation is assigned a Late Cretaceous age, based on $^{40}Ar/^{39}Ar$ dating by J.A. Maxson (reported in Wynne *et al.*, 1995) in the Mount Tatlow area. She obtained a date of 92±1.3 Ma (Cenomanian) from near the base of the formation and a date of 79±4.1 Ma (Campanian) from the highest levels of the formation exposed in the core of the Mount Tatlow syncline.

CRETACEOUS SEDIMENTARY AND VOLCANIC ROCKS NORTHEAST OF THE YALAKOM FAULT IN THE FISH LAKE - CHAUNIGAN LAKE AREA

Pre-Miocene bedrock exposures on the northeast side of the Yalakom fault, near Fish Lake, are largely restricted to the steep slopes bordering the Taseko River, the Elkin Creek canyon, and a wooded ridge system to the northwest of Chaunigan Lake (Figure 4). The exposures in this area comprise sedimentary and volcanic rocks that were assigned to the Upper Cretaceous Kingsvale Group by Tipper (1978), which also included rocks now assigned to the Powell Creek formation on the southwest side of the fault. The sedimentary rocks in this area were remapped as the Lower Cretaceous Jackass Mountain Group by Riddell *et al.* (1993a, b) and Hickson and Higman (1993). The latter authors also assigned the volcanic rocks in the area an Early Cretaceous age, based on their lithologic similarity to 106 Ma (Albian) volcanics near Mount Alex, about 60 kilometres to the east. The geology was further revised by Schiarizza (1996), based on paleontologic reports on fossils collected during the 1992 field season, and two additional days of fieldwork in 1995. These new data suggest that, in addition to Aptian or Albian conglomerates (Vick Lake unit) that might correlate with the Jackass Mountain Group, the area also includes an older succession of Hauterivian sedimentary and volcanic rocks (Elkin Creek, Fish Creek and Chaunigan Lake units) that may correlate with Hauterivian rocks found within Niut domain.

ELKIN CREEK UNIT (lKs)

Rocks included in the Elkin Creek unit on Figure 4 consist of sandstone, siltstone, shale and local occurrences of conglomerate. These rocks are locally well exposed on the lower slopes adjacent to Elkin Creek and Elkin Lake, where they are overlain by Miocene to Pliocene plateau basalts of the Chilcotin Group. The unit is also represented by sparse exposures a short distance to the east, on the east side of Big Lake. Sandstone-dominated intervals adjacent to the Taseko River farther to the east are also tentatively included in the Elkin Creek unit, although these may actually belong to the younger Vick Lake unit.

The exposures along Elkin Creek and Big Lake are dominated by green to brownish grey, fine to coarse-grained sandstone containing feldspar, volcanic-lithic grains and quartz. The sandstones are typically massive, but locally occur in medium to very thick beds separated by interbeds of friable siltstone or shale. Granule to pebble conglomerate occurs locally and contains rounded clasts of mainly intermediate volcanic rocks, but also includes clasts of granitoid rock. Plant fragments are present in most exposures, and marine fossils occur locally. An ammonite collected from the east bank of Elkin Creek directly northeast of the Yalakom fault has been tentatively identified as *Olcostephanus* sp., which suggests a late Valanginian to early Hauterivian age (GSC Loc. C-207832; J.W. Haggart, report JWH-1992-10). A nearby fossil collection includes belemnites, oyster shell fragments, scaphopod shells and abundant shell fragments of large-valved inoceramids suggestive of the *paraketzovi* group, which also suggests a Hauterivian age (GSC Loc. C-207836; J.W. Haggart, report JWH-1992-10).

The rocks assigned to the Elkin Creek unit on either side of the Taseko River comprise green lithic-arkosic sandstones with lesser shale and conglomerate. They are lithologically similar to the Hauterivian rocks exposed near Elkin Creek and Big Lake, but have not been dated. Their inclusion in the Elkin Creek unit is tentative, however, because they also resemble sandstones intercalated with Aptian or Albian conglomerates of the Vick Lake unit, which also outcrop in this area. The relationship between the Vick Lake conglomerates and the sandstone-dominated intervals is not exposed, and it is therefore not clear if the sandstones are actually a part of the Vick Lake unit or belong to the older Elkin Creek unit.

The nearest dated Hauterivian rocks that might correlate with the Elkin Creek unit occur in the upper part of the Jura-Cretaceous Relay Mountain Group, which is exposed about 30 kilometres to the east, on the southwest side of the Yalakom fault. The Relay Mountain Group in this area occupies a stratigraphic position between the Lower to Middle Jurassic rocks of Methow Terrane and the Lower Cretaceous Jackass Mountain Group (Figures 3 and 4). Correlation with the Relay Mountain Group would therefore be consistent with the spatial association of the Elkin Creek unit with the Vick Lake unit, which may correlate with the Jackass Mountain Group. Alternatively, the Elkin Creek unit may correlate with the Hauterivian Cloud Drifter formation of Niut domain (informal; Rusmore and Woodsworth, 1993; Mustard and van der Heyden, 1994), which is a lithologically similar succession of sandstones, shales and conglomerates derived from a volcanic and plutonic source area. This correlation is consistent with the 115 kilometres of dextral offset established for the Yalakom fault (Riddell *et al.*, 1993a), as a pre-Yalakom reconstruction based on removal of this offset would place the Elkin Creek exposures opposite the north end of the Niut domain (Figure 2). It is also consistent with the presence of Hauterivian(?) volcanic rocks in the Chaunigan Lake - Fish Lake area, as the Cloud Drifter formation is stratigraphically underlain by volcanic rocks of the Hauterivian (and older?) Ottarasko formation (informal; Rusmore and Woodsworth, 1993; Mustard and van der Heyden, 1994). The relationship between the Ottarasko - Cloud Drifter succession and the Hauterivian part of the Relay Mountain Group is not well established, but the two sequences may represent, respectively, a proximal volcanic facies within a west-facing Hauterivian arc and an adjacent back-arc basinal facies (Umhoefer *et al.*, 1994).

FISH CREEK SUCCESSION (UNIT lKsv)

An assemblage of sedimentary and volcanic rocks that outcrops along the east side of the Taseko River near the mouth of the creek that drains Fish Lake has been designated the Fish Creek succession (unit lKsv) on Figure 4. These rocks may correlate with the volcanic and sedimentary package (observed only in drill core) that hosts the Fish Lake porphyry copper-gold deposit a few kilometres to the east. The Fish Creek succession includes hornblende-feldspar-phyric andesite, dacite containing quartz and feldspar phenocrysts (Photo 9), tuffaceous sandstone, well bedded flinty siltstone, dark grey shale, and pebbly sandstone and pebble conglomerate containing volcanic and granitoid clasts. The sedimentary rocks are in part lithologically similar to the those of the Elkin Creek unit, and this correlation is supported by a single fossil collection containing *Inoceramus* bivalves, tentatively identified as *I. colonicus* (Anderson) which is common in Hauterivian to lower Barremian strata of the region (GSC Loc. C-207834; J.W. Haggart, report JWH-1992-10). The associated vol-

Photo 9. Columnar jointed dacite of the Lower Cretaceous Fish Creek succession, west of Fish Lake.

canic rocks are probably the same age, and a sample of columnar jointed quartz-feldspar-phyric dacite has been submitted for U-Pb dating of zircons in an attempt to test this assertion.

CHAUNIGAN LAKE UNIT (lKv)

Volcanic rocks that are exposed on an isolated ridge system northwest of Chaunigan Lake, and on a low hill west of the Taseko River along the northern boundary of the map area, are assigned to the Chaunigan Lake unit on Figure 4. These rocks have not been dated, and their stratigraphic relationships to the Elkin Creek and Vick Lake units have not been established. They consist mainly of andesitic flows and breccias that show varying degrees of chlorite-calcite-epidote alteration. Medium green, rusty brown weathering flows contain small feldspar and mafic phenocrysts, and locally quartz amygdules, within a very fine grained groundmass. Breccias comprise angular to subrounded fragments of green, grey and purple intermediate volcanics, up to 30 centimetres across, in a matrix dominated by smaller volcanic-lithic grains and feldspar crystals. More felsic volcanic rocks occur locally, and dominate the unit at the east end of the ridge north of Chaunigan Lake. They comprise maroon to mottled green/red-weathering flows containing feldspar and quartz phenocrysts, and associated breccias that contain fragments of similar quartz feldspar porphyry and, locally, a variety of other dacitic to andesitic rock fragments.

The Chaunigan Lake unit is suspected to be of Hauterivian age, as it is compositionally similar to the volcanics of the Fish Creek succession and is also spatially associated with the Hauterivian Elkin Creek unit. As noted previously, the volcanic and sedimentary rocks of the Elkin Creek, Chaunigan Lake and Fish Creek successions may correlate with the Ottarasko and Cloud Drifter formations of the Niut belt, which are part of a volcanic-bearing facies that occurs west of coeval sedimentary rocks of the Relay Mountain Group (Umhoefer *et al.*, 1994).

VICK LAKE UNIT (lKcg)

Rocks assigned to the Vick Lake unit crop out east of the Taseko River, and comprise pebble to boulder conglomerates with only minor amounts of intercalated sandstone and shale. The conglomerates are massive to weakly stratified, with poorly sorted, rounded clasts that commonly range up to 20 centimetres across and locally are as large as 60 centimetres in diameter. The clasts consist mainly of intermediate volcanic rocks, together with a significant proportion of plutonic and mafic volcanic rock fragments; chert and foliated plutonic clasts occur locally. The interstitial sandy matrix is composed of feldspar, lithic grains and quartz. Plant fragments are generally common in the matrix and occur locally as carbonaceous remnants plastered to clast margins. Green coarse-grained sandstone and pebbly sandstone occur as relatively rare intervals up to at least several metres thick within the dominant conglomerates. The sandstones are locally crossbedded, and contain feldspar and lithic grains, in places accompanied by substantial quartz. Woody debris is common, and associated siltstones and shales locally contain moderately well preserved plant fragments. A Cretaceous, probably Aptian to Albian age, has been assigned to plant fossils, including *Pterophyllum* sp. and *Pseudocycas unjiga* (Dawson) Berry, collected from a locality 600 metres east of the mouth of Fish Creek (GSC Loc. C-207838; E.E. McIver, report EM-93-12-1).

The Vick Lake unit is lithologically very similar to parts of the Lower Cretaceous Jackass Mountain Group. In particular, it resembles conglomerates of probable Albian age that are exposed in the Noaxe Creek and Big Bar Creek map areas between 80 and 130 kilometres to the east-southeast (including the French Bar Formation of MacKenzie, 1921; unit lKJMc2 of Schiarizza *et al.*, 1993c; and the polymictic conglomerate unit of Hickson *et al.*, 1994). Correlation of the Vick Lake unit with these Jackass Mountain conglomerates is tentative, however, as no good section of the unit is exposed, and its stratigraphic context is not understood. Furthermore, associated Hauterivian rocks of the Elkin Creek, Chaunigan Lake and Fish Creek successions differ significantly from rocks which stratigraphically underlie the Jackass Mountain Group to the east, although it has not been established that these rocks are in stratigraphic contact with the Vick Lake unit, rather than being entirely in fault juxtaposition.

JURASSIC VOLCANIC ROCKS AND ASSOCIATED INTRUSIVE ROCKS NORTHEAST OF THE YALAKOM FAULT NEAR CHOELQUOIT LAKE

Bedrock exposures northeast of the Yalakom fault in the northern part of the Tatlayoko map area are assigned to unit Jv on Figure 4. They include volcanic and volcaniclastic rocks of probable Jurassic age, as well as a variety of mafic to intermediate intrusive rocks, some of which may be coeval with the volcanics and some of which are younger. The volcanic rocks include tuffs, breccias and volcanic conglomerates as well as andesitic flows. Fragmental volcanic rocks are poorly stratified and include angular green, red and purple aphyric and feldspar-phyric volcanic fragments, generally less than 5 centimetres across, in a silty to sandy matrix that commonly includes feldspar and mafic crystals as well as volcanic-lithic grains. Less common epiclastic rocks include compositionally similar volcanic conglomerates that are better stratified and include rounded clasts, as well as thin beds of feldspathic sandstone. Andesitic flow rocks are medium to dark green or mottled green and purple. They are fine to very fine grained, and locally contain small feldspar and less common mafic phenocrysts, as well as quartz-epidote amygdules.

Medium-grained, equigranular diorite and gabbro occur locally as poorly defined masses within andesitic volcanics and may be of broadly the same age. Medium-grained hornblende quartz diorite that outcrops at the southeast end of the western outcrop belt north of Choelquoit Lake is probably younger, as is a small stock of coarse feldspar porphyry exposed in the belt east of the Chilko River. Northeast and northwest-striking dikes of feldspar porphyry, hornblende feldspar porphyry and very fine grained mafic rock are common north of Choelquoit Lake, where they cut the volcanic rocks as well as a gabbroic intrusion.

The volcanic rocks of unit Jv are not dated within the Tatlayoko map area, but Tipper (1969a) reports that correlative rocks near Puntzi Lake, about 50 kilometres to the north, contain fossils of probable Bajocian age. These fossiliferous strata are part of succession of volcanic and sedimentary rocks that are widespread, but nowhere well exposed, in the Anahim Lake map area, where they were included in the Hazelton Group by Tipper (1969b). These rocks continue northward into the Nechako River map sheet, where they are assigned to the Entiako and Naglico formations (informal subdivisions of the Hazelton Group), which contain fossils of early Toarcian to early Bajocian age (Diakow and Webster, 1994; Diakow *et al.*, 1995; L.J. Diakow, personal communication, 1996).

NEOGENE PLATEAU BASALTS

Flat-lying basalt flows of the Chilcotin Group (Tipper, 1978; Bevier, 1983) are the youngest rocks exposed in the Tatlayoko project area, where they unconformably overlie all older rock units and structures, including the Yalakom fault. They are part of the southwestern margin of an extensive belt of Early Miocene to early Pleistocene plateau lavas that covers 25 000 square kilometres of the Interior Plateau of south-central British Columbia (Mathews, 1989). The most extensive exposures are in the Intermontane Belt near Fish Lake and Elkin Creek, with isolated remnants extending northwestward to the Chilko River (Figure 4). The base of the group in these areas is generally between 1300 and 1500 metres elevation. Small outliers of the Chilcotin Group also extend into the Coast Mountains, north of the Ts'yl-os ridge system and on the east side of West Nadilla Creek, where the basal contact of the group is locally as high as 2300 metres elevation.

The Chilcotin Group is dominated by dark to medium grey, orange-brown weathering basalt that locally contains olivine and plagioclase phenocrysts. Individual flows commonly range from a few metres to more than 10 metres thick. Columnar jointing at the bases of flows is common and well developed, and flow tops are normally vesicular. In almost all locations layering is near horizontal, the rocks are undeformed and the minerals are unaltered.

Spectacular debris flows are exposed beneath columnar jointed flows in the cliffs east of the Taseko River, south of Fish Creek. They are unsorted and unstratified and contain clasts up to 50 centimetres across. Clasts include Chilcotin-type rocks (amygdaloidal basalt, black glassy shards and dense black basalt with glassy rims) and foreign rocks (feldspar-porphyritic andesite, feldspathic sandstone and limestone). Unconsolidated, locally well bedded conglomerate, sedimentary breccia and sandstone, which may represent both fanglomerates and fluvial sediments, occur beneath Chilcotin basalt flows in the southwest corner of the Fish Lake deposit (Caira *et al.*, 1993).

LATE MESOZOIC AND TERTIARY INTRUSIVE ROCKS

The largest plutons in the Tatlayoko project area are terrane-specific Triassic bodies, including the Mount Skinner Igneous Complex, the Crazy Creek pluton and the Niut Mountain pluton, which have been discussed previously. Mesozoic rocks in the area are cut by an assortment of younger plutons and dikes, of mainly Late Cretaceous and Tertiary age, which are described here.

ANVIL MOUNTAIN PLUTON

Hornblende diorite, quartz diorite and hornblende feldspar porphyry occur as stocks, plugs and dikes that are common within the Taylor Creek Group east of Taseko Lake (Figure 4). The largest mappable pluton comprises diorite to quartz diorite that underlies the Anvil Mountain ridge system, northeast of Beece Creek. These bodies were assigned tentative Eocene ages by Tipper (1978), but Riddell *et al.* (1993a) suggested that at least some of the intrusive activity was mid-Cretaceous in age, because intrusive bodies of this composition were far more abundant in the Taylor Creek Group than in the overlying Powell Creek formation. Zircons extracted from a sample of quartz diorite from the Anvil Mountain pluton have subsequently yielded a U-Pb date of 93.4±0.1 Ma. This compares closely with the Ar-Ar date of 92±1.3 Ma obtained from volcanic rocks near the base of the Powell Creek by J.A. Maxson (reported in Wynne *et al.*, 1995) in the Mount Tatlow area. It suggests that the intrusive rocks cutting the Taylor Creek Group may be comagmatic with the overlying Powell Creek formation.

FISH LAKE - CONE HILL INTRUSIVE SUITE

Numerous dikes and plugs of quartz dioritic composition intrude Lower Cretaceous sedimentary and volcanic rocks of the Elkin Creek unit and Fish Creek succession on the east side of the Taseko River near Cone Hill and Fish Creek. Most are porphyries containing feldspar, hornblende and quartz phenocrysts in a light grey aphanitic groundmass. They resemble the synmineralization Fish Lake Intrusive Complex of the Fish Lake porphyry copper-gold deposit to the southeast (Riddell *et al.*, 1993a; Caira *et al.*, 1993, 1995). They are therefore assumed to be Late Cretaceous in age, as a core sample of hornblende-quartz-feldspar porphyry from the Fish Lake Intrusive Complex has yielded a U-Pb zircon date of 80 Ma (J. E. Gabites, written communication, 1993).

BEECE CREEK PLUTON

The Beece Creek pluton consists of light grey, medium-grained hornblende-biotite quartz monzonite to granodiorite of Eocene age. It intrudes the Taylor Creek Group and Powell Creek formation on the ridges east and west of Beece Creek near its headwaters, and extends south into the Warner Pass map area (Glover and Schiarizza, 1987; Schiarizza *et al.*, 1993d). Biotite from a sample collected on the west side of Beece Creek, just north of the southern boundary of the Tatlayoko project area, yielded an Ar-Ar total fusion date of 43.9±0.6 Ma (Archibald *et al.*, 1989).

TONALITE STOCKS IN METHOW DOMAIN

Two small stocks of hornblende biotite tonalite intrude the Huckleberry formation on the south limb of the Tsuniah Lake syncline, one to the south of Huckleberry Mountain and one on the ridge directly west of Mount Nemaia. These stocks must be Middle Jurassic or younger in age, but neither is dated. Similar hornblende biotite tonalite to granodiorite outcrops along the southern margin of the Mount Skinner Igneous Complex and may be the same age. Alternatively, this body may be older and related to the Middle to Late Triassic Mount Skinner Complex.

DIKES

Dikes and sills are common throughout most of the area. They have a variety of compositions, the most common being fine-grained diorite, hornblende feldspar porphyry, and light grey felsite with or without quartz and feldspar phenocrysts.. They are particularly abundant in all belts of Taylor Creek Group exposure, where they may represent, at least in part, subvolcanic intrusions related to the overlying Powell Creek formation and coeval Anvil Mountain pluton. Dikes are also abundant in the vicinity of Huckleberry Mountain and to the southwest of Tullin Mountain, between the Lingfield Creek and Cheshi Creek faults.

STRUCTURE

THE YALAKOM FAULT

Leech (1953) first used the name Yalakom fault for a system of steeply dipping faults bounding the northeast margin of the Shulaps Ultramafic Complex along the Yalakom River, 60 kilometres southeast of the Tatlayoko project area. The fault system was traced northwestward through the Taseko Lakes and Mount Waddington map areas by Tipper (1969, 1978) who postulated that it was the locus of 80 to 190 kilometres of right-lateral displacement. It was traced southeastward through the northeastern corner of Pemberton map area by Roddick and Hutchison (1973), from where it extends into the western part of the Ashcroft map area (Duffell and McTaggart, 1952; Monger and McMillan, 1989). There, it is truncated by the more northerly trending Fraser fault system, along which it is separated by about 90 kilometres from its probable offset equivalent, the Hozameen fault, to the south (Monger, 1985).

Within the Tatlayoko project area the Yalakom fault is well defined, although not well exposed, on either side of the Taseko River in the central part of the area, and near Skinner Creek to the northwest (Figure 4); elsewhere its trace is hidden beneath Miocene or Quaternary cover. Although indications of dextral movement were not observed along the fault itself, many structures within Methow domain to the southwest fit the pattern expected for subsidiary structures related to a major dextral strike-slip fault (Wilcox *et al.*, 1973). These include the east-striking Tsuniah Lake syncline, a northwest-striking synthetic dextral fault northeast of Tatlayoko Lake, and northeast-striking antithetic sinistral faults along Lingfield and(?) Cheshi creeks (Figure 4).

Near the Taseko River the Yalakom fault truncates, on its southwest side, a succession of east-striking fault panels that include, from north to south, Methow Terrane and overlying Jackass Mountain Group of the Tyaughton-Methow basin, Cadwallader Terrane, and the Bridge River Complex. Recognition of these truncated fault panels is an important result of the present study, as they correlate with an identical three-part structural succession that is truncated on the northeast side of the Yalakom fault in the Camelsfoot Range to the southeast (Schiarizza *et al.*, 1993b,c), and thus provide an estimate of 115 kilometres of dextral offset along the fault (Riddell *et al.*, 1993a; Schiarizza and Garver, 1995). This correlation refines and strengthens the argument of Kleinspehn (1985) who postulated 150±25 kilometres of displacement by matching only a part of this structural succession, the Jackass Mountain Group of the Tyaughton - Methow basin.

The Yalakom fault displaces mid-Cretaceous and older rocks, and is overlapped by Neogene plateau lavas of the Chilcotin Group (Figure 4; Schiarizza *et al.*, 1993b,c,d). Coleman and Parrish (1991) relate dextral shear within Bridge River schists and associated 46.5-48.5 Ma intrusions in the southern Shulaps Range to movement on the adjacent Yalakom fault, suggesting that at least some of the displacement was Eocene in age. Eocene movement is also indicated by relationships just to the north and northwest of the Tatlayoko Lake map area, where the Yalakom fault defines the southwestern boundary of the Tatla Lake Metamorphic Complex (Figure 2). Friedman and Armstrong (1988) document 55 to 47.5 Ma extensional shear along subhorizontal west-northwest-trending mineral lineations within the mylonite zone comprising the upper part of the complex, followed by folding and brittle faulting during the final stages of uplift. Although they implicate the Yalakom fault only in the post-ductile deformation phase of folding and brittle faulting, the earlier ductile strain is also kinematically compatible with dextral slip along the Yalakom system. The Yalakom fault has not been mapped beyond the Tatla Lake Complex but Schiarizza *et al.* (1995a) infer that it, or a kinematically linked extensional fault segment, extends north-northwestward from there, along the Dean River, to mark the western limit of a belt of metamorphic tectonites that are locally exposed beneath an extensive cover of Quaternary alluvium and Late Tertiary volcanics (Figure 2; Tipper, 1969b). The right-stepping, extensional geometry of the system is consistent with the regional pattern of Eocene dextral strike-slip and associated extension that has been documented by numerous workers in the province, including Price (1979), Ewing (1980), Price and Carmichael (1986), Coleman and Parrish (1991) and Struik (1993).

STRUCTURE OF SOUTH CHILCOTIN DOMAIN SOUTHEAST OF THE NEMAIA VALLEY

The southeastern part of the map area, east of the Taseko River and Upper Taseko Lake, is underlain mainly by the Taylor Creek Group and overlying Powell Creek formation. The contact is an angular unconformity that was observed 2 kilometres east of Taseko Lake, and is well exposed at several localities in the Warner Pass map area to the south (Glover and Schiarizza, 1987). The mid-Cretaceous deformation documented by this unconformity included southwest-vergent folding and thrusting that is well displayed in the Taseko - Bridge River area to the southeast (Schiarizza and Garver, 1995). Younger structures in this area include a series of northerly striking faults along the southern boundary of the area between Taseko Lake and Beece Creek. These faults have apparent west-side-down displacement of the Powell Creek formation, but their actual sense of movement is unknown.

Farther northwest, the structure of the East Chilcotin domain is dominated by three fault panels separated by east to east-northeast striking faults. The northernmost panel comprises Cadwallader Terrane, which is separated from Methow domain to the north by an inferred fault (the Konni Lake fault) in the Nemaia Valley. The central panel consists of a narrow fault-bounded sliver of Bridge River Complex, which is separated from Cadwallader Terrane by the Taseko fault. The southern panel includes a belt of Tyaughton basin rocks, dominated by the Taylor Creek

Group, which is in contact with the Powell Creek formation, and locally with intervening Upper Cretaceous sedimentary rocks of the Robertson Creek unit, to the south. The latter contact is at least locally faulted (Mount Tatlow fault of Riddell *et al.*, 1993a), but this is probably not a major structure as it separates units that are in stratigraphic contact at both the eastern and western ends of the belt.

The rocks of the Cadwallader Terrane, the Bridge River Complex and the Taylor Creek Group are strongly deformed by east-plunging folds that are observed on the mesoscopic scale, and indicated on a larger scale by domains of opposing facing directions. Folds with both north and south vergence were mapped, but the macroscopic geometry of the belts is not well constrained. It is suspected, but not proven, that much of the internal deformation within these belts occurred during the mid-Cretaceous contractional deformation documented beneath the sub-Powell Creek unconformity to the southeast. The Powell Creek formation directly to the south does not display this internal deformation and comprises the north limb of a major east-trending syncline, the axial trace of which occurs just to the south of the study area (Tipper, 1978; McLaren, 1990). The orientation of this structure suggests that it may be related to the Yalakom dextral strike-slip fault system. This interpretation is corroborated by paleomagnetic studies which suggest that the fold formed in latest Cretaceous time (Wynne *et al.* 1995), as the oldest dextral strike-slip faults related to the Yalakom system are also of latest Cretaceous age (*e.g.* the Castle Pass fault: Garver, 1991; Umhoefer and Schiarizza, 1993).

STRUCTURE OF METHOW DOMAIN BETWEEN THE NEMAIA VALLEY AND TATLAYOKO LAKE

The rocks of the Methow domain between Tatlayoko Lake and the Nemaia valley are separated into three structural blocks by the northeast-striking Lingfield Creek and Cheshi Creek faults. The western block encompasses the Potato Range and adjacent mountains between Tatlayoko Lake and Lingfield Creek. The structure of this area is dominated by an open syncline cored by the Relay Mountain Group. The trace of the fold's axial surface is broadly Z-shaped, as it plunges north-northwest and south-southeast at its south and north ends, respectively, but trends north-northeasterly in the central part of the range (Potato Range syncline of Figure 4). The fold is truncated by a prominent northwest-striking fault east of the north end of Tatlayoko Lake. Its probable continuation to the north is a tight syncline within the Huckleberry formation, which shows 2 to 3 kilometres of dextral offset from the southern fold segment. The Potato Range fold deforms Barremian(?) and older rocks, and is cut by a northwest-trending dextral strike-slip fault that may be related to the Yalakom fault system. It is suspected that it is mid to early Late Cretaceous in age, as this was a period of major contractional deformation within the eastern Coast Belt (McGroder, 1989; Journeay and Friedman, 1993; Rusmore and Woodsworth, 1991b). The present sigmoidal trace of the fold may reflect rotation during later dextral strike-slip faulting (Umhoefer and Kleinspehn, 1995).

The structure of the Tullin Mountain area, between the Lingfield Creek and Cheshi Creek faults, is also generally synclinal in nature, as it includes Relay Mountain Group strata which are underlain by the Huckleberry formation to both the northeast and west (Figure 4). A northerly trending syncline that is well defined by the internal stratigraphy of the Relay Mountain Group 1.5 kilometres southwest of Tullin Mountain, is apparently the dominant structure within this domain (Tullin Mountain syncline of Figure 4). A subsidiary anticline-syncline pair deforms the basal contact of the Relay Mountain Group into a Z-shape north of Tullin Mountain, and an S-shaped fold pair is outlined by the same contact to the southwest, on the opposite side of the main syncline. Just to the north of the latter area the contact is offset several hundred metres to a kilometre across a northwest-trending dextral strike-slip fault. If this fault correlates with the dextral fault north of the Potato Range, then it shows about 1.5 kilometres of apparent sinistral offset across the Lingfield Creek fault. Farther southwest, the Lingfield Creek fault apparently becomes a relatively minor northwest-side-down normal fault in the southern Potato Range, and the main displacement transfers to a south-striking splay that extends from the head of Lingfield Creek southward to the Cheshi Creek valley. This fault separates east-facing rocks of the Huckleberry formation within the Tullin Mountain block from correlative west-facing strata on the east limb of the Potato Range syncline.

The strata southeast of the Cheshi Creek fault are disposed as a large, upright, gently east-plunging, open to closed syncline (the Tsuniah Lake syncline) that is truncated by the Yalakom fault to the east. The fold is cored by the Jackass Mountain Group, which is underlain by the Huckleberry formation throughout most of the block, but by an intervening eastward-tapering sliver of Relay Mountain Group in the western part of its southern limb. West of Chilko Lake, Huckleberry strata on the southern limb of the fold are deformed by a series of south-dipping thrust faults and associated northerly overturned folds (Photo 10). The Tsuniah Lake syncline deforms the Albian Jackass Mountain Group and so is Late Cretaceous or younger in age. It is discordant to the more northerly trending folds to the west, suggesting that it may have formed in a different structural regime. The orientation of the fold is consistent with it having formed during dextral movement on the adjacent Yalakom fault (Wilcox *et al.*, 1973); this was predominantly an Eocene event, although Late Cretaceous deformation is documented on parts of the Yalakom system (Umhoefer and Schiarizza, 1993). The thrust faults and

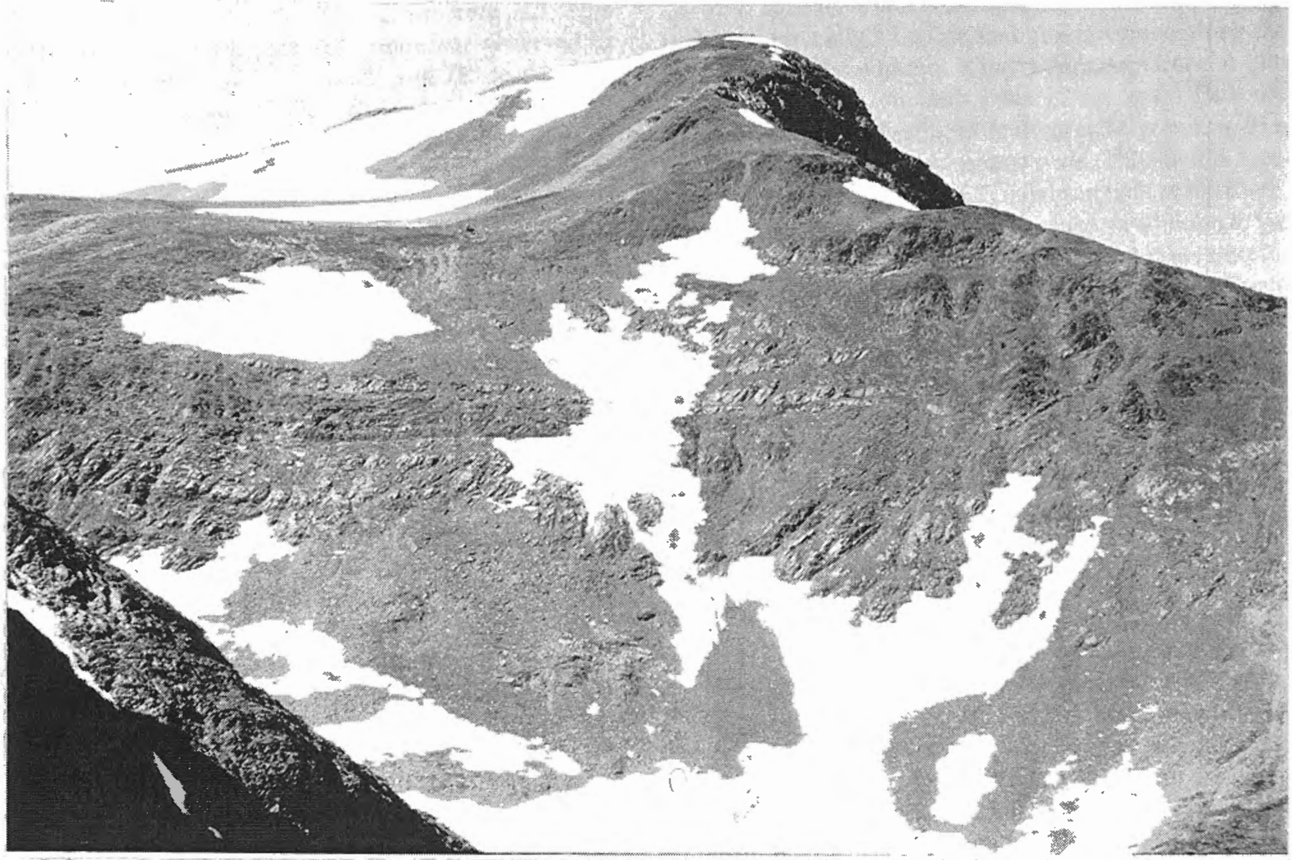

Photo 10. Looking west-southwest at an overturned antiform in the Huckleberry formation, south limb of the Tsuniah Lake syncline, west of Chilko Lake.

overturned folds on the south limb of the syncline may be older structures, but their age is not well constrained.

The southern boundary of the Tsuniah Lake block is an inferred fault which occupies the Nemaia valley and is truncated by the Yalakom fault to the east. This structure, referred to as the Konni Lake fault, separates Methow Terrane to the north from Cadwallader Terrane to the south. The reconstruction of Riddell *et al.* (1993a) suggests that it is the offset counterpart of the Camelsfoot fault, which is truncated by the Yalakom fault along the Yalakom River, 115 kilometres to the southeast (Schiarizza *et al.*, 1993b,c). The Camelsfoot fault is interpreted as a mid-Cretaceous structure with components of contractional and sinistral displacement (Schiarizza and Garver, 1995).

STRUCTURE OF THE CRAZY CREEK PLUTON AND RELAY MOUNTAIN GROUP WEST OF TATLAYOKO LAKE

Plutonic rocks of the Crazy Creek pluton appear to be bounded by faults on all sides. The eastern contact was not observed, but is suspected to be a northerly striking fault or shear zone, as easternmost exposures of plutonic rock west of the north end of Tatlayoko Lake display a steeply east dipping mylonitic foliation and an associated stretching lineation that plunges 45° to the south-southeast. This fault system is inferred to truncate the belt of Relay Mountain Group to the south and from there extend into Tatlayoko Lake (Figure 4). Its presence there is suggested by a zone of steeply east dipping brittle faults and fractures within Jurassic sedimentary rocks of the Methow Terrane along the lake shoreline. The northern boundary of the Crazy Creek pluton is a northwest-striking fault that places it against unmetamorphosed sedimentary rocks of the Jackass Mountain Group near the northern boundary of the map area. This fault has been traced from near Lingfield Creek, and is thought to be a component of the Yalakom dextral strike-slip fault system. The southwestern margin of the Crazy Creek pluton is a fault or system of faults that Tipper (1969a) called the Niut fault, and which is here referred to as the East Niut fault. This structure juxtaposes the plutonic rocks, together with a pendant of hornfelsed metasedimentary rocks, against unmetamorphosed sedimentary rocks of the Relay Mountain Group. It was observed locally, where it is vertical to steeply east or northeast dipping. Although no movement sense was established along it, a component of northeast-side-up movement is suspected.

A fault that is thought to have accommodated southwest-directed thrust or reverse movement has also been

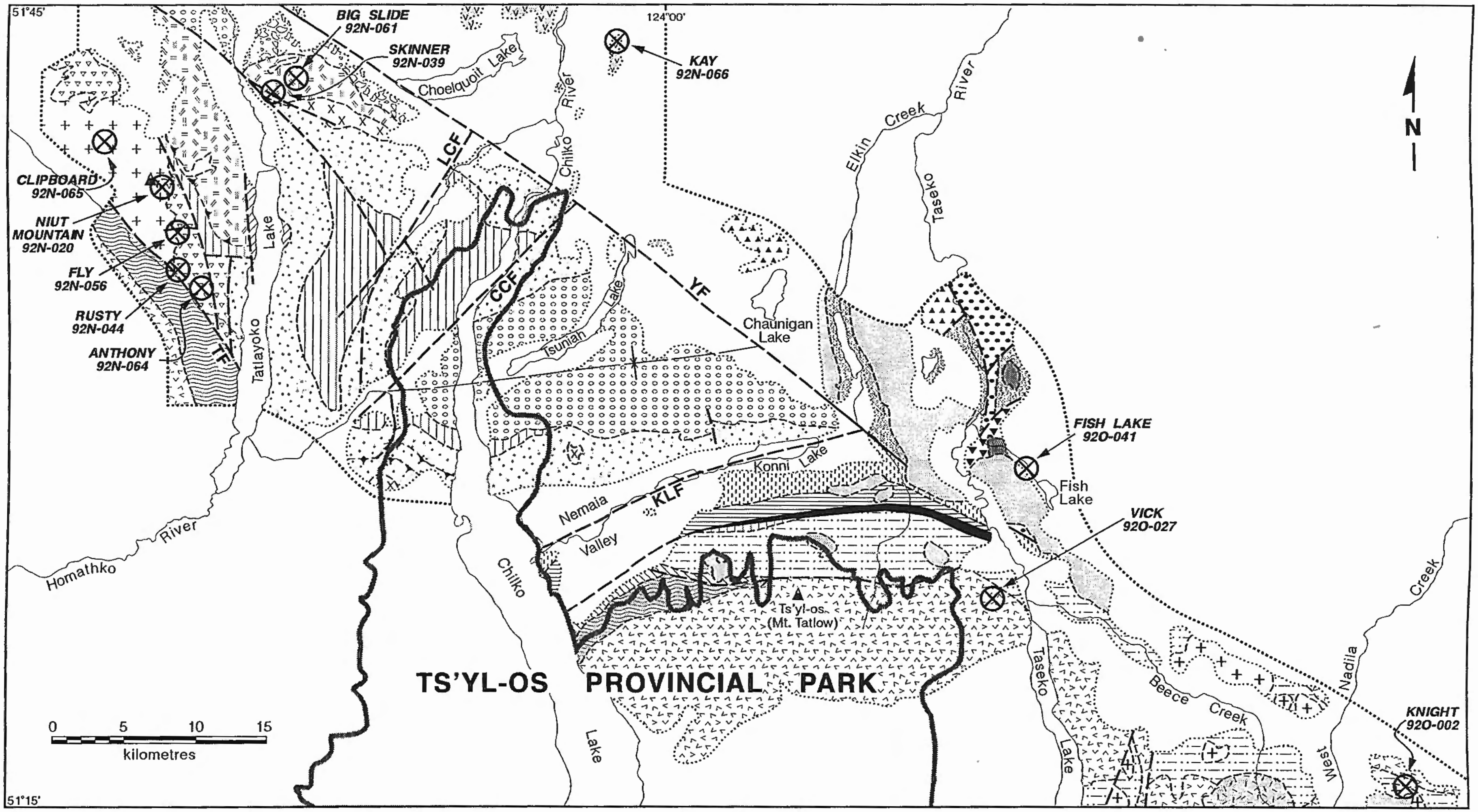

Figure 5. Main mineral occurrences in the Tatlayoko project area, identified by name and MINFILE Number. Also shown is the boundary of Ts'yl-os Provincial Park.

traced for several kilometres within the southern part of the Relay Mountain Group belt. This fault was observed in several places and dips between 35° and 75° to the east-northeast. It is generally parallel to bedding in the footwall rocks, and commonly places them against small bodies of quartz diorite in the immediate hangingwall. In one place this fault places quartz diorite that intrudes upright, northeast-dipping *Buchia*-bearing Upper Jurassic conglomerates and sandstones above shales, siltstones and sandstones that are thought to be Early Cretaceous in age. This older-over-younger relationship suggests reverse movement along the fault, as does a tight syncline within the footwall rocks directly beneath it.

STRUCTURE OF NIUT DOMAIN

Steeply dipping, east-striking faults cut volcanic and sedimentary rocks in the southeastern part of Niut domain, and two northeast-striking faults are mapped within the Niut Mountain pluton to the northwest (Schiarizza *et al.*, 1995a, b). The latter faults are marked by steeply dipping zones of fracturing and brecciation, several tens of metres wide, that are colinear with prominent topographic lineaments. The structure of the northwestern pendant is poorly understood because it contains few bedded rocks and no distinctive markers. Where observed, bedding dips at moderate angles to the north or west, and the strata are right way up, based on graded beds and pillow shapes.

The northwest-striking Tchaikazan fault bounds the Triassic rocks of Niut domain to the southwest, and separates them from Upper Cretaceous volcanic rocks of the Powell Creek formation. Tipper (1969a) interpreted the Tchaikazan fault as a right-lateral transcurrent fault based on speculative correlation of two faults that were offset by about 30 kilometres along it. More recently Mustard and van der Heyden (1994) have postulated 7 to 8 kilometres of apparent dextral displacement based on offset of a distinctive fossiliferous limestone unit within the Mount Moore formation, a short distance to the northwest of the Tatlayoko Lake map area.

The northeastern limit of plutonic, volcanic and sedimentary rocks of the Niut domain is a system of north to northwest-trending faults that separates them from Jurassic and Cretaceous sedimentary rocks to the northeast. The oldest of these faults is an unexposed north-striking structure that separates a panel of sedimentary and volcanic rocks, tentatively included within Niut domain, from rocks assigned to the Huckleberry formation a short distance west of Tatlayoko Lake (Figure 4). This fault is truncated by an east-striking fault to the north, which in turn is truncated by a northwest-striking fault to the west. The latter structure, referred to as the West Niut fault, forms the northeastern boundary of Niut domain east of Niut Mountain, and juxtaposes it against a narrow lens of Relay Mountain Group (Figure 4). Where exposed, this fault dips steeply east to east-northeast, and is commonly marked by a metre-wide zone of brittle faults and fractures; Niut domain rocks are typically silicified and quartz veined along the fault whereas the adjacent Relay Mountain Group is not. Locally, the rocks on both sides of the main fault are slivered into several parallel fault strands, resulting in a fault zone several hundred metres wide. This fault is truncated by, or merges with, the Tchaikazan fault to the south. It is a relatively young structure because, in addition to the east-striking fault on its east side, it also truncates a northeast-dipping thrust fault within the Relay Mountain Group and east-striking faults within Niut domain to the west (Schiarizza *et al.*, 1995b). It is suspected that it may be a splay from the dextral-slip Tchaikazan fault, which was probably active in Eocene time (Umhoefer and Kleinspehn, 1995). Neither the age nor the sense of movement are known for the older north-striking fault segment that locally forms the domain boundary to the east.

STRUCTURE NORTHEAST OF THE YALAKOM FAULT

The structure of the Mesozoic rocks northeast of the Yalakom fault is poorly understood because much of the area is covered by Neogene basalts and thick glacial deposits. The only structures mapped in this area are north and northeasterly trending faults that in part control the distribution of Cretaceous rocks along the Taseko River. Major structures outlined by diamond drilling at the Fish Lake deposit to the east include the Carramba fault, an east-striking subvertical fault that juxtaposes the southern part of the deposit against unmineralized clastic rocks, and a gently east-southeast-dipping fault that marks the base of the deposit (Caira *et al.*, 1993, 1995). The latter structure, referred to as the Fish Lake fault, places mineralized volcanic and intrusive rocks above unmineralized sedimentary rocks. The 10° to 25° dip of the fault suggests that it will intersect the surface 2 to 4.5 kilometres west of the deposit, and thus might constitute part of the boundary between the Fish Creek succession and adjacent sedimentary rocks of the Elkin Creek and Vick Lake units, where they outcrop near the mouth of Fish Creek (Riddell *et al.*, 1993a).

Outcrop-scale brittle faults, most dipping at moderate to steep angles to the northeast, are common within Jurassic volcanic and intrusive rocks exposed near Choelquoit Lake. Where movement sense could be determined these faults typically show components of normal and dextral displacement. They may be Eocene in age, and related to the east to northeast-dipping fault system that separates this same package of rocks from the Tatla Lake Metamorphic Complex a short distance to the northwest.

MINERAL OCCURRENCES

The known mineral occurrences within the Tatlayoko project area are shown on Figure 5. They are described by Riddell *et al.* (1993a) and Schiarizza *et al.* (1995a), and are

TABLE 1
SUMMARY OF MINFILE OCCURRENCES IN THE TATLAYOKO PROJECT AREA

MINFILE No.	NAME	COMMODITY	CAPSULE DESCRIPTION
092N-020	Niut Mountain	Cu, Au	A gossanous zone within pyritized volcanic rocks of unit muTv locally contains malachite, chalcopyrite and traces of gold.
092N-039	Skinner	Au, Cu	Northeast-striking gold-quartz veins, of Eocene age, occur within Trassic diorite and quartz diorite of the Mount Skinner Igneous Complex. A 172-tonne bulk sample extracted from the Victoria vein in 1992 and 1993 produced over 11 000 grams of gold and 8000 grams of silver.
092N-044	Rusty	Cu	Disseminated chalcopyrite occurs in faulted sedimentary rocks of unit muTv.
092N-056	Fly	Cu	Disseminated malachite, azurite, pyrite and chalcopyrite occur within quartz-epidote-carbonate veins and fracture fillings hosted in quartz diorite of unit LTqd and an associated body of hornblende feldspar porphyry.
092N-061	Big Slide	Au, Cu	Gold and copper mineralization occurs within a number of subparallel northwest-striking sheeted quartz veins hosted in Triassic quartz diorite of the Mount Skinner Igneous Complex.
092N-064	Anthony	Cu, Zn, Ag	Malachite, pyrite, chalcopyrite and sphalerite occur in quartz veins and silica-flooded andesite of unit muTv
092N-065	Clipboard	Cu	Disseminated malachite occurs in a small stock of granite porphyry that intrudes quartz diorite of unit LTqd.
092N-066	Kay	Cu	Disseminated malachite and azurite occur in calcite veinlets within a mafic porphyry of unit lmJv
092O-002	Knight	Au, Ag	Gold and silver occur within silicified and pyritized sedimentary rocks of the Taylor Creek Group which are intruded by dikes and stocks of Late Cretaceous diorite and hornblende feldspar porphyry
92O-027	Vick	Au, Cu, Ag	Pyrite, chalcopyrite, malachite, azurite and iron carbonates occur within quartz veins that follow a northeast-striking shear zone cutting volcanic rocks of the Upper Cretaceous Powell Creek formation.
92O-041	Fish Lake	Cu, Au, Ag, Mo, Zn	Porphyry Cu-Au mineralization occurs within and adjacent to a Late Cretaceous quartz diorite stock and associated quartz feldspar porphyry dikes, which intrude Lower Cretaceous(?) andesitic volcanic rocks and a pre-mineralization diorite plug. Geological reserves are 1148 million tonnes averaging 0.22 % Cu and 0.41 g/t Au.

summarized in Table 1. The present study has provided insights into the age and genesis of several of these occurrences, as described in the following sections.

FISH LAKE PORPHYRY COPPER - GOLD DEPOSIT (MINFILE 92O-041)

The Fish Lake porphyry copper-gold deposit is located in an area of virtually no bedrock exposure about 5 kilometres east of the Taseko River (Figure 5). Recent summaries of the geology of the deposit are provided by Riddell *et al.* (1993a) and Caira *et al.* (1993, 1995), who report geological reserves of 1148 million tonnes at an average grade of 0.22% Cu and 0.41 g/t Au. The Fish Lake deposit is spatially and genetically related to a steeply dipping lenticular body of porphyritic quartz diorite which is surrounded by an east-west elongate complex of steep, southerly dipping, subparallel quartz feldspar porphyry dikes. These rocks, referred to as the Fish Lake Intrusive Complex, cut volcanic and volcaniclastic rocks as well as an older intrusive body of porphyritic diorite, which may be coeval with the volcanics. Mineralization occurs within both the intrusive complex and adjacent volcanic, volcaniclastic and plutonic country rocks.

A core sample of hornblende-quartz-feldspar porphyry from the Fish Lake Intrusive Complex was collected in 1992 and submitted to the Geochronology Laboratory at the University of British Columbia for U-Pb dating of zircons. Two zircon fractions define a discordia line with a lower intercept of about 80 Ma, which is interpreted as the probable age of the syn-mineralization intrusion (J. E. Gabites, written communication, 1993). This is consistent with a previous whole-rock K-Ar date of 77.2±2.8 Ma obtained from a hornfels containing 40% secondary biotite, which was interpreted as the date of mineralization (Wolfhard, 1976). The volcanic rocks which host the Fish Lake Intrusive Complex and associated mineralization are not dated at the deposit, but are possibly Hauterivian in age, based on correlation with volcanics of the Fish Creek succession just to the west, which are also intruded by small stocks and dikes of hornblende-quartz-feldspar porphyry that may be related to the Fish Lake Intrusive Complex (Fish Lake - Cone Hill intrusive suite of Riddell *et al.*, 1993a, b). This correlation suggests that the host volcanics and syn-mineralization intrusions represent completely different magmatic episodes separated by 40 to 50 million years, in contrast to earlier suspicions that they might be related (Wolfhard, 1976).

AGE AND STRUCTURAL CONTROL OF THE SKINNER GOLD-QUARTZ VEIN SYSTEM

The Skinner gold-quartz vein system occurs within early Late Triassic quartz diorite and diorite of the Mount Skinner Igneous Complex, 5 kilometres north of the north end of Tatlayoko Lake (Figure 5). It is a system of en echelon veins within a presumably structurally controlled lineament that trends 070° (Berniolles, 1991). Work to date has been concentrated on the Victoria vein, at the southwest end of the system, which strikes between 050° and 060° and dips steeply to the northwest. A 172-tonne bulk sample extracted from the vein by Ottarasko Mines Limited in 1992 and 1993 produced over 11 000 grams of gold (average grade 65.83 g/t) and 8000 grams of silver (Meyers, 1993, 1994; Schroeter, 1994).

The Victoria vein has been traced for more than 130 metres. It pinches and swells, locally attaining a thickness of 1.4 metres. The vein walls are defined by slickensided faults, and the veins themselves are cut by parallel faults, at least some of which accommodated sinistral movement. Clay gouge commonly occurs along the vein walls, and sericite and chlorite occur locally along fault surfaces. The vein consists almost entirely of quartz, with minor amounts of pyrite, chalcopyrite, malachite and rare visible gold. Gold values are variable, and concentrations as high as 136 grams per tonne across 0.65 metre have been recorded (Berniolles, 1991). Copper shows little relationship to gold, and is locally concentrated in the wallrock adjacent to the vein.

White mica locally lines vugs and open fractures in quartz of the Victoria vein. A sample provided by Louis Berniolles in 1994 was submitted to the Geochronology Laboratory at the University of British Columbia for K-Ar dating of the mica. The mica separate has recently yielded a preliminary Early to Middle Eocene date of 50 to 54 Ma (J. Mortensen, personal communication, 1995). This provides a minimum age for the vein and most likely dates the late stages of the hydrothermal system responsible for the veining. If this interpretation is correct, then the veining was coincident with dextral movement along the Yalakom fault, which is just 5 kilometres northeast of the Skinner occurrence. This suggests that the Skinner vein system formed along an antithetic sinistral fault system related to the Yalakom fault, although its orientation is slightly more easterly than would be expected for antithetic riedel shears in an ideal simple shear model (*e.g.* Wilcox *et al.*, 1973). The Lingfield Creek and Cheshi Creek faults to the southeast may have had a similar origin, but are likewise oriented slightly more easterly than would be expected. These departures may reflect varying degrees of clockwise rotation in the structural blocks southwest of the Yalakom fault, as is suggested by the structural analysis of Umhoefer and Kleinspehn (1995), who relate this block rotation to the area's position between the Tchaikazan and Yalakom faults.

MINERAL OCCURRENCES OF NIUT DOMAIN

The rocks of the Niut domain contain a higher density of mineral occurrences than rocks elsewhere in the Tatlayoko project area (Figure 5). Most of the exploration work to date has been concentrated on the Fly occurrence (MINFILE 92N-056), about 4 kilometres southeast of Niut Mountain. Most of the mineralization occurs in the Ridge zone, which extends for more than 200 metres within quartz diorite of the Niut Mountain pluton and an adjacent body of hornblende feldspar porphyry that intrudes along the contact between the quartz diorite and altered volcanic and sedimentary rocks of unit muTv to the east. It consists of malachite and azurite, with lesser amounts of pyrite and chalcopyrite, that occur as disseminations and as a minor component of quartz-epidote-carbonate veins and fracture fillings. A pyrite halo is developed mainly within altered volcanic rocks to the east of the intrusions. The intrusive and volcanic rocks display a predominantly vein-controlled propyllitic alteration suite of epidote-chlorite-sericite±silica±carbonate.

The Triassic rocks of Niut domain host four other mineral occurrences that contain disseminated or fracture-controlled pyrite, chalcopyrite and malachite, either within the Niut Mountain pluton or in bordering volcanic and sedimentary rocks. An additional four occurrences are known in the same belt, 1 to 7 kilometres northwest of the Tatlayoko project area, and other occurrences of malachite are scattered throughout the Niut Mountain pluton and bordering volcanic rocks. These showings probably represent a series of porphyry-style mineralizing systems within and adjacent to the Niut Mountain pluton. The Mount Moore formation, which hosts the pluton and much of the mineralization, is correlated by Rusmore and Woodsworth (1991a) with the Upper Triassic Stuhini Group, which comprises part of the Stikine Terrane in northern British Columbia. This correlation is strengthened by the association of the Niut Mountain pluton with the Mount Moore formation, as plutons of similar age intrude the Stuhini Group and are locally responsible for porphyry-style mineralization. This relationship is exemplified by the Hickman batholith, which was emplaced into the Stuhini Group at about 220 Ma, and is genetically related to the Schaft Creek porphyry deposit which is hosted mainly by Stuhini volcanic rocks (Spilsbury, 1995). This correlation also sheds a favourable light on the mineral potential of the Niut domain, as Schaft Creek is one of the largest calcalkaline porphyry deposits known within the Canadian Cordillera (McMillan *et al.*, 1995).

SUMMARY OF MAIN CONCLUSIONS

The following points summarize some of the main contributions that the Tatlayoko mapping program has made toward an improved understanding of the geology and mineral occurrences of the project area.

- Rocks of the Bridge River Complex had not been recognized within the map area prior to this study. Their presence in a narrow belt bounding the Relay Mountain and Taylor Creek groups north of Mount Tatlow suggests that Bridge River Terrane underlies the main outcrop belt of the Jura-Cretaceous Tyaughton basin from Tyaughton Creek northwestward to the Nemaia valley.
- Rocks of the Upper Triassic Hurley Formation (Cadwallader Terrane) had not been recognized within the map area prior to this study. They, together with overlying Jurassic rocks of the Junction Creek unit, are now mapped in a belt that extends for 35 kilometres within and south of the Nemaia valley.
- Upper Triassic and Lower to Middle Jurassic rocks that outcrop between the Nemaia valley and Tatlayoko Lake had previously been assigned to the Cadwallader Terrane (*e.g.* Wheeler *et al.*, 1991). These rocks are here assigned to the Methow Terrane, based mainly on the lithologic characteristics of the Middle Jurassic portion of the Huckleberry formation. These strata are characterized by thick beds of volcanic-derived sandstone and granule conglomerate, as well as local occurrences of andesitic breccias, tuffs and flows, within a succession of predominantly siltstones, shales and fine-grained sandstones. They are readily correlated with the age-equivalent Dewdney Creek Formation of Methow Terrane (O'Brien, 1986, 1987; Mahoney, 1993), but are distinct from the Middle Jurassic portion of the Cadwallader Terrane, which is predominantly shale with no coarser clastics and no volcanic rocks (Umhoefer, 1990; Schiarizza *et al.*, 1993b).
- The Upper Triassic rocks of units us and ucg, which apparently underlie the Huckleberry formation, are not recognized within Methow Terrane anywhere to the southeast. These rocks do resemble, in some respects, the Upper Triassic Tyaughton Group of the Cadwallader Terrane, which includes a redbed sequence of conglomerates and sandstones containing volcanic and plutonic clasts, as well as overlying nonmarine to shallow-marine clastic rocks that include a similar *Cassianella* fauna to the one collected from unit us on the east side of Tatlayoko Lake (Tipper, 1969a). This, in combination with their mutual association with late Paleozoic ophiolitic rocks farther to the south (Ray, 1986, 1990; Schiarizza and Garver, 1995), suggests that the Cadwallader and Methow terranes may represent different parts of a single intra-oceanic arc-basin complex.
- Quartz diorite and tonalite of the Mount Skinner Igneous Complex have yielded Middle to Late Triassic U-Pb zircon dates. These plutonic rocks were previously thought to be younger, and intrusive into Triassic and Jurassic rocks now included in Methow Terrane. They are now interpreted as part of the basement on which these Late Triassic and Jurassic sedimentary sequences were deposited. Their uplift and erosion reflects an important pulse of Late Triassic tectonism within Methow Terrane.
- The Jura-Cretaceous Relay Mountain Group rests stratigraphically above Methow Terrane east of Tatlayoko Lake. In its type area, about 100 kilometres to the southeast, the Relay Mountain Group is inferred to overlie Bridge River Terrane, although locally preserved remnants may also be above Cadwallader Terrane (Schiarizza and Garver, 1995). It therefore constitutes an overlap assemblage that ties Bridge River, Cadwallader and Methow terranes together by latest Middle Jurassic time. This linkage closely follows a protracted episode of Triassic to latest Middle Jurassic accretion-subduction style deformation within the Bridge River Complex (Cordey and Schiarizza, 1993), as well as Triassic and Middle Jurassic arc-related magmatism within Cadwallader and Methow terranes (Rusmore, 1987; Umhoefer, 1990; Mahoney, 1993). Cadwallader and Methow terranes are therefore reasonably interpreted as part of an arc-basin system that formed in response to subduction of Bridge River oceanic crust. The present distribution of these three terranes suggests that the Bridge River Complex originated west of the Cadwallader and Methow terranes, and therefore accumulated above an east-dipping subduction zone.
- This study, in combination with MDA-funded research by P. van der Heyden and P.S. Mustard, directly to the northwest, has established that volcanic, sedimentary and plutonic rocks within Niut domain are Middle to Late Triassic in age, rather than Cretaceous as previously mapped. The volcanic and sedimentary rocks are assigned to the Mount Moore formation, which is correlated by Rusmore and Woodsworth (1991a) with the Upper Triassic Stuhini Group of Stikine Terrane. The recognition that the Niut Mountain pluton is Late Triassic strengthens this correlation, as plutons of similar age intrude the Stuhini Group.
- The geology on the southwest side of the Yalakom fault near the Nemaia valley, as mapped during the

present study, consists of fault-bounded panels derived from the Methow, Cadwallader and Bridge River terranes. This three-part structural succession is correlated with an identical structural succession truncated on the northeast side of the fault in the Camelsfoot Range (Schiarizza *et al.*, 1993b). This correlation provides a compelling estimate of about 115 kilometres of dextral offset along the Yalakom fault. It corroborates and improves an earlier estimate of 150±25 kilometres by Kleinspehn (1985), who matched facies within the Lower Cretaceous Jackass Mountain Group, which overlies Methow Terrane.

- Zircons from the Fish Lake Intrusive Complex have yielded an 80 Ma U-Pb age, which dates the Fish Lake porphyry copper-gold deposit. The host volcanic rocks were previously assumed to also be of Late Cretaceous age (Wolfhard, 1976; Tipper, 1978). Hauterivian fossils collected from the volcanic and sedimentary Fish Creek succession a short distance west of the deposit suggest, however, that the hostrocks are actually Lower Cretaceous. They are tentatively correlated with the Ottarasko and Cloud Drifter formations of the Niut domain. This correlation is consistent with a pre-Yalakom fault reconstruction based on removing the 115 kilometres of displacement which was established by independent evidence, as described above.

- Gold-quartz veins at the Skinner deposit are controlled by an east-northeast striking fault system that, at least locally, accommodated sinistral movement. White mica from the Victoria vein has yielded an Early to Middle Eocene K-Ar date. This suggests that the veining was coincident with dextral movement along the Yalakom fault, 5 kilometres to the northeast. The Skinner vein system is therefore interpreted to have formed within an antithetic riedel fault system related to Eocene displacement along the Yalakom dextral strike-slip fault.

- The highest density of mineral occurrences within the Tatlayoko project area is in Triassic rocks of the Niut domain, where porphyry-style mineralization occurs within the Mount Moore formation and adjacent intrusive rocks of the Niut Mountain pluton. Correlative rocks within Stikine Terrane include the Stuhini Group and Hickman batholith of northern British Columbia, which host the Schaft Creek porphyry deposit. This correlation sheds a favourable light on the mineral potential of the Niut domain, as Schaft Creek is one of the largest calcalkaline porphyry deposits known within the Canadian Cordillera.

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GEOLOGY OF TATLA LAKE (92N/15) AND THE EAST HALF OF BUSSEL CREEK (92N/14) MAP AREAS

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KEYWORDS: Tatla Lake, Bussel Creek, Tchaikazan fault, Coast Belt, Tyaughton trough, Stikine Terrane, Eastern Waddington thrust belt, Triassic stratigraphy, Cretaceous stratigraphy, geochronology.

INTRODUCTION

Geologic mapping at 1:50 000 scale of the Tatla Lake map area (NTS 92N/15), the east half of the Bussel Creek map area (92N/14), and a small part of northern Razorback map area (92N/10) was conducted in 1993, with minor additional fieldwork in 1994 (Figure 1). This paper summarizes the results of this mapping project, which redefined the structure and stratigraphy of the area; resulted in several new fossil collections (Haggart, 1995), eight new U-Pb zircon dates from plutons and volcanic rocks in the area, one set of U-Pb ages of detrital zircons obtained from the

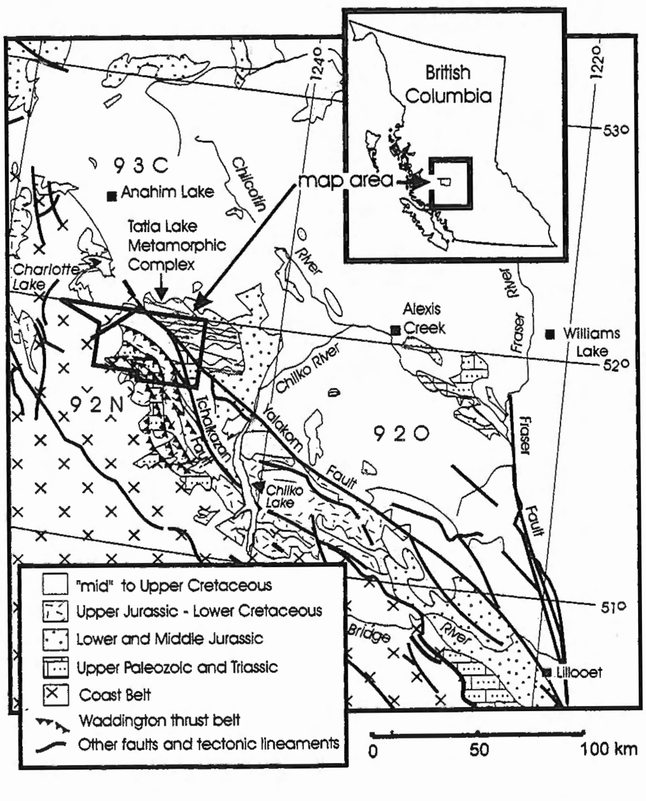

Figure 1. Regional location and geology. Geology modified and greatly simplified from Wheeler and McFeely (1991) with additions from Rusmore and Woodsworth (1993).

Late Cretaceous Silverquick formation exposed in this map area, and several $^{40}Ar/^{39}Ar$ ages from micas and hornblendes within igneous units or shear zones. The 1:50 000 scale geologic map for this area has been published (Mustard *et al.*, 1994a, b). Earlier reports on the results of this project are available in the Geological Survey of Canada current research publications (Mustard and van der Heyden, 1994, van der Heyden *et al.*, 1994).

REGIONAL GEOLOGIC SETTING

Recent mapping south of the present study area (Rusmore and Woodsworth, 1988, 1989, 1991a, 1993) defined the Late Cretaceous (*ca.* 87-84 Ma) Eastern Waddington thrust belt (Figure 2), along which the Jura-Cretaceous Coast Belt magmatic arc was thrust northeastward over Mesozoic strata of the Tyaughton trough. Both Tipper (1969) and Rusmore and Woodsworth (1993) showed the thrust system projecting into the Tatla Lake and Bussel Creek map areas, but its northerly continuation, as well as contact relations and ages of most rock units and structures in the present study area, remained enigmatic until this study.

In the Anahim Lake (93C) map area, northwest of the present study, the eastern Coast Belt consists dominantly of Jura-Cretaceous plutonic and metamorphic rocks (van der Heyden, 1990, 1991, van der Heyden *et al.*, 1994); structures are dominated by steeply dipping, northeast-trending ductile fabrics, and the area is disrupted by steeply dipping brittle shear zones. Thrust faults that might correlate with the Eastern Waddington thrust belt, and rocks correlative with Tyaughton trough strata, are not present in the Anahim Lake map area.

The study area can be subdivided into several fault-bounded, west to northwest-trending domains (Figures 2 and 3). Rocks of the Jura-Cretaceous Coast Belt magmatic arc in the southwest are thrust over a strongly imbricated zone consisting of multiple thrust slices of Upper Triassic arc rocks. The arc rocks are thrust over Lower Cretaceous marine strata of the Tyaughton trough, which, in turn, are thrust over Upper Cretaceous nonmarine strata that record the final stages in the evolution of the trough. Further northeast, between the trend of the Tchaikazan and Yalakom faults, Upper Triassic strata are intruded by two newly dated Late Triassic to earliest Jurassic plutons. The

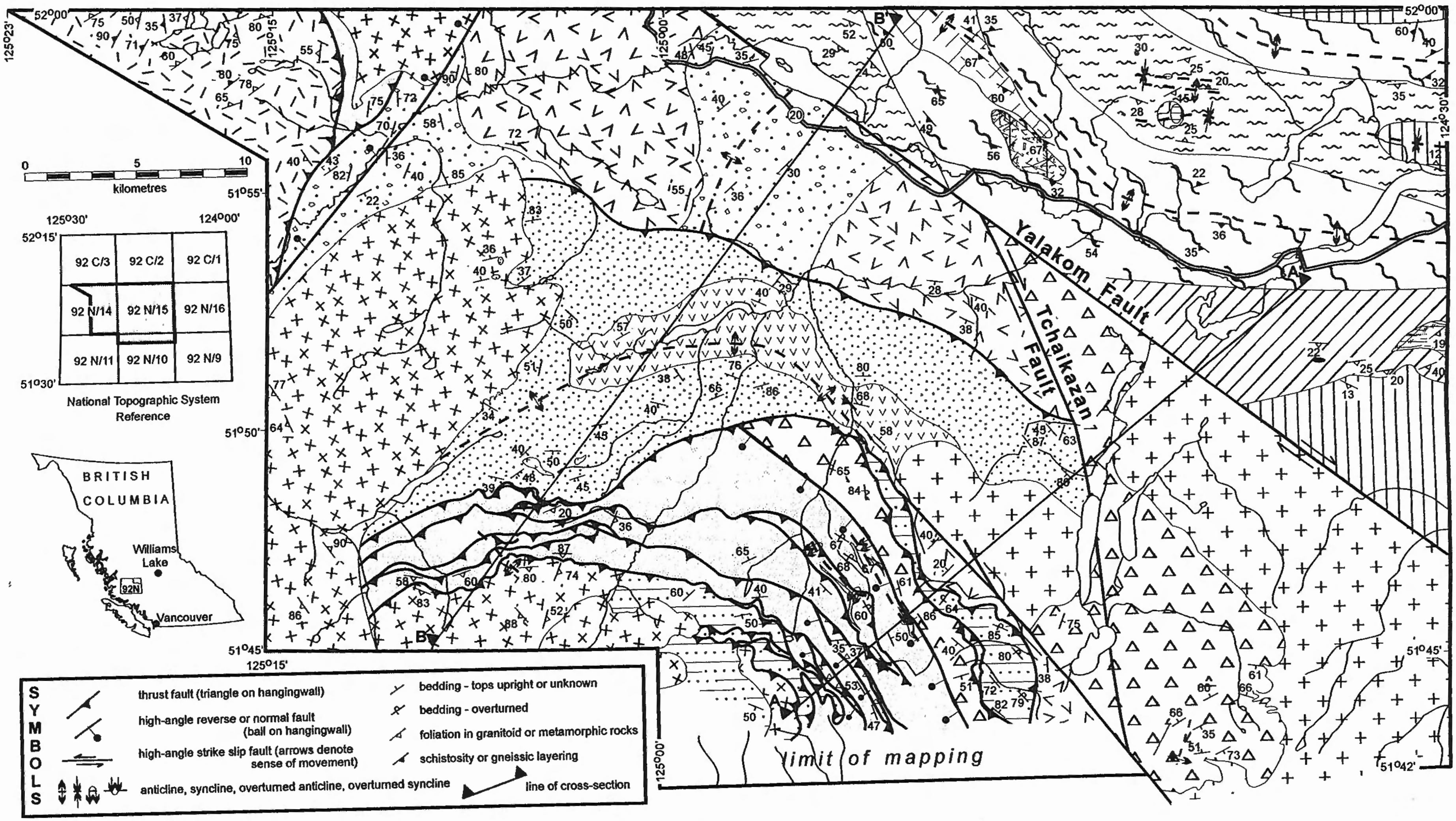

Figure 2. Simplified geology of the project area (modified from Mustard *et al.*, 1994b). Map legend is shown on facing page.

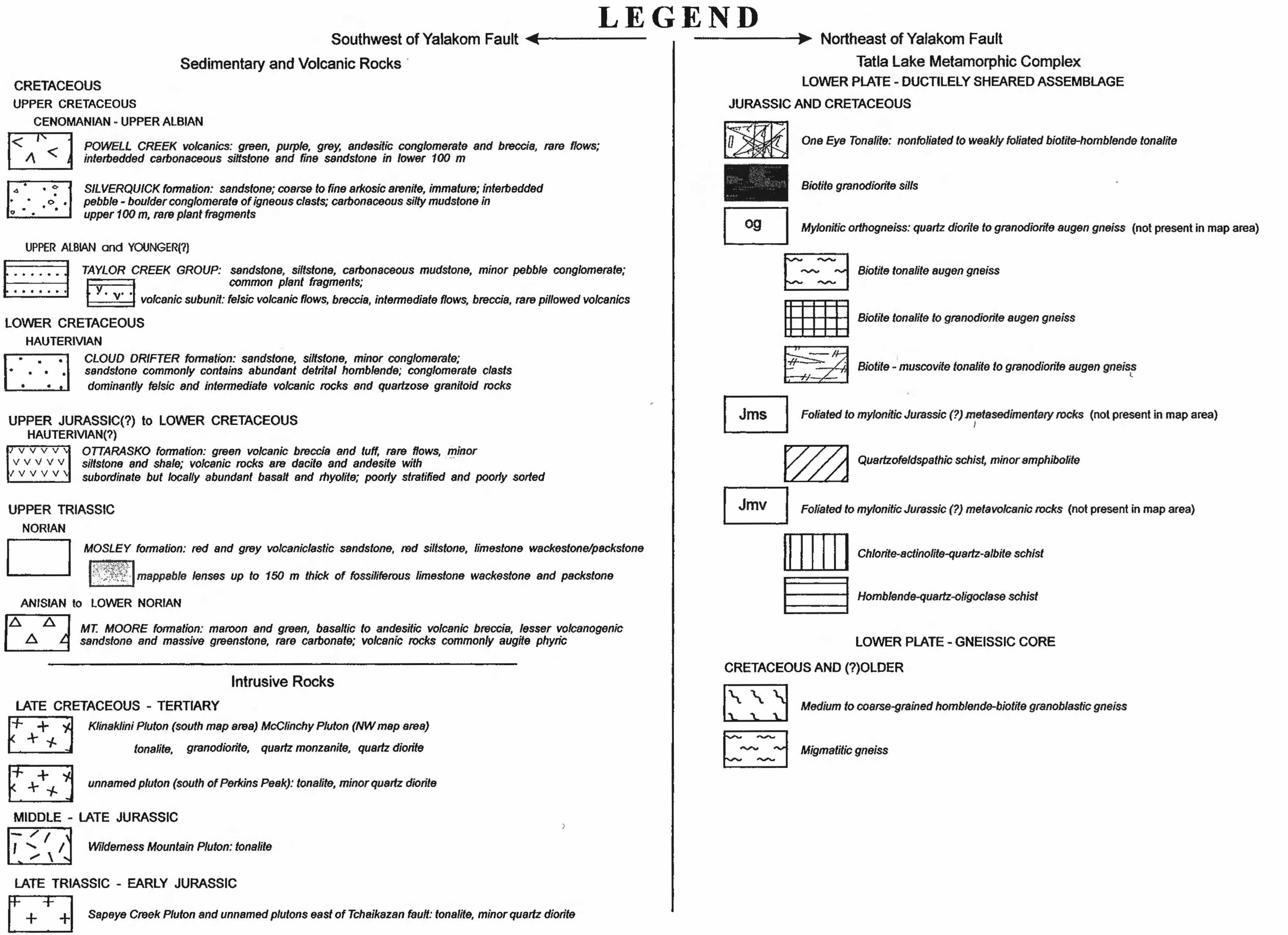

Figure 2. LEGEND

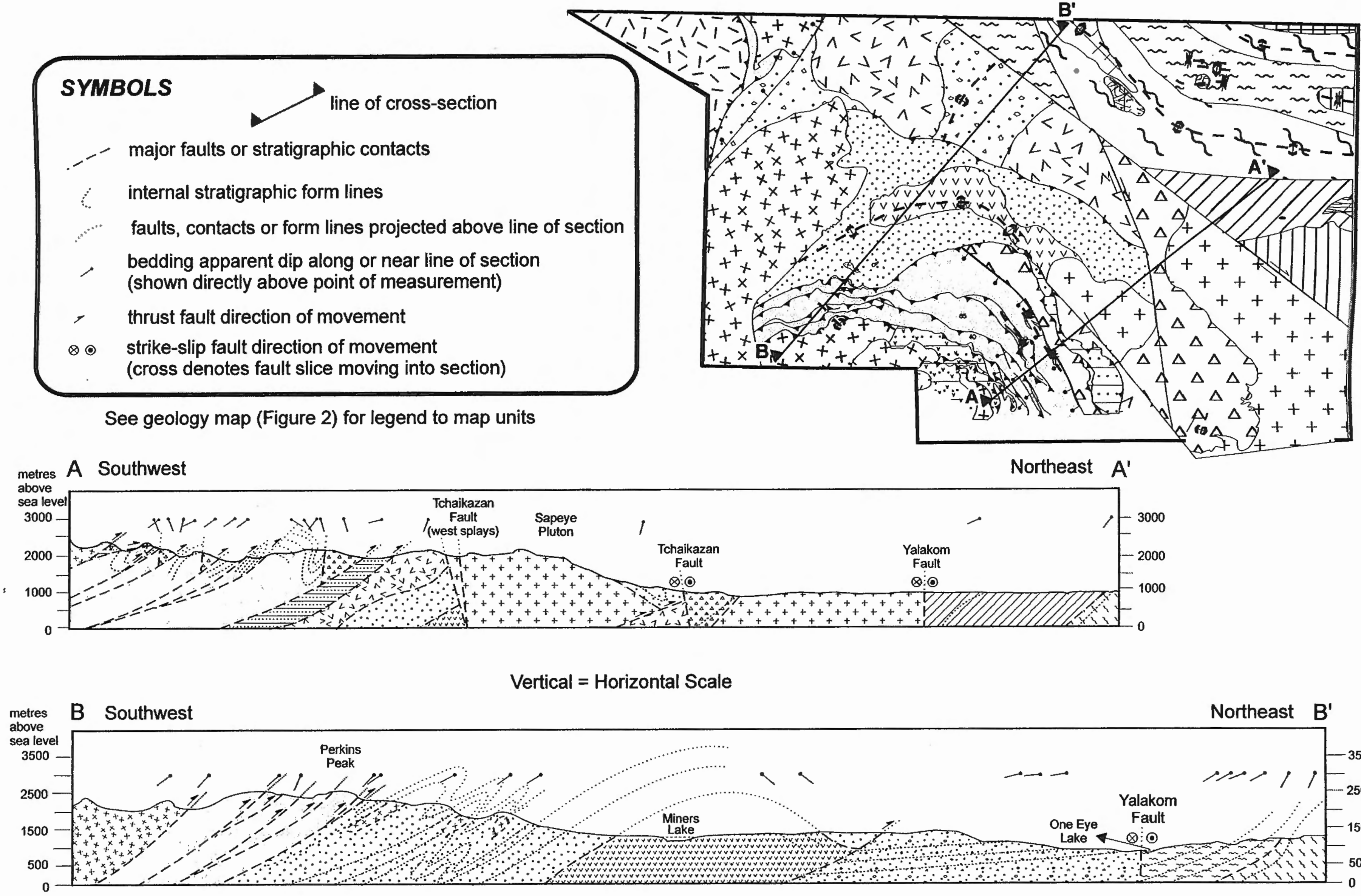

Figure 3. Simplified cross-sections through the study area (modified from Mustard *et al.* 1994b)

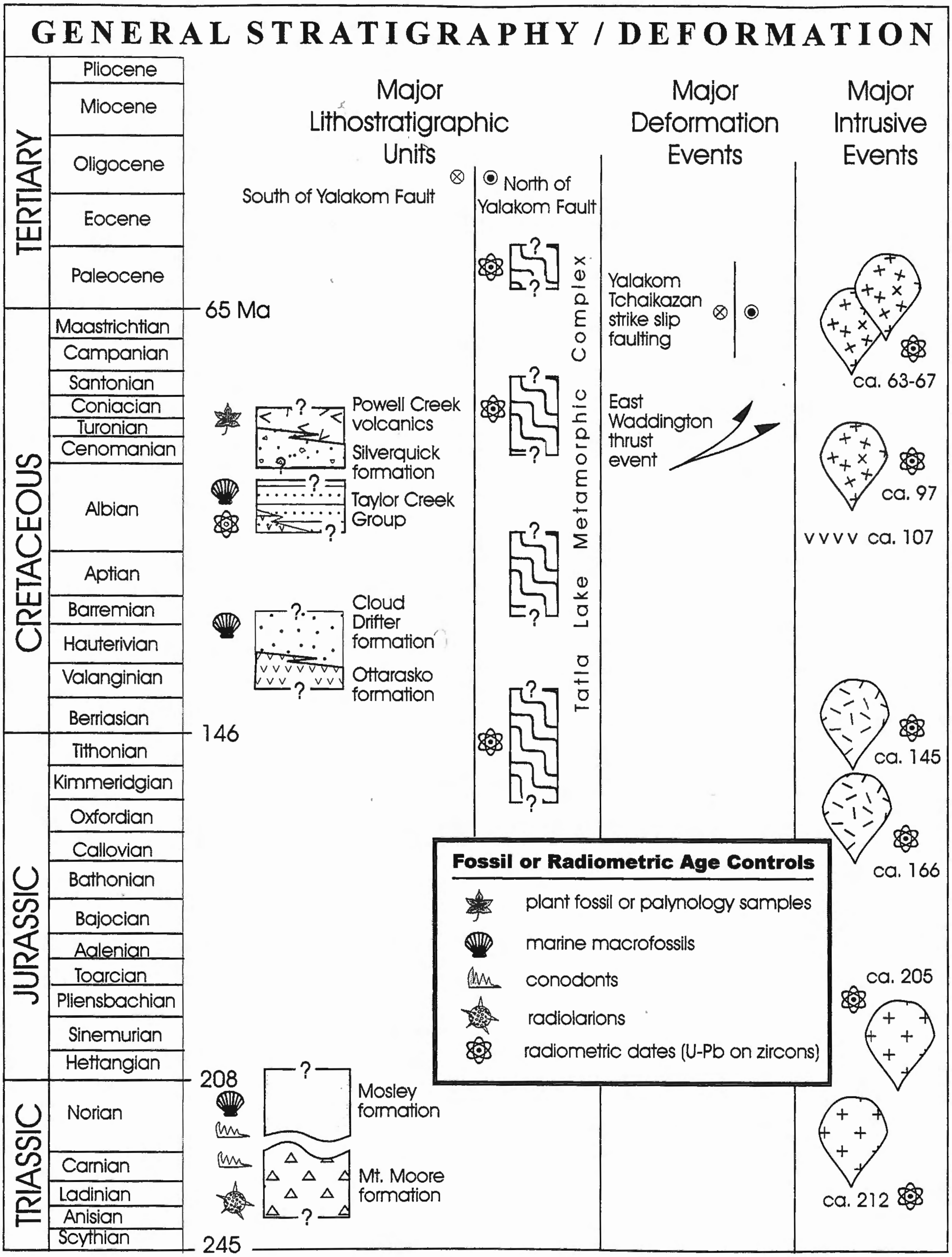

Figure 4. Schematic representation of major lithostratigraphic units, deformation, and intrusive events in the map area.

TABLE 1
SUMMARY OF FORMATIONS

PERIOD	STAGE	LITHO-STRATIGRAPHIC UNIT	MAP UNIT AND LITHOLOGY	DEPOSITIONAL ENVIRONMENT	MAXIMUM THICKNESS (METRES)
Cretaceous	Upper Albian-Cenomanian?	Powell Creek volcanics	**uKPC** green, purple, grey andesitic conglomerate and breccia, rare flows; interbedded carbonaceous siltstone and fine sandstone in lower 100 m	Subaerial to rarely subaqueous volcanic arc lahars, debris flows and reworked pyroclastic flows. Fluvial sandstone and mudstone in lower part of unit.	>500?
conformable - gradational over a few tens of metres					
Cretaceous	Upper Albian-Cenomanian?	Silverquick formation	**uKSQ** medium to light grey, coarse to fine-grained arkosic arenite, immature; interbedded pebble-boulder conglomerate of igneous clasts; carbonaceous silty mudstone in upper 100 m, rare plant fragments	Subaerial alluvial fan and lower fan to braidplain debris flow and braided fluvial deposits. First cycle, locally derived sediment from high-relief plutonic/volcanic source.	750-1000
contact not seen - probably unconformable					
Cretaceous	latest Valanginian to Albian	Taylor Creek Group	**KTC** dark to medium grey sandstone, siltstone, carbonaceous mudstone, minor pebble conglomerate; common plant fragments; **KTCv** volcanic subunit: felsic volcanic flows and breccia, intermediate flows and breccia; rare pillowed volcanics	Deep shelf to off-shelf marine turbidites. Rare chert grains in sandstone may suggest eastern provenance?	>500
contact not seen - probably unconformable					
Cretaceous	Hauterivian	Cloud Drifter formation	**lKCD** medium grey to brown-grey sandstone, siltstone, minor conglomerate; sandstone commonly contains abundant detrital hornblende; conglomerate clasts dominantly felsic and intermediate volcanic rocks and quartzose granitoid rocks	Outer shelf turbidites, sand waves and storm deposits. Immature volcanic lithic sand composition suggests first cycle derivation from volcanic arc (possibly eroded Ottarasko formation?)	>2000
conformable - gradational over about 200 metres, probably lateral intertonguing relationship					
Cretaceous (& Upper Jurassic?)	Hauterivian (or older?)	Ottarasko formation	**lKO** green-grey volcanic breccia and tuff, rare flows, minor siltstone and shale; volcanic rocks are dacite and andesite with subordinate, but locally abundant basalt and rhyolite; poorly stratified and poorly sorted.	Volcanic arc debris flows, reworked pyroclastics and locally abundant volcanic flows. Generally appears nonmarine but marine in upper part where grades into turbidites of overlying Cloud Drifter formation	>1000
contact not seen - major unconformity suspected					
Triassic (& possibly Lower Jurassic)	Norian (and younger?)	Mosley formation	**uTM** red and grey volcaniclastic sandstone, red siltstone; fossiliferous wackestone and packstone in distinctive discontinuous unit up to 150 m thick; lateral facies change to west to red and green-grey massive volcaniclastic breccia (Perkins Peak area).	pyroclastic debris in shallow marine bars, debris flows and channels. Laterally restricted but locally long lived carbonate reef and off-reef facies of bivalves and corals in shallow-marine setting. Changes laterally to west to subaerial volcanic ediface dominated by volcanic debris flows and lahars	>650
contact not seen - possibly conformable?					
Triassic	Anisian to mid-Norian?	Mt. Moore formation	**uTMM** maroon and green, basaltic to andesitic volcanic breccia; less common volcanogenic sandstone and massive volcanic flows, rare volcanic-clast pebble conglomerate, very rare fossiliferous limestone wackestone beds; volcanic rocks commonly augite phyric	Extensive volcanic arc dominated by debris flows, breccia slopes and lahars. Less common volcanic flows. Generally appears nonmarine but rare coral-bearing carbonate marine facies	>2000
base not exposed					

Eocene Tatla Lake metamorphic core complex underlies the northeastern part of the study area; it is separated from the other domains by the transcurrent Yalakom fault. All rocks east of and including the imbricate zone are here included in the Intermontane Belt.

VOLCANIC AND SEDIMENTARY LITHOSTRATIGRAPHIC UNITS

The study area contains a diverse assemblage of Upper Triassic to Upper Cretaceous volcanic and sedimentary successions. Most contacts are faults, although a few lithologic contacts between units are preserved. The main lithostratigraphic units are shown on Figure 4 and summarized in Table 1. For summary, the map area is subdivided into four fault-bounded, west to northwest-trending tectonostratigraphic domains, described below, starting in the south.

UPPER TRIASSIC

Upper Triassic sedimentary and volcanic rocks make up the bulk of complexly interleaved thrust panels in the southwest quarter of the Tatla Lake map area, continuing to the southeast into the Razorback map area and for a short distance to the west into the Bussel Creek and Siva Glacier (92N/11) map areas (Figure 2,). Mapping in the Razorback and Queen Bess map areas prompted Rusmore and Woodsworth (1991b) to recognize two informal formations; the Carnian to lower Norian volcanic-dominated Mt. Moore formation and an overlying Norian sedimentary package they termed the Mosley formation. Our detailed mapping, supplemented by two stratigraphic sections measured in well exposed areas and new fossil collections, generally supports the Rusmore and Woodsworth divisions (although the age range of the Mt. Moore formation is expanded to Anisian to lower Norian) and we retain their proposed, although informal names.

MT. MOORE FORMATION

Volcanic and rare interbedded sedimentary rocks of the Mt. Moore formation occur in two areas (Figure 2): as thrust slices within the main imbricated thrust zone in the southwest Tatla Lake and southeast Bussel Creek map areas; and in two outcrop belts offset by the Tchaikazan Fault on the west and east sides of Bluff Lake. The Mt. Moore formation is at least 2000 metres thick east of Bluff Lake, but is everywhere in fault or intrusive contact with other units and thus the true thickness and contact relationships are unknown.

The formation is dominated by mafic to intermediate volcanic breccia, conglomerate, flows and sills. The breccia and conglomerate comprise angular green to, less common, maroon-volcanic clasts in a green or maroon volcaniclastic matrix. Clasts are identical in composition to flows of this unit, with ubiquitous plagioclase and, in some places, distinctive pyroxene phenocrysts in a fine groundmass. This unit resembles the younger Ottarasko formation, but differs in the presence of pyroxene (augite?) phenocrysts up to 3 centimetres long. Rare interbeds of siliceous mudstone and thin-bedded tuffaceous sandstone occur in thrust slices west of Bluff Lake.

Age control was previously limited to late Carnian to early Norian based on conodonts recovered from an interbedded limestone lens near Mount Moore (M. J. Orchard *in* Rusmore and Woodsworth, 1991b). The intrusive relationship of the *ca.* 212 Ma Niut pluton southeast of Bluff Lake (Figures 2 and 5) also suggests an early Norian or older age for the Mt. Moore formation in this region, compatible with the age suggested from the Mt. Moore area. Rare chert in the central to lower part of the large volcanic unit east of Bluff Lake contains middle Triassic radiolarians (Cordey, 1994), which supports our correlation of this unit with the Mt. Moore formation and suggests the lower Mt. Moore formation in this area is at least as old as Anisian to Ladinian.

The Mt. Moore formation rock types and field relationships suggest an island arc setting, an interpretation also suggested by Rusmore and Woodsworth (1991b) for the formation in the map areas to the south, with additional supporting evidence from basalt and pyroxene chemistry. The presence of rare coral-bearing limestone beds suggests that at least part of the formation was deposited in a shallow marine setting. The bulk of the formation consists of volcanic breccia and massive volcanics, probably reflecting extensive flows and reworking of eroded volcanic flows as debris flows or lahars.

MOSLEY FORMATION

Most of the Triassic succession in the map area is distinctive dark red to cream-pink siliciclastic and tuffaceous sandstone. Less abundant grey limestone clastics occur as a mappable, but laterally discontinuous facies within the red unit. In the best-exposed area of the Mosley formation, a lower facies of massive to faintly laminated grey-brown limestone/mudstone to fine-grained wackestone is also present. The Mosley formation occurs in several thrust slices and no formation contacts are preserved, inhibiting formal formation definition (Figure 2). A measured stratigraphic section in one well exposed thrust slice documents a minimum thickness of 650 metres for this formation with a thickness exceeding 1 kilometre indicated by the map pattern in other places.

Previous fossil collections from the Mosley formation (Tipper, 1969; Rusmore and Woodsworth, 1991b, 1993) indicated an early to late Norian age. New collections include *Halobia* in the lower part of this unit, which suggests a Carnian to early Norian age for the lower Mosley formation. The upper age of the Mosley formation is not constrained. The late Norian bivalve *Monotis subcircularis* has been collected in several places, but these occurrences are overlain by at least several hundred metres of unfossiliferous sandstone and mudstone. Thus the upper part of the formation could be considerably younger, possibly extending into the Lower Jurassic.

Features of the noncalcareous clastics indicate deposition in a generally nonmarine setting, probably a lower alluvial fan to coarse fan delta or debris apron with a nearby volcanic source area providing the abundant volcaniclastic material. However, the fossiliferous carbonate sandstone-mudstone facies suggests lateral transition to shell banks and rare patch reefs of a marine platform.

LOWER CRETACEOUS

Lower Cretaceous strata consist of two regional units informally designated the Cloud Drifter and Ottarasko formations, respectively, by Rusmore and Woodsworth (1989, 1993) in map areas to the south, a practice we continue.

OTTARASKO FORMATION

The volcanic to volcaniclastic Ottarasko formation is preserved beneath the Cloud Drifter formation in the central map area and in one thrust-bound panel in the main imbricate thrust zone in the southwest (Figure 2). No basal formation contact is known from our map area or from areas to the south, thus the true thickness is unknown, although a thickness exceeding 500 metres is suggested by the map patterns and extent. A gradational contact over 50 metres where the Ottarasko formation changes into the overlying Cloud Drifter formation is preserved on a ridge northwest of Perkins Peak, the first documented contact of these formations.

No diagnostic fossils have been recovered from the Ottarasko formation, and no radiometric dates have been successfully measured from the volcanic flows. The age is constrained only by the gradational contact with the overlying Cloud Drifter formation, which contains abundant fossils indicating a Hauterivian age. Thus the Ottarasko formation is early Hauterivian or older, and we speculate it is not older than Early Cretaceous.

The formation generally consists of greyish yellow-green to grey-green volcanic breccia and conglomerate with less common intermediate to mafic volcanic flows (rarely pillowed). The volcanic conglomerate and breccia are matrix supported, poorly stratified to unstratified and massive, with rare pyroclastic bombs.

The volcanic nature of the formation indicates a renewed period of volcanism, probably in the Early Cretaceous. Much of the volcanic material appears to be slightly reworked pyroclastic detritus, probably redeposited as debris flows from the margins of the main volcanic centres. Primary flows and some primary pyroclastic deposits are present however, suggesting a very local volcanic source. The gradational change upward to marine sandstone and mudstone of the Cloud Drifter formation probably reflects a slow transgressive interval in the region, with late stages of Ottarasko volcanism, possibly subaerial, coinciding with early Cloud Drifter formation deposition in an adjacent marine shelf environment.

CLOUD DRIFTER FORMATION

The Cloud Drifter formation is a thick package of lower Cretaceous sandstone, siltstone, minor mudstone and conglomerate preserved in the central map area thrust sheets (Figure 2). Characterized by fine to medium-grained lithic arenite or wacke in medium to thick beds, the lower contact is gradational over a few hundred metres with the underlying Ottarasko formation. The upper contact of the formation is not preserved and thus the true thickness is unknown. A minimum thickness of about 1500 metres is suggested in parts of the map area where cross-sections can be drawn with some confidence.

Fossils collected by Tipper (1969) and new collections from this project include common inoceramid bivalves and rare ammonites and belemnites. Poorly preserved carbonaceous plant fragments also occur in some siltstone. Although the ranges of several of the identified fossils are broad, the suite of fossils together indicates a Hauterivian age for Cloud Drifter deposition (Jeletzky, 1968; Tipper, 1969; Haggart, 1994, 1995).

Deposition of the Cloud Drifter formation in this area is interpreted in terms of a sand-dominated, open clastic shelf environment. A general lack of high-energy or wave structures suggests deposition in relatively deep shelf conditions, although rare hummocky cross-stratification and *Skolithos* ichnofacies indicate at least some deposition above storm wave base. Rare conglomerate beds represent coarse-sediment gravity flow deep onto the shelf. The volcanic-rich lithic composition of the sandstone, and volcanic-clast dominated conglomerate, are compatible with derivation from Ottarasko formation or exhumed volcanic arc sources, with source areas probably to the southwest or south.

LOWER TO "MID" CRETACEOUS

TAYLOR CREEK GROUP

A thrust slice preserved a few kilometres west of Bluff Lake (Figure 2) consists of about 50 to 60% thickly bedded feldspathic to lithic arenite including sedimentary chert clasts and interbedded with dark grey siltstone and mudstone, the latter commonly slightly carbonaceous and containing plant debris. We correlate this unit with the Taylor Creek Group, in agreement with the interpretation of Tipper (1969). The slice is contained by thrust faults and moderately deformed, but appears to encompass at least 500 metres of stratigraphic thickness.

In addition, in the range east of Perkins Peak, poorly stratified, dominantly felsic volcaniclastic rocks are preserved in thrust slices. We also include this felsic volcani-

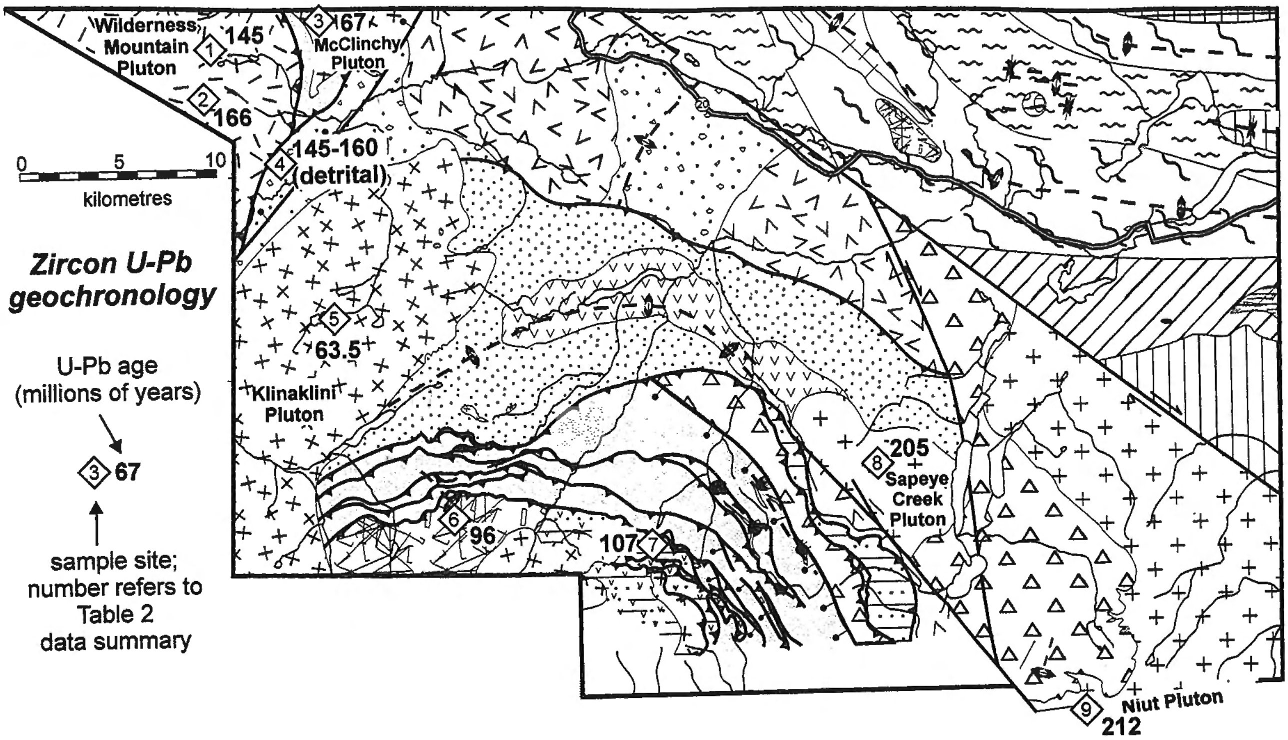

Figure 5. Location and age (rounded to nearest million years) of U-Pb on zircon analyses from plutons, volcanic and metamorphic rocks, and detrital zircons from sandstone. Numbers within location diamond are keyed to location and analysis information provided in Table 2. See legend for Figure 2 for explanation of geology map unit symbols.

TABLE 2
SUMMARY OF U-Pb ZIRCON GEOCHRONOLOGY AGES RESULTING FROM THIS STUDY

Sample Site	Map Unit	Rock Type	Interpreted U/Pb Date (Ma)	Interpreted Geological Significance
1	Wilderness Mountain Pluton	biotite-hornblende tonalite	145.4 +/- 1.0	emplacement age, part of complex composite igneous event
2	Wilderness Mountain Pluton	mylonitized tonalite	166 +7.7/-1.1	emplacement age, part of complex composite igneous event
3	McClinchey Pluton	tonalite	67.0 +/-0.5	emplacement age
4	Silverquick formation	arkosic sandstone	145-160 (8 grains)	detrital, derived from Coast Belt, immediately west
5	Klinaklini Pluton	biotite granodiorite	63.5 +/- 0.2	emplacement age
6	unnamed pluton	biotite hornblende tonalite	96.1 +/- 0.8	emplacement age
7	Taylor Creek Group	felsic volcanic	106.8 +7.0/-0.4	age of volcanic flow deposition
8	Sapeye Creek Pluton	hornblende tonalite	204.6 +10.0/0.8	emplacement age
9	Niut Pluton	quartz diorite	212 +/- 0.6	emplacement age

clastic unit within the Lower Cretaceous Taylor Creek Group, based on a U-Pb age from zircons in this unit of *circa* 107 Ma (Figure 5 and Table 2).

Several new fossil collections from the fault-bounded slice of sedimentary rock preserved west of Bluff Lake include bivalves identified as several types of pholadomyids, known from other areas to span an age range of upper Valanginian to Albian (Haggart, 1995). As discussed by Haggart, the unit is most likely post-Hauterivian age and this supports correlation of this fault slice with the Albian Taylor Creek Group.

UPPER CRETACEOUS

SILVERQUICK FORMATION

A thick unit of nonmarine, very coarse to medium-grained arkosic arenite interbedded with pebble-cobble conglomerate and rare mudstone, is preserved in the west Klinaklini River valley and well exposed on west-facing cliffs of a prominent ridge locally known as Finger Peak (Figure 3). We correlate this unit with the Silverquick formation known from areas to the southeast.

The lower contact is not exposed; the upper contact is gradational over several tens of metres into an overlying volcaniclastic and volcanic unit we correlate with the Powell Creek formation. Map relationships suggest the sedimentary unit is at least 750 metres thick and possibly more than 1000 metres thick.

Leaves in the upper part of the gradational contact strata between the top of the Silverquick formation and the base of the Powell Creek formation were tentatively identified as Cenomanian (W.A. Bell *in* Tipper, 1969, p. 95). New collections of leaves from within the gradational contact strata were identified as Albian to Cenomanian, although some types are thought by some workers to be restricted to the late Albian to Cenomanian (McIver, 1994a). Thus a broad late Albian to Cenomanian age seems most likely for Silverquick formation and the overlying Powell Creek formation.

Sandstones are immature with abundant subangular plagioclase and potassic feldspar grains and quartz making up the bulk of most, although volcanic lithic grains are more abundant in the upper part of the formation. Some sandstones have compositions of typical granitoids and appear to be slightly transported grus or other first cycle derivatives of a plutonic source.

Paleocurrents from imbricated pebbles and sandstone crossbeds define a radial pattern of transport varying from northeast to southeast. This, together with the sedimentary features described above, suggest deposition in a lower alluvial fan to braidplain environment with a western source. Uranium-lead dating of these zircons resulted in ages ranging from about 145 to 160 Ma. Zircons of these ages are known from the Wilderness Mountain Plutonic Complex, which is in fault contact with the Silverquick formation immediately to the west (Figure 5 and Table 2). It seems likely that this complex was the source for much of the Silverquick detritus. We suggest that the thrust fault which marks the contact between the Silverquick formation and the Wilderness Mountain pluton was a synsedimentary thrust, with the Silverquick formation detritus shed as a clastic wedge in front of the thrust slice carrying the complex.

POWELL CREEK VOLCANICS

A gradational change over tens of metres marks the contact between the Silverquick conglomerate and an overlying volcaniclastic and volcanic unit we correlate with the Powell Creek volcanics of areas to the southeast. This unit is best exposed in the northeast Bussel Creek and northwest Tatla Lake map area (Figure 2). The upper contact is not exposed and probably is cut off by the Yalakom fault to the northeast. A minimum thickness of several hundred metres (probably greater than 500 m) is suggested from the outcrop extent.

The unit is dominated by matrix-supported volcaniclastic breccia and conglomerate. Bedding is rarely definable, with tens to hundreds of metres of apparent thickness of massive, green-grey medium to fine-grained volcaniclastic wacke containing 5 to 30% subangular to angular volcanic pebbles to boulders randomly distributed throughout.

Age constraints for this unit come from the plant remains preserved in the basal gradational contact strata with the underlying Silverquick formation. As discussed for that formation, the age of these plants is most likely late Albian to Cenomanian. Thus the Powell Creek formation is this age and possibly slightly younger; there is no constraint on the upper age of the unit.

The depositional environment of this volcaniclastic-volcanic unit is interpreted as a nonmarine, debris flow dominated, alluvial fan system; part of an area of active volcanism. The tentative Cenomanian age supports correlation with Powell Creek volcanics described in areas to the southeast (Garver, 1989; Glover *et al.*, 1988).

PLUTONIC ROCKS

TRIASSIC - EARLY JURASSIC PLUTONIC ROCKS

Two plutons in the eastern part of the Bussel Creek map area (Sapeye Creek and Niut plutons on Figure 5) were previously undated and assumed to be Late Cretaceous or early Tertiary in previous studies (Tipper, 1969; Rusmore and Woodsworth, 1993). Both are massive, fine to medium-grained hornblende tonalites to quartz diorites. Both are cut by the Tchaikazan fault on one margin and have exposed intrusive contacts with volcanic and sedimentary rock units we correlate with the Middle to Upper Triassic

Mt. Moore formation. The Sapeye Creek pluton is bounded on its northern and west margin by Cretaceous sedimentary or volcanic rocks, however, the contacts with these units are not exposed and are interpreted as either faults or unconformities (Figure 2, and Mustard *et al.* 1994b).

Zircons from both plutons yielded U-Pb ages interpreted as the age of intrusion (R.M. Friedman, unpublished UBC geochronology report, 1994). The intrusive age for the Sapeye Creek pluton is reported as 204.6 + 0.6/-0.8 Ma, an earliest Jurassic age. The Niut pluton yielded a latest Triassic U-Pb age of 212.2±0.6 Ma. Both results support the correlation of the volcanic and sedimentary succession intruded by these plutons with the Middle to Upper Triassic Mt. Moore formation and negate earlier suggestions that these units could be Cretaceous in age (Tipper, 1969; Rusmore and Woodsworth, 1993).

COAST BELT PLUTONIC ROCKS

The eastern boundary of the Coast Belt in the study area is interpreted as a south-southwest-dipping thrust fault which marks the upper boundary of a major imbricate thrust zone (Figure 2). We correlate the imbricate zone with a similar zone at the base of the Coast Belt in the Razorback (92N/10) and Mount Queen Bess (92N/7) map areas (Rusmore and Woodsworth, 1988, 1989, 1993); as in those areas, the Coast Belt rocks in the study area occupy the highest thrust sheet in the East Waddington thrust belt. South of Perkins Peak this thrust sheet is dominated by biotite hornblende tonalite with a locally well developed, south-southwest-dipping mylonitic foliation. Zircons from an unfoliated part of the tonalite yielded a 96 +4.2/-0.8 Ma date, interpreted as the emplacement age of the pluton (Figure 5 and Table 2). Mylonites are particularly well developed adjacent to the thrust contact with underlying metavolcanic schists and phyllites at the top of the imbricate zone. Tonalite dikes in volcanic breccia near the shear zone are clearly derived from the adjacent pluton, and the shear zone is interpreted as a strongly disrupted intrusive contact. Rare southwest-dipping lineations and slickensides suggest top-to-the-northeast sense of shear.

In the range east of Perkins Peak, rocks closely resembling and here correlated with the 96 Ma tonalite are present only as small, locally sheared, but demonstrably intrusive domains within poorly stratified, dominantly felsic volcaniclastic rocks correlated with the Taylor Creek Group. The southern extent of these plutonic domains is unknown, and their connection with the 96 Ma tonalite south of Perkins Peak is obscured by a younger granodiorite intrusion. The 96 Ma tonalite and the felsic volcanic rocks which it is inferred to intrude apparently represent different parts of the same thrust sheet; they are here both included in the Coast Belt.

The northwest corner of the study area is underlain by tonalite of the Wilderness Mountain pluton, a large Middle to Late Jurassic intrusive complex (van der Heyden, 1991; van der Heyden *et al.*, 1993), which we include in the upper Coast Belt thrust sheet. It is characterized by a strongly developed, northwest-dipping mylonitic fabric. A relatively undeformed tonalite sample from the northwestern limit of the present map area has yielded a concordant 145.4±1.0 Ma zircon U-Pb age (Figure 5 and Table 2). Zircon U-Pb dating of a strongly mylonitic tonalite sample yielded a U-Pb age of 166 +7.7/-1.1 Ma, suggesting Wilderness Mountain pluton is probably a composite of several intrusions. (Figure 5 and Table 2). The contact with adjacent supracrustal rocks is not exposed, but rocks on both sides of the contact are cut by well developed, west to northwest-dipping brittle shear zones; we tentatively infer the contact to be a major thrust fault.

The upper thrust sheet, the adjacent imbricate zone, and the structurally underlying rocks of the Tyaughton trough are intruded by the Klinaklini pluton west and north of Perkins Peak, and by the McClinchy pluton north of Klinaklini River. The Klinaklini pluton is dominated by coarse-grained tonalite and lesser granodiorite with conspicuous accessory titanite. Zircons from a granodiorite sample yielded concordant 63.5±0.2 Ma U-Pb dates, interpreted as the emplacement age of the Klinaklini pluton (Figure 5 and Table 2). Granodiorite and quartz monzonite, with locally conspicuous potassium feldspar megacrysts, at the southwestern limit of the study area are probably compositionally distinct phases of the Klinaklini pluton. A satellitic granodiorite stock southeast of Perkins Peak has a strongly silicified and pyritized contact aureole; pyrite-galena-quartz boulders found in float near the contact are probably derived from veins related to this intrusion. The McClinchy pluton is dominated by medium-grained, locally porphyritic tonalite and granodiorite. Zircons from this pluton have yielded concordant U-Pb ages of 67.0± 0.5 Ma, comparable to the age of the Klinaklini pluton (Figure 5 and Table 2).

STRUCTURAL GEOLOGY SOUTHWEST OF YALAKOM FAULT

Several phases of deformation have effected the map area. Most prominent are the effects of northeasterly directed thrusting in the Late Cretaceous, which have deformed the area southwest of the Yalakom fault into a series of generally southwest to south-dipping thrust sheets, each internally deformed into folds (generally northeast vergent) and in places cut by minor high-angle faults apparently restricted to individual thrust sheets (Figures 2 and 3). The other major deformation event is a phase of latest Cretaceous to early Tertiary dextral strike-slip faulting, most evident as the Yalakom and Tchaikazan faults, two major linear dextral strike-slip fault zones which cut across older structures in the map area (Figure 2). Possibly related to the dextral strike-slip faulting is the existence of a broad, upright northeast-trending open fold which is evident in the upper central part of the map area, folding Silverquick formation and Powell Creek volcanic units (Figures 2 and 3).

More than 2000 structural measurements were taken in the course of mapping of the area. Major structural domains became evident during detailed mapping, and were defined more precisely by plotting field data onto stereonets in several different combinations of possible domains. The main data set is presented directly on the published geologic map (Mustard *et al.*, 1994b). A summary of the main features is given below.

IMBRICATE ZONE STRUCTURAL DOMAIN

The Coast Belt is separated from Cretaceous strata of Tyaughton trough by a major imbricate thrust zone, consisting of multiple thrust-bounded panels of Upper Triassic volcanic and sedimentary rocks (Figures 3 and 4). The imbricate zone is about 8 kilometres wide in the Tatla Lake map area, narrows abruptly to about 3 kilometres in the Bussel Creek area near Perkins Peak, and appears to be represented only by a single fault sliver of Upper Triassic volcanic rocks north of Klinaklini River. The imbricate zone of this study continues to the southeast into the Razorback map area (92N/10) where it was defined by Rusmore and Woodsworth (1991b, 1993, 1994) as part of a major thrust belt they termed the Eastern Waddington thrust belt. Data from the Razorback and Queen Bess map areas to the south provide indirect evidence that it was active at 84 Ma, and probably at 87 Ma (Rusmore and Woodsworth, 1994). Our data suggest it may have also been active during emplacement of the *circa* 96 Ma pluton south of Perkins Peak (van der Heyden *et al.*, 1994).

LOWER CRETACEOUS STRUCTURAL DOMAIN

Lower Cretaceous strata of the Ottarasko and Cloud Drifter formations are restricted to one thick thrust sheet which intersects the surface immediately north of the imbricate zone (Figures 2 and 3). Within it, strata are deformed in both tight, inclined folds which generally display a north or northeast sense of vergence, or in the Miners Lake area a larger, broader anticline cored by the Ottarasko formation (Figure 3, cross-section B-B').

UPPER CRETACEOUS STRUCTURAL DOMAIN

The Upper Cretaceous Silverquick formation and Powell Creek volcanics are, with one exception, confined to a region north of the thrust fault carrying the Lower Cretaceous strata discussed above. This domain is bounded on the west by the margins of the younger Klinaklini and McClinchy plutons, by a thrust contact with the older Wilderness Mountain pluton, and by an unconformity contact with a small remnant of Upper Triassic Mosley formation (Figure 2).

The Upper Cretaceous structural domain may be part of a northerly sheet of the East Waddington thrust belt, but if so, the northern thrust contact has been cut out by the younger Yalakom fault. The main influence on the structure of the Upper Cretaceous domain is a broad, open anticline which trends to the northeast and is displayed in the map pattern by a core of Silverquick formation with Powell Creek volcanics exposed on both east and west.

TCHAIKAZAN FAULT STRUCTURAL DOMAIN

A major right-lateral strike-slip fault is present in the valley containing Bluff, Horn and Sapeye lakes on the eastern side of the map area (Figure 3), and is thought to be a continuation of the Tchaikazan fault originally recognized by Tipper (1969). Tipper mapped this fault as continuing to the west of the Sapeye Creek pluton, and not in the major valley as we show it on Figure 3. Our new mapping suggests the western faults Tipper considered the main Tchaikazan fault are splays of the main fault and can only be traced to the central part of the map area. We believe the main Tchaikazan fault cuts the Mt. Moore formation east of Bluff and Sapeye lakes and appears to merge into the main Yalakom fault system about 10 to15 kilometres west of the village of Tatla Lake (Figure 3). This conclusion is strongly supported by the regional aeromagnetic data for the area, which shows a prominent linear feature continuing along the east side of Bluff and Sapeye lakes and apparently merging with the Yalakom fault (Geological Survey of Canada, 1994; Teskey *et al.*, 1997, this volume).

A unique facies, containing rare limestone beds with silicified corals, is present in the Mt. Moore formation on both sides of the main fault in the ridges near Bluff Lake, and offset of this marker unit indicates 7 to 8 kilometres of right-lateral movement on the Tchaikazan fault.

TATLA LAKE COMPLEX

The northwestern part of the Tatla Lake map area is underlain by crystalline rocks of the Tatla Lake Metamorphic Complex. It was not examined in detail during the present study, and no significant new observations were made, in deference to the detailed mapping and research reported in Friedman (1988, 1992) and Friedman and Armstrong (1988).

ECONOMIC GEOLOGY

Exploration activity in the map area has been relatively minor, and only a few gold, copper and iron prospects are known. Only the Perkins Peak gold prospect (described below) is the site of active (though minor) continuing exploration as of 1995. The following descriptions of properties in the area are summarized from the B.C. Geolocial Survey Branch MINFILE database, supplemented by new information from this study.

NEWMAC CLAIM GROUP (PORPHYRY Cu, Au)

The Newmac claims (MINFILE 92N-55) are currently owned by Canevex Resources Ltd and Noranda Exploration Company Limited. The area is underlain by thick packages of andesitic volcanic breccias and flows with lesser tuffaceous layers and felsic flows and tuffs; minor conglomerates, arkosic sandstone, and a few interbeds of coral-bearing limestone. Quartz diorite intrudes the volcanics to the north, south and east of the claims, smaller dioritic and felsic dikes and stocks intrude the volcanic rocks on the property. All rocks are cut by strongly developed northwest and northeast-trending fracture sets and some minor faults.

The property was originally staked due to the presence of minor placer gold (including one nugget) in the main drainage, copper-gold soil anomalies, high induced polarization responses, and supposed similar host (thought to be Early Cretaceous) and intrusive ages (thought to be Late Cretaceous to Tertiary) to the porphyry copper-gold deposit at Fish Lake. Nine core holes were drilled during 1988 to 1991. Elevated copper assays and, rarely, minor gold values were returned from some drill core sections. Results were not sufficiently encouraging for continued drilling after the 1991 program.

Uranium-lead dating of zircons from the Niut pluton, which intrudes the host volcanic-volcaniclastic succession at the south end of the property (and possibly is part of a continuous plutonic complex on the east and north side of the property) provide a Late Triassic age (*ca.* 212 Ma) for the pluton. A single chert sample from the property yielded radiolarians interpreted as Middle Triassic age (Cordey, 1994). Thus the volcanic-volcaniclastic unit is not Early Cretaceous and is here correlated with the Mt. Moore formation.

PERKINS PEAK (VEIN Au)

The Perkins Peak claim group (also known as Mountain Boss, Commodore, Mountain King claims; MINFILE 92N-010) are owned by Kleena Kleene Gold Mines Ltd. Gold and minor silver-bearing arsenopyrite-quartz veins and silicified argillite zones have been drilled and explored by adits and exploration trenches since the 1930s. Currently several hundred metres of tunnelling from two adits is in place and active underground drilling and minor gold recovery from the vein systems is continuing.

Quartz veins and silicified argillite occur in both Early Cretaceous sedimentary rocks of the Cloud Drifter formation and in quartz diorite stocks and dikes of probable Late Cretaceous to early Tertiary age, which cut the sedimentary package. The sedimentary succession and mineralized zones occur within a generally southwest-dipping thrust plate, part of the northeast-vergent, Late Cretaceous East Waddington thrust system. The sedimentary rocks are folded into northeast-vergent, inclined anticline-syncline pairs. Well developed fractures and minor faults occur in distinctive east, northwest, and northeast trending sets, and mineralized zones are slightly offset by some of the faults. The auriferous quartz veins may be extension fractures that formed perpendicular or obliquely at high angles to thrust faults in late stages of the thrusting event.

OTHER MINERAL PROSPECTS

South of Perkins Peak the imbricate zone is extremely gossanous and pyritic schist is common; much of the valley south of Perkins Peak is covered with strongly oxidized ferricrete breccias. The iron alteration in this area is locally associated with stratiform hematite replacement and quartz-specularite veining in the Upper Triassic volcaniclastic rocks (Briton iron prospect, MINFILE 092N-011). Sheared quartz-calcite-magnetite-malachite-azurite and chlorite-epidote-magnetite veins are locally present in thrust-related shear zones. Bornite-chalcopyrite-chalcocite-malachite float and disseminated chalcopyrite and malachite in altered Upper Triassic volcanic rocks southeast of Perkins Peak (Pin copper showing, MINFILE 92N-053), is also associated with shear zones of the imbricate zone. Several auriferous quartz veins in the study area (Orwill Au-Ag-Cu-Zn-Pb-Sb-Bi prospect, MINFILE 92N-053; Golden Rose Au-As showing, MINFILE 92N-046) also appear to be spatially associated with thrust faults of the imbricate zone.

A satellitic granodiorite stock of the 63.5 Ma Klinaklini pluton, southeast of Perkins Peak, has a strongly silicified and pyritized contact aureole; pyrite-galena-quartz boulders found in float near the contact during mapping for this study are probably derived from veins related to this intrusion.

REGIONAL SIGNIFICANCE

This study has resulted in several significant advancements in the understanding of the geology of the Coast Belt - western Intermontane Belt in west-central British Columbia. We have extended the length of the Late Cretaceous Eastern Waddington thrust belt several tens of kilometres northwest of its previous known extent. The thrust belt continues at least to the Perkins Peak area, where it is intruded by the *ca.* 63 Ma Klinaklini pluton. There are two possibilities for the continuation of the belt beyond the pluton, to the west or to the north. West of the Klinaklini pluton, Roddick and Tipper (1985) show a steeply dipping structure separating Central Gneiss Complex to the south (their unit nsc) from an Early Cretaceous pluton (their unit lKqd, correlative with the Late Jurassic Wilderness Mountain pluton of this study) to the north. However, we do not believe this contact represents a continuation of the Eastern Waddington thrust belt. In the thrust belt, rocks of the Coast complex, which locally include Late Jurassic orthogneiss (Rusmore and Woodsworth, 1993), are typically thrust over relatively unmetamorphosed supracrustal rocks. We include the locally strongly mylonitic Wilderness Mountain pluton in the Coast Belt, and suggest that the northeast-trending thrust fault which separates it from underlying supracrustal rocks north of Klinaklini River represents the northern continuation of the thrust belt (Figure 2, Mustard *et al.*, 1994b). This fault is intruded by the *circa* 67 Ma McClinchey pluton. The imbricate zone of the thrust belt is relatively wide in the south study area and in the Razorback map area to the southeast. It narrows near Perkins Peak and is largely missing north of the Klinaklini River, suggesting that the numerous thrusts of the belt merge into only one or two strands at the base of the Wilderness Mountain pluton, and that the belt dies out to the north.

Our study also extends the known Cretaceous strata of the Tyaughton trough to the northwest. Cretaceous marine strata of Tyaughton trough (Cloud Drifter formation and Taylor Creek Group) are almost absent northwest of Klinaklini River (a small isolated exception is shown on the map of Roddick, 1994, and discussed in Rusmore *et al.*, in press). Jurassic marine strata of the trough (Relay Mountain Group and Last Creek formation) are absent north of the Potato Range (*ca.* 35 km southeast of the study area). It seems likely that the Tyaughton trough may have had a northwestern margin in or near the present map area.

Our study provides the first direct evidence of a gradational contact between the Lower Cretaceous Ottarasko and overlying Cloud Drifter formations. We suggest the Ottarasko formation represents the deposits of a western volcanic arc, in turn the source of the clastic facies of the Cloud Drifter formation to the east of the arc complex. This interpretation is also suggested by Umhoeffer *et al.* (1994).

The known extent of Upper Triassic rocks in northern Mount Waddington map area has been greatly expanded due to recognition of more extensive preservation of the Mt. Moore formation than previously mapped and the dating of the Sapeye Creek and Niut plutons as earliest Jurassic and Late Triassic, respectively. Recent mapping to the east of the study area (NTS 92N/09) has identified Triassic sedimentary and volcanic successions from the northeast of Chilko Lake to the Yalakom fault which are intruded by several plutons, at least one of which is probably Late Triassic in age based on preliminary U-Pb geochronology (Schiarizza *et al.*, 1995, Schiarizza and Riddell, 1996).

Rusmore and Woodsworth (1993) and Umhoeffer *et al.* (1994) correlated Upper Triassic rocks of the northern Mount Waddington area with Stikinia. Our new information supports this correlation, most significantly in the recognition of Early Jurassic and Late Triassic plutons in this area, intrusive ages and types common and distinctive of Stikinia in northern British Columbia (Anderson and Bevier, 1992; Anderson, 1993). The presence of Upper Triassic rocks between the Yalakom and Tchaikazan faults, together with Lower Cretaceous strata of Tyaughton trough, suggests that the northern margin of the basin was underlain by Stikinia. A similar suggestion was made by Umhoeffer (1990) and more recently by Umhoeffer *et al.* (1994). Schiarizza *et al.* (1995) suggested Triassic successions in their study area, immediately east and southeast of the Bussel Creek area, are similar to Cadwallader Terrane successions to the southeast, although Late Triassic plutons have not been recognized in classical Cadwallader Terrane. A reasonable interpretation of these similarities to the Triassic successions of both Stikine and Cadwallader terranes is that they were part of the same volcanic-arc system and have been juxtaposed by later, relatively minor translation (Umhoeffer, 1990; Rusmore and Woodsworth, 1991b; Umhoeffer *et al.*, 1994; Schiarizza *et al.*, 1995)

SUMMARY

The Tatla Lake and Bussel Creek map areas southwest of the Yalakom fault contain the northern terminations of the East Waddington thrust belt and Tyaughton trough. Foliated plutons and volcanics of the Jura-Cretaceous Coast Belt arc are thrust northeast over an Upper Triassic arc succession correlated with Stikine Terrane, although with some similarities to the Cadwallader Terrane to the southeast. Triassic strata include the Anisian to lower Norian, volcanogenic Mt. Moore formation, and the Norian Mosley formation, a mixed siliciclastic-carbonate nonmarine and shallow-marine succession which changes laterally to the west to a subaerial volcaniclastic breccia complex. The Triassic arc rocks, in turn, are thrust over a central series of thrust sheets containing two Early Cretaceous units: the volcanogenic Ottarasko formation and gradationally overlying Cloud Drifter formation, a succession of shelf clastics containing Hauterivian fossils. These Early Cretaceous units are interpreted as the northwestern deposits of the Cretaceous Tyaughton trough, in part derived from a westerly, mixed volcanic-plutonic source. At the northern limit of the map area, Coast Belt plutons and Triassic rocks are thrust directly on Late Cretaceous nonmarine Silverquick formation; marine strata of Tyaughton trough are absent, and the thrust belt is intruded by the *circa* 63-67 Ma Klinaklini and McClinchy plutons. The northeasterly structural panels contain the youngest units: a single slice of Albian to Cenomanian marine turbidites correlated with the Taylor Creek Group; a nonmarine immature sandstone and conglomerate unit correlated with the Silverquick formation; and a volcanic breccia/conglomerate unit correlated with the Powell Creek volcanics, the latter two units of probable late Albian to Cenomanian age.

A much more extensive Triassic succession than previously recognized includes the newly dated *circa* 205 Ma Sapeye Creek pluton, and the *circa* 212 Ma Niut pluton exposed in the southeast part of the map area. Possibly a

southern extension of Stikine Terrane, this succession may underlie the Tyaughton trough between the Yalakom and Tchaikazan faults. The area northeast of the Yalakom fault is underlain by the Eocene Tatla Lake metamorphic core complex.

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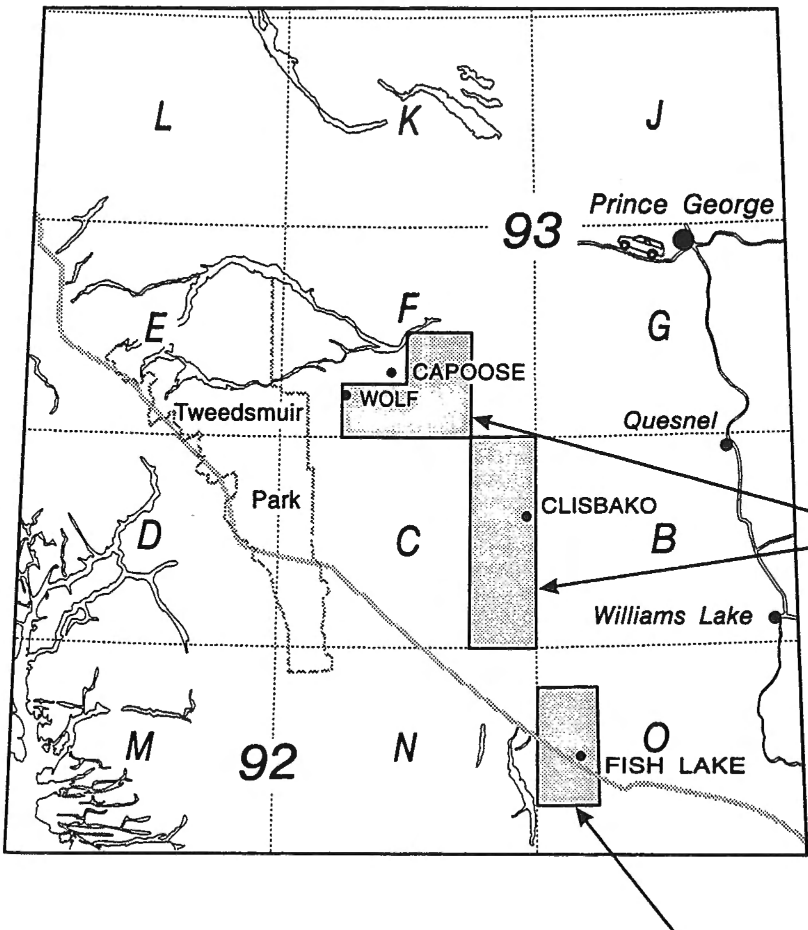
Surficial Geology and Till Geochemistry



Levson:
Nechako and Fraser plateaus

Plouffe:
Southern Fraser Plateau

QUATERNARY GEOLOGY AND TILL GEOCHEMISTRY STUDIES IN THE NECHAKO AND FRASER PLATEAUS, CENTRAL BRITISH COLUMBIA (NTS 93 C/1, 8, 9, 10; F/2, 3, 7; L/16; M/1)

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KEYWORDS: Surficial geology, Quaternary stratigraphy, drift exploration, till geochemistry, ice-flow history, glaciation, soil geochemistry

INTRODUCTION

Mineral exploration programs in the Interior Plateau physiographic region in central British Columbia have been hindered as a result of a widespread and often thick mantle of glacial drift including till, glaciofluvial sediments and glaciolacustrine sediments. In order to address this problem, 1:50 000-scale surficial geology mapping, regional till geochemical surveys (Table 1) and case study investigations were conducted in the region by the British Columbia Geological Survey as part of the Canada/British Columbia Mineral Development Agreement (1991-1995). Stratigraphic and sedimentologic studies of Quaternary deposits were also conducted in order to define the glacial history and aid in interpreting till geochemical data. The program focused on areas of perceived high mineral potential in the northern Fraser Plateau (1992/3), the southern Nechako Plateau (1993/4 and 1994/5) and the northern Nechako Plateau (1995/6) regions (Figure 1). The main objectives of the program were to:

- understand and map the distribution of Quaternary deposits;
- decipher the glacial history and ice-flow patterns;
- locate areas most suitable for conducting drift exploration programs;
- identify geochemically anomalous sites for follow-up by the mineral exploration industry;
- evaluate the effects of surficial processes on geochemical distribution patterns;
- refine models of glacial dispersal in montane and plateau areas; and
- develop methods of drift exploration applicable to the Interior Plateau.

A number of publications relating to this program have been released, including surficial geology and till geochem-

TABLE 1
REGIONAL TILL GEOCHEMISTRY SURVEYS CONDUCTED IN THE NECHAKO PLATEAU AREA: 1992-1995

Survey Date	1:50,000 Survey Area	NTS	Area (km^2)	Sites	Sampling Density (#/km^2)
1992	Chilanko Forks	93C/01	952.6	71	13.4
	Chezacut	93C/08	947.3	83	11.4
	Clusko River	93C/09	942	86	11.0
	Toil Mountain	93C/16	936.7	91	10.3
1993	Fawnie Creek	93F/03	931.3	171	5.4
1994	Tsacha Lake	93F/02	931.3	195	4.8
	Chedakuz Creek	93F/07	925.9	143	6.5
1995	Fulton Lake	93L/16	893.3	304	2.9
	Old Fort Mountain	93M/01	887.8	293	3.0
	Totals:		**8348.2**	**1437**	**5.8**

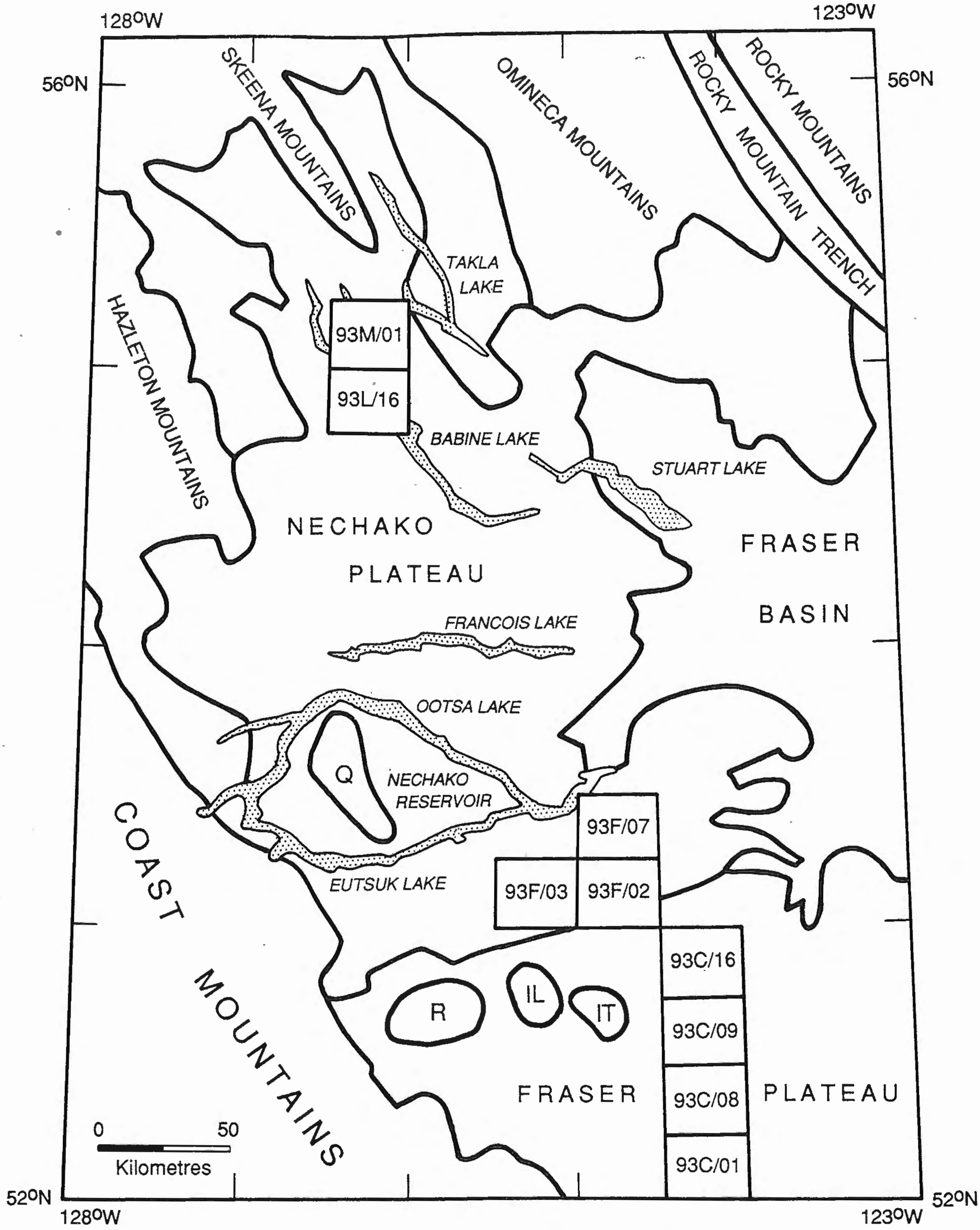


Figure 1. Physiography of the study region (after Holland, 1976); location map of areas studied in 1992 (93C/1, 8, 9, 16), 1993 (93F/3), 1994 (93F/2 and F/7) and 1995 (93L/16, M/1); R-Rainbow Range, IL-Ilgachuz Range, IT- Itcha Range, Q- Quanchus Range.

istry data for the Fawnie Creek map area (93F/3; Giles and Levson, 1994a, b; Levson and Giles, 1994; Levson *et al.*, 1994) and surficial geology data for the Chilanko Forks - Chezacut map areas (93C/1 and 8, respectively; Giles and Kerr, 1993, Kerr and Giles, 1993a, b), Clusko River - Toil Mountain map areas (93C/9 and 16, respectively; Proudfoot, 1993, Proudfoot and Allison, 1993a, b), Tsacha Lake - Chedakuz Creek map areas (93F/2 and 7, respectively; Giles and Levson, 1995, Giles *et al.*, 1995; Weary *et al.*, 1995), and Fulton Lake - Old Fort Mountain map areas (93L/16 and M/1, respectively; Huntley *et al.*, 1996). Detailed investigations around areas of known mineralization have also been conducted as part of this program (Levson and Giles, 1995; O'Brien *et al.*, 1995; Stumpf *et al.*, 1996). This paper provides an overview of these studies. This work is part of a multidisciplinary program in the Interior Plateau that includes bedrock geology mapping, lake sediment geochemical sampling and mineral deposit studies (see Diakow *et al.*, Cook, and Lane and Schroeter, respectively, 1996, this volume).

RELATED STUDIES

Reconnaissance (1:250 000-scale) mapping of Quaternary deposits in the Interior Plateau was conducted by Tipper (1971). Howes (1977) completed 1:50 000-scale terrain mapping in the southern part of the Nechako Plateau. Most recently, Plouffe (1994a, b) completed 1:100 000-scale surficial geology mapping in the central part of the Nechako Plateau. Nine regional (1:50 000 scale) surficial geology maps have been published as part of this program throughout the study area (Figure 1). An annotated bibliography of published studies dealing with glacial dispersal processes in British Columbia was provided by Kerr and Levson (1995). An overview of drift prospecting methods and research of particular relevance to the Interior Plateau region is provided by Kerr and Levson (1996). A wealth of information is also contained in unpublished assessment reports filed with the B.C. Ministry of Employment and Investment (Kerr, 1995). A review of these reports, filed for the southern Nechako Plateau area, was conducted by Levson and Giles (1995) and examples were used to illustrate current methods of exploration in the region, identify typical problems encountered and present information that can be used to develop and refine drift exploration methods. Reconnaissance till geochemical sampling programs in the Interior Plateau have been conducted in the Manson River - Fort Fraser area (93K, N; Plouffe and Ballantyne, 1993; Plouffe, 1995) and the Mount Tatlow - Elkin Creek area (93O/5, 12; Plouffe and Ballantyne, 1994). More detailed till geochemical studies have also been completed around mineral properties in the region such as the Wolf property (MINFILE 93F 045; Delaney and Fletcher, 1994; Levson and Giles, 1995), Mount Milligan (Sibbick and Kerr, 1995), Arrow Lake (Bohme, 1988; Levson and Giles, 1995) and the CH mineral claims (Edwards and Campbell, 1992; Levson and Giles, 1995; O'Brien *et al.*, 1995).

PHYSIOGRAPHY AND LANDFORMS

The study area includes parts of the Nechako Plateau and the northern Fraser Plateau, in the west-central part of the Interior Plateau (Holland, 1976). These plateaus are areas of low relief compared to the Coast and Hazelton Mountains to the west and the Skeena Mountains to the north (Figure 1). Surface elevations generally range from about 1200 to 1500 metres. Topographic relief in the southern part of the Nechako Plateau is provided mainly by the Quanchus, Fawnie and Nechako ranges (Figures 1 and 2). The highest peaks in each are Michel Peak at 2255 metres (7396 ft), Fawnie Nose at 1925 metres (6319 ft) and Kayakuz Mountain at 1780 metres (5842 ft), respectively. The boundary between the Nechako and Fraser Plateaus occurs at the Blackwater (or West Road) River. The dominant physiographic features in the northern Fraser plateau are a series of Tertiary volcanic centres forming, from oldest to youngest, the Rainbow, Ilgachuz and Itcha ranges (Figure 1).

Flat lying or gently dipping Tertiary lava flows, locally forming steep escarpments, cover older rocks throughout much of the Nechako and, especially, the Fraser plateaus. Glacial drift is extensive and often as little as 5 or 10% of the bedrock is exposed. During Late Wisconsinan glaciation, ice moved into the Nechako and Fraser plateaus from the Coast Mountains to the west and southwest and from the Skeena Mountains to the northwest, before flowing easterly and northeasterly towards the Rocky Mountains (Tipper, 1963, 1971). Well developed flutings and drumlinoid ridges, oriented parallel to the regional ice-flow direction, are dominant features on the plateaus. During deglaciation, stagnant ice topography, large esker complexes, glaciofluvial deposits and meltwater channels, developed in many areas. Much of the variation in topography and surficial geology in the plateau areas is due to these features. In low-lying regions, such as the valleys now occupied by Nechako River, Babine Lake, Nechako Reservoir and Fraser River, large glacial lakes formed and deposited extensive belts of glaciolacustrine sediments, generally below 950 metres elevation. Topography in these areas is subdued and older glacial landforms are often difficult to recognize.

PROCEDURES

The following field and laboratory procedures have been developed and refined over the course of this four-year study. The methods outlined below are those used during the more recent regional surficial geology mapping and till geochemical sampling programs in the Interior Plateau.

FIELD METHODS

Surficial geology mapping was completed by compilation of existing terrain-mapping data, interpretation of air photographs, field checking and stratigraphic and sedimentologic investigations of Quaternary exposures in the study areas. Ice-flow history was largely deciphered from the measurement of the orientation of crag-and-tail features, flutings, drumlins and striae.

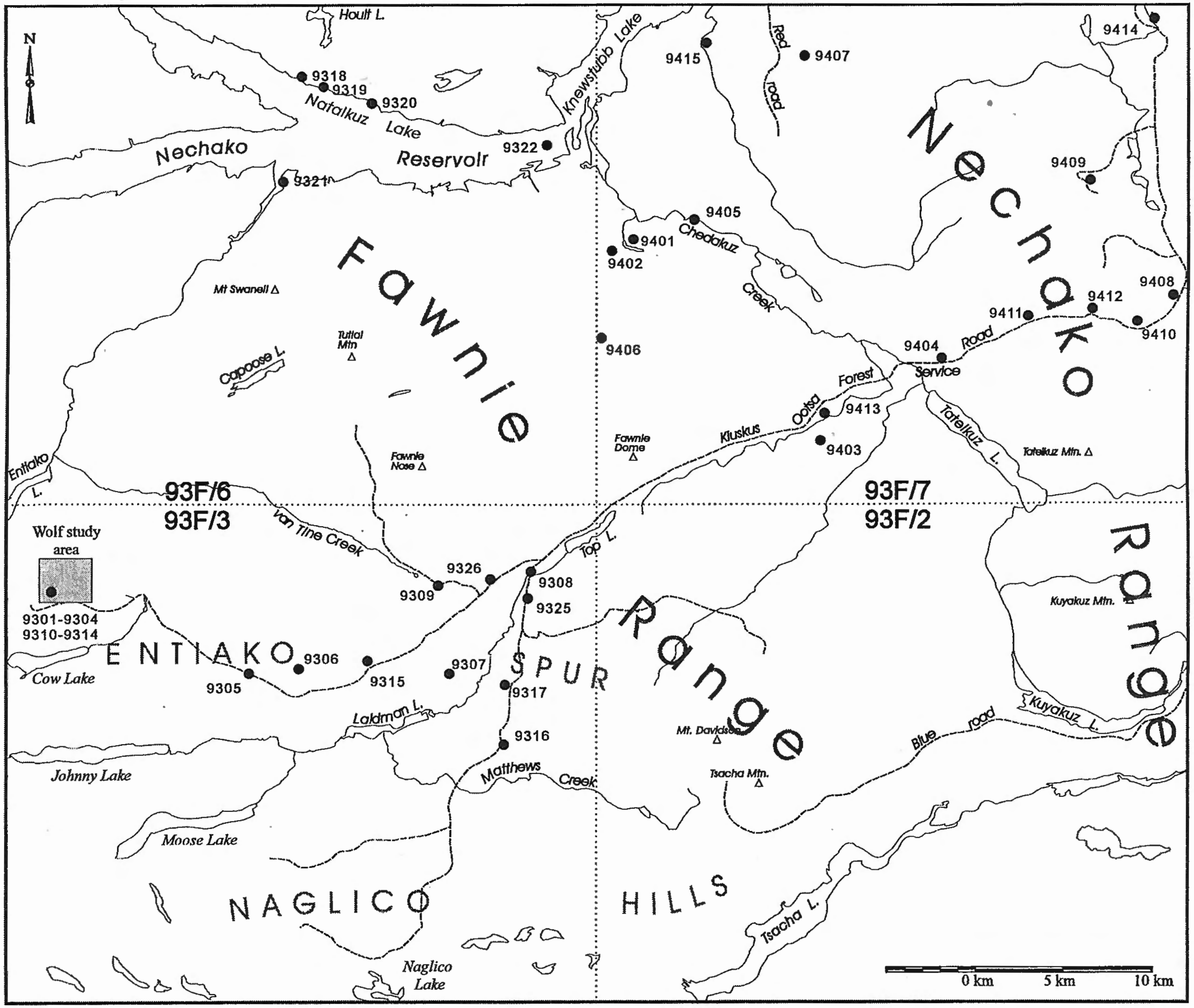


Figure 2. Location map of Quaternary stratigraphic sections described in the southern Nechako Plateau area. Shaded area is the Wolf prospect study area shown in Figure 4.

In the regional till geochemistry program, basal till samples (each 3 to 5 kg in weight) were collected for geochemical analysis in order to locate glacially dispersed metallic minerals in the region. Sample sites were selected to provide complete coverage of the map areas, 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, wide spaced 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 depths averaged about 1 metre but varied from about one-half to several metres. Locations were plotted on a 1:50 000 topographic base maps. Sampling was conducted mainly in truck accessible areas near logging roads and forest clear-cuts. Trail bikes, boats and helicopters were also used where feasible. Foot traverses were completed in otherwise inaccessible regions.

Detailed till and soil geochemical sampling were also conducted at several mineral prospects: Wolf (MINFILE 93F 045), Malaput (MINFILE 93F 056), Buck (MINFILE 93F 050), CH (MINFILE 93F 04), Uduk Lake (MINFILE 93F 057), Pem (Blackwater-Davidson, MINFILE 93F 037), Yellow Moose (MINFILE 93F 058) and Stubb (MINFILE 93F 066) properties, in the southern Nechako Plateau, and the Bell mine (MINFILE 93M 001), Babs (MINFILE 93L 325), Lennac (MINFILE 93L 190, 191), Hearne Hill (MINFILE 93M 006) and Saddle Hill (MINFILE 93M 008) properties, in the northern Nechako Plateau (Giles and Levson, 1994a; O'Brien *et al.*, 1995; Stumpf *et al.*, 1995). Samples were collected along linear or fan-shaped traverses to document glacial dispersal and transport distance at these sites and to provide a clearer understanding of glacial dispersal processes. Follow-up studies of newly discovered geochemical anomalies based on results from the Fawnie Creek survey of 1993 (Levson *et al.*, 1994) were also completed.

To reflect mechanical dispersal processes, samples were collected from within the C mineral horizon, which is comparatively unaffected by the pedogenic processes operative in the A and B soil horizons (Agriculture Canada Expert Committee on Soil Survey, 1987; Gleeson *et al.*, 1989). The utility of C-horizon sampling of basal tills for outlining areas of mineralization has long been known (*e.g.*, Shilts, 1973a, b) but, until recently, exploration companies working in the Interior Plateau have generally favoured B-horizon sampling (Kerr, 1995). Although C-horizon samples can be effectively used to identify glacial dispersal trains, important data can also be obtained by sampling the upper soil horizons because, in terms of elemental concentrations, local pedological and hydromorphic processes often favour one soil horizon over another (Bradshaw *et al.*, 1974; Gravel and Sibbick, 1991; Sibbick and Fletcher, 1993). However, it is important to remember that the heterogeneity of elemental concentrations in various soil horizons is dependent on the overburden composition and underlying bedrock lithology as well as geochemical processes acting within the environment (Boyle and Troup, 1975).

Sedimentologic data were collected at all sample sites in order to distinguish till from glacigenic debris flow, colluvium, glaciofluvial or glaciolacustrine sediments. These sediments have different processes of transportation and deposition which must be recognized in order to understand associated mineral anomaly patterns. For example, local variations will be reflected in some sediments while regional trends may be observed in others. Analysis of these sediments will be useful only where their origin is understood. Sedimentologic data collected at each sample site included descriptions of sediment type, primary and secondary structures, matrix texture, presence of fissility, compactness, total percentage and modal size of clasts, rounding of clasts, presence of striated clasts, and sediment genesis and thickness. Further information was noted on soil horizons, local slope, bedrock striae, bedrock lithology, clast provenance and abundance and type of mineralized clasts.

ANALYSIS OF CLASTS IN TILLS

The till sampling program included an evaluation of clasts in the till at each sample site. The objectives were to look for mineralized clasts, decipher patterns of glacial dispersal, determine the distances of glacial transport and rates of clast abrasion and rounding, and relate till-clast lithology to the bedrock lithology to aid in bedrock mapping. The procedure involved field identification of lithology, angularity and abrasion characteristics of each of five categories of clasts: 1) subangular to angular clasts in the basal tills with little or no evidence of glacial transport (*i.e.*, clasts of very local origin); 2) distally derived surface erratics (*i.e.*, clasts of probable supraglacial origin; often cobble to boulder sized); 3) clasts showing abundant evidence of glacial abrasion such as striae and faceting (*i.e.*, basally transported clasts of probable local to intermediate provenenace); 4) clasts of any size or shape showing evidence of potential mineralization (*e.g.*, sulphides, heavy iron oxidation, drusy quartz); and 5) other rock types. A visual survey of a wide area around the sample sites was conducted to locate rocks of category 4, the main focus of the sampling program; these clasts were described and collected for assay.

LABORATORY METHODS AND QUALITY CONTROL

Till samples collected during the regional geochemical surveys were air dried, split and sieved to -230 mesh (<62.5 µm). This fraction was analyzed by instrumental neutron activation analysis (INA) and inductively coupled plasma analysis - atomic emission spectroscopy (ICP-AES) for a total of about 47 elements. The -230 mesh fraction is frequently dominated by phyllosilicates which are generally enriched in metallic elements (Shilts, 1993, 1995) and for this reason it is the preferred fraction to analyze. Half of each sample split was reserved for grain size or other follow-up analyses.

In order to discriminate geochemical trends related to geological factor from those that result from spurious sam-

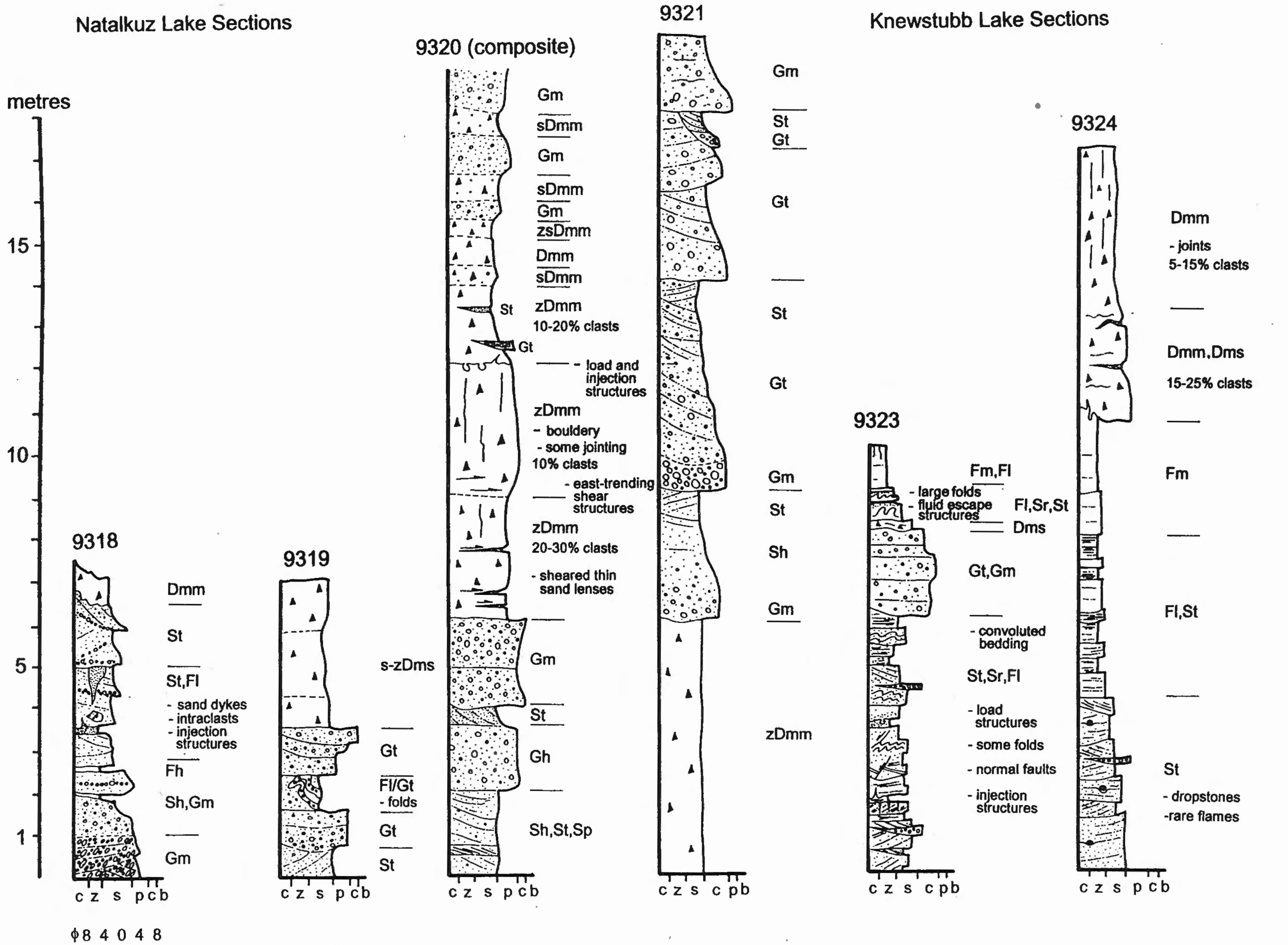


Figure 3. Quaternary stratigraphic sections in the Nechako Reservoir area. Sections located on the Natalkuz Lake reach (9318 to 9321) are shown on Figure 2. Sections 9323 and 9324 are on the Knewstubb Lake Reach just north of the area outlined in Figure 2.

pling or analytical errors, a number of quality control measures were included in both the field and laboratory analysis components of the program. These included the use of field duplicates, analytical or blind duplicates and control standards, one of each being randomly inserted into each set of 17 routine field samples to make a block of 20 samples that were submitted for analysis. Field duplicates were taken from randomly selected field locations and were subjected to the identical laboratory preparation procedures as their replicate pairs. Analytical duplicates consisted of sample splits taken after laboratory preparation procedures but prior to analysis. Control reference standards included several British Columbia Geological Survey (Analytical Sciences Unit) geochemical reference materials comprising the -180 micron size fraction of a variety of bulk samples. A geochemical reference standard of the Canada Centre for Mineral and Energy Technology (Lynch, 1990) was also used.

QUATERNARY STRATIGRAPHY

LATE WISCONSINAN GLACIAL DEPOSITS AND OLDER SEDIMENTS

Morainal sediments in the Nechako Plateau region were assigned by Tipper (1971) to the Fraser glaciation which is dated in several parts of British Columbia as Late Wisconsinan (Ryder and Clague, 1989). A Late Wisconsinan age for the last glaciation in the region is also indicated by radiocarbon dates on wood and mammoth bones recovered from lacustrine deposits under till at the Bell Copper mine (NTS 93 L/16) on Babine Lake. Single fragments of spruce (*Picea* sp.) and fir (*Abies* sp.), yielding dates of 42 900±1860 years B.P. (GSC-1657) and 43 800±1830 years B.P. (GSC-1687), and a date of 34 000±690 years B.P. (GSC-1754) on mammoth bone collagen from the interglacial sediments (Harington *et al.*, 1974), indicate that the overlying till was deposited during the Late Wisconsinan glaciation. Palynological data from interglacial lake sediments are indicative of a shrub tundra vegetation.

The Quaternary stratigraphy of the southern Nechako Plateau has been reconstructed from a number of exposures in the region (Figure 2). Quaternary sediments underlying till are rarely exposed in the survey areas.

The most complete stratigraphic sections encountered in the region mainly occur in the vicinity of the Nechako Reservoir (Figure 2). The stratigraphic record of pre-Late Wisconsinan events elsewhere in the area was largely removed during the last glaciation. Representative stratigraphic sections from the Nechako Reservoir area are provided in Figure 3. Exposures there reveal a widespread, massive diamicton unit, interpreted as a till, that is stratigraphically underlain by both stratified sands and gravels of inferred fluvial and glaciofluvial origin (sections 9318 to 9320, Figure 3) and horizontally bedded sand, silt and clay sequences, interpreted to be advance-phase glaciolacustrine sediments (base of section 9324, Figure 3). The upper part of the older glaciofluvial sequence locally contains sand wedges and dikes (section 9318, Figure 3) that may be relict permafrost features formed in cold environments just prior to the last glaciation. Advance-phase glaciolacustrine deposits are rarely seen, but they are locally well preserved and include well bedded fine sands and silts with dropstones (section 9324, Figure 3).

Morainal sediments of the last glaciation are the most widespread Quaternary deposits in the region and include dense, matrix-supported, silty diamictons interpreted as lodgement and melt-out tills. Compressive deformation structures, such as shear planes, occur near the base of the till, and overturned folds and thrust faults, interpreted as glaciotectonic structures, are locally present in the upper part of the underlying glaciofluvial sediments. Also common are loose, massive to stratified, sandy diamictons of inferred debris-flow origin. These diamictons are often interbedded with gravels and sands (*e.g.*, upper part of section 9320, Figure 3) or may contain thin laminae or lenses of fine sediments (*e.g.*, lower diamicton at section 9324, Figure 3). Debris-flow diamictons commonly have loaded or gradational contacts with interbedded sediments. These data indicate that debris-flow deposition occurred during both the advance and retreat phases of the last glaciation in both subaerial glaciofluvial and subaqueous glaciolacustrine environments (Figure 3).

Glacial deposits form a cover of variable thickness across much of the Interior Plateau and may occur as hummocky, kettled, fluted or relatively flat topography. Basal tills usually unconformably overlie bedrock or, more rarely, older deposits. They seldom occur at the surface, usually being overlain by glacigenic debris-flow deposits, glaciofluvial deposits or, on steep slopes, by diamicton of colluvial origin. Till thickness varies from less than a metre along bedrock ridges and steep slopes to several tens of metres in main valleys and in the lee (down-ice) of bedrock highs. Thick exposures of till (>10 m) also occur locally in narrow valleys oriented at high angles to the regional ice-flow direction. In many valleys, morainal sediments are largely buried by glaciofluvial, fluvial and organic sediments.

LATE WISCONSINAN DEGLACIAL DEPOSITS

Deposits formed during deglaciation of the area include both glaciofluvial and glaciolacustrine sediments. Exposures of glaciolacustrine sediments occur mainly in low-lying areas, generally at elevations below 750 to 950 metres, often near modern lakes. Lake levels were at least locally controlled by ice dams, as in the southern Nechako Plateau (*e.g.*, Levson and Giles, 1994). Maximum lake levels are recorded by the upper elevation of deltaic deposits (*e.g.*, Levson *et al.*, 1994; Huntley *et al.*, 1996). Two common sediment associations are recognized, based on grain size and structure: rhythmically bedded fine sands, silts and clays, and horizontally bedded and trough crosslaminated fine to coarse sands (Figure 3). A shallow-water delta or proximal glaciolacustrine origin is inferred for the sand-dominated facies and the finer grained sediments are interpreted to be deeper water or more distal glaciolacustrine deposits. Dropstones, load structures, normal faults, deformed beds, fluid escape structures and gravel lenses may occur in either sediment association (*e.g.*, section 9323, Figure 3), and indicate the proximity of retreating glaciers or stagnant ice blocks. Beds commonly fine upwards from coarse sand dominated units to fine sand, silt and clay units, reflecting the transition from proximal to distal environments as glaciers retreated from the lake basins.

Meltwater channels of all scales are common in the region and glaciofluvial sediments occur extensively as outwash plains, eskers, kames, terraces and fans in valley bottoms and along valley flanks. They consist mainly of poorly to well sorted, stratified, pebble and cobble gravels and sands of variable thickness. Clasts are typically rounded to well rounded and vary in size from small pebbles to cobbles with rare boulders. If present in upland areas, glaciofluvial sands and gravels usually occur as a veneer or thin blanket. Many of these deposits are interbedded with gravelly diamictons suggesting a proximal outwash origin. Eskers and esker complexes are locally common features. They are characterized by sinuous, gravel ridges (Photo 1) that formed in subglacial tunnels. They are composed mainly of well stratified gravels and sands but normal faults, deformed strata and diamicton beds are common, especially on the outer edges of the eskers, reflecting collapse and deposition of meltout till as the supporting ice melted. Hummocky topography, consisting of ridges and knobs of sand and gravel with large kettles, locally indicates the presence of ice blocks within gravelly sediments during deposition of glaciofluvial outwash. Large kame deposits are uncommon but locally developed along the margins of the stagnating ice and in association with eskers. Gravel and sand terraces on valley sides are deposits of ice-marginal streams formed during ice retreat or stagnation.

HOLOCENE FLUVIAL, COLLUVIAL AND ORGANIC DEPOSITS

Holocene fluvial sediments in the region are dominated by floodplain silts, fine sands and organics and channel gravels in meandering streams. In upland areas, small gravelly creeks have reworked glacial, glaciofluvial and colluvial sediments and locally are incised into bedrock. The flat, open terrain of many large valleys is characterized by marshes and shallow lakes filled with organic sediment consisting of decayed marsh vegetation with minor sand, silt and clay. Organic deposits also occur in low areas in the floors of some valleys, as a thin veneer of decaying vegetation over cobble and boulder gravel.

A thin veneer of weathered and broken bedrock clasts in a loose sandy matrix occurs on steep slopes throughout the area. These deposits grade downhill into a thicker cover of colluvial diamicton derived from both local bedrock and till remobilized by gravity after deposition. Colluvial veneers commonly overlie thin tills on steep slopes. Thick accumulations of talus are relatively uncommon due to the

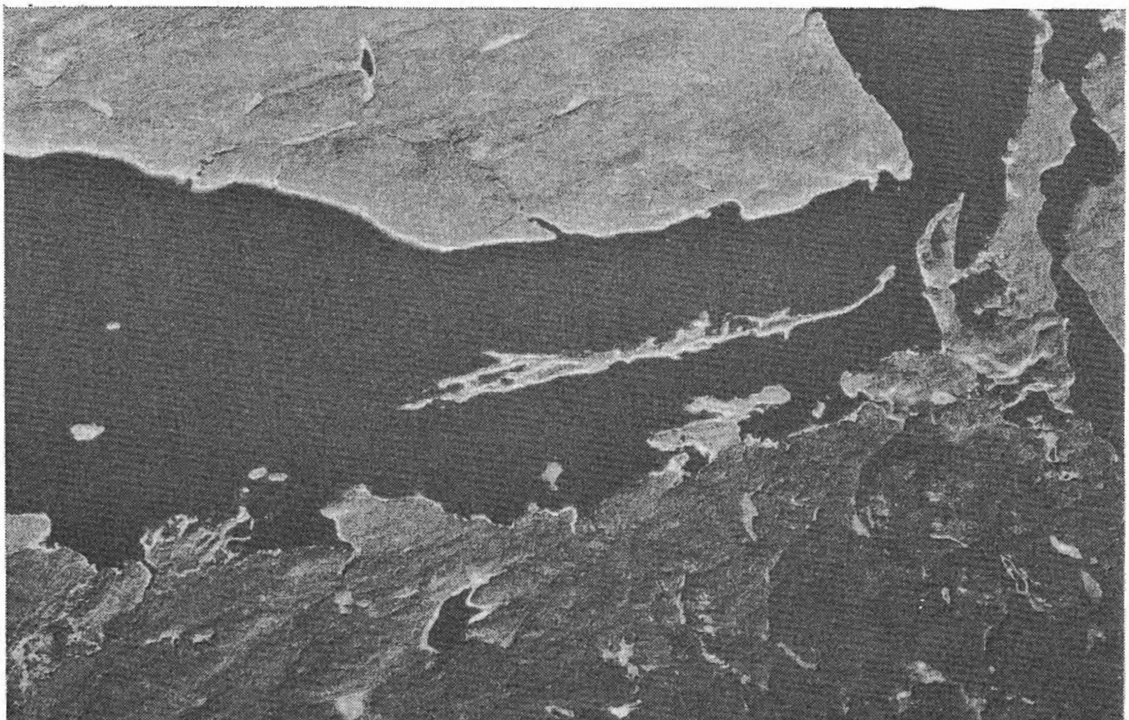


Photo 1. Upper part of glaciofluvial esker-kame complex exposed above water level in the Nechako Reservoir at the junction of the Knewstubb and Natalkuz reaches; also note, in the southwest and northern parts of the area, northeast-trending linear landforms formed by subglacial water and/or ice erosion (north towards top of photo).

overall subdued topography, but they do occur below steep rocky cliffs that are locally present in the more mountainous areas.

Postglacial alluvial fans occur where steep-gradient streams issue onto valley floors. These fans are still active in some areas, as evidenced, for example, by major channel shifts on a large fan at the west end of Top Lake in the Fawnie Range. Coarse cobble to boulder gravels and large trees were transported in the main fan channel during flood events in recent years, and twice rendered a large logging-road bridge over the channel unusable. Evidence for many such events is indicated by numerous channel scars on the surfaces of this and other fans in the area (Giles and Levson, 1994a; Levson and Giles, 1994).

ICE-FLOW HISTORY

A basic understanding of ice-flow direction, glacial dispersal patterns and transportation distances is required for successful drift exploration programs. Interpretation of data with respect to glaciation provides new avenues to explore for bedrock sources of mineralized float or geochemically anomalous soil samples.

In the Nechako Plateau, results of ice-flow studies indicate that in most areas there was one dominant flow direction during the Late Wisconsinan glaciation, that shifted from southeast, in the north part of the plateau (Babine Lake region), to east in the central part (Francois Lake area) and east-northeast in the south (Nechako Reservoir area; Figure 1). Crag-and-tail features, drumlins and glacial flutings are present throughout the region and typically reflect these regional trends (Photo 1). Although some of these features may have formed by subglacial water erosion (*cf.* Shaw, 1989; Shaw and Kvill, 1984; Shaw and Sharpe, 1987; Shaw *et al.*, 1989; Shoemaker, 1992), they generally tend to parallel regional dispersal patterns (Levson and Giles, 1995) and for this reason they are considered to reflect the dominant ice-flow direction. In addition, subglacial meltwater flow and ice-flow directions are expected to be parallel because both respond to the same driving potential created by the surface slope of the ice sheet (Kor *et al.*, 1991).

At the Late Wisconsinan glacial maximum, ice covered the highest peaks in the region and movement appears to have been unaffected by topography. In the Fawnie Range, the ice surface was in excess of 1750 metres as indicated by glacial erratics and regionally trending striae and flutings on top of topographic highs such as Tsacha Mountain (elevation 1734 m). In the Rainbow, Ilgachuz and Itcha mountains in the southern part of the region (Figure 1), the ice reached an elevation of at least 2000 metres and was about 1000 metres thick (Tipper, 1971). Topographic control of ice flow during early glacial phases is locally indicated by valley-parallel striae on bedrock surfaces that are buried by thick till sequences. Similarly, during deglaciation, ice flow was increasingly controlled by topography as the glaciers thinned. Striae and other ice flow indicators that locally diverge from the regional trend reflect this topographically influenced ice-flow during waning stages of glaciation. A more complex local ice-flow history is indicated by highly variable striae trends at a few sites.

In the northern Fraser Plateau, north to northeastward ice flow also dominated during the last glaciation, but there is some evidence for later easterly ice flow in the west part of the region, reflecting a re-advance of Fraser ice (Tipper, 1971). This ice originated to the west in the Coast Mountains and was named the Anahim Lake advance. Proudfoot (1993) observed that northeasterly trending striae, flutings and crag-and-tail ridges dominate the Clusko River (93C/9) and Toil Mountain (93C/16) map sheets, but to the southwest a limited number of easterly trending (about 080°) flutings occur. The eastward limit of this advance is identified on the basis of differential ice-flow directions and pitted or kettled terrain (Tipper 1971). A second late-glacial re-advance may also have reached the northern Fraser Plateau in the Chilanko Forks map area (93C/1). This event, named the Kleena-Kleene advance, originated to the south and terminated in the Tatla Lake Creek area in the southern part of the Chilanko Forks map sheet. The terminus areas of the Anahim Lake and Kleena-Kleene advances are indistinct and not marked by well developed end moraines (Tipper, 1971). Hummocky morainal sediments locally may have been deposited along the margins of these late-glacial advances but no unequivocal deposits of either advance were identified by Giles and Kerr (1993) in their studies in the region.

SUMMARY OF QUATERNARY EVENTS

The first lobes of Late Wisconsinan, Fraser Glaciation ice advancing into the Nechako and Fraser plateaus were probably confined to major valleys. Damming of tributary drainages and the development of proglacial lakes occurred locally. The advancing glaciers also caused local reversals in the regional drainage (Giles and Levson, 1995). At the margins of the advancing ice, coarse-grained proglacial outwash was deposited locally in the valley bottoms. Debris-flow sediments were deposited with the outwash and in proglacial lakes. Lodgement and melt-out tills were eventually deposited by the glaciers as they advanced over the entire region. Results of ice-flow studies indicate that in most areas there was one dominant flow-direction. Drumlins, crag-and-tails, flutings and striae in many areas crosscut major topographic highs, such as the Fawnie and Nechako ranges (Levson and Giles, 1994; Giles and Levson, 1995; Weary *et al.*, 1995), and indicate that the ice was thick enough to be relatively unaffected by topography during full-glacial times. Glacial dispersal patterns appear to be dominated by this regional ice-flow direction (Levson and Giles, 1995), which varies from southeasterly, in the northern part of the study area, to northeasterly in the south. In many areas, the regional ice flow was modified by topographic control during both early and late stages of glaciation, but effects of these modifications on glacial dispersal patterns are not well documented.

During deglaciation, loose, sandy, gravelly diamictons were deposited on top of the tills by debris flows. Stagnant ice masses locally resulted in the development of large esker complexes and dammed meltwater to create glacial lakes and associated glaciofluvial deltas (Giles and Levson, 1994a; Levson and Giles, 1994). Deeply incised meltwater channels also commonly formed. In some areas, kame deposits and extensive meltwater channels developed parallel to the ice margin and indicate prolonged ice stagnation. Moderately sorted, crudely bedded gravel and sand terraces high on valley sides are deposits of high-level ice-marginal channels formed during ice retreat and ablation. Gravelly outwash plains covered the main valley bottoms as large volumes of sediment and water were removed from the ice margin.

During postglacial times, the surficial geology of the area was modified mainly by fluvial activity and the local development of alluvial fans in the valley bottoms, as well as by colluvial reworking of glacial deposits along the valley sides.

TILL GEOCHEMISTRY

The primary objectives of till geochemical studies conducted in the region were to identify geochemically anomalous sites that reflect areas of buried mineralization and investigate patterns of glacial dispersal. Several regional till geochemistry surveys have been conducted in the area for this purpose (Table 1). The average density of samples per square kilometre has increased from less than 0.1 in the 1992 survey areas to about 0.2 in the 1993 and 1994 programs to about 0.3 in the 1995 surveys (Table 1). The results of the 1993 survey (Levson *et al.*, 1994), conducted in the Fawnie Creek map area (NTS 93 F/3), are summarized below as an example of the utility of till geochemistry programs.

Till geochemical anomalies identify areas where glaciers eroded mineralized bedrock and redeposited the mineral debris in down-ice dispersal trains. As glacial dispersal trains may be hundreds to thousands of times larger in area than their original bedrock source, they provide a cost effective target for mineral exploration programs in drift-covered terrains (Shilts, 1976; DiLabio, 1990; Levson and Giles, 1995). In addition, tills are 'first-derivative' products of bedrock and, having been transported to their present location mainly by the relatively linear flow of glaciers during one or more glacial episodes, they are more readily traced to source than higher order derivatives such as glaciofluvial or glaciolacustrine sediments (Shilts, 1993). In the simplest case of unidirectional ice flow, mineralized material at a point source is eroded, transported and redeposited to produce a ribbon-shaped dispersal train parallel to ice flow. Although these processes were first documented in Canada in shield areas (Shilts, 1973a, b; 1976), some examples have also been described from the interior of British Columbia (*e.g.*, Fox *et al.*, 1987; Kerr *et al.*, 1992, 1993; Levson and Giles, 1995; see also references in Kerr and Levson, 1995, 1996, this volume). Variations in the ice-flow direction, caused by topographic irregularities or changing dynamics at the base of the ice, may produce a fan-shaped dispersal train. In more complex areas, where there have been numerous flow directions during glaciation, or multiple glaciations, the dispersal train may be diffuse or irregularly shaped, making it difficult to trace to its source. Consequently, geochemical exploration programs in drift-covered regions must rely on an understanding of glacial processes and the glacial history of the area.

SAMPLING MEDIUM

Basal till was selected as the preferred sampling medium for this program rather than other types of surficial materials, for several reasons:

- Basal tills are deposited in areas directly down-ice from their source and therefore mineralized material dispersed within the tills can be more readily traced to its origin than can anomalies in other sediment types. 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.
- Due to the potential for the development of large dispersal trains, mineral anomalies in basal tills may be readily detected in regional surveys.
- The dominance of one main regional ice-flow direction throughout much of the last glacial period in the survey area has resulted in a simple linear, down-ice transport of material. This makes tracing of basal till anomalies to source relatively easy compared to regions with a more complex ice-flow history.

Sampled deposits, interpreted as basal tills, typically consist of compact, fissile, matrix-supported, sandy-silt diamicton (defined as poorly sorted deposits consisting of mud, sand and gravel). They are typically overconsolidated and often exhibit moderate to strong subhorizontal fissility (Photo 2). Vertical jointing and blocky structure are also common, especially in dry exposures. Oxidation of the till, characterized by reddish brown staining, is common and may occur pervasively or along vertical joint planes and horizontal partings. Subhorizontal slickensided surfaces are sometimes present, especially in clay-rich parts of the till. Clasts are mainly medium to large pebbles but they range in size from granules to large boulders. Total gravel content generally is between 10 and 30% but locally may be up to 50%. Subangular to subrounded clasts are most common and typically up to about 20% are glacially abraded. Striated clasts are commonly bullet shaped, faceted or lodged; the a-axes of elongate clasts are often aligned parallel to ice-flow direction. Lower contacts of basal till units are usually sharp and planar. All of these characteristics are consistent with a basal melt-out or lodgement till origin (Levson and Rutter, 1988; Dreimanis, 1990). Injections of till into bedrock fractures locally indicate high pressure conditions at the base of the ice during deposition. The presence of sheared, folded and faulted bedrock slabs within these deposits indicates the local development of deformation tills.

Basal till deposits can be confused with other facies of morainal sediments such as glacigenic debris-flow deposits or with other poorly sorted sediments such as colluvial deposits (Photo 3). A summary of some characteristics useful for distinguishing basal tills from other deposits of glacial or nonglacial origin is provided in Table 2. This distinction is critical as the dispersal characteristics of different sediment types vary widely (*see* below). Basal tills are first order derivative products whereas glacigenic debris-flow deposits, for example, have undergone a second depositional

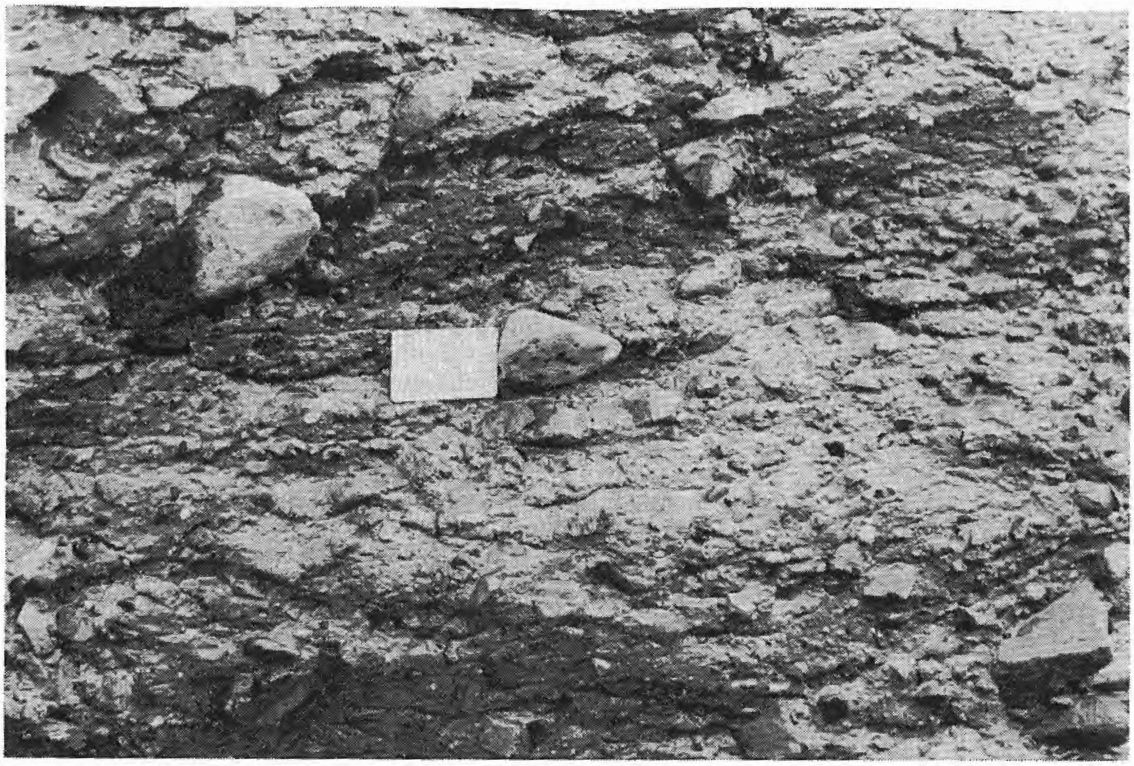


Photo 2. Massive, matrix-supported diamicton interpreted as basal till; note the well developed subhorizontal fissility and presence of subrounded to subangular clasts; scale in centimetres.

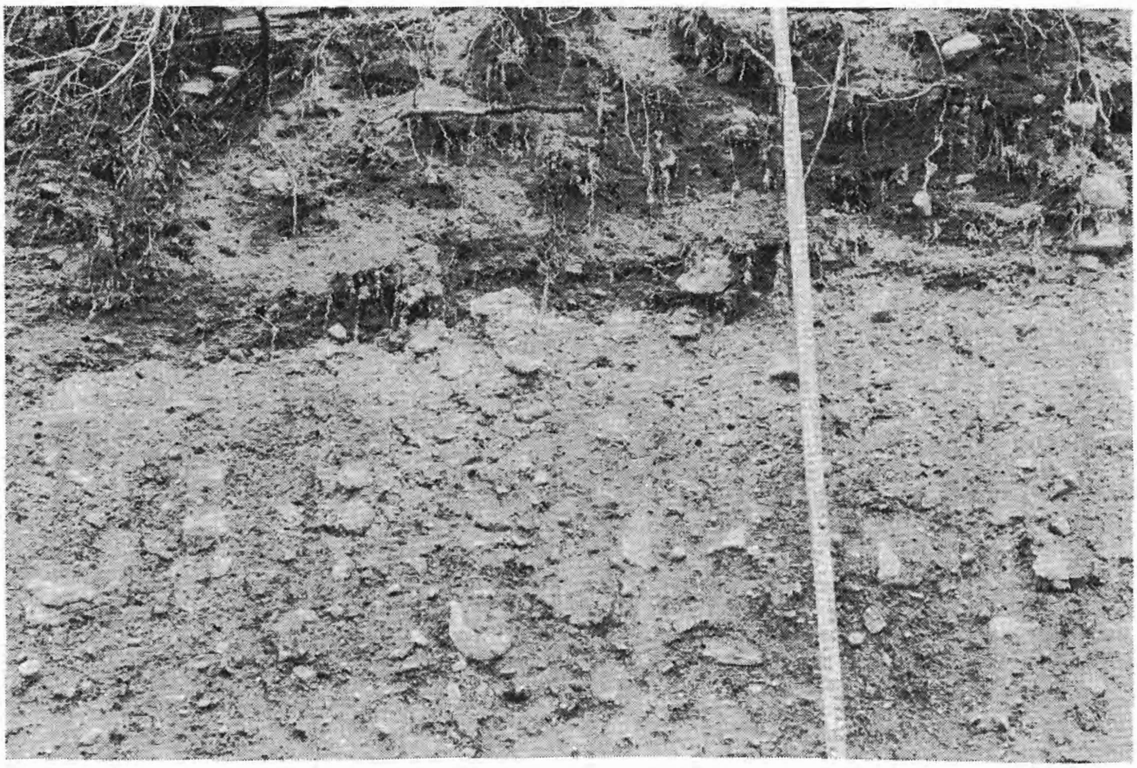


Photo 3. Massive gravelly sand (colluvium), about 70 centimetres thick, overlying 1 metre of massive, sandy diamicton interpreted as glacigenic debris-flow deposits (resedimented till).

TABLE 2
DISTINGUISHING CHARACTERISTICS OF BASAL TILL, SUPRAGLACIAL TILL, DEBRIS FLOW DEPOSITS AND COLLUVIAL DIAMICTON

SEDIMENT TYPE	TYPICAL CHARACTERISTICS AND SEDIMENTARY STRUCTURES	MATRIX TEXTURE/ DENSITY	CLAST PROVENANCE[2]/ SHAPE	PEBBLE FABRIC[3]	LOWER CONTACT	ASSOCIATED LANDFORMS
Basal till[4]	massive, matrix-supported, diamicton; overconsolidated; fissile; oxidized blocky joint planes; shear structures; thrust faults	sand-silt-clay; very dense	mainly local; striated, faceted; subangular to subrounded	mod. to strong fabric, parallel to paleoflow	sharp and planar (erosional)	level to rolling moraine, drumlins, flutings, crag-and-tails
Supraglacial till[5]	massive to crudely stratified, diamicton; matrix- or clast-supported; normally faulted or collapsed sand and gravel lenses	sandy; usually loose	far-traveled, from high elevations; large angular to subangular	chaotic or weak, random orientations	gradational, irregular	hummocky moraine, kames, kettles
Cohesive debris flow[6]	massive to crudely stratified, diamicton; matrix-supported, ungraded or coarse-tail inverse grading; thin discontinuous sandy or gravelly strata	sand-silt-clay; loose to compact	local to distal; subangular to subrounded	weak fabric, parallel to slope or paleoslope	clear to gradational; subhorizontal	streamlined or hummocky moraine; gentle to moderate slopes
Non-cohesive debris or flood flow[7]	crudely stratified diamicton / poorly sorted gravel; clast-supported; ungraded or normal grading; often interbedded with trough-shaped sand and gravel lenses	sand-silt; usually loose	distal and local; well rounded to subangular	weak to moderate fabric; rare imbrication	gradational to sharp; often trough-shaped (scoured)	proximal glaciofluvial: sandurs, eskers, kame terraces, kame deltas, fans
Subaqueous flows & ice-rafted debris	massive to stratified, diamicton / gravelly mud; matrix-supported, silt and clay laminae; folded and convoluted strata	silt-clay-sand; compact	distal; subangular to subrounded; mainly pebbles	chaotic or weak a-axis fabric	sharp, horizontal, loaded	lacustrine basins in valley bottoms; often near large lakes
Colluvium	massive to crudely stratified, diamicton; clast-supported, strata parallel slope	sandy; often very loose	dominantly local; subangular to angular	weak to strong downslope dip	clear, parallel to slope	moderate to steep bedrock slopes

[1] based on data from Levson and Rutter (1986, 1988), Dreimanis (1988, 1990), Levson and Giles (1993) and Giles and Levson (1994a, b).
[2] local provenance indicates source rocks within a few kilometres; distal indicates source is more than a few kilometres
[3] fabric strength (S_1) is a normalized measure of clustering, varying from weak ($S_1 <$ about 0.5) to strong ($S_1 >$ about 0.7)
[4] mainly lodgement and melt-out till
[5] also referred to as ablation till
[6] also referred to as mudflow; locally includes colluviated (remobilized) till
[7] includes gravelly debris flows, hyperconcentrated flood flows and washed tills

phase, related either to the paleo-ice surface or the present topography, and they are therefore more difficult to trace to their source. Glacigenic debris-flow deposits include some supraglacial tills, basal tills reworked by gravity (often producing cohesive debris flows) or water (often producing non-cohesive debris flows) and subaqueous debris flows (Table 2). Subaerial varieties typically consist of loose, massive to stratified, sandy diamicton (Photo 3). They are usually loose to weakly compact and either massive or interbedded with stratified silts, sands or gravels. Clasts vary in size from small pebbles to large boulders, but are usually medium to large pebbles. These diamictons typically contain 20 to 50% gravel, but locally may have up to 70% clasts. Subangular to subrounded clasts are most common, but local angular fragments dominate in some shallow exposures over bedrock. Lenses and beds of sorted silt, sand and gravel occur in many exposures and may be continuous for up to 5 metres, although they are most frequently 10 to 100 centimetres wide. Debris-flow deposits may exhibit weak to strong preferential oxidization along more permeable sandy or gravelly horizons. These deposits commonly are in gradational contact with underlying basal tills. Colluvial diamictons are differentiated from basal tills by their loose unconsolidated character, the presence of coarse, angular clasts of local bedrock, crude stratification and lenses of sorted sand and gravel (Table 2).

CHARACTERISTICS OF GLACIAL DISPERSAL IN THE NECHAKO PLATEAU REGION

SOIL GEOCHEMICAL ANOMALIES

The main characteristics of glacial dispersal trains in the study region and surrounding parts of the Nechako Plateau, as indicated by soil geochemical anomaly patterns, were discussed by Levson *et al.* (1994) and Levson and Giles (1995) and are summarized here. This information was compiled in 1993 from existing industry records, in order to provide geochemical orientation data reflecting glacial dispersal patterns in the region and to aid in the design of a sampling strategy for regional till geochemistry programs. Limitations of the industry data for these purposes include the use of a variety of different surficial sediment types as sample media, although mainly tills were sampled, and the use of mainly B-horizon, rather than C-horizon samples. The industry samples are referred to here as soil geochemical samples in order to distinguish them from basal till samples (*see* below).

Soil geochemical anomalies associated with glacial dispersal of mineralized bedrock in the region studied generally are a few kilometres long and several hundred metres or more wide; isolated anomalies associated with the trains may cover much larger areas. The dispersal trains show a pronounced elongation parallel to ice-flow direction, with mineralized source rocks occurring at or near their up-ice end. They are commonly very narrow in comparison with their length and have clear lateral and vertical contacts with the surrounding till. Length to width ratios of 5:1 are typical. Progressive dilution of the mineralized material generally occurs in a down-ice direction until the train can no longer be detected. Erratics trains in the region appear to be much longer (up to several km long) and more readily detected than soil anomalies (typically 1-2 km long). For example, the Arrow Lake mineral showing was discovered in 1987 by tracing a train of stibnite-bearing quartz feldspar wacke/tuff erratics, 7 kilometres long (Bohme, 1988), whereas soil geochemical anomalies in the area are much shorter. This emphasizes the importance of pebble studies and clast provenance investigations (*e.g.*, boulder tracing) in drift exploration programs.

The elongate nature of soil geochemical anomalies resulting from glacial dispersal in the region is well evidenced by the Arrow Lake antimony anomaly which is about 1 kilometre long and only 200 metres wide (Levson and Giles, 1995). At the Wolf epithermal deposit, anomalous silver concentrations occur as much as 2.3 kilometres directly down-ice from the deposit (Dawson, 1988). Similarly, at the CH property, dispersal of mineralized material is defined by an elongate, multi-element, geochemical soil anomaly as well as by a boulder train that extends for over a kilometre down-ice from the mineralized outcrop (Warner and Cannon, 1990; Edwards and Campbell, 1992). Zinc, silver and lead geochemical anomalies at the property are typically 200 to 300 metres wide and 1 to 1.5 kilometres long. The copper soil anomaly is much broader (800 m) and longer (2 km). These anomalies typically have relatively sharp lateral boundaries and cigar or fan shapes, characteristic of trains formed by mechanical dispersal processes at the base of glaciers. Geochemical data from tills reflect the geochemistry of the up-ice bedrock sources and not that of the immediately underlying bedrock. In areas of thick till, near-surface geochemical anomalies may be offset, in a down-ice direction, by 500 metres or more from their bedrock source. Drill targets in these areas should be sought up-ice, rather than at the head of the anomaly.

Except along some creeks and steep slopes, hydromorphic dispersion effects have apparently not modified anomaly patterns in tills in the region to any great degree. The main influence of topography seems to be the preferential deposition of till in lee-side settings. Although topography may also have temporarily effected local ice-flow directions, dispersal of mineralized materials appears to have been dominated by the regional ice-flow; subsequent local variations have not obscured this primary pattern. This is well illustrated by the predominant down-ice dispersal of molybdenum in the Chutanli Lake region, even though the down-ice direction is mainly up-slope from the deposit (Mehrtens, 1975).

Pathfinder elements vary with deposit type, and elements most abundant in the mineralized material appear to produce the largest and strongest soil geochemical anomalies (*e.g.*, Sb at the stibnite-bearing Arrow Lake deposit, Cu at the CH porphyry copper prospect, and Ag at the Wolf Au-Ag epithermal deposit). However, multi-element analysis of all samples is recommended, to increase the likelihood of discovering unexpected mineralization, even in property-scale investigations.

GLACIAL DISPERSAL AT THE WOLF PROSPECT USING TILL GEOCHEMISTRY

Recent investigations of glacial dispersal patterns using C-horizon basal till samples, rather than B-horizon soil samples, indicate that dispersal trains can be detected over much larger areas in tills than in soils. In the Wolf area, for example, a study of dispersal patterns, conducted in conjunction with the regional till sampling program (Levson *et al.*, 1994), shows more than 5 kilometres of down-ice dispersal from areas of known mineralization (Figure 4). At these distances, gold concentrations in basal till are still elevated (greater than the 90th percentile compared to the regional data set). This contrasts with soil geochemical dispersal patterns in the area that extend for only about 2 kilometres down-ice from the deposit (*see* Levson and Giles, 1995, their Figure 6-4). The maximum down-ice extent of gold dispersal in till is not known but at least 5 kilometres of transport below mineralized outcrop is indicated. It is also important to note that the head of the gold anomaly is about 500 metres down-ice from the prospect and gold concentrations directly over the mineralized area are much lower. The same pattern is observed in the soil geochemistry data (Levson and Giles, 1995) and again highlights the importance of exploring up-ice, and not directly below, anomalous zones in areas with a thick till cover. The highest gold concentrations in soils (305 and 495 ppb) occur at the up-ice end of the dispersal plume (Figure 4) 1 to 1.5 kilometres from the mineralized area, but the highest gold concentration encountered in till is about 3.7 kilometres down-ice from the prospect.

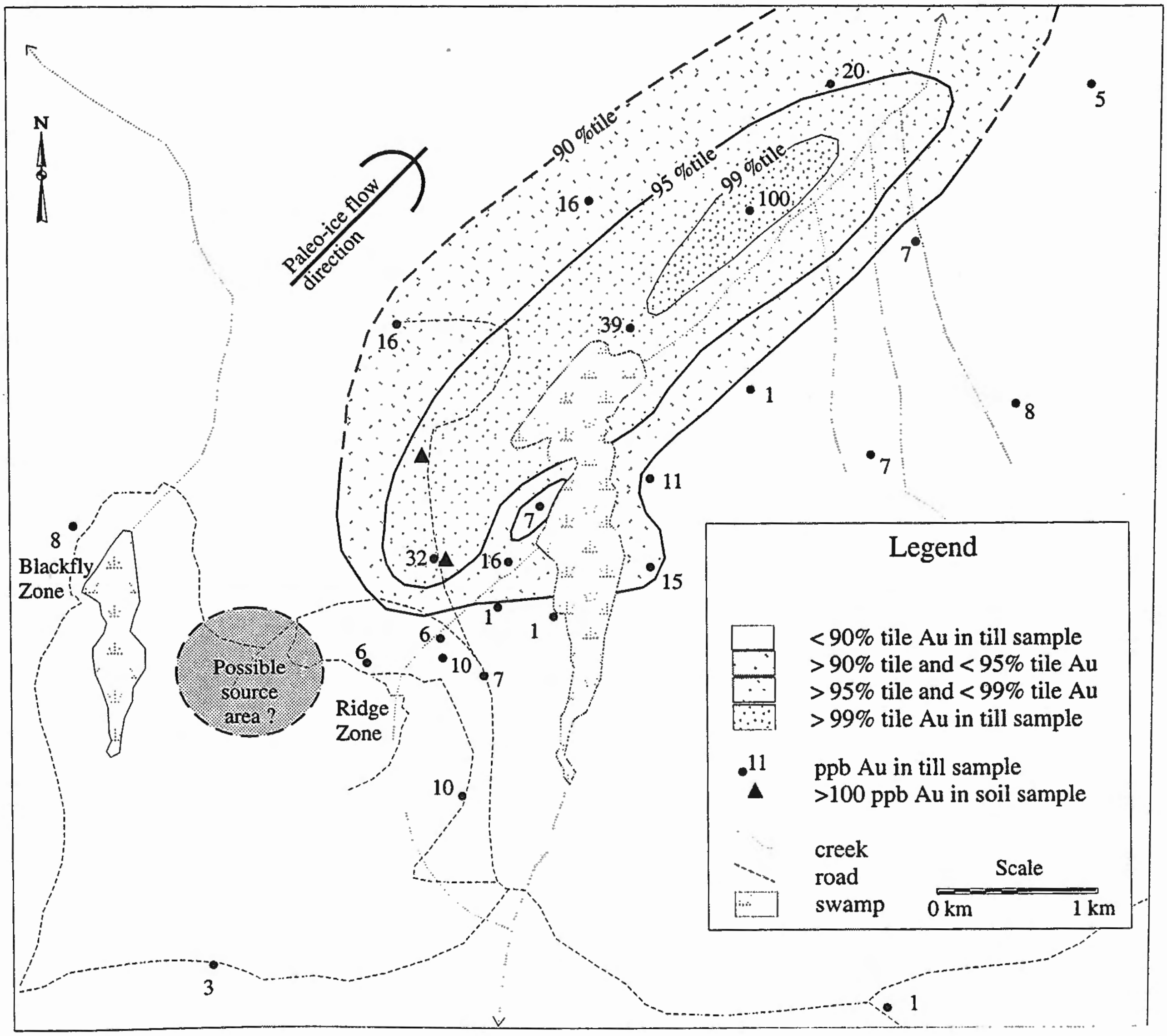


Figure 4. Gold concentrations in basal till (-63 μm fraction, analyzed by INAA) down-ice of the Wolf prospect (*see* text for explanation); area shown is located on Figure 2.

The northwest margin of the gold anomaly in till below the Wolf prospect (Figure 4) is not constrained by samples with background gold concentrations. Elevated gold concentrations in this area are not what would be expected if the Ridge zone was the only source of the gold anomaly and they may reflect down-ice dispersal of mineralization from the Blackfly zone (*cf.* Levson and Giles, 1995), located about 2 kilometres west-northwest of the Ridge zone. This interpretation is supported by arsenic concentrations in till on the northwest side of the dispersal plume that are generally two to three times higher than on the southwest side (the Blackfly zone is the only part of the mineralized system known to have anomalous arsenic; Schroeter and Lane, 1994). In addition, the highest gold concentrations in till occur down-ice of the area between the Ridge and Blackfly zones, suggesting that the main source of the gold dispersal plume may occur between the two areas of known mineralization.

BACKGROUND VARIATIONS

Background levels of various elements in tills are controlled in part by the background concentrations in their source rocks. The influence of bedrock geology, therefore, must also be considered when interpreting regional till geochemical data. To evaluate the effect of bedrock geology on the regional geochemical data set for the Fawnie Creek map area, for example, Levson *et al.* (1994) related background metal concentrations for gold, silver, arsenic, antimony, lead, zinc and molybdenum to the lithology of the underlying bedrock. Background concentrations, as defined by median values, are generally similar in tills underlain by mafic volcanics and sediments of the Hazelton Group, but are distinctive in tills underlain by rhyolitic Ootsa Lake Group rocks or Tertiary mafic volcanics (*e.g.,* Chilcotin Group rocks). For example, Ootsa Lake Group sites have the highest median gold concentrations and Chilcotin Group sites have the lowest gold, arsenic and antimony concentrations. Sites underlain by these two groups also have low background concentrations of lead, zinc and copper relative to other rock types in the area.

COMPARISON OF TILL WITH OTHER SAMPLING MEDIA

Different types of surficial sediments have distinctly different provenances based on their transportation and depositional histories. Six genetic categories of surficial sediment are common in the Interior Plateau region: morainal, glaciofluvial, glaciolacustrine, fluvial, colluvial and organic sediments. It is critical, for interpretation purposes, that detailed descriptions of the sampling media are obtained and that different types of materials are distinguished (Giles and Levson, 1994a, b; Levson *et al.,* 1994). The importance of separating overburden geochemical data into populations that correspond to different types of surficial materials (and bedrock lithologies) was demonstrated by a study in the Nechako Plateau region by Boyle and Troup (1975). Regional variations due to surficial geology (or bedrock lithology) can therefore be minimized in favour of processes relating to mineralization. There is a particularly significant difference between till-covered areas and colluvial deposits in more mountainous areas. For example, mean copper, molybdenum, zinc, nickel and lead concentrations in the A and B soil horizons over a large part of the Capoose Lake region (Boyle and Troup, 1975) were all higher in colluvium (17-24 ppm Cu, 0.9-1 ppm Mo, 51-79 ppm Zn, 11-14 ppm Pb and 5-7 ppm Ni) than in till (7-15 ppm Cu, 0.5-0.9 ppm Mo, 31-41 ppm Zn, 5-6 ppm Pb and 5-6 ppm Ni). In addition, mean C-horizon concentrations in till (12-18 ppm Cu, 0.5-8 ppm Mo, 22-27 ppm Zn, 5 ppm Pb, and 5-6 ppm Ni) were similar or higher than A or B-horizon concentrations. In order to minimize this variability related to different surficial sediment types or soil horizons, the regional geochemical surveys conducted as part of this program relied on samples collected only from the C-horizon of basal tills.

It is also important to emphasize that glacial sediments can be eroded, transported and deposited by a wide variety of mechanisms, all of which may produce deposits of distinctly different character (Table 2). Tills may form by primary processes involving the direct release of debris from a glacier, or by secondary resedimentation processes in the glacial environment (Dreimanis, 1988). Till characteristics are dependent on their position of deposition (subglacial, supraglacial or ice marginal), place of transport (basal, englacial or supraglacial) and dominant depositional mechanism (lodgement, melt-out, flow or deformation). For the purposes of drift prospecting, distance of transport is especially critical and two main varieties of till are commonly distinguished: basal tills, comprised of debris transported at or near the glacier base, and supraglacial tills, comprised of debris transported on or near the top of the glacier (Dreimanis, 1990). The latter are usually deposited as debris flows and are comprised of relatively far-traveled debris. Basal tills, deposited by lodgement or melt-out processes, are typically more locally derived than supraglacial tills. Supraglacial tills may be distinguished from basal tills by higher total clast contents, more angular and fewer striated clasts, typically weaker and more randomly oriented pebble fabrics, and the common presence of interbedded sand and gravel deposits (Levson and Rutter, 1988; Table 2). The two till varieties may also be distinguished geomorphologically; supraglacial tills typically occur in areas of hummocky topography and basal tills in fluted or drumlinized regions. However, geomorphic data alone are not always diagnostic as, for example, fluted and drumlinized areas may be blanketed by a thin cover of supraglacial till. Similarly, basally derived, flow tills may be confused with relatively far-traveled, supraglacial, flow tills (Table 2). Because of this difficulty in distinguishing different till facies, a multiple criteria approach using sedimentologic, stratigraphic and geomorphic data is recommended for the interpretation of glacial deposits (Levson and Rutter, 1988; Dreimanis, 1990).

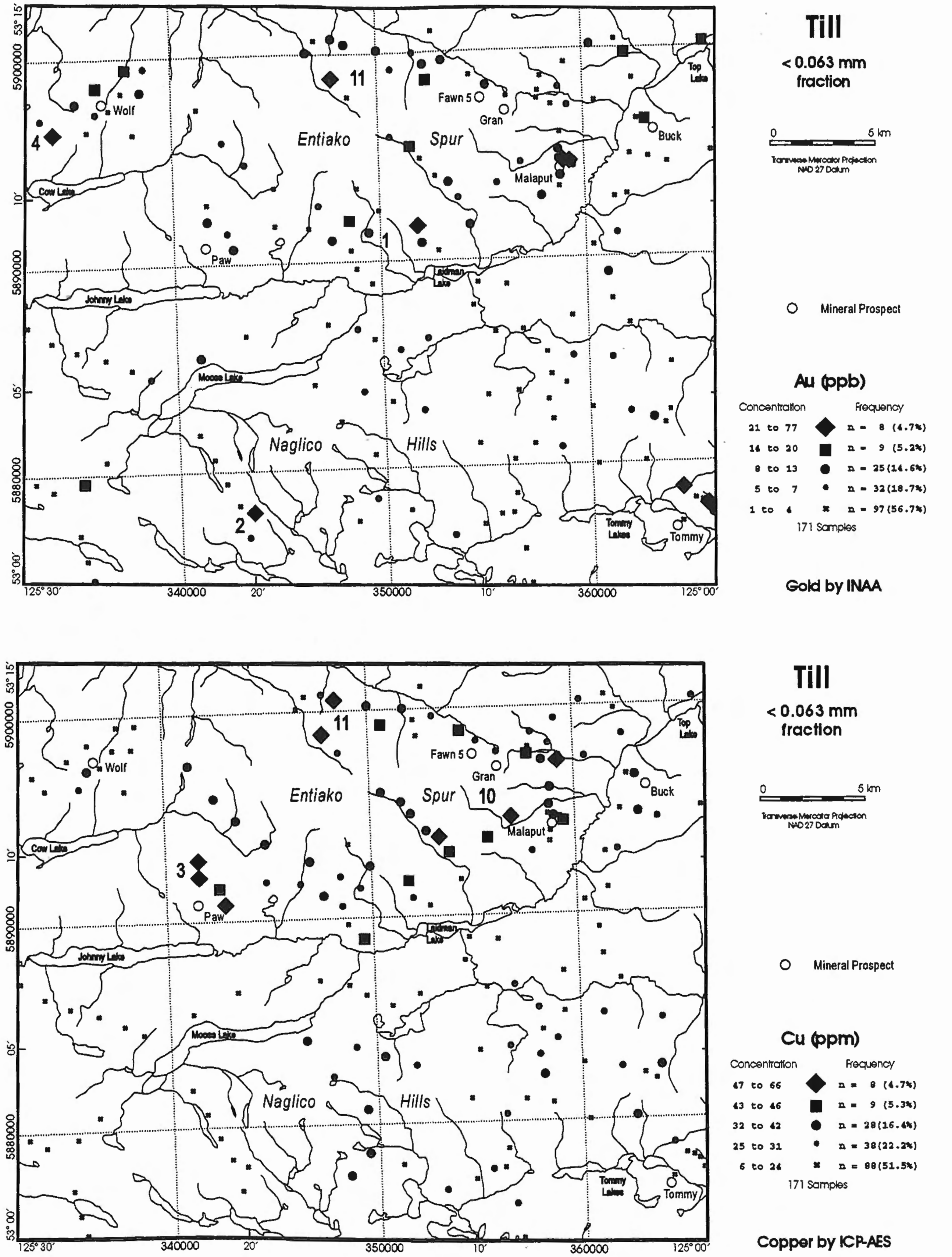


Figure 5. Gold (a) and copper (b) concentrations in basal till (-63 µm fraction) in the area covered by the Fawnie Creek regional till geochemical survey; numbers refer to areas discussed in the text.

EFFECTIVENESS OF REGIONAL TILL SAMPLING PROGRAMS

Regional till geochemical sampling, combined with surficial geology mapping, has proven to be a useful method for detecting buried mineralization in the Interior Plateau region. This was demonstrated by the detection of all existing mineral occurrences in the Fawnie regional till geochemical survey (Figures 5 and 6; *cf.* Levson *et al.*, 1994), including several sites not known to the samplers before the survey was conducted.

The effectiveness of till geochemical sampling programs, together with lake sediment sampling, surficial geology mapping and bedrock geology mapping, is discussed by Cook *et al.* (1995). In the 1:50 000 map area included in the Fawnie survey, described in more detail below, eleven new exploration targets with multi-element geochemical anomalies were highlighted by till and lake sediment geochemical surveys. Six of these target areas are indicated by both lake sediment and till geochemical data, three by till data alone and two by lake sediment data alone (Table 3). These targets include strongly 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. Strongly 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. The till geochemical anomalies discovered, show values comparable to those down-ice of advanced prospects in the area. These data strongly suggest that geochemical surveys, using basal tills as a sampling medium, are an effective tool for regional exploration in the Interior Plateau region, especially when integrated with other types of geological and geochemical surveys.

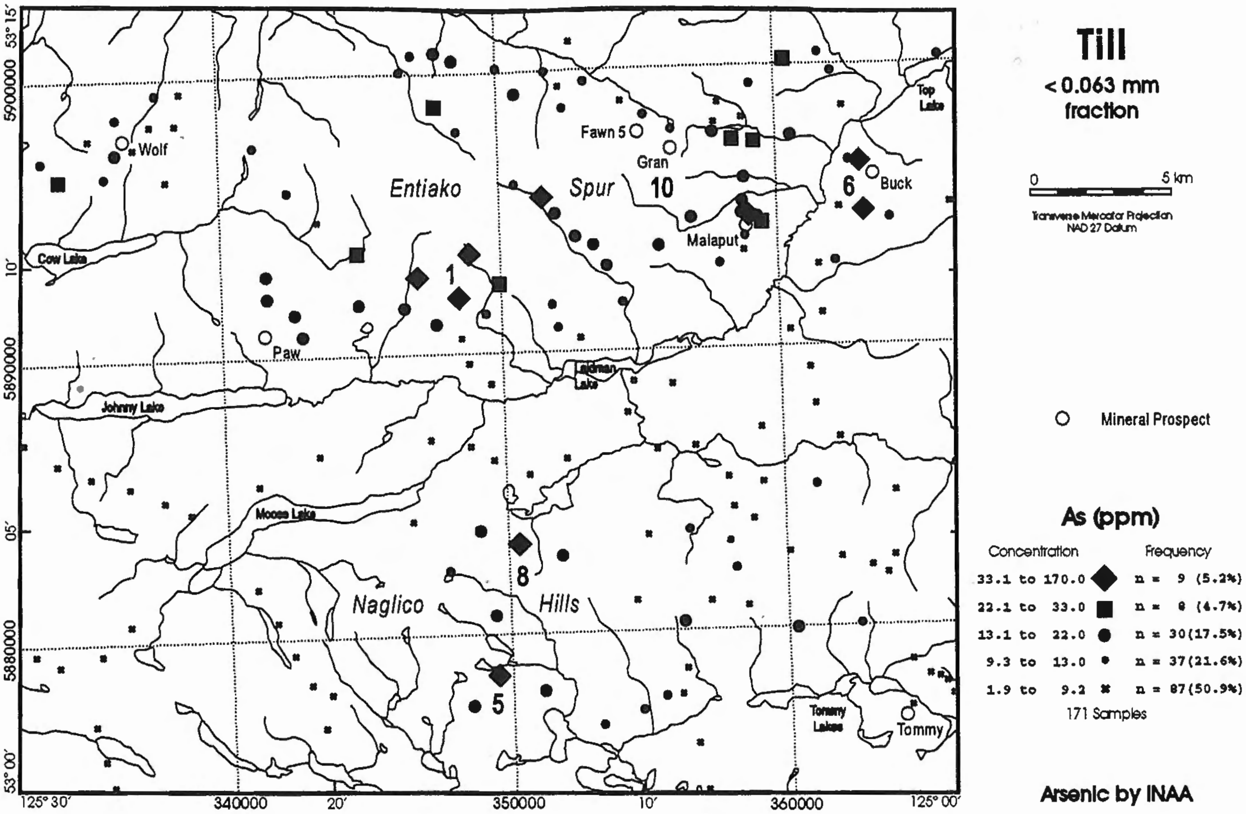
FAWNIE REGIONAL TILL GEOCHEMICAL SURVEY

The results of the Fawnie regional till geochemical survey are summarized here to illustrate the effectiveness (and limitations) of this type of program in highlighting new exploration targets (Figures 5 and 6). Some of the multi-element anomalies were found in till at several adjacent sample sites, such as in an area along the western margin of the

TABLE 3
ANOMALOUS ELEMENTS IN TILL AND LAKE SEDIMENTS IN THE VICINITY OF KNOWN AND POTENTIAL MINERAL PROSPECTS

Location of prospect or geochemical anomaly[1]	Anomalous Elements[2] (>95th percentile) at geochemical sites[3]	Method of Detection[4] 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) SW Naglico Hills (SE of Trophy Lake)	Au-Pb	T & L
3) SE of Cow Lake	Au-Cu-Pb-Zn-Mo	L & T
4) NW of Cow Lake	Au-Mo	T
5) S Naglico Hills	Pb-Zn-As-Sb	T & L
6) SW of Top Lake	Pb-Zn-As-Sb	T & L
7) S of Cow Lake	Cu-Pb-Zn	L
8) SE of Moose Lake (North Naglico Hills)	Pb-Zn-Mo-As-Sb	T & L
9) SW corner of mapsheet	Cu-Mo	L
10) South and east sides of Entiako Spur	Cu-As-Sb	T
11) N Entiako Spur	Cu-Au	T

[1] Numbers of potential prospects correspond to bold numbers on Figures 5 and 6 (from Levson *et al.*, 1994 and Cook *et al.*, 1995).
[2] Only seven elements considered (Au, Cu, Pb, Zn, Mo, As, Sb).
[3] For known prospects, only sample sites within a few kilometres down-ice (for tills) or down-slope (for lake sediments) are included.
[4] Geochemical media listed in order of significance for each prospect.



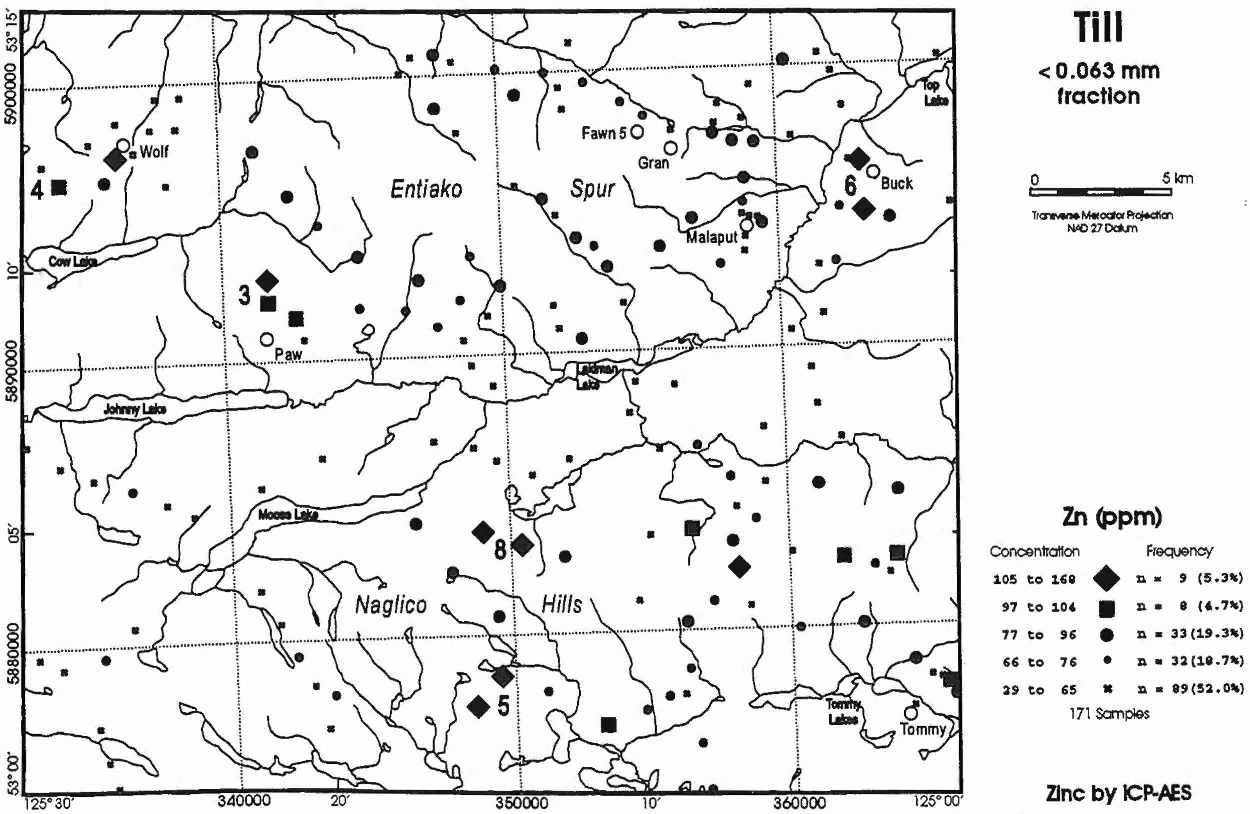


Figure 6. Arsenic (a) and zinc (b) concentrations in basal till (-63 µm fraction) in the area covered by the Fawnie Creek regional till geochemical survey; numbers refer to areas discussed in the text.

Capoose batholith, described by Levson *et al.* (1994) and studied in more detail by Best *et al.* (1996). Anomalous gold values, including the highest gold concentration encountered in the regional sampling program, were detected in this area along a zone that is about a kilometre wide and several kilometres long (area 1, Figure 5a, b) and trends easterly, parallel to the local ice-flow direction (Figure 7). Till samples at several sites in the area contain anomalous gold, arsenic, silver and antimony.

Another area of interest identified in the Fawnie regional survey lies between the southern margin of the Capoose batholith and a small associated intrusion in the south-central part of the map sheet (areas 5 and 8, Figure 6a, b). Anomalous zinc, lead, silver, molybdenum, arsenic and antimony concentrations occur here and tills in the vicinity of the small southern intrusion (area 5) also contain anomalous barium, iron and aluminum. Rocks around the intrusion are oxidized and contain finely disseminated and fracture-controlled pyrite. The former ice-flow direction is almost due east near the anomalies (Figure 7), indicating that mineralized source rocks are located farther to the west.

A third multi-element geochemical anomaly identified in the Fawnie survey occurs northeast of Johnny Lake (area 3, Figure 5b and 6b). Tills in this area contain anomalous copper, zinc, lead, silver and molybdenum. Rocks in the area contain disseminated and fracture-controlled sulphides. The Paw mineral showing occurs south of the main part of the anomalous region and, as the local ice-flow there is northeasterly (Figure 7), it is unlikely to be the only source of the high metal concentrations in the tills. The area is considered to have potential for porphyry-style mineralization.

An area of potential stratabound sulphide mineralization on the Buck property is reflected in the till geochemical data by a fourth multi-element anomaly (area 6, Figures 6a, b). Significantly, the highest lead, zinc, arsenic and antimony concentrations occur at a site south of the main zone of interest, suggesting that bedrock mineralization may be present up-ice of that location. Other exploration targets identified include: high gold concentrations in till and mineralized float south of Moose Lake (area 2, Figure 5a); moderately high gold, silver, arsenic and antimony and high copper concentrations in till overlying altered rocks south of Entiako Spur (area 10, Figure 5b, 6a); and high gold and copper concentrations north of Entiako Spur (area 11, Figure 5a, b).

In addition to identifying new exploration targets, the till geochemical data suggest that mineralization in the vicinity of the known Wolf, Tommy Lakes (Tascha) and Malaput prospects (Figures 5 and 6) may be more significant than previously recognized. For example, in the Wolf area, the highest gold concentration in the regional till samples is southwest or up-ice (Figure 7) of the known mineralized zones, suggesting that there is potential for discovery of a new auriferous zone southwest of the main part of the property (area 4, Figure 5a). This area also shows moderately anomalous arsenic, molybdenum, lead and zinc. Similarly, at the Tommy Lakes (Tascha) site, anomalous gold in till north of the known showings suggests that the bedrock mineralization may extend farther to the north than initially

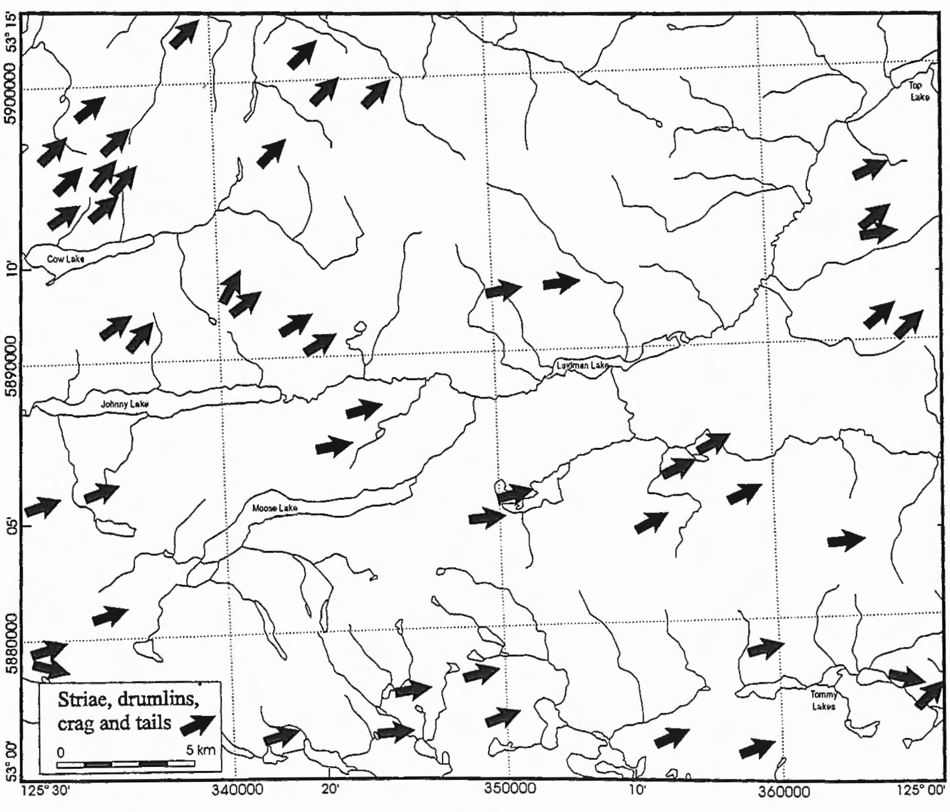


Figure 7. Ice-flow directions in the Fawnie Creek map area (NTS 93 F/3) as indicated by drumlin, fluting, crag-and-tail and striae data.

TABLE 4
DRIFT EXPLORATION POTENTIAL: SURFICIAL SEDIMENT TRACEABILITY AND DISPERSAL CHARACTERISTICS

Terrain map unit	Dominant surficial materials[1]	Traceability (to bedrock source)	Transport distance[2] (order of magnitude)	Probable dispersal pattern[3]	Applicable survey scale; and type[4]
VERY HIGH POTENTIAL					
Cv/R	colluvial diamicton: < 1 m thick with sporadic rock outcrops	very good	< 1 to ~100 m; increasing with slope	downslope, linear to fan shaped	1:5 000 (property-scale); S, C
Cb	colluvial diamicton and rubbly talus deposits: typically 1 to 10 m thick	good to very good	~10 to ~100 m, increasing with slope	downslope, fan shaped	1:5 000 (property-scale); S, C
HIGH POTENTIAL					
Mv	Morainal diamicton: mainly basal till deposits, < 1 m thick	good	often 10s to 100s m; varies with topography	down-ice, linear ribbon or narrow fan shape	1:5 000 to 1:50 000; S, C, T, HM
Mb	Morainal diamicton: dominantly basal tills, 1 to 10s of m thick	good to moderate	~100 m to ~2 km, increases with thickness	down-ice, narrow or elongated fan	1:5 000 to 1:100 000; S, C, T, HM
MODERATE POTENTIAL					
Mu,h	Resedimented morainal diamicton: (often with glaciofluvial (F^G) veneer)	moderate; poor if transport is supraglacial	100s m to ~ 5 km; many km if supraglacial	down-ice, broad, elongated fans	1:10 000 to 1:100 000; S, C, T, HM
LOW POTENTIAL					
F^G, F	glaciofluvial and fluvial gravels and sands: often 1 to 10s of m thick	generally poor; may be moderate if shallow	100s m to 10s km; thickness dependent in part	down-flow, discontinuous ribbons and fans	1:50 000 to 1:250 000 (mainly regional scale); C, HM
VERY LOW POTENTIAL					
L^G	glaciolacustrine silt, fine sand and clay: often 1 to 10s of m thick	generally very poor	generally 10s km or more (basin wide)	discontinuous; irregular; possible textural control	1:100 000 to 1:250 000 (regional scale): N

[1] Analysis excludes common geochemical sample media such as modern lake, organic and stream sediments.
[2] Transport distances are approximate and refer to the bulk (but generally not all) of the sediment.
[3] Refers to mechanical dispersal by sedimentary processes (does not include hydromorphic dispersion patterns).
[4] S- soil geochemistry; T - till geochemistry; C - clast provenance surveys (boulder tracing, clast indicator surveys, pebble lithology studies); HM - heavy mineral sampling; N - not recommended for sampling in most cases. See text for explanation.

indicated by bedrock exposures in the area. Likewise, gold concentrations in till at the Malaput showing, that are several times higher than in assayed bedrock, suggest that a more significant mineralized zone is yet to be found there.

DRIFT EXPLORATION POTENTIAL

Drift exploration potential, also known as drift prospecting potential, refers to the ease with which a surficial sediment can be traced back to its original bedrock source using common methods of sampling near-surface sediments (Levson *et al.*, 1994; Proudfoot *et al.*, 1995). Maps that portray drift exploration potential on a regional basis are derived from surficial geology or terrain map data (*e.g.*, Giles and Levson, 1994b; Levson and Giles, 1994). Maps with a similar theme have also been referred to as sample reliability maps (Kerr *et al.*, 1992) and sample media confidence maps (Meldrum and Bobrowsky, 1994). The use of the concept in the Interior Plateau is discussed at length by Levson *et al.* (1994) and is summarized in Table 4.

Drift exploration potential refers only to the relative usefulness of different surficial sediments for geochemical, lithological and heavy mineral sampling programs, particularly those conducted at property scales (~ 1:5000 or more detailed), and does not apply to other types of surveys such as biogeochemistry, vapour geochemistry, lake and stream sediment geochemistry and geophysical surveys. Factors involved in determining drift exploration potential include sediment genesis, number of erosional and depositional cycles (derivative phases), sediment thickness, transport distance (proximity to source) and the size, shape and continuity of the dispersal plumes. Mechanical dispersal by glacial, colluvial, fluvial and other sedimentary processes is considered in the assessment, whereas the effects of hydromorphic dispersion or weathering are not directly included. Drift exploration potential maps are intended primarily to aid in the planning of exploration surveys. The use of mapped drift exploration categories to select priority sampling areas saves time and effort and also yields more useful information than indiscriminate surveys. This approach thus provides a cost-effective means of conducting an exploration program and also has greater potential for success than sampling programs that do not discriminate between different surficial sediment types.

The drift exploration potential of each of the main types of surficial materials in the Interior Plateau is categorized into very high, high, moderate, low and very low in Table 4. During anomaly follow-up surveys, sampling of surficial materials with high or very high potential will provide results that are more readily interpreted and more likely to lead to the discovery of the source of the anomaly, than will sampling sediments with lower potential. The main characteristics of each of five different drift exploration categories are summarized in Table 4; the probable dispersal pattern of mineralization and the applicable type and scale of survey to locate such mineralization are also indicated. Transport distance is the expected distance of sediment travel, measured from the bedrock source to the place of deposition. It may vary substantially, within each sediment type, due to variations in the entrainment, transport and depositional processes and variable effects of factors such as grain size and topography. For these reasons, sediment transport distances must be determined for each deposit of interest and distances cited in the table should only be used as a general guide.

In addition to transport distance, traceability to bedrock source is a reflection of the number of derivative phases and the processes of dispersal. One cycle of erosion, transport and deposition of bedrock material to form a sedimentary deposit is considered to be one derivative phase (Shilts, 1993). If the sediment is then re-eroded, transported and redeposited, then the sediment is a second derivative. Colluvial deposits are first derivatives of bedrock and they can be traced up-slope along linear to fan-shaped dispersal paths, commonly less than 100 metres long, to their original source. These deposits typically consist of unsorted or very poorly sorted diamicton with abundant angular clasts of bedrock. Basal till, formed of comminuted bedrock material, transported by ice and deposited directly by lodgement or melt-out processes, is also a first derivative of bedrock. Basal tills are considered to have high drift exploration potential as they can be readily traced to their bedrock sources in an up-glacier direction along linear cigar-shaped or narrow, elongated, fan-shaped dispersal paths (*e.g.*, Figure 4). Thin tills tend to be closer to source than thicker tills but anomalous element concentrations, in both cases, are separated or offset from the bedrock source by an area of 'barren' sediment with background or only slightly elevated element concentrations.

Resedimented glacial deposits are considered to be second derivatives and have a moderate drift exploration potential. Dispersal paths in these deposits are typically dominated by a down-ice component modified to varying degrees (depending mainly on local relief) by down-slope movement. Morainal sediments in areas of hummocky topography are even more difficult to trace to source, due to their more complicated sedimentary history.

Secondary dispersal vectors in these deposits are often chaotic and difficult to determine, sometimes being more related to the position of former ice blocks than the present topography. Pebble fabric analyses, however, can help decipher the last direction of debris-flow movement. Distance of transport is largely dependent on the original position of transportation within the glacier, more distally derived deposits generally being derived from higher levels in the ice. Supraglacial deposits are typically the farthest traveled, sometimes exceeding tens or even hundreds of kilometres. They have low drift exploration potential and must be differentiated in the field from other resedimented glacial deposits by characteristics such as abundant, far-traveled erratics, that are commonly angular with few or no glacial abrasion features, and by sedimentologic studies.

Glaciofluvial sediments, derived from till or from material within the ice, have undergone at least two episodes of transport and are viewed as second or third derivatives of bedrock. Transport distances are highly variable and dependent on factors such as paleostream energy, bedrock lithology (resistance to abrasion) and grain size. Processes of entrainment, transportation and redeposition result in discontinuous, irregular, often sinuous dispersal patterns. These deposits are not expected to reflect nearby mineralization except in areas where they are less than a few metres thick and erosionally overlie bedrock. Glaciolacustrine sediments are at least third-derivative sedimentary products of bedrock, invariably having undergone multiple cycles of erosion, transportation and deposition by glaciers, streams and finally in the lacustrine environment. Due to this complex history, the potential for locating the original source of any mineralized material that may be discovered in these sediments is very low. Geochemical anomalies in glaciolacustrine sediments are more likely to reflect grain size or sedimentologic controls such as heavy mineral concentrations in coarser beach sands, than bedrock sources. In addition, these deposits are often comprised of sediment transported from a wide region and the potential for dilution of mineralized material by barren sediment is therefore much higher.

SUMMARY

Morainal sediments deposited during the last glaciation are widespread in the Interior Plateau and form a cover, varying in average thickness from a few to several metres in low-lying areas, to less than a metre in upland regions. 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. Glaciolacustrine sediments are common in some valleys, generally at elevations below 750 to 950 metres, often near modern lakes. Stratigraphic studies of Quaternary deposits in the region indicate ice damming during both advance and retreat stages of the last glaciation. The Late Wisconsinan ice-flow record in most areas is dominated by one regional flow direction. In areas of relatively high relief, the regional flow was modified by topographic control during both early and late stages of glaciation. Glacial dispersal patterns in most areas tend to reflect mainly the influence of the last regional flow direction and they are not obscured by the effects of topography or earlier glaciations.

Soil geochemical anomalies associated with glacial dispersal of mineralized bedrock in the region are up to a few kilometres long and several hundred metres or more wide, but isolated anomalies associated with the dispersal trains may cover much larger areas. Erratics trains and till geochemical anomalies are up to several kilometres long and more readily detected than soil anomalies. They show a pronounced elongation parallel to ice-flow direction, with mineralized source rocks occurring at or near the up-ice end of the trains and dispersal plumes. 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 metres or more down-ice from their bedrock source. Subsurface exploration targets in these areas should be up-ice, rather than at the head, of the geochemical anomaly.

Results of till geochemical surveys indicate that basal till sampling programs are an effective tool for locating mineralized zones in drift-covered parts of the Interior Plateau. To reflect mechanical dispersal processes, samples should be collected from within the C mineral soil horizon. Sedimentologic data should be collected at all sample sites in order to distinguish till from glacigenic debris-flow, colluvial, glaciofluvial or glaciolacustrine sediments. These sediments have different processes of transportation and deposition which must be recognized in order to understand associated mineral anomaly patterns. Local variations will be reflected in some sediments while regional trends may be evident in others. Analysis of these sediments will be useful only if their origin is understood.

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 in this region. Interpretation of data with respect to glaciation may provide new avenues to explore for bedrock sources of mineralized float or geochemically anomalous soil samples.

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RECONNAISSANCE TILL GEOCHEMISTRY ON THE CHILCOTIN PLATEAU (92O/5 AND 12)

By A. Plouffe, Geological Survey of Canada

Geological Survey of Canada Contribution 22495

KEYWORDS: Drift prospecting, applied geochemistry, mineral exploration, ice-flow direction, till, glaciofluvial sediments, dispersal train, porphyry copper-gold.

INTRODUCTION

As part of the Canada - British Columbia Agreement on Mineral Development (1991-1995), a reconnaissance surficial sediment sampling program was carried out in 1992 and 1993 over the Chilcotin Plateau, in west-central British Columbia (Figure 1). The survey was designed for two purposes: to test the potential of drift prospecting for detecting mineralization, and to determine background metal concentrations in surficial sediments. A total of 118 till and 26 glaciofluvial sediment samples were collected during this survey (Figure 2).

The Chilcotin Plateau was selected for investigation because it hosts several important deposits such as the Fish Lake porphyry copper-gold deposit. It is characterized by an extensive cover of unconsolidated sediments which inhibit the use of conventional exploration methods and glacial ice-flow history in the area is uncomplicated (Figure 3), facilitating the use of drift prospecting methods.

Plouffe and Ballantyne (1994) presented brief notes on the glacial history of the area and the results of geochemical analyses of till and glaciofluvial samples. The objectives of this report are to summarize the ice-flow history, to elaborate on the interpretations of geochemical anomalies in till, and relate geochemical data for till to geophysical and biogeochemical data obtained from other studies. New geochemical data for till samples from the Newton Hill area are also presented.

LOCATION AND PHYSIOGRAPHY

The study area covers two 1:50 000-scale NTS map sheets : 92O/5 and O/12 (Mount Tatlow and Elkin Creek, respectively) and extends over the southern part of a third map 92O/13 which covers the Newton Hill area (Figures 1 and 2). The southwestern part of the study area lies in the

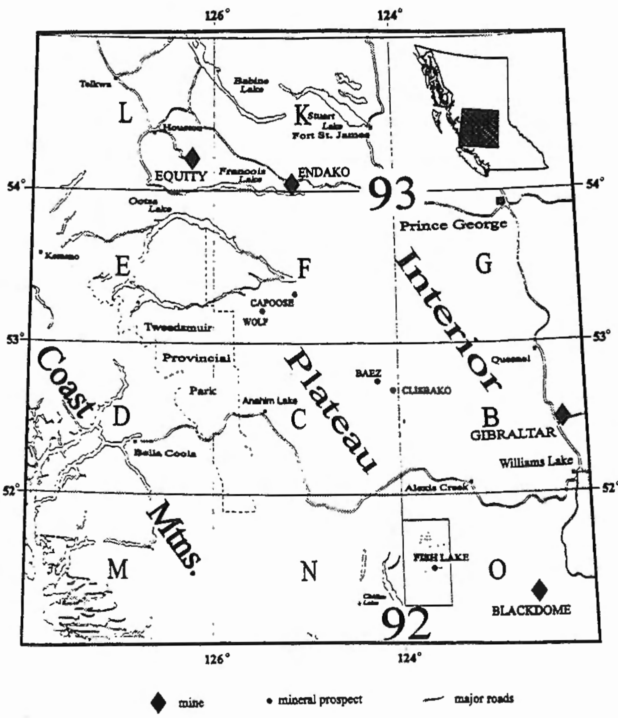

Figure 1. Study area location.

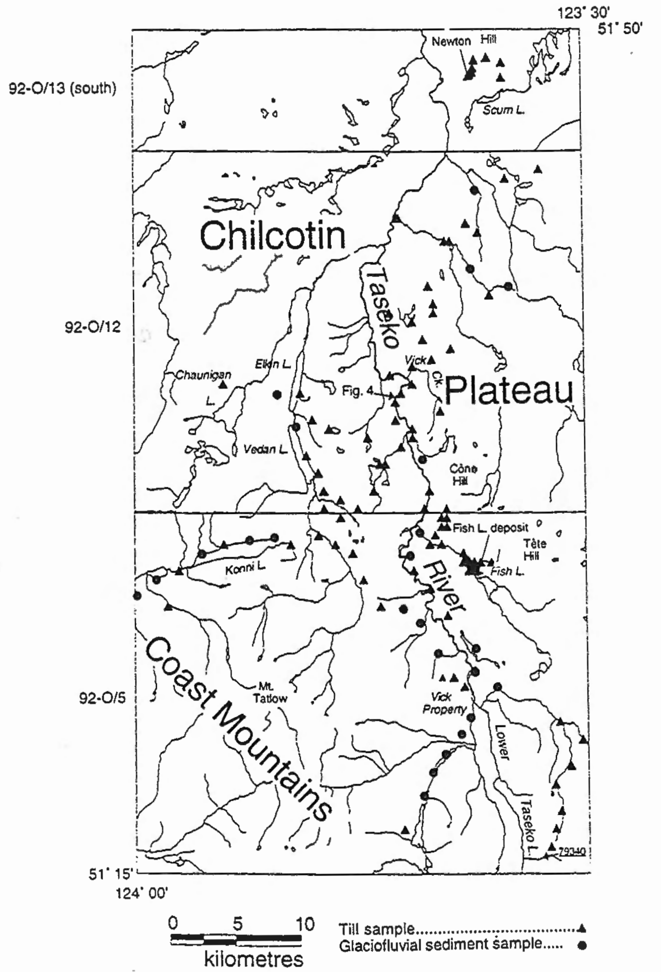

Figure 2. Till and glaciofluvial sediment sample locations.

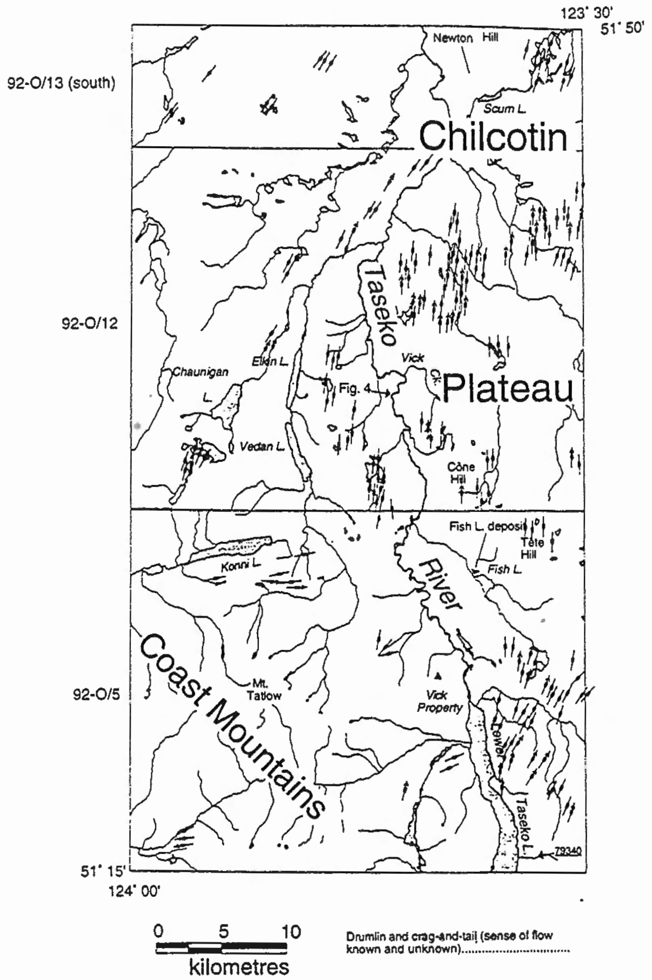

Figure 3. Major physiographic divisions and ice-flow patterns reconstructed from drumlin, fluting, and glacial striation orientations. Modified from Heginbottom (1972), Huntley and Broster (1993) and Plouffe and Ballantyne (1994).

Pacific Ranges of the Coast Mountains (Mathews, 1986) which are characterized by peaks and arêtes with summits of more than 2400 metres above sea level (8000 ft). No sampling was undertaken in the Coast Mountains because of poor accessibility. The remainder of the area, where all sampling was completed, forms part of the Chilcotin Plateau, which has a rolling to relatively flat landscape and an average elevation of 1400 metres (4500 ft). Tête and Cone hills, with elevations of 1818 metres (6000 ft) and 1758 metres (5800 ft) respectively, are prominent topographic features on the plateau surface.

METHODOLOGY

FIELDWORK

At the beginning of the survey, till was selected as the only sampling medium for two reasons. First, as sediment directly deposited by ice, till represents the first derivative of bedrock (Shilts, 1993) and second, the uncomplicated ice-flow history of the area facilitates its use for prospecting purposes. However, it became apparent that most valleys are filled with thick accumulations of glaciofluvial sand and gravel and that till exposures are not present. Consequently, glaciofluvial sediments were sampled in those valleys.

Samples were collected in hand-dug pits, roadside sections and river bluffs at a minimum depth of 1 metre. Care was taken to collect samples below the depth of maximum oxidation (B-horizon) in the transitional zone between the B and C-horizons. During the first year of this survey, detailed sampling was completed on the Fish Lake property, in order to establish the mineralization signature in surficial sediments (Figure 2). Sample intervals along roads average 2 kilometres.

SELECTED GRAIN SIZE FRACTIONS FOR GEOCHEMICAL ANALYSES

Previous studies of metal partitioning in till indicate that base metals tend to concentrate in the clay-size fraction material (DiLabio, 1995; Nikkarinen *et al.*,1984; Shilts, 1984; 1995). At Fish Lake and other test sites, gold in till is concentrated in the silt-size fraction (Delaney and Fletcher, 1993, 1995; DiLabio, 1982a, 1982b, 1985, 1988). Consequently, all geochemical analyses were conducted on the silt plus clay-size fraction (<63 µm, -230 mesh). In order to test the usefulness of the clay-size fraction in comparison to the silt plus clay-size fraction for prospecting in the area, multi-element analyses were also completed on the clay-size fraction of the 1993 samples. The silt plus clay-size fraction was analyzed for 31 elements (Ag, Al, As, Ba, Be, Bi, Ca, Cd, Co, Cr, Cu, Fe, Ga, K, La, Mg, Mn, Mo, Na, Ni, P, Pb, Sb, Sc, Sr, Ti, Tl, U, V, W and Zn) by inductively coupled plasma-atomic emission spectrometry (ICP-AES) following an aqua regia digestion at Chemex Labs Ltd. in North Vancouver, British Columbia, and for 35 elements (Au, Ag, As, Ba, Br, Ca, Co, Cr, Cs, Fe, Hf, Hg, Ir, Mo, Na, Ni, Rb, Sb, Sc, Se, Sn, Sr, Ta, Th, U, W, Zn, La, Ce, Nd, Sm, Eu, Tb, Yb and Lu) by instrumental neutron activation analyses (INAA) at Activation Laboratories Ltd. in Ancaster, Ontario. The clay-size fraction was only analyzed by ICP-AES, also following an aqua regia digestion. Data on quality controls are reported in Plouffe and Ballantyne (1994).

Geochemical results for both grain-size fractions (<2 µm and <63 µm) are presented in a spreadsheet format in three ASCII files (tab delimited) together with a sample location file on CD-ROM (Table 1).

BEDROCK GEOLOGY

The study area lies along the eastern margin of the Coast Belt (Riddell *et al.*, 1993b; Monger, 1986). It is underlain by late Paleozoic to Cretaceous bedrock lithologies which were originally deposited in ocean basin, volcanic arc and clastic basin environments (Riddell *et al.*, 1993b). These rocks were accreted to North America dur-

TABLE 1
LIST OF DIGITAL FILES ON CD-ROM

Name of file	Content
README.1ST	Information about files format and content
2ICP.TXT	Geochemical results - clay-size fraction (<2 µm) - ICP-AES (till and glaciofluvial sediment samples)
63ICP.TXT	Geochemical results - silt plus clay-size fraction (<63 µm) - ICP-AES (till and glaciofluvial sediment samples)
63NA.TXT	Geochemical results - silt plus clay-size fraction (<63 µm) - INAA (till and glaciofluvial sediment samples)
LOC.TXT	Sample information: number, type, location (latitude, longitude and UTM coordinates).

ing Jurassic to Cretaceous time. They are intruded by granitic rocks of Cretaceous and Tertiary age and are overlain by Neogene plateau lavas (Riddell *et al.*, 1993b). The two major mineralized zones in the area are located at Fish Lake (porphyry Au-Cu) and Newton Hill (epithermal), in windows through the Eocene cover.

Tipper (1978) presents a regional bedrock geology map of the area which was revised by more recent mapping (Hickson, 1993; Hickson and Higman, 1993; Riddell *et al.*, 1993a, 1993b). The Fish Lake area was also mapped in detail by Wolfhard (1976) as part of mineral exploration investigations. The reader is referred to these publications and to Schiarizza and Riddell (1997, this volume) for more detailed descriptions of the bedrock geology.

GLACIAL GEOLOGY

Heginbottom (1972), Huntley and Broster (1993) and Plouffe and Ballantyne (1994) present data on patterns of glacial ice-flow within the study area during the Fraser Glaciation (*i.e.* the last glaciation) which are summarized below and in Figure 3. At the onset of the glaciation, valley glaciers advanced to the north, south and west from accumulation zones in the Pacific Ranges. During the initial stage, when ice was thin, glaciers where confined to the major valleys and flow patterns were controlled by topography. As ice accumulated, valley glaciers coalesced into piedmont glaciers which soon invaded the higher areas. At the glaciation climax, ice on the Chilcotin Plateau was flowing to the north, north-northeast and northeast (Figure 3).

Deglaciation is thought to have taken place by a combination of processes: rapid frontal retreat towards the accumulation zones and ice stagnation (Fulton, 1967, 1991). In some places, ice in the valleys influenced and modified the drainage pattern. For example, meltwater channels in Vick and Fish Creek valleys formed at a time when Taseko valley was plugged by ice so that the northward drainage was taking place on higher ground and along the ice margin. Drainage into the Taseko valley was re-established when the obstructing ice melted. Thick

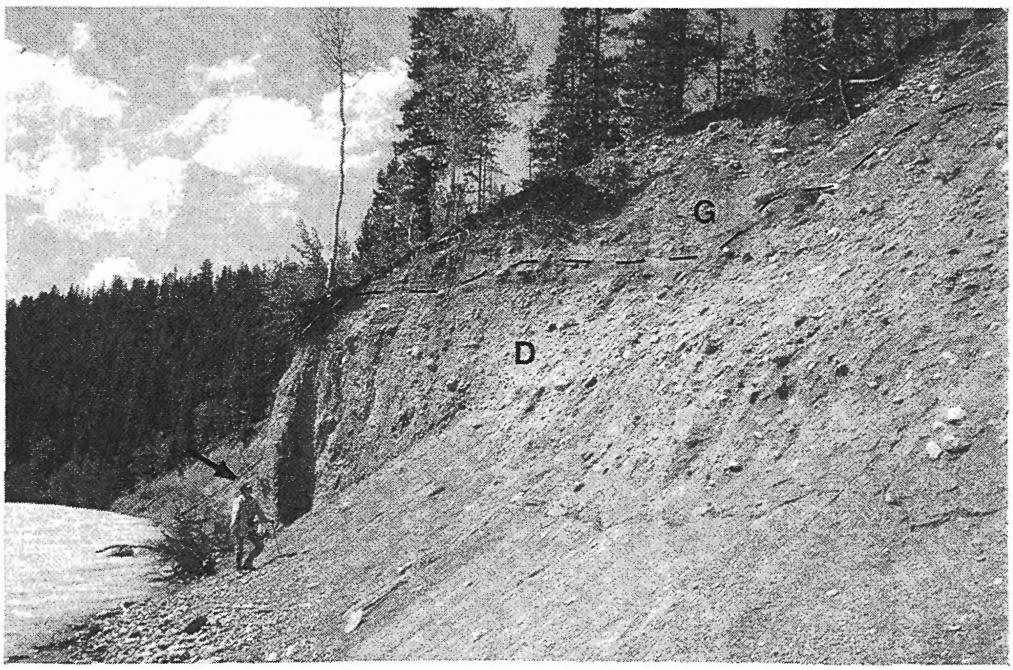

Photo 1. Glaciofluvial sediments (G) underlain by a diamicton (D) along Taseko River (*see* Figure 2 for location).

accumulations of glaciofluvial sand and gravel were deposited in the valley during ice retreat (Photo 1).

RESULTS

Geochemical results for till and glaciofluvial sediments are treated separately in this report, for the following reasons:

- The two sediment types have been transported by different media (till by ice and glaciofluvial sediments by ice and water) and, consequently, have been transported over differing distances and directions.
- Within the study area, glaciofluvial sediments are consistently more sandy and, hence, more porous than till. As a result, the depth of oxidation is greater in glaciofluvial deposits and, consequently, they contain a greater proportion of iron and manganese oxides. Shilts (1972) demonstrates that metal concentrations in glaciofluvial sediments are commonly higher than in the surrounding till, which he attributes to the coprecipitation of metals with iron and manganese oxides and hydroxides during weathering. These conclusions seem to be applicable to this study area as background base metal concentrations are slightly higher in glaciofluvial sediments than in till. For example, the average copper concentration in till away from mineralized zones is 44 ppm and in glaciofluvial sediments 61 ppm.

FISH LAKE MINERALIZED ZONE AND VICINITY

A multi-element geochemical anomaly has been detected in till directly overlying the Fish Lake porphyry copper-gold deposit. It consists of high levels of gold (16 ppb), arsenic (15 ppm), copper (166 ppm), nickel (70 ppm) and antimony (2.3 ppm) (Figures 4 to 8). Moderately high cobalt (18 ppm) and chromium (62 ppm) concentrations are also present, but of smaller extent (Figures 9, 10). High gold (37 ppb) and copper (162 ppm) levels were also detected in the glaciofluvial sediments (Figures 11,12). This multi-element anomaly extends to the northwest of

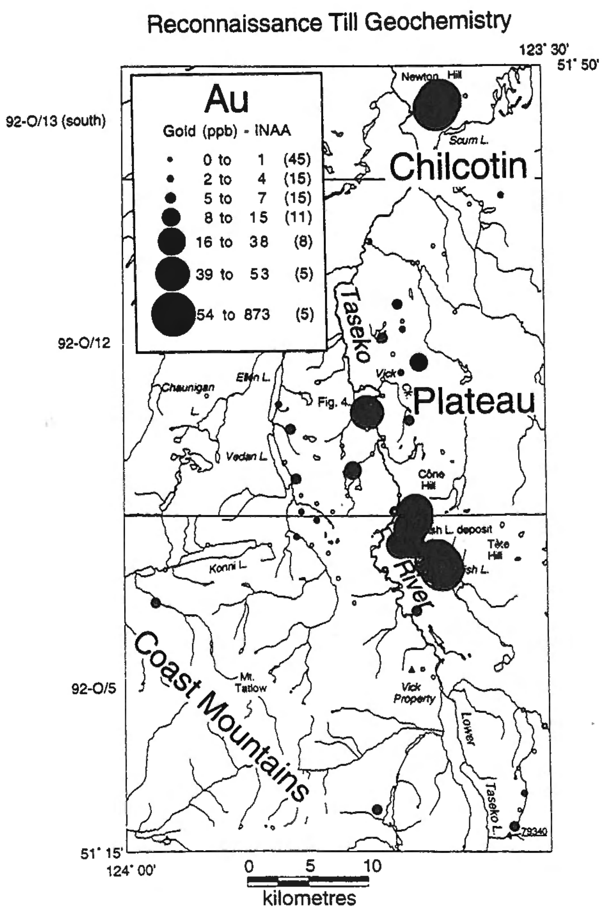

Figure 4. Gold in the silt plus clay size fraction (<63µm - 230 mesh) of till. Analyses completed by instrumental neutron activation technology.

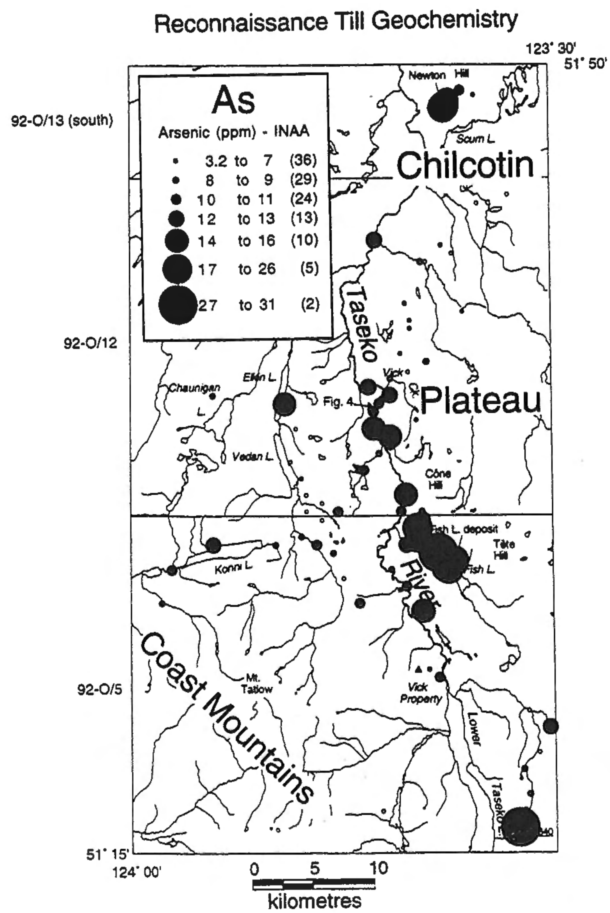

Figure 5. Arsenic in the silt plus clay size fraction (<63µm - 230 mesh) of till. Analyses completed by instrumental neutron activation technology.

Fish Lake, where Pioneer Metals Corporation identified drilling targets in the basis of soil geochemical and induced polarization anomalies (D. Dunn, personal communication, 1994). Although this multi-element anomaly in till does not directly overlap with biogeochemical anomalies (Dunn, 1997, this volume), high levels of gold, arsenic and nickel were detected in needles of lodgepole pine tree-tops in the near vicinity.

TASEKO VALLEY

A single sample significant gold anomaly (45 ppb) in till was detected in Taseko valley directly west of Vick Creek. There are moderate levels of arsenic (15 ppb) and high concentrations of mercury (1000 ppb) to the south (Figure 5). Of economic significance is the fact that this anomaly is located on the flank of a total field aeromagnetic anomaly (Teskey, *et al.*, 1997, this volume) and on the northern end of a major gamma ray potassium anomaly which parallels the Taseko valley [Shives, 1995, (Figure 13]. However, the potassium anomaly may be related to the presence of thick, well drained accumulations of glaciofluvial sand and gravel as gamma ray emissions are generally greater from dry soils (Shives *et al.*, 1995). High concentrations of zinc (151 ppm) and cobalt (20 ppm) in the till, and of nickel and molybdenum in needles from tree tops (Dunn, 1997, this volume), were also detected near the aeromagnetic anomaly. No mineral occurrences are shown on bedrock maps for this sector of the Taseko River (Hickson, 1993; Hickson and Higman, 1993).

VICK PROSPECT

The Vick prospect is located northwest of Lower Taseko Lake (Figure 2) and consists of a series of northeast-striking gold, silver and copper-bearing quartz-sulphide veins which extend from the top of the hill to its east face (Riddell *et al.*, 1993b). Two till samples collected east of the prospect in the Taseko valley have higher concentrations of gold (15 ppb), arsenic (11 ppm), cobalt (24 ppm), chromium (67 ppm), copper (69 ppm), mercury (530 ppb) and nickel (63 ppm) than at least 90% of the samples collected in this project (Figures 4 to 10). Anomalous levels of these elements in till are closely associated with high

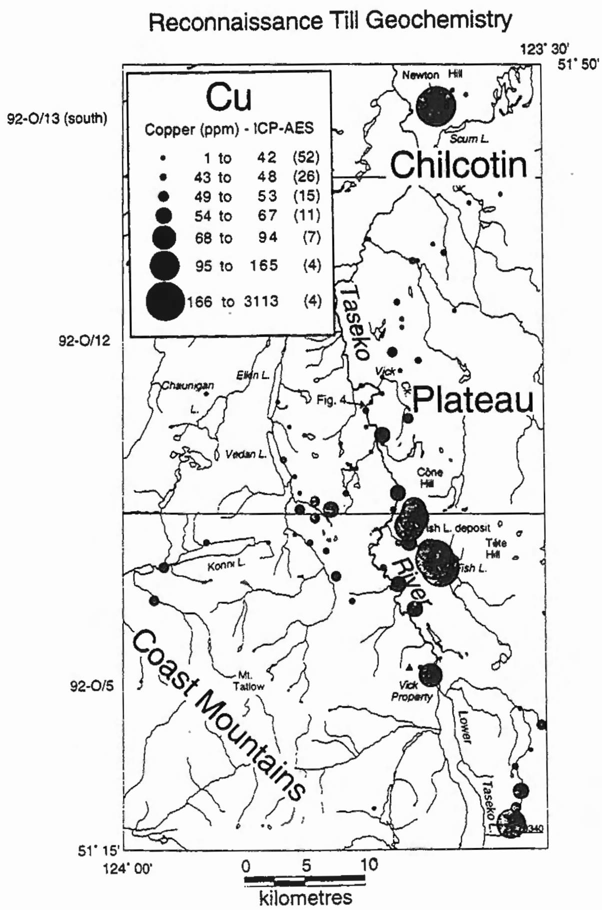

Figure 6. Copper in the silt plus clay size fraction (<63μm - 230 mesh) of till. Analyses completed by inductively coupled plasma-atomic emission spectrometry.

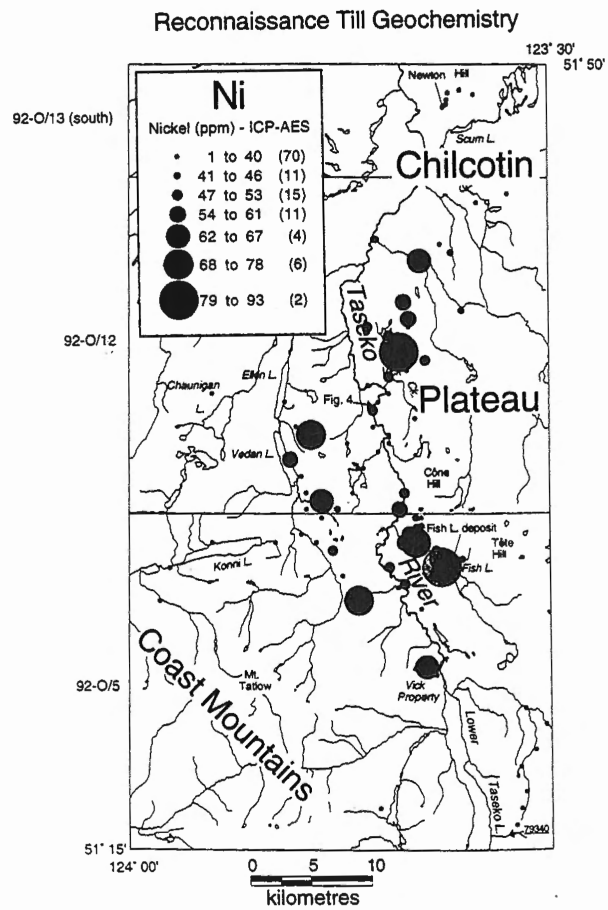

Figure 7. Nickel in the silt plus clay size fraction >63μm - 230 mesh) of till. Analyses completed by inductively coupled plasma-atomic emission spectrometry.

concentrations of arsenic, cesium and copper measured in needles of lodgepole pine tree-tops in the same area (Dunn, 1997, this volume). Although the orientation of glacial striations or macro ice-flow indicators have not been measured in this area, it is likely that debris from the veins was transported to the east and northeast by ice flowing out of the Pacific Ranges down into the Taseko valley. Thus, high metal levels measured in till and in needles of lodgepole pine were probably derived from the mineralized veins.

TILL GEOCHEMISTRY VS. REGIONAL GEOCHEMICAL SURVEY (RGS)

Following the re-analysis of stream sediment samples collected during the Regional Geochemical Survey, an important coincident copper-arsenic-gold anomaly was detected in an unnamed creek east of Lower Taseko Lake (sample 793140; Figure 2; Jackaman *et al.*, 1992). Till samples collected down-ice from the creek watershed also contained high arsenic (31 ppm), copper (100 ppm) and zinc (154 ppm) levels (Figures 5, 6 and 14). A fault and two hornblende feldspar porphyry bodies have been mapped by Riddell *et al.* (1993a) in the vicinity. The source of the till and stream sediment anomalies is possibly linked and may be related to an unknown mineral occurrence.

NEWTON HILL

The Newton Hill area is underlain by Upper Cretaceous sedimentary and volcanic bedrock which has been intruded by felsic dikes, sills and stocks of Eocene age (Durfeld, 1991). These rocks are affected by hydrothermal alteration, with kaolinite and sericite being the dominant replacement minerals. The alteration event is thought to be related to the Eocene intrusion and occurred with pyritization and gold-copper mineralization. Soil sampling conducted in 1987, 1988 and 1989 showed gold and pathfinder element anomalies (Ag, As, Cu and Hg; Durfeld, 1991).

Till samples collected on Newton Hill and to the north and northeast (*i.e.* down-ice) contain high concentrations of gold (720 ppb), arsenic (23 ppm), copper (437 ppm), mercury (500 ppb), antimony (6.1 ppm) and zinc (188 ppm) (Figures 4, 5, 6, 8, 14 and 15). These geochemical anomalies in the till are also concordant with the high potassium,

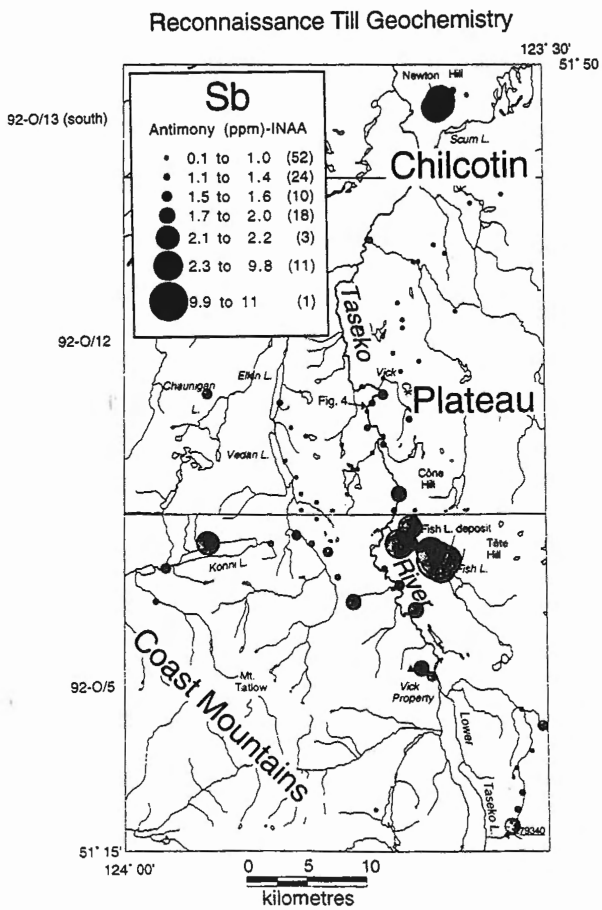

Figure 8. Antimony in the silt plus clay size fraction (<63µm - 230 mesh) of till. Analyses completed by instrumental neutron activation technology.

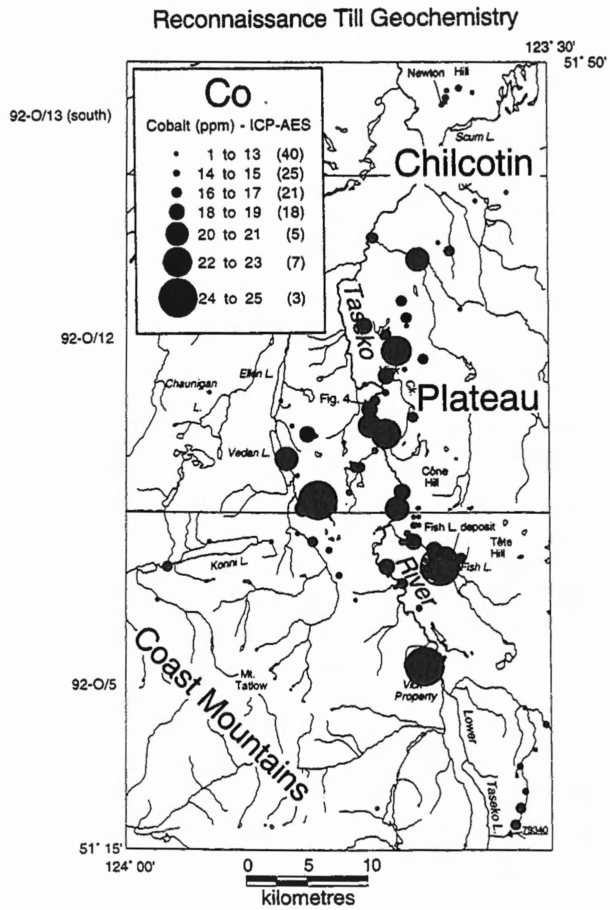

Figure 9. Cobalt in the silt plus clay size fraction (<63µm - 230 mesh) of till. Analyses completed by inductively coupled plasma-atomic emission spectrometry.

uranium and thorium concentrations measured for Newton Hill (Shives, *et al.*, 1995) and a significant total field aeromagnetic anomaly (Teskey, *et al.*, 1997, this volume) (Figure 13).

DISCUSSION

GLACIAL TRANSPORT

The Chilcotin Plateau is characterized by a thick cover of poorly indurated Tertiary sedimentary and volcanic bedrock which was extensively eroded by ice and water during the last glaciation. In contrast, the intrusive rocks hosting porphyry mineralization of the Fish Lake deposit were less susceptible to glacial erosion. They are massive, have a small outcrop area and are located in a low-lying area. It can therefore be assumed that unmineralized debris in the ice was diluting any small amount of mineralized material derived from the mineralized zone. The till sample density in the Fish Lake area is not high enough to reliably establish the length of the glacial dispersal train of detectable gold and base metals (see DiLabio, 1990). However, because of the effects of dilution, the geochemical anomalies in till in the Fish Lake area are all very small in area. Likewise, results of the airborne gamma ray survey do not show a potassium anomaly over the Fish Lake deposit (Shives, 1995), suggesting that the altered zone is masked by unmineralized debris derived from the surrounding Tertiary bedrock.

Unlike the Fish Lake deposit, the mineralized zone on Newton Hill was more readily available for glacial erosion as the altered rocks are poorly indurated and located on a topographic high. Consequently, if the mineralized zone on Newton Hill is the sole source of gold, the minimum length of the gold dispersal train is estimated at 1.1 kilometres.

A major impediment to mineral exploration in the area is the thick Eocene volcanic and sedimentary bedrock cover. Fish Lake (porphyry Au-Cu) and Newton Hill (epithermal), the two major known mineralized zones, occur in windows through the Eocene cover. A combination of geochemical (surficial sediments and plants) and geophysical exploration techniques in conjunction with bedrock geology mapping might serve to define more inliers of economic significance within the Eocene volcanics.

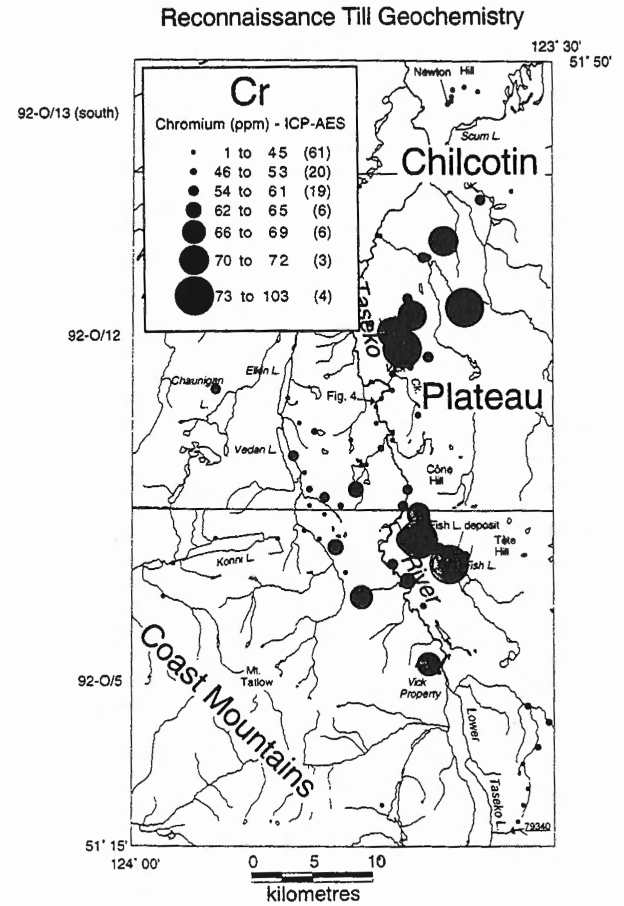

Figure 10. Chromium in the silt plus clay size fraction (63µm — 230 mesh) of till. Analyses completed by inductively instrumental neutron activation analyses.

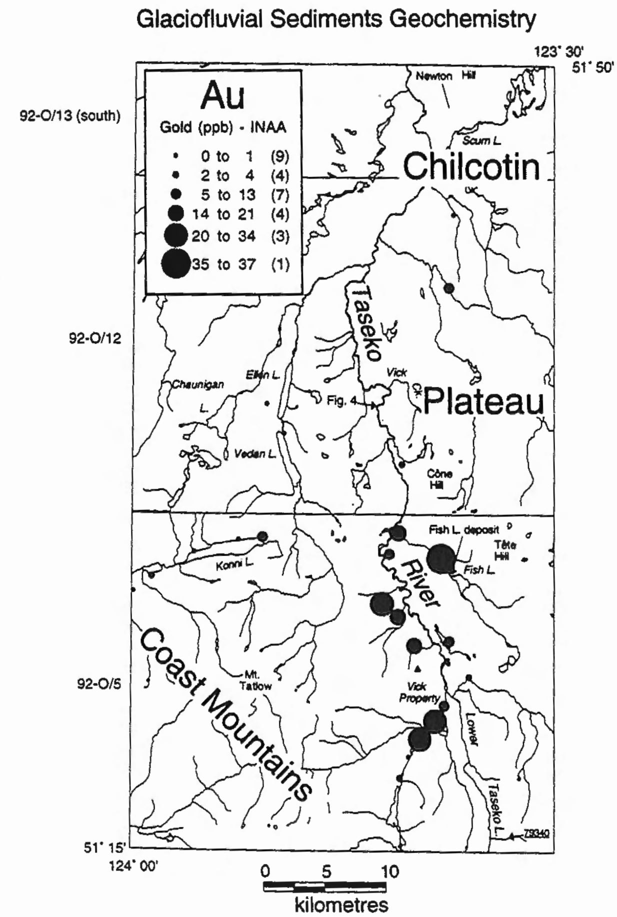

Figure 11. Gold in the silt plus clay (63µm — 230 mesh) size fraction of glaciofluvial sediments. Analyses completed by instrumental neutron activation analysis.

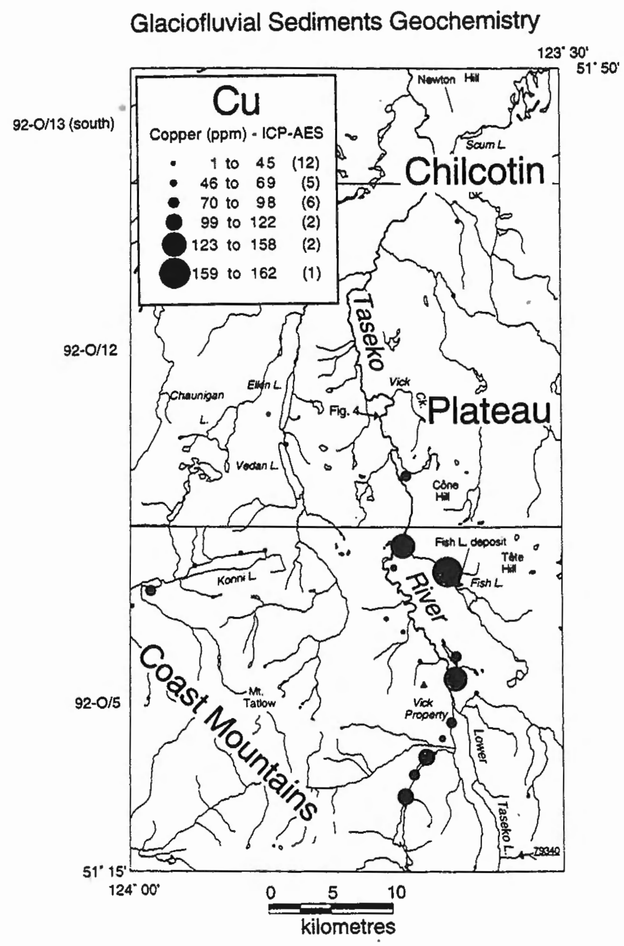

Figure 12. Copper in the silt plus clay (<63µm - 230 mesh) size fraction of glaciofluvial sediments. Analyses completed by inductively coupled pasma-atomic emission spectrometry.

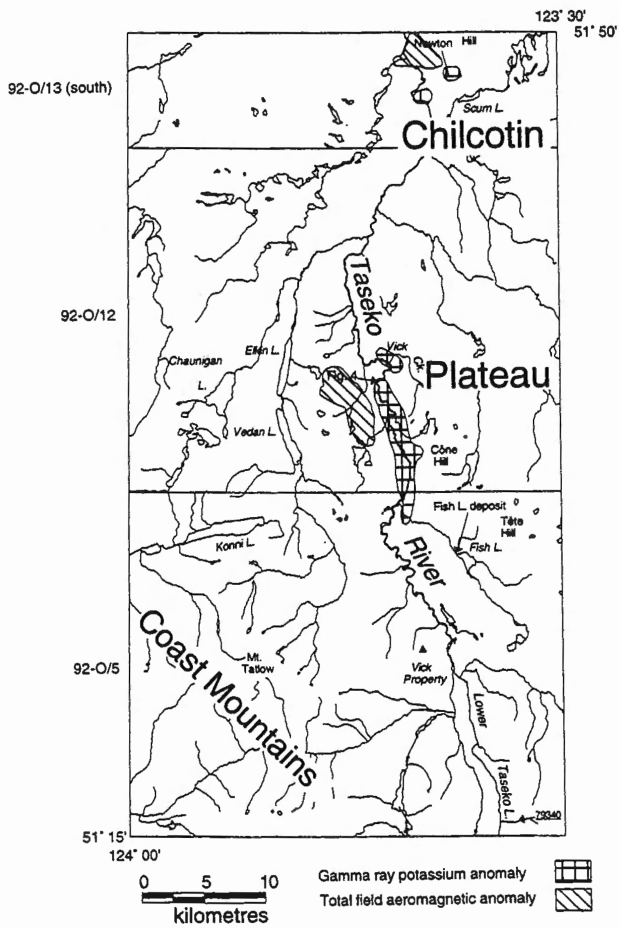

Figure 13. Gamma ray, potassium (approximately >0.92%K) and total field aeromagnetic (approximately >57 500 n tesla) anomalies in the Fish Lake area, as mentioned in the text. Data from Teskey, *et al.*, (1996, this volume).

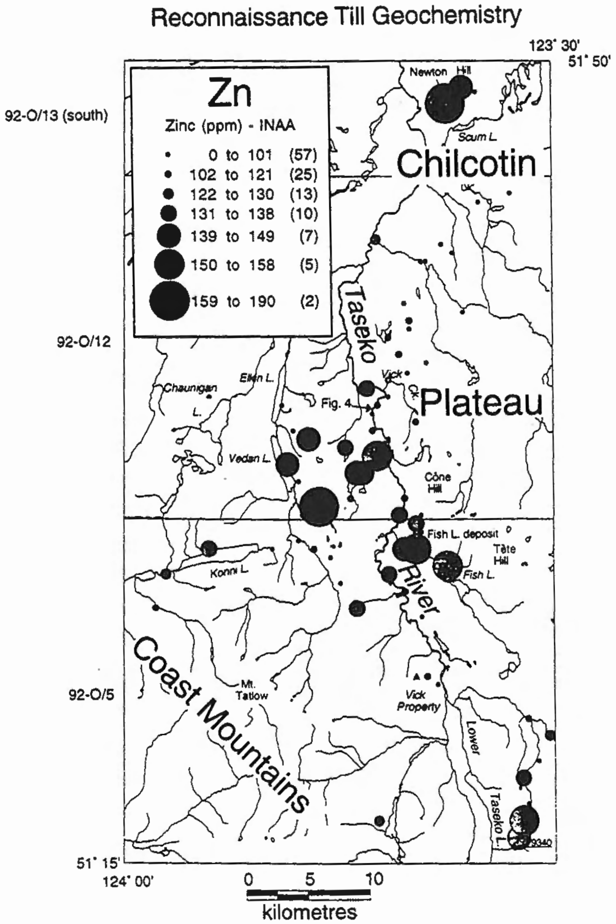

Figure 14. Zinc in the silt plus clay size fraction (<63µm - 230 mesh) of till. Analyses completed by instrumental neutron activation analysis.

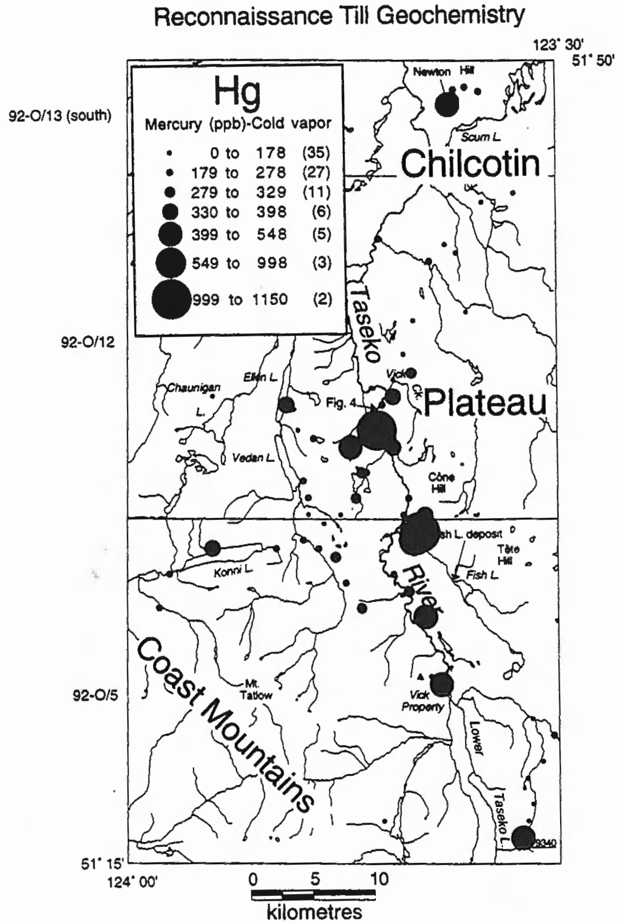

Figure 15. Mercury in the silt plus clay size (<63µm - 230 mesh) of till. Analyses completed by instrumental neutron activation analysis.

FUTURE ENVIRONMENTAL ASSESSMENT

The data presented in this and other reports [Plouffe and Ballantyne, 1994; Dunn (1997, this volume)] provide baseline information on background concentrations of metals and thus, serve as an aid to mineral exploration. These data may also be useful in the future for environmental assessment work in the area, as they demonstrate that natural metal background concentrations in surficial material in the Taseko valley vary over short distances. For example, the high levels of mercury in till encountered sporadically in the area (Figure 15) may be related to the presence of faults (Azzaria, 1992; Rasmussen, 1993; Plouffe, in press) or cinnabar occurrences.

ACKNOWLEDGMENTS

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DRIFT PROSPECTING ACTIVITIES IN BRITISH COLUMBIA: AN OVERVIEW WITH EMPHASIS ON THE INTERIOR PLATEAU

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Geological Survey of Canada Contribution No. 1996601)

KEYWORDS: Surficial geology, Quaternary stratigraphy, drift prospecting, till geochemistry, clast provenance, soil geochemistry, biogeochemistry

INTRODUCTION

Drift prospecting is playing an increasingly greater role in the search for mineral resources in British Columbia, as exploration progresses into areas with extensive surficial sediments and complex glacial histories. Yet, relatively few detailed studies, in the province, have been published that integrate geochemical and geophysical surveys with surficial geology and glacial history data. Drift prospecting, used here in its most general sense, includes all types of exploration activities for mineral deposits covered by surficial, especially glacial, deposits (drift). This paper provides an overview of drift prospecting studies in British Columbia (Figure 1) for the purpose of planning and assessing the usefulness and application of different techniques. Several different types of drift prospecting methods are discussed, focusing mainly on geological and geochemical techniques. For more detailed information on specific methods and case studies in British Columbia, reference should be made to an annotated bibliography on drift prospecting recently compiled as a research tool for mineral exploration in drift-covered areas (Kerr and Levson, 1995).

Emphasis in this paper is placed on drift prospecting activities in the British Columbia Interior physiographic system (Holland, 1976) where the greatest number of published drift-prospecting investigations have been carried out in the province (Figure 1). The highest concentrations of research are in the central and southern Interior; relatively little has been published on research in the Coast Mountains or Rocky Mountains.

The Interior System is the largest and most diversified physiographic subdivision in British Columbia and includes the Interior Plateau (including the Nechako, Fraser and Thompson plateaus, the Quesnel, Shuswap and Okanagan highlands and the Fraser Basin), the Cassiar, Omineca and Skeena mountains, the Yukon and Stikine plateaus, and the Columbia Mountains (Holland, 1976). The region is largely underlain by flat-lying or gently dipping Cenozoic lava flows, folded and faulted sedimentary and volcanic rocks of Mesozoic age, as well as intrusive and metamorphic rocks. The area has a complex history of ice flow due to multiple ice sources and varied topography, although within any one area, the ice-flow history may be relatively simple. More information on the Quaternary geology of central British Columbia can be found in Clague (1987, 1989, 1991), Ryder and Clague (1989) and Levson *et al.* (1995).

Drift exploration methods commonly used in British Columbia are numerous and diverse. They include geochemical, geological and geophysical exploration techniques. Geological methods include terrain mapping, Quaternary stratigraphic studies and boulder tracing. Geochemical techniques involve the sampling and chemical analysis of a wide variety of materials including soils (A or B soil horizon samples), tills or other surficial deposits (C-horizon samples), stream sediments, lake sediments, plants and soil gas (Hg, He, Ra). Geophysical techniques, not discussed in detail here, include both airborne and ground geophysical methods such as electromagnetic (Klein and Lajoie, 1981) and electrical (resistivity and induced polarization) surveys (Seigel, 1989; Best, 1995), gamma-ray spectrometry (Hansen, 1981), seismic (reflection and refraction) surveys (Pullan *et al.*, 1987; Pullan, 1995), ground-penetrating radar studies, aeromagnetic surveys and remote sensing techniques (Schreier, 1976; Goetz *et al.*, 1983; Watson and Raines, 1989). Regional lake sediment and stream sediment geochemical surveys are included for completeness, but also are not discussed at length.

A brief review of drift exploration methods is presented, together with their potential applications and associated problems and limitations, in the context of the Quaternary geology. Emphasis is placed mainly on British Columbia research and does not make substantial reference to the extensive literature dealing with studies in shield areas. For more information on drift prospecting and glacial indicator tracing in areas covered by continental glaciers, the reader is referred to articles in three excellent reference volumes compiled by DiLabio and Coker (1989), Kujansuu and Saarnisto (1990) and Kauranne *et al.* (1992).

GEOLOGICAL EXPLORATION METHODS

In glaciated terrain, mineral exploration is often hindered by the thickness and complexity of surficial deposits which may show little direct relationship with the underlying bedrock. If drift exploration programs are to be successful, it is essential to know the type and origin of the surficial sediments in the study area, their stratigraphic relationships and the local ice-flow history (Hoffman, 1986; Brummer *et al.*, 1987; Levson and Giles, 1995). This information can be

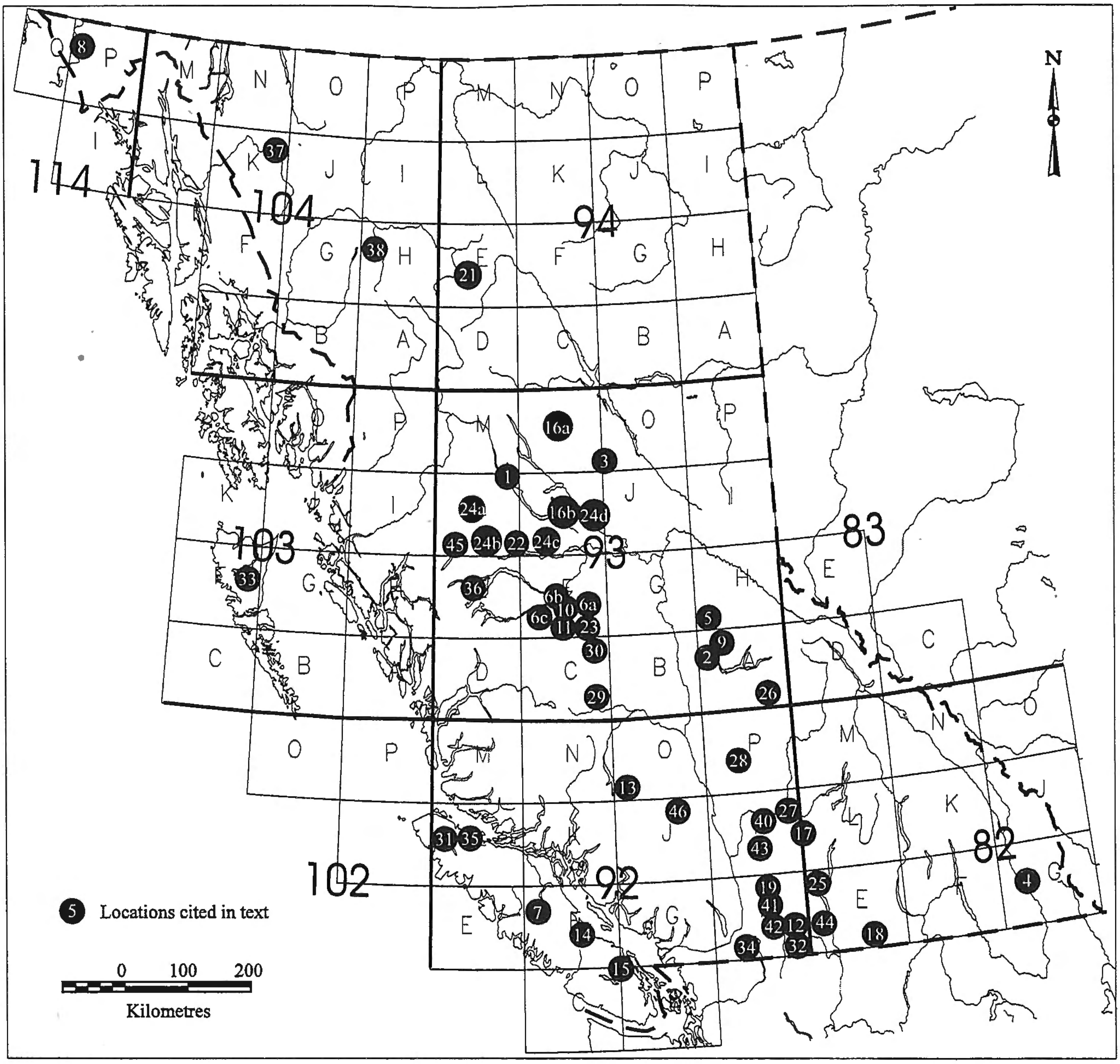

Figure 1. Location of published drift prospecting studies conducted in British Columbia. Note the concentration of research in the interior parts of the province where thick drift is a common obstacle to exploration

obtained by mapping the surficial deposits, studying landforms, stratigraphic investigations (requiring drilling if natural exposures are not available) and clast provenance studies. These geological methods also provide information required for the interpretation of various types of geophysical and geochemical data.

SURFICIAL GEOLOGY MAPPING

The mapping of surficial deposits and landforms and the identification of lithostratigraphic units should be the first stage in drift prospecting investigations. Terrain mapping conventions in the province are outlined in the British Columbia terrain classification system (Howes and Kenk, 1988), subsequently updated by the Resource Inventory Committee (1995). Surficial mapping generally involves air photo interpretation to determine the distribution and extent of surficial sediments, depositional and erosional landforms and structures, and regional ice-movement indicators such as drumlins and flutings. Follow-up ground inspections are also required to verify interpreted surficial map units and to compile sedimentologic, stratigraphic and local ice-flow data. An example of a simplified surficial geology map compiled as part of a drift exploration program in the Interior Plateau is provided in Figure 2. Although unconsolidated surficial sediments in British Columbia are extremely variable and have complex distributions controlled largely by physiography and glacial history, most types of surficial deposits can readily be identified by conventional mapping techniques.

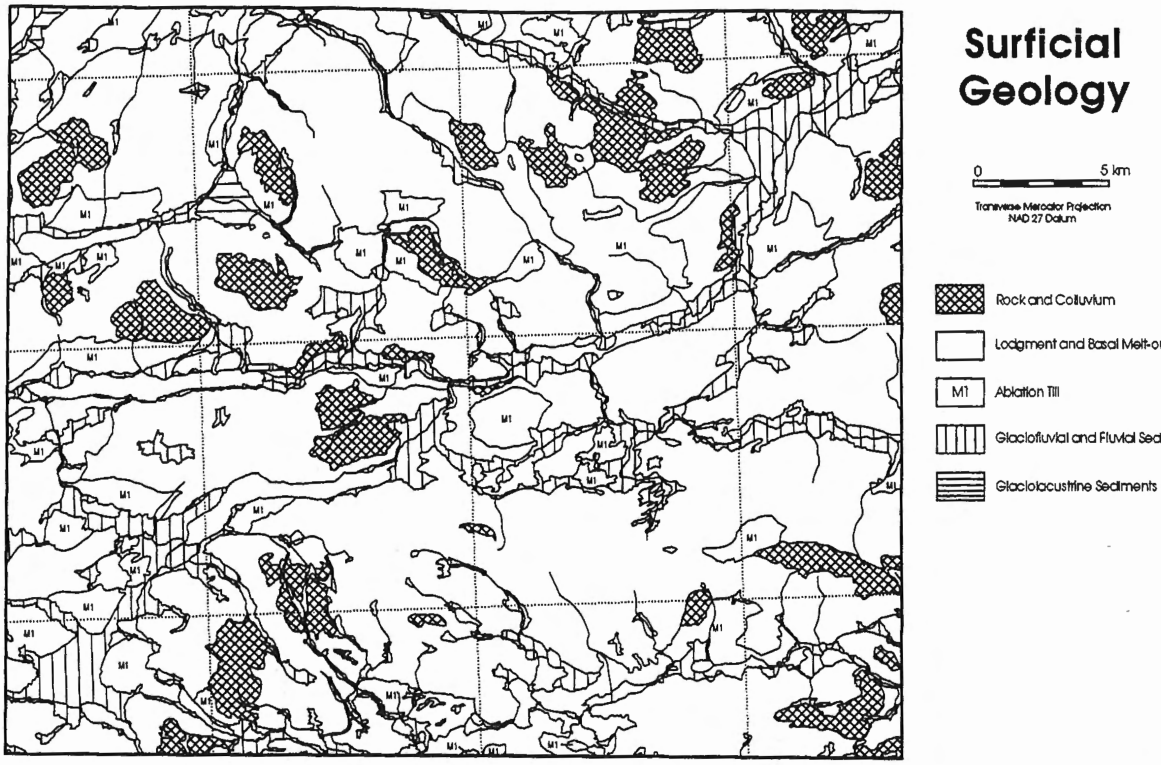

Figure 2. Surficial geology map of the Fawnie Creek map area (NTS 93 F/3). Simplified from Levson and Giles (1994). Note the dominance of morainal deposits throughout the region.

The origin and mode of deposition of surficial deposits often has a direct influence on their degree of usefulness as sampling media in the search for mineralization. For instance, mineralized materials, discovered in residual soils or basal tills, can be more easily traced to their source than glaciolacustrine or glaciofluvial deposits (Levson *et al.*, 1994). These latter sediments contain relatively distal material that may have little relation to any local mineralization. A progressive ranking of surficial materials, in terms of their utility for tracing geochemical anomalies to source, from least to most useful, is as follows: marine, glaciomarine, glaciolacustrine, glaciofluvial, lacustrine, fluvial, morainal, colluvial and residual soils. The importance of differentiating surficial sediments in geochemical surveys has been illustrated by numerous authors in British Columbia including Levinson and Carter (1979) in the Babine Lake area (location 1, Figure 1), Fox *et al.* (1987) at the Quesnel River gold deposit (location 2, Figure 1), Kerr and Bobrowsky (1991) at Mount Milligan (location 3, Figure 1) and Levson *et al.* (1994) in the Fawnie Ranges (location 11, Figure 1).

Terrain maps, showing the distribution of surficial deposits, landforms and ice-flow patterns, are available for many parts of British Columbia. A list of terrain and surficial geology maps in the province, with information on the scale and type of maps (*i.e.*, detailed, inventory or reconnaissance maps) was compiled by Bobrowsky *et al.* (1992). Surficial geology map coverage exists for most areas in the interior of the province and for most coastal regions.

GLACIAL DEPOSITS

Till is probably the most common surficial material in the province and typically consists of massive, matrix-supported diamicton. There are many different varieties of till, reflecting different depositional environments (*e.g.*, Figure 2). Till characteristics also change regionally as a result of differences in source materials. For example, tills derived from volcanic rocks, carbonates, mudstone and shale typically have a fine-grained (silt and clay) matrix, whereas a sandy matrix is often derived from the erosion of granite, gneiss, quartzite or sandstone. In the Interior Plateau region, extensive till-blankets cover most of the plateaus and lowlands, as well as the floors of many valleys and adjacent slopes. Unconsolidated deposits locally attain thicknesses of 200 metres or more. Drumlins and other streamlined landforms cover large parts of the area and indicate an eastward to northeastward ice flow in the region north and west of Prince George and northward flow near Quesnel. A thick mantle of drift also covers much of the bedrock in the Kamloops-Okanagan area, with flutings oriented toward the south and southeast. The divide between northward and southward-flowing ice was south of Williams Lake.

During the Late Wisconsinan, widespread valley glaciation in high-elevation areas in the Coast Mountains and Rocky Mountains preceded the development of the Cordilleran ice sheet over the Interior Plateau. Alpine valley glaciers also persisted in these high areas after retreat of the main ice sheet. Evidence of these glaciers includes numerous cirques and hanging valleys as well as extensive ice fields. Holocene glacial advances occurred in the northern and southern Coast Mountains and Rocky Mountains as recently as 100 years ago (Ryder, 1989). Till in these areas is common in most valley bottoms and sides, but generally forms a veneer or is absent at higher elevations and on steeper slopes. Colluviated drift, landslide deposits and aprons are found on steep to moderate slopes.

GLACIOFLUVIAL AND GLACIOLACUSTRINE DEPOSITS

Glaciofluvial sands and gravels, including ice-contact deposits in kames and eskers and more distal deposits in terraces and outwash plains, are as readily mapped as glacial deposits (Figure 2). Esker and kame complexes are common in the Interior Plateau (Armstrong and Tipper, 1948; Tipper, 1971a, b) and thick accumulations of postglacial fluvial deposits, in the form of terraces, fans and deltas, are also widespread.

Glaciolacustrine deposits, consisting mainly of well stratified sand, silt and clay, may be difficult to recognize in regional mapping programs, but they usually can be identified by ground surveys. Glaciolacustrine sediments are common in large valleys, as well as in some plateau areas, where they may completely mask the morphology of underlying deposits. In the central Interior Plateau, for example, widespread glaciolacustrine clays were deposited in a series of ice-dammed lakes in basins around Prince George, Fort St. James, Vanderhoof and Williams Lake. These may attain 30 metres or more in thickness, often overlying drumlins and locally obscuring the underlying topography. Thick and extensive deposits of glaciolacustrine origin are also common in the southern Interior (Mathews, 1944; Fulton, 1969). Many of the larger valleys are partially infilled with these sediments, including the Fraser, Thompson and North Thompson River valleys; unconsolidated surficial deposits are 230 metres thick in the lower Okanagan Lake region and over 400 metres in thickness near Enderby (Holland, 1976).

STRATIGRAPHIC STUDIES

Exposures of Quaternary sediments are commonly less than 10 metres thick and typically reveal only one or two major stratigraphic units. Consequently, in order to reconstruct the Quaternary history of an area, it is generally necessary to compile composite stratigraphic sections by correlating units between several sections (*e.g.*, Figure 3).

Much Quaternary stratigraphic data can be obtained from natural exposures but, because of limited exposure in many areas, it is often necessary to use overburden drilling techniques such as augering, reverse circulation and rotasonic drilling (Coker and DiLabio, 1989; Plouffe, 1995a). Only rotasonic drilling provides a continuous solid core, but other drilling methods have been used effectively for Quaternary stratigraphic studies in British Columbia. For example, Levson *et al.* (1993) demonstrated the utility of reverse circulation drilling for stratigraphic investigations of Quaternary deposits in the Cariboo region (location 5, Figure 1). In regions of thin overburden, stratigraphic data and samples may also be obtained by trenching.

Although the majority of the surficial sediments in British Columbia were deposited during the last (Fraser) glaciation and during postglacial time, older materials underlie these Late Wisconsinan glacial deposits in many valleys and lowlands and it is not uncommon to find sequences of till underlain and overlain by glaciofluvial, glaciolacustrine and nonglacial sediments. However, some valleys are filled by a complex succession of sediments representing several glacial cycles (more than one till with intervening glaciofluvial,

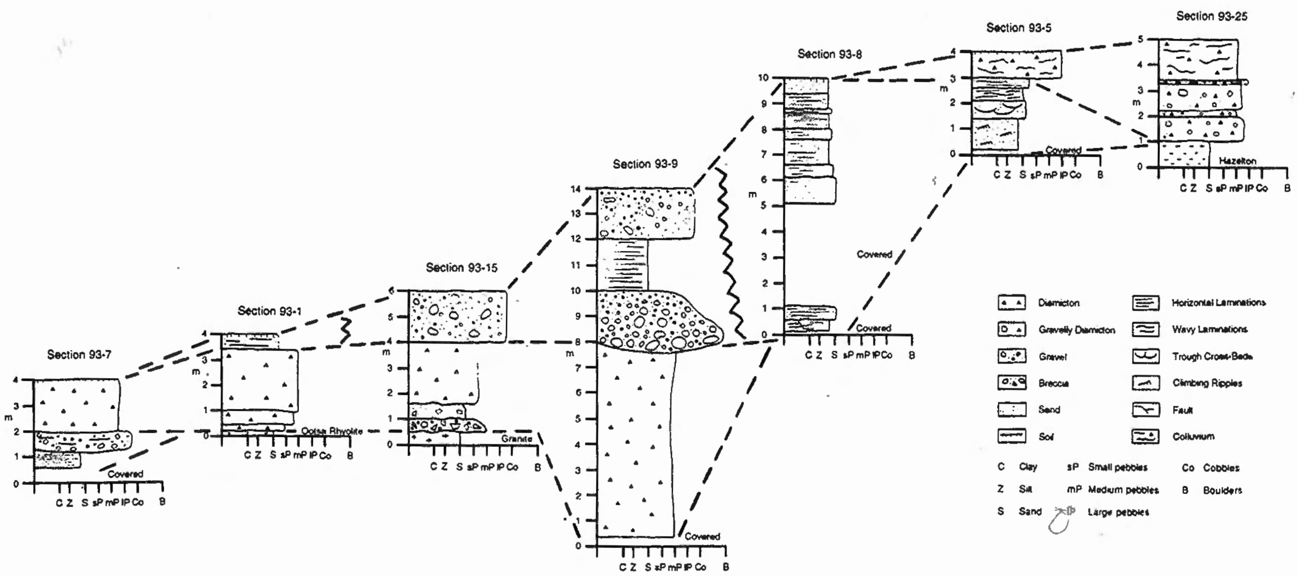

Figure 3. Representative stratigraphic columns of Quaternary deposits exposed in the Fawnie Creek map area (Figure 2) and interpretive correlation of main units (from Giles and Levson, 1994).

glaciolacustrine, fluvial, lacustrine and/or deltaic deposits; Ryder and Clague, 1989; Levson *et al.*, 1995; Plouffe *et al.*, 1996). Pre-Wisconsinan nonglacial deposits are known from only a few sites in the central Interior of British Columbia, including one at Babine Lake (location 1, Figure 1) and two sites in the Cariboo region (Clague *et al.*, 1990; Levson *et al.*, 1995; area 5, Figure 1). Fulton (1975) reported 180 metres of interglacial fluvial and lacustrine sediments in the Nicola-Vernon area. Three tills have been identified stratigraphically in the Lillooet area and Fulton and Smith (1978) recorded the presence of at least two tills and three interglacial periods in south-central British Columbia (location 17, Figure 1).

The presence of multiple tills in an area may result in complex, but traceable, patterns of mechanical and hydromorphic dispersion (Maurice and Meyer, 1975; Plouffe *et al.*, 1996). Ice-flow history data, fundamental to tracing dispersal trains to source, may be obtained from different stratigraphic units by measuring till fabrics, paleocurrent directions and orientations of glaciotectonic structures and striae in sediments or rock underlying tills. Broster *et al.* (1979) for example, identified two glacial-flow directions in the Cranbrook area (location 4, Figure 1) by studying glacially induced fracturing and faulting.

CLAST PROVENANCE INVESTIGATIONS

Tracing of mineralized clasts in glacially-derived deposits in an up-ice direction to their bedrock source has been a successful method of drift exploration in many glaciated areas (Evenson *et al.*, 1979; Hyvarinen *et al.*, 1973; Stobel and Faure, 1987; Shilts, 1993; Levson and Giles, 1995; Bobrowsky, 1995). Linear to fan-shaped erratics trains may extend for many kilometres down-ice of their bedrock sources. Erratics trains occur at a variety of scales: continental, regional, local and small-scale (Shilts, 1984a). Many examples of trains up to several kilometres long are known (Rose *et al.*, 1979; Levson and Giles, 1995; locations 6a, b, c, Figure 1). Maximum concentrations of mineralized boulders, occurring 6 kilometres, and as much as 9 to 18 kilometres, down-ice from bedrock sources, have been documented in shield areas (Shilts, 1973; Steele, 1988). Examples of the application of this technique in British Columbia were provided by Hicock (1986, 1995), who documented ore dispersal from a known mineral deposit in the Buttle Valley on Vancouver Island (location 7, Figure 1), and by Clague (1975) who used till provenance investigations to determine glacier flow patterns in the southern Rocky Mountain Trench. Another example of tracing mineralized erratics is reported from the St. Elias Mountains (Day, 1985; Day *et al.*, 1987; location 8, Figure 1). Distinctive properties of indicator clasts in erratics trains include: unique lithologies, the presence of metallic minerals, radioactivity, alteration and structural features such as quartz veinlets (*e.g.*, Stephens *et al.*, 1990).

GEOCHEMICAL EXPLORATION METHODS

The purpose of geochemical surveys is to identify anomalous concentrations of economic or pathfinder elements which may assist directly or indirectly in locating mineral occurrences. Till geochemistry programs are usually conducted at regional scales (commonly 1:50 000) and are designed to identify areas with potential for more detailed follow-up studies, whereas soil and biogeochemical surveys are often used in property-scale investigations. Till geochemical sampling programs are discussed in detail by Levson *et al.* (1994) and Levson and Giles (1996, this volume). Stream and lake sediment geochemical surveys are also mainly used in regional exploration programs. In all types of surveys, multi-element approaches using statistically adequate sampling densities are recommended, and detailed records of sample site and medium characteristics should be maintained. Geochemical analytical methods commonly used in drift exploration programs are discussed by Lett (1995).

SOIL GEOCHEMICAL SURVEYS

This method, in general terms, involves: sampling of soil horizons or parent materials of surficial deposits; analyzing for anomalous concentrations of elements; and tracing anomalies along dispersal paths to their bedrock sources. Soil geochemical programs conducted at property scales in British Columbia generally sample illuvial or enriched (B) soil horizons or, less commonly, eluvial or leached (A) horizons, whereas more regional drift or till sampling programs focus on parent material (C-horizon) samples. Advantages and disadvantages of these two different types of sampling programs are discussed by Bradshaw *et al.* (1974; location 9, Figure 1), Boyle and Troup (1975; location 10, Figure 1), Giles and Levson (1994), Levson *et al.* (1994; location 11, Figure 1) and Levson and Giles (1994, 1995, 1996, this volume; locations 1, 11 and 6a to 6c, Figure 1). Sampling media, sample density, preparation procedures and analytical methods should be selected to optimize anomaly to background contrasts. This information may be obtained from the literature or by conducting orientation surveys to determine patterns of mechanical dispersal in the region. Preferred methods will generally vary with the type of deposit and surficial geology setting. Geochemical soil anomalies may result from dispersal of mineralized bedrock by glacial, glaciofluvial, colluvial, fluvial or other processes as well as by hydromorphic dispersion. Reconnaissance stages of soil geochemistry sampling programs, like regional till sampling programs, are typically carried out with sample densities on the order of one sample per 1 to 10 square kilometres. Once elevated element concentrations have been identified in an area, detailed sampling on the order one sample per 0.02 to 0.1 square kilometre is usually then required to outline the size and shape of the anomaly and to determine the source area.

Most soil geochemical surveys in British Columbia recover and analyze the -80 mesh (<180μm), clay to fine sand fraction, although some evidence suggests preferential enrichment of trace metals in specific grain sizes in some sediment types (Lett, 1995). Shilts (1984a, 1995), for example, has shown that anomalous concentrations of copper, uranium and arsenic can best be observed in till samples when the fine fraction (<50µm) is analyzed, and that the clay (<2µm) fraction may be the most enriched in metals. However, high separation costs generally make exclusive use of the clay fraction economically unviable (Coker and DiLabio, 1989). Another important factor in the sampling, analysis and interpretation stages of soil geochemical surveys is the influence of post-depositional hydromorphic remobilization of certain soluble elements. Groundwater and surface water percolation may alter the original clastic dispersal train by spreading it down slope, partially obscuring its initial shape and outline. Surface weathering processes may also alter original dispersal patterns in till (Sibbick and Fletcher, 1993). Shilts (1984a) and Coker and DiLabio (1989) noted that very low concentrations of copper, lead, zinc, cobalt and nickel occurred in heavy mineral samples from surface horizons 1 to 2 metres deep due to oxidation and weathering of detrital sulphides; the less than 2 micron fraction provided a better representation of the original distribution of certain elements such as nickel and chromium throughout the studied profiles.

TILL GEOCHEMICAL SURVEYS

Due to the extensive cover of till in British Columbia, the most common type of dispersal trains in the province are formed by mechanical dispersal by glacial ice (Levson and Giles, 1995). Idealized models illustrating characteristic features of glacial dispersal trains have been described by Miller (1984), Shilts (1984a) and DiLabio (1990). Three-dimensional aspects of dispersal trains were studied using drilling results from areas of thick glacial overburden in various parts of Canada (Coker and DiLabio, 1989). Dispersal trains may vary in length from tens of metres to hundreds of kilometres (Shilts *et al.*, 1979) and they are commonly ribbon or fan shaped with sharp lateral boundaries. They generally broaden and become more diluted with distance from source, in the down-ice direction, due to lateral and vertical mixing with surrounding barren material. The size, shape and strength of a glacial dispersal train are controlled in part by the size, erodability and orientation, relative to ice flow, of the bedrock source. Local topography can also play an important role as, for example, transported mineralization may be trapped in low areas. The broad tail regions of dispersal trains are often detected first during regional till geochemical surveys.

Most till geochemical sampling programs analyze the -230 mesh (<62.5µm) fraction. The clay and silt (<62.5µm) fraction of tills is geochemically the most active due to surface electrostatic charges and adsorption capacities of surface (Fe, Mn) coatings (DiLabio, 1979). Work by Shelp and Nichol (1987) illustrated that anomalous gold concentrations in glacial dispersal trains can occur in both heavy mineral concentrates and the clay/silt fraction. By contrast, at Hemlo, gold within heavy mineral concentrates from drift is restricted to the zone overlying mineralization and only the clay/silt fraction shows significant down-ice dispersal, suggesting that these two material types, when used in conjunction with one another, can provide complimentary data (Coker and DiLabio, 1989). Gold grain-shape analyses may also be used with other methods to provide relative indications of source proximity (Sauerbrei *et al.*, 1987) but estimates of transport distances made on the basis of clast shape may be misleading if the glacial setting is not well understood. For example, angular gold grains, incorporated by ice-thrusting or other mechanisms into the englacial zone of an ice sheet, may be transported over long distances without being significantly rounded or abraded.

Although morainal deposits are the principal sampling media of drift sampling programs (Levson *et al.*, 1994; Levson and Giles, 1996, this volume), colluvial deposits may also be used effectively as shown, for example, at Mount Milligan by Gravel *et al.* (1991; location 3, Figure 1) and at the Pellaire prospect by Sibbick and Gravel (1991; location 13, Figure 1). Dispersal patterns in colluvial deposits are generally smaller than in tills but they better reflect local bedrock conditions. In spite of typical dilution problems, glaciofluvial sediments may also be utilized if they include significant amounts of local material (Gravel and Sibbick, 1991). Other investigations of glaciofluvial deposits for drift prospecting purposes include studies by Baker (1982), Shilts (1984b), Martin and Eng (1985), Perttunen (1989) and Lilliesköld (1990).

As noted by Coker and DiLabio (1989) and Levson and Giles (1995), correct identification of sediment type sampled in a geochemical survey is key to tracing anomalies back to bedrock sources. For example, up-ice tracing of anomaly patterns will lead to discovery of mineralization only if glacial transport was the principal dispersal mechanism and the sampled media was basal till. Exotic debris in supraglacial tills can mask the lithology and geochemistry of mineralized debris in locally derived basal tills (Geddes and Kristjansson, 1986; Gleeson and Sheehan, 1987). In addition, due to the effects of multiple glaciation in many areas, the stratigraphic position and origin of each stratigraphic unit should be determined, especially in overburden sampling or drilling programs in areas of complex stratigraphy. In all geochemical surveys, the glacial and ice-flow history and stratigraphy of the area must be determined as part of the program.

BIOGEOCHEMICAL SURVEYS

Biogeochemical exploration methods can provide useful complimentary data in the search for mineralization in drift-covered areas (Dunn, 1989, 1995). For example, Warren and Horsky (1986) noted a close relationship between gold and thallium in plants growing above a zone of gold mineralization. Similarly, a down-ice dispersal train of gold at the QR deposit (location 2, Figure 1) was detected by tree-top sampling (Dunn and Scagel, 1989). Living plant tissues, as well as peat, forest litter and plant sap have served as sampling media for biogeochemical exploration for uranium and precious and base metals (Dunn, 1989). Plants not only extract and concentrate elements from soils, bedrock and groundwater but some plant root systems may penetrate thin exotic overburden (*e.g.*, lacustrine clays). Element concentrations in these plants may be more representative of underlying bedrock than concentrations in the surface sediments. Cohen *et al.* (1987) concluded from several case studies that plant anomalies over gold mineralization were often more extensive than those in soils, suggesting that exploration targets may be identified by collecting a smaller number of plant samples than soil samples. DiLabio *et al.* (1982) identified a metalliferous glacial dispersal train which was reflected in zinc concentrations found in local conifers and grasses.

In spite of some advantages over other methods, plant geochemistry does not always reflect local soil or rock geochemistry. Dunn (1983), for example, noted that plant chemistry in glaciated areas may be more heavily influenced by groundwater than the soil composition itself. Furthermore, preferred indicator plants may not be available or ubiquitous in potentially mineralized areas. The interpretation of biogeochemical data must also take into consideration seasonal and annual chemical variations observed in different plant parts.

OTHER GEOCHEMICAL METHODS

Other exploration methods applicable to drift prospecting studies in British Columbia include regional stream sediment, lake sediment, moss-mat sediment, stream water and lake water geochemical surveys. Regional geochemical surveys undertaken by the British Columbia Geological Survey in cooperation with the Geological Survey of Canada, cover many areas of the province. They provide data on the distribution and concentration of a number of elements for each of the different media sampled.

Stream sediments represent a mixture of mineral debris derived from bedrock and/or overburden found within a drainage basin. It is therefore possible to detect a source of mineralization if downstream mechanical and/or chemical transport produces stream sediments enriched in commodity or pathfinder elements. Anomaly length within the stream is a function of the means of transport (mechanical and/or chemical), size of the drainage system, size of the mineral occurrence, physiography, abundance of barren material also in transit and several other local and regional environmental factors. A recent discussion of stream sediment sampling procedures was provided by Fletcher (1990) and an example of a regional stream sediment sampling program is provided Matysek *et al.* (1990) for central Vancouver Island (location 14, Figure 1). The ability of moss mats growing within active stream channels to trap both fine-grained light sediment and heavy minerals was demonstrated by Gravel *et al.* (1990) on southern Vancouver Island (location 15, Figure 1) where fine-grained stream sediments are otherwise lacking. Moss mats grow on top of, or on the downstream side of boulders and logs; they require a cool, moist climate and seasonal stream flooding, as is the case on Vancouver Island and in some mountain ranges of western and eastern British Columbia (Plant *et al.*, 1989). In comparison to routine fine-grained stream sediments, moss mats contain similar concentrations of elements associated with fine sediment (either as hydroxide coatings or adsorbed/absorbed ions) and enhanced concentrations of elements transported as discrete heavy mineral grains.

Stream sediment sampling is of limited use in large drainage basins (Plant *et al.*, 1989) and in areas where fine-grained stream sediments are lacking, making the search for representative samples a time consuming process. Contamination from transported (non-local) deposits such as streambank and floodplain sediments may give erratic results in the case of semi-mobile metals (Rose *et al.*, 1979). Another problem is encountered in glacially deranged drainage systems where short stream sections are interrupted by small lakes, ponds and swamps. Under such conditions, it is difficult to obtain representative samples of the drainage basin. In addition, low-gradient streams in these areas often do not penetrate the glacial drift; this results in stream sediments which reflect the nature of the drift and not that of the underlying bedrock. However, stream sediments can still be used to detect mineralization if the nature and origin of the drift is understood.

Lake sediment geochemistry involves the analysis of lake sediments for trace elements as a mineral exploration tool. Like streams, lakes represent the catchment point for a basin. Sampling of lake sediment/water, therefore, may reveal hidden mineral occurrences within the catchment basin. The interaction of chemical, physical and biological processes in lacustrine environments leads to the fixation of elements on sediments (Coker *et al.*, 1979). Lake sediment sampling has been used for base metal and uranium exploration and, more recently, for gold, tin, tungsten, platinum group and rare earth elements (Hornbrook, 1989). It is particularly useful in areas with abundant lakes, where streams are difficult to access. Regional lake sediment geochemical sampling programs have recently been conducted in the Nechako Plateau region in central British Columbia (Cook and Jackaman, 1994). Lake sediment geochemical sampling programs have proven to be particularly effective when conducted in conjunction with till geochemical surveys and geological mapping programs (Cook *et al.*, 1995).

A knowledge of sediment provenance and hydromorphic dispersion in lake basins is necessary to identify factors that could affect the interpretation of geochemical data, notably complications due to adsorption capacities and rates of sedimentation (Rose *et al.*, 1979). However, these effects may be accounted for by using selective extraction (Hoffman and Fletcher, 1981a, b), and by selective sampling of the basin, that is near stream inlets and along the breaking slope of the lake basin. Sub-bottom acoustic profiling can be used to map the distribution of lacustrine sedimentary facies and aid in the geochemical interpretation. Care must also be taken that the surrounding landscape has not been geochemically contaminated (Hornbrook, 1989). The effectiveness and specific problems of gold data for lake sediment exploration are discussed by Coker *et al.*, (1982), Schmitt and Friske (1987) and McConnell (1987).

In the northern part of British Columbia, 1:250 000-scale regional geochemical sampling programs mainly have focused on stream sediments and stream waters (NTS sheets

104B, F, G, I, K, M, N, O and P; 114O and P), but lake sediment and lake water samples were also collected in 104N and O. Regional geochemical sampling programs in central parts of the province (93A, B, E, G, H, J, L, M and N; 103I, J, O and P) and in the southern interior (82E, F, L, M and 92H, I, J, O, P) have focused principally on stream sediments and water. The 93E and L map areas and parts of 93F and K were also sampled for lake sediments and lake water. In the southwest part of the province, stream sediment and stream water surveys have been conducted in 92F, G, K, L, N and 102I. Moss-sediment data were also collected in several map areas on Vancouver Island (92B, C, E, F, K and L and 102I). In the southern Rocky Mountain Trench and Rocky Mountain areas (82G, J and K), as in most central regions, regional geochemical sampling programs involved the sampling of stream sediments and water.

DRIFT PROSPECTING ACTIVITIES IN BRITISH COLUMBIA

A brief review of drift exploration studies in British Columbia is presented here to provide sources of information which may be of assistance in the interpretation stages of geochemical surveys.

Early drift prospecting surveys, such as those by White and Allen (1954) in the southern Okanagan area (location 18, Figure 1) and Warren *et al.* (1957) in the Ashcroft-Kamloops region (locations 19 and 20, Figure 1) demonstrated the usefulness of geochemical sampling for mineral exploration in the Interior physiographic system. However, despite these early successes in geochemical applications, relatively few results of systematic exploration surveys have since been published, even though several thousand exist in the form of assessment reports and private industry internal reports. The south-central and central interior of British Columbia have received the greatest attention in the published literature in recent years, but these investigations remain isolated, few in number and generally of a preliminary nature.

The importance of a multidisciplinary approach, involving soil and stream geochemistry, geophysics, mapping and drilling programs, in this largely drift-covered region, is particularly well illustrated by studies on the Shasta (Downing and Hoffman, 1987) and Chapelle (Barr, 1978) deposits (area 21, Figure 1). Work on the Sam Goosly (Equity Silver) deposit (location 22, Figure 1) by Ney *et al.* (1972) and Sutherland Brown (1975a) and the QR deposit (location 2, Figure 1; Fox *et al.*, 1987) demonstrate the usefulness of incorporating local ice-flow history into the interpretation of geochemical data. Other studies in the region deal with mechanical and hydromorphic dispersion, such as at the Chutanli deposit (location 6a, Figure 1; Mehrtens, 1975), and mercury dispersion halos in soils at several sites in the Nechako region (locations 24a, b, c, d, Figure 1; Sutherland Brown, 1967). In the southern interior, soil and stream geochemical surveys contributed to the discovery of the Brenda and Boss Mountain deposits (locations 25 and 26, Figure 1; Soregaroli, 1975a, b) and a recent study of glacial dispersal processes was conducted on the Galaxy property near Kamloops (location 27, Figure 1; Kerr *et al.*, 1993). Published accounts of boulder tracing of mineralized clasts are reported from the southern Okanagan (location 18, Figure 1; White and Allen, 1954) and southern Cariboo (location 28, Figure 1; Hoffman, 1972) regions. Recognition of the importance of surficial geology mapping and regional (1:50 000 scale) till geochemistry surveys in areas with thick drift cover in the Interior Plateau region, has resulted in several recent regional surficial mapping and till geochemistry programs there [Giles and Kerr, 1993 (location 29, Figure 1); Proudfoot, 1993 (location 30); Levson and Giles, 1994, Levson *et al.*, 1994 and Cook *et al.*, 1995 (location 11); Giles and Levson, 1994 (location 23)]. The results of a regional till geochemistry survey in the Quatsino map area (92L/12) on Vancouver Island (location 31, Figure 1) were also recently presented by Kerr *et al.* (1992). Additional reconnaissance (1:250 000 scale) till geochemistry survey data are also available in certain areas, such as the Manson River (NTS 93N; location 16a, Figure 1) and Fort Fraser (NTS 93K; location 16b, Figure 1) map regions (Plouffe and Ballantyne, 1993; Plouffe, 1995b).

Multidisciplinary studies using several different drift exploration techniques have been conducted at the Ashnola deposit (location 32, Figure 1; Montgomery *et al.*, 1975) and in the Deadwood camp in the Boundary district (location 18, Figure 1; White and Allen, 1954). Combined soil and stream sediment geochemical surveys produced successful results at the Cinola gold deposit on the Queen Charlotte Islands (location 33, Figure 1; Champigny and Sinclair, 1982) and Giant Copper east of Hope (location 34, Figure 1; Wilton and Pfuetzenreuter, 1990). An integrated approach using geochemistry and magnetic and induced polarization surveys, was instrumental in the discovery of the Island Copper orebody (location 35, Figure 1; Young and Rugg, 1971; Sutherland Brown, 1975b; Witherly, 1979).

More detailed geochemical studies of soil profiles were carried out in central British Columbia at Babine Lake (location 1, Figure 1; Levinson and Carter, 1979), at the Huckleberry deposit (location 36, Figure 1; Sutherland Brown, 1975c) and in the Capoose Lake area (location 10, Figure 1, Boyle and Troup, 1975). Similar detailed studies were conducted in the southern interior near the Pellaire deposit (location 13, Figure 1; Sibbick and Gravel, 1991) and in the Tulameen region (location 41, Figure 1; Cook and Fletcher, 1993), as well as in northwestern British Columbia at the Sheslay (location 37, Figure 1; Coope, 1975) and Red-Chris prospects (location 38, Figure 1; Peatfield and Armstrong, 1980). Similar investigations in the southern Interior discuss the behavior of gold in soils and soil profiles over strong, medium and weak copper mineralization [*e.g.*, Carr *et al.*, 1975 (location 40); Fletcher, 1989 (location 41); Sibbick, 1990; Sibbick and Fletcher, 1993 (Nickel Plate Mine, location 12, Figure 1)]. A number of relevant studies emerged from industry interest in porphyry copper deposits in the Cordillera including the Afton, Morrison, Cariboo-Bell, Endako, Catface, O.K., Maggie, Highmont, Poison Mountain, Mount Milligan and Kemess deposits [see papers in Sutherland Brown (1976) and Schroeter (1995); also Gravel and Sibbick (1991), Sibbick *et al.* (1992) and Sibbick and Kerr (1995)].

Other published studies in the region have dealt with hydromorphic metal dispersion and remobilization of elements [Nichol and Bjorklund, 1973; Gunton and Nichol, 1974 (location 42, Figure 1); Horsnail, 1975 (location 43, Figure 1); Levinson *et al.*, 1984; (location 44, Figure 1)]. Biogeochemical methods have focused on the sampling of bark, twigs and needles in various regions of the central Interior [Hornbrook, 1970a, b (location 45, Figure 1); Boyle and Troup, 1975 (location 10, Figure 1); Dunn and Scagel, 1989 (location 2, Figure 1)] and the southern Interior [Warren *et al.*, 1957; Montgomery *et al.*, 1975 (location 32, Figure 1); Cooke and Barakso, 1987 (location 46, Figure 1)].

CONCLUSIONS

The integration of surficial geology studies, together with several geochemical and geophysical techniques, provides the best means of locating buried mineral deposits throughout British Columbia in areas where bedrock is partially or totally obscured by overburden. In areas of thick overburden such as the Interior Plateau, till geochemical sampling programs and surficial geology mapping programs can be carried out at relatively low cost and are best in early stages of investigations. In conjunction with other methods such as seismic surveys, these techniques can assist in guiding exploratory drilling by providing an approximation of bedrock topography and overburden thickness. In areas where bedrock is totally or partially obscured by overburden, it may also be beneficial to undertake till provenance studies and determine the effects of exotic drift on local soil geochemistry. Stratigraphic investigations of surficial deposits and ice-flow patterns assist in the correlation of tills and in developing a better understanding of glacial dispersal in areas of complex stratigraphy. Regional reconnaissance stream, lake, soil and biological geochemical sampling programs are also often beneficial in the early stages of mineral exploration, depending on the geologic setting. Post-depositional remobilization of elements in soils should be considered, and orientation surveys performed to determine the physical characteristics of dispersal of ore minerals (*e.g.*, such as appropriate grain sizes for analytical procedures).

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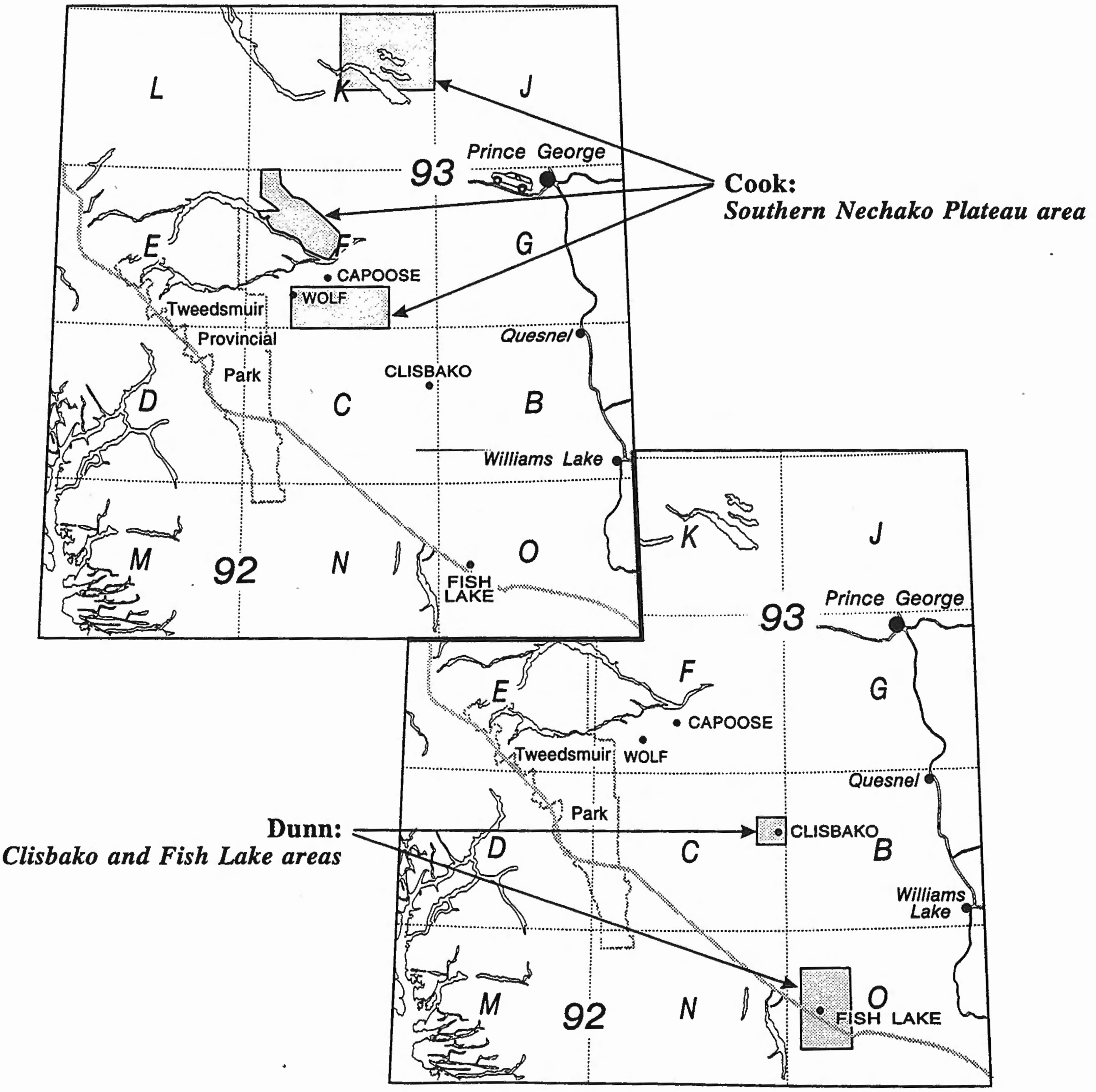
Geochemistry



REGIONAL AND PROPERTY-SCALE APPLICATION OF LAKE SEDIMENT GEOCHEMISTRY IN THE SEARCH FOR BURIED MINERAL DEPOSITS IN THE SOUTHERN NECHAKO PLATEAU AREA, BRITISH COLUMBIA (93C, E, F, K, L)

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KEYWORDS: Applied geochemistry, lake sediments, Nechako Plateau, mineral deposits, mineral exploration, limnology, gold, molybdenum

INTRODUCTION AND OBJECTIVES

The purpose of the Interior Plateau lake sediment studies program is to improve the existing geochemical database of the Nechako Plateau area of the northern Interior to better assess the mineral potential of the region, thus increasing the possibility of significant new discoveries. Stream sediments are the preferred sampling medium for reconnaissance scale Regional Geochemical Surveys (RGS) over most of British Columbia, but lake sediments are a more appropriate geochemical medium in the Nechako Plateau, which is characterized by subdued topography and an abundance of lakes. Mineral exploration here has been limited, in part, by extensive drift and forest cover, poor bedrock exposure and a barren Tertiary volcanic cover.

Lake sediment geochemistry can be an effective tool to delineate both regional geochemical patterns and anomalous metal concentrations related to potentially economic deposits (Hoffman, 1976; Coker *et al.*, 1979; Cook and Jackaman, 1994b), but most prior Canadian lake sediment geochemical studies have focused on Shield and Appalachian environments where there are considerable differences in climate, physiography and surficial geology relative to the Cordillera. Publicly funded regional lake sediment surveys have been conducted primarily in central and Atlantic Canada. These, covering an area of 1.2 million square kilometres (Friske, 1991) and 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 (McConnell and Batterson, 1987). In contrast, regional lake sediment surveys in British Columbia, jointly undertaken by the British Columbia Geological Survey Branch and the Geological Survey of Canada, have until recently 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. Many regional surveys have been conducted, including those of Spilsbury and Fletcher (1974), Hoffman (1976) and Gintautas (1984). Exploration industry regional lake sediment surveys, such as those of Rio Tinto Canadian Exploration Limited (Coker *et al.*, 1979) have covered large tracts of central British Columbia and led to the discovery of numerous base and precious metal prospects. Nevertheless, there is little regional geochemical data available in the public domain, and few orientation studies and case histories have been conducted to formulate exploration models for the area. These studies are important for the successful application of lake sediment geochemistry surveys at both reconnaissance and property scales. Field surveys, emphasizing both site-specific methods development studies and regional inventory, were conducted during 1992-1995 as part of the Canada - British Columbia Mineral Development Agreement (MDA). This paper outlines program objectives and summarizes the results of fieldwork performed. Primary objectives of the program were threefold:

- Evaluate the effectiveness of lake sediment geochemistry in reflecting the presence of adjacent mineral deposits, hence its usefulness as a sample medium for regional geochemical surveys of the area.
- Design and conduct effective regional lake sediment surveys in the northern Interior Plateau, particularly in 1:250 000 NTS map areas 93F (Nechako River), 93K (Fort Fraser) and 93C (Anahim Lake), where RGS coverage is lacking.
- Design more effective follow-up lake sediment geochemical studies to better trace regional geochemical anomalies back to their buried sources within lake watersheds.

LAKE SEDIMENTS AND THEIR USE IN MINERAL EXPLORATION

Geochemical dispersion of gold and other metals into lake basins typically occurs in ground water, stream water, or a combination of the two. The metals subsequently accumulate in sediments within lake basins of varied size, depth, physiography and hydrology. These sediments consist of organic gels, organic 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 characteristic of deep-water basins. Organic sediments are immature mixtures of organic gels, organic debris and mineral matter occurring in shallow water and near drainage inflows (Jonasson, 1976). Inorganic sediments, by contrast, are mixtures of mineral particles with little organic matter. Of the three, organic gels are 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, presence of 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). It also reflects the presence of nearby mineral prospects such as the Mac porphyry molybdenum prospect (Cope and Spence, 1995), base metal prospects near Capoose Lake (Hoffman, 1976; Hoffman and Fletcher, 1981) and Chutanli Lake (Mehrtens, 1975; Mehrtens *et al.*, 1972), and the presence of epithermal precious metal prospects such as the Wolf (Dawson, 1988; Andrew, 1988), Fawn (Hoffman and Smith, 1982) and Tsacha (Cook *et al.*, 1995) occurrences. 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. In all, Earle (1993) has recognized nine such limnological classes in the Nechako Plateau.

Trophic status of a lake may influence interpretation of the sediment geochemistry. Earle (1993) and Hoffman and Fletcher (1981) have shown that there are distinct geochemical differences between the sediments of eutrophic and oligotrophic lakes, particularly with respect to the abundance of organic matter and of hydrous oxides of iron and manganese. 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). Generally, high organic matter content is characteristic of eutrophic lakes, while precipitates of hydrous iron and manganese oxides are products of more oxygen-rich conditions within larger oligotrophic lakes. The effects of within-lake limnological variations on these constituents and, in particular, on the transport and accumulation of trace elements, has been summarized for southern Shield regions (Timperley and Allan, 1974). Cordilleran lakes, however, have received little attention.

LOCATION AND GEOLOGY OF THE STUDY REGION

The study region lies between 124° and 127°W longitude in central British Columbia (Figure 1), and is bounded by Vanderhoof on the east and Houston on the west. It extends northward from the Clisbako River to the Babine and Stuart lakes area. Most of the region, centred on the Nechako River map area (NTS 93F), is within 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 and 1500 metres elevation. The area is thickly forested, and bedrock is obscured by an extensive surficial cover of predominantly till and glaciofluvial outwash. Further information on the glacial history and deposits of the Nechako Plateau are provided by Levson and Giles (1995; 1996, this volume), Giles and Levson (1994) and Giles *et al.* (1995).

Geology of this part of the Interior Plateau is outlined by Diakow *et al.* (1996, this volume). The study region covers parts of the Stikine Terrane and, to a lesser extent, the Cache Creek and Quesnel terranes. Here, volcanic and sedimentary rocks of the Lower and Middle Jurassic Hazelton Group are intruded by Late Jurassic and Tertiary plutons (Tipper, 1963; Diakow *et al.*, 1993, 1994, 1995a, b). These strata are unconformably overlain by Eocene volcanics of the Ootsa Lake Group, Oligocene-Miocene volcanics of the Endako Group, and Miocene-Pliocene Chilcotin Group basalt flows. Metallogeny and mineral deposits of the area are outlined by Schroeter and Lane (1994) and Lane *et al.* (1996, this volume). Porphyry molybdenum, porphyry copper-molybdenum and, in particular, epithermal gold deposits are the main mineral exploration targets in the region.

FIELD AND LABORATORY METHODS

SCOPE OF FIELD STUDIES

The lake sediment program comprised three main components, each addressing a specific objective: (1) a series of orientation studies in the vicinity of known mineral prospects (Cook, 1993a, b; 1995); (2) ongoing regional lake sediment surveys (Cook and Jackaman, 1994a, b; Cook *et al.*, 1995); and (3) follow-up studies of regional lake sediment anomalies (Cook and Luscombe, 1995). Detailed geochemical studies of 25 lakes in 18 different areas were conducted over the course of the project (Photos 1 and 2), and ongoing regional lake sediment coverage of approximately eight 1:50 000 NTS map areas has been completed.

ORIENTATION STUDIES ADJACENT TO BASE AND PRECIOUS METAL PROSPECTS

Orientation studies of 17 Interior Plateau lakes at 11 localities (Figure 1) were conducted during the period July to September, 1992 to evaluate the suitability of lake sediments as a sample medium for regional geochemical surveys of the area. A total of 625 sediment samples were

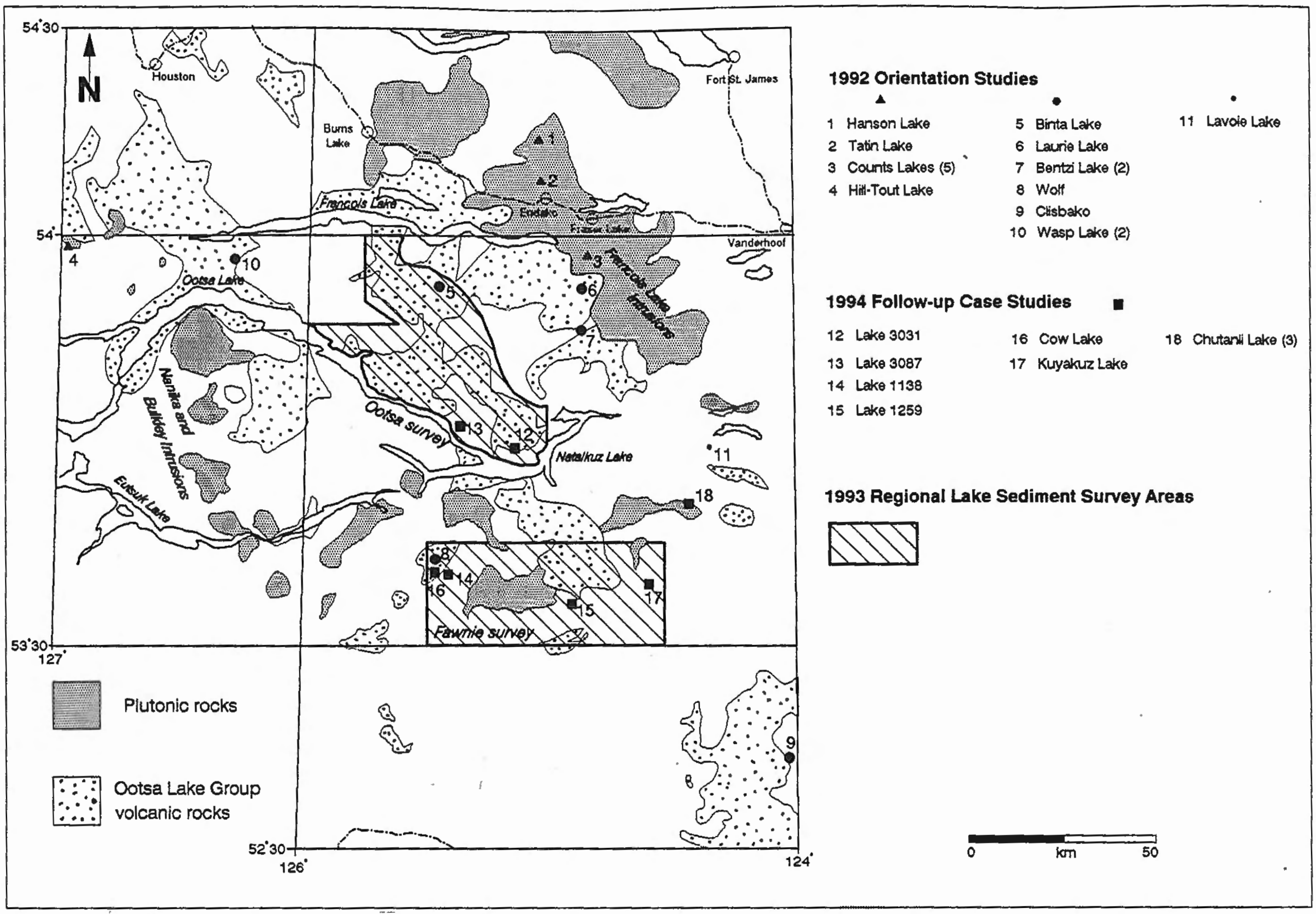


Figure 1. Locations of lake sediment orientation studies and case studies in the Nechako Plateau and adjoining regions of central British Columbia, showing their relation to Eocene-Jurassic plutonic rocks and Eocene volcanic rocks of the Ootsa Lake Group. Locations of regional lake sediment surveys of Cook and Jackaman (1994b) are outlined. Geology modified from Tipper *et al.* (1979).

collected at 437 sites (Table 1). The lakes are characteristic of a range of limnological environments (eutrophic, mesotrophic, oligotrophic, unstratified) above two contrasting geological rock types. These units, areally extensive and of considerable economic interest, are:

- Jura-Cretaceous and Late Cretaceous plutonic rocks of the Francois Lake and Bulkley plutonic suites, respectively, hosting porphyry molybdenum and copper-molybdenum deposits and occurrences.

- Eocene Ootsa Lake Group volcanic rocks, hosting epithermal gold-silver occurrences.

The program design was based partly on recommendations of Earle (1993). Lakes within each geological grouping were chosen on the basis of documented trophic status (Balkwill, 1991), proximity to known mineral occurrences, exploration industry lake sediment data, road access and, in a few cases, available RGS copper and gold lake sediment geochemistry (Johnson *et al.*, 1987a) from adjoining NTS map area 93E. One lake underlain by typically barren Miocene-Pliocene Chilcotin basalt, Lavoie Lake, was also surveyed as a "background" lake.

Francois Lake Intrusives and Related Rocks

Three lakes above the Jura-Cretaceous Francois Lake intrusive suite adjacent to the Hanson Lake, Ken and Nithi Mountain molybdenum occurrences were sampled. The fourth lake is adjacent to quartz monzonite, probably of the Late Cretaceous Bulkley intrusions hosting the Dual copper-molybdenum occurrence. The Francois Lake plutonic suite, comprised predominantly of quartz monzonite, contains a major porphyry molybdenum deposit and many occurrences. The most significant is the Endako orebody west of Fraser Lake, where molybdenite occurs in east trending subparallel quartz veins (Kimura *et al.*, 1976). The Bulkley plutonic suite, a northwesterly belt of granodiorite and quartz monzonite stocks in the western part of the study area (Figure 1), defines one 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

Three of the surveyed lakes are adjacent to the Clisbako, Wolf and Holy Cross epithermal gold-silver prospects (Table 1). These lakes are above Eocene continental volcanic rocks of the Ootsa Lake Group, which are exposed in two broad areas of the study region. The first, where most of the orientation and case study areas are located, extends from the Nechako River to the southwest side of Francois Lake (Figure 1); the second, smaller, area is west of Quesnel

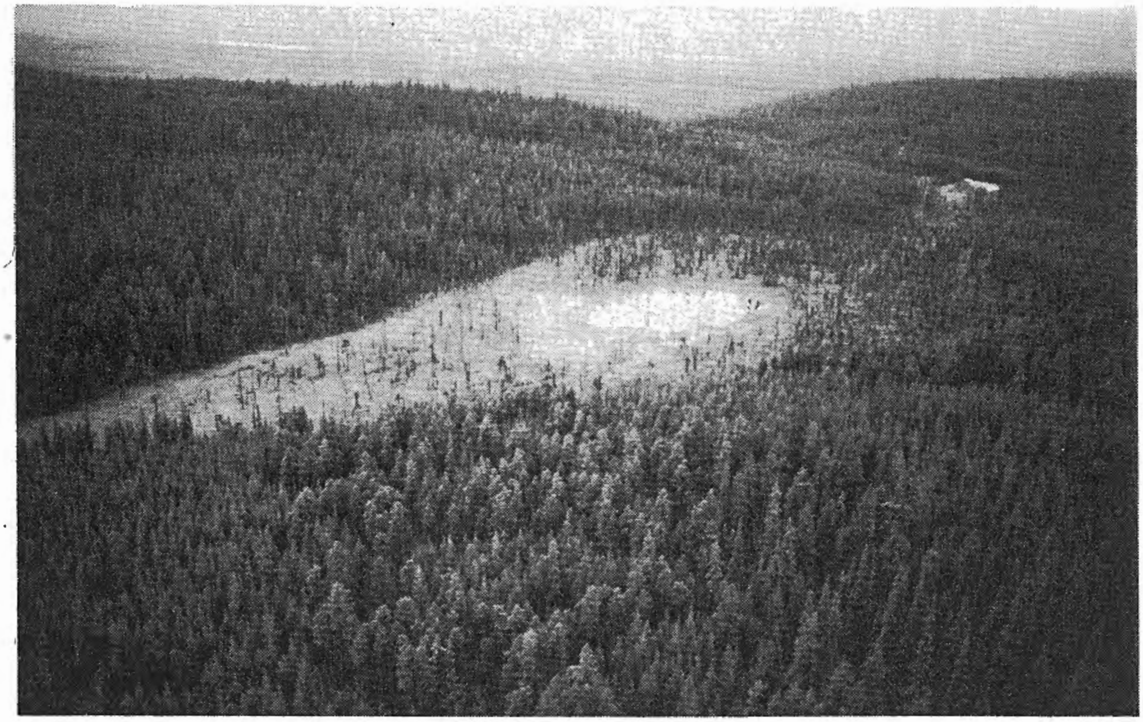


Photo 1. Wolf Pond, looking to the northwest.

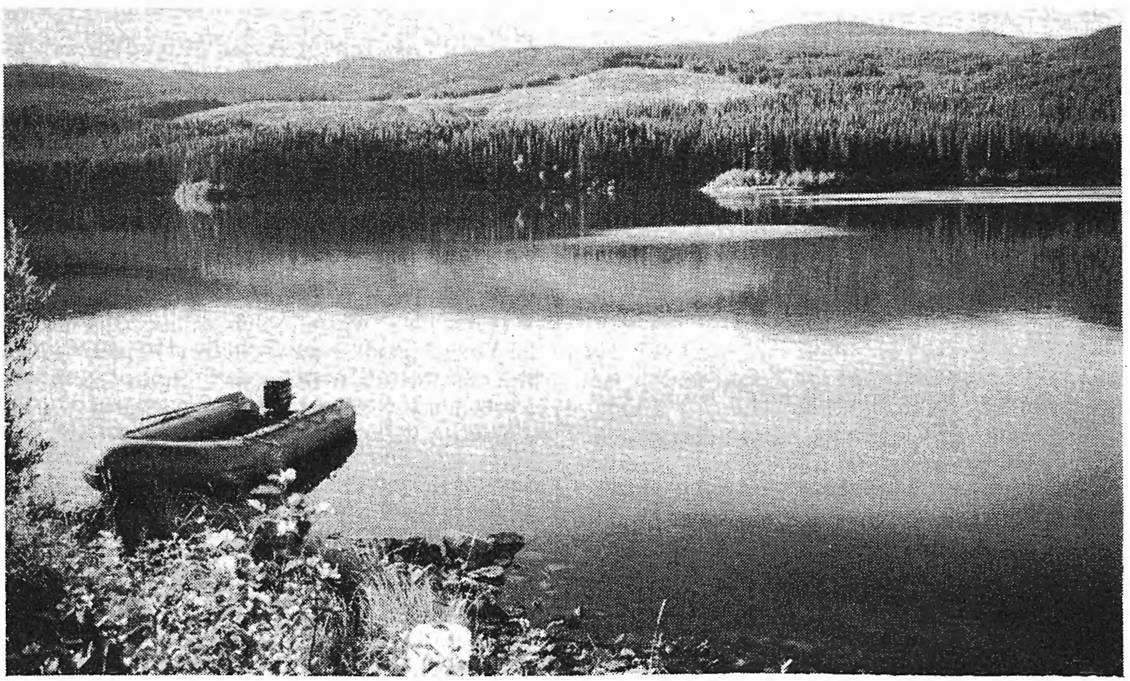


Photo 2. Hanson Lake, looking to the south.

TABLE 1
SUMMARY LISTING OF LAKES SURVEYED

ORIENTATION STUDIES: 1992

Bedrock Lithology	Lake Name	NTS	Easting	Northing	Trophic Status	Lake Size (km^2)	Max. Sample Depth (m)	Sediment Sites	Sediment Samples	Temperature and Oxygen Profiles	Adjacent Mineral Occurrences
Eocene - Jurassic	Hanson	93K03	365500	6012300	Unstratified	1 to 5	7	44	62	5	Hanson Lake (Mo, Cu)
Plutonic Rocks	Tatin	93K03	365000	6001000	Oligotrophic	1 to 5	22	38	52	6	Ken (Mo, Cu)
(Cu, Mo)	Hill-Tout	93E14,15	630750	5981000	Mesotrophic	0.25 to 1	14	52	74	5	Dual (Cu, Mo)
	Counts (5)	93F15	379450	5980000	Eutrophic	0.25 to 1	12	63	99	9	Nithi (Mo)
			379850	5979750							
			381300	5980250							
			383300	5980200							
			382750	5979550							
Eocene	Binta	93F13,14	337000	5972500	Oligotrophic	> 5	> 40	37	50	3	*None*
Ootsa Lake Group	Bentzi (2)	93F15	376950	5959750	Mesotrophic	1 to 5	35	66	92	7	Holy Cross (Au,Ag,Cu,Zn)
Volcanic Rocks			372550	5959350							
(Au, Ag)	Laurie	93F15	376000	5971500	Eutrophic	1 to 5	22	25	35	5	*None*
	Wolf	93F03	335477	5897395	Eutrophic	< 0.25	8	7	12	1	Wolf (Au, Ag)
	Clisbako	93C09	429500	5841950	-	1/4 to 1	10.5	40	57	3	Clisbako (Au, Ag)
	Wasp (2)	93E 16	678350	5978200	-	1/4 to 1	6	13	19	1	*None*
			677800	5977400							
Miocene-Pliocene Volcanic Rocks	Lavoie	93F08	410000	5927100	Unstratified	1 to 5	9	52	73	4	*None*
							Total:	**437**	**625**	**49**	

FOLLOW-UP CASE STUDIES: 1994

	Lake Name	NTS	Easting	Northing	Trophic Status	Lake Size (km^2)	Max. Sample Depth (m)	Sediment Sites	Sediment Samples	Temperature and Oxygen Profiles	Adjacent Mineral Occurrences
Drainage Lakes	Kuyakuz	93F02	393510	5888934	Unstratified	> 5	16	68	94	3	*None*
	Cow	93F03	335683	5893966	Unstratified*	1 to 5	15	50	68	-	*None*
Seepage Lakes	Lake 3031	93F06	359566	5928408	Eutrophic	< 0.25	5.5	13	17	4	*None*
	Lake 3087	93F11	341085	5935677	Eutrophic	< 0.25	7.5	24	32	5	*None*
	Lake 1138	93F03	341174	5894518	Unstratified	< 0.25	3.5	15	21	1	*None*
	Lake 1259	93F02	374503	5886097	Unstratified	< 0.25	3	17	23	1	*None*
CH Area Study	Chutanli	93F08	403000	5911800	Unstratified	1 to 5	10	50	70	7	CH (Mo, Cu)
	CH-1	93F07	398250	5911400	Unstratified	< 0.25	6	19	25	4	CH (Mo, Cu)
	CH-2	93F07	398850	5911950	Unstratified	< 0.25	4	9	12	2	CH (Mo, Cu)
							Total:	**265**	**362**	**27**	

Note: Where lakes were surveyed as part of a group (*e.g.* Counts Lakes), individual lake UTMs are shown, but summary data is for the group. Trophic status of Cow Lake (*) from data of Coombes (1986). Names of seepage lakes are from regional site locations of Cook and Jackaman (1994b). All UTM data are zone 10 with exceptions of Hill-Tout and Wasp lakes (Zone 9).

between the Chilcotin and West Road rivers (Duffell, 1959; Tipper, 1963). The Ootsa Lake Group 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 for the Ootsa Lake Group (Diakow and Koyanagi, 1988; Andrew, 1988). Interest in the precious metal potential of the Ootsa Lake Group has increased in recent years. The Wolf and Clisbako epithermal prospects (Figure 1), described in more detail later in this paper, are both hosted by this volcanic succession.

REGIONAL LAKE SEDIMENT GEOCHEMISTRY SURVEYS

Helicopter-supported regional lake sediment and water collection was conducted in three parts of the Nechako River (NTS 93F) and Fort Fraser (NTS 93K) map areas during the Interior Plateau Project. The Fawnie survey (237 sites) and the Ootsa survey (224 sites) were carried out by GSB personnel during the period June-September, 1993. A centre-lake sediment and water sample were systematically collected at each site from a float-equipped Bell 206 helicopter. Average sampling density was approximately 1 site per 7.9 square kilometres in the Fawnie area versus 7.4 square kilometres in the Ootsa area (Table 2). Further details are provided by Cook and Jackaman (1994a, b). Regional geochemical coverage of the northeast part of the Fort Fraser map area (NTS 93K/9, 10, 15, 16) was completed in October 1995. Results of this, the Pinchi Lake survey (413 sites), have not yet been released.

The Fawnie survey area (NTS map areas 93F/02 and 03) covers about 1860 square kilometres in the southern part of the Nechako Plateau (Figure 1). The area, recently remapped by Diakow *et al.* (1994, 1995a), is underlain largely by a volcanic succession with interspersed fossil-bearing sediments of Early and Middle Jurassic age. These rocks are intruded by Jura-Cretaceous quartz monzonite and granodiorite of the Capoose batholith and locally unconformably overlain by Eocene felsic volcanics of the Ootsa Lake Group. Metallogeny and mineral deposits of the Fawnie area are outlined by Schroeter and Lane (1994).

The Ootsa survey area (parts of NTS map areas 93F/06,11,12,13 and 14) lies to the north of the Fawnie area and covers about 1650 square kilometres south of Burns Lake. The irregular shaped area, bounded by Ootsa and Natalkuz lakes of the Nechako Reservoir in the south and Francois Lake in the north (Figure 1), is centred on a northwest-trending belt of Eocene felsic volcanic rocks (Tipper, 1963) that underlie about 65 to 70% of the area. Other units, the Oligocene-Miocene Endako Group and older Mesozoic successions, are less extensively exposed. Detailed bedrock mapping has been restricted to the southernmost part of this area (Diakow *et al.,* 1993). Exploration for bulk-tonnage epithermal precious metal deposits has been ongoing in the Ootsa survey area since the 1980s, and a brief summary of exploration prospects, compiled from assessment reports, is provided by Cook and Jackaman (1994b).

TABLE 2
SUMMARY OF NECHAKO PLATEAU LAKE SEDIMENT SURVEYS: 1993-1995

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

Note: Sampling density is in sites per square kilometre. Results of Pinchi Lake survey not yet released.

FOLLOW-UP CASE STUDIES OF ANOMALOUS WATERSHEDS

Case studies of nine lakes in seven localities (Figure 1) were conducted during July to September 1994, to determine the most appropriate methods of locating the potential sources of elevated sediment metal concentrations within lake watersheds. A total of 362 sediment samples were collected at 266 sites (Table 1). Earlier orientation studies were designed, in part, to guide the design and implementation of regional geochemical surveys. This, more advanced, component of the project examined sampling and interpretive strategies for more effective follow-up surveys of anomalous watersheds.

The main objective was to characterize differences in sediment metal distribution patterns between two types of lakes, seepage lakes and drainage lakes, both of which commonly occur in the Nechako Plateau. Earlier results (Cook, 1995) indicated that differences in metal distribution patterns and geochemical signatures between lakes might be related to differing watershed characteristics: in particular, to differences in metal input and accumulation between lakes with differing ground water and stream water flow patterns. Seepage and drainage lakes have been described by Wetzel (1983). Seepage lake basins receive predominantly ground water seepage or spring input below the lake surface, but lack significant stream outflow. Water loss in these lakes, other than that due to evaporation, is restricted to seepage back into ground water. For purposes of this study, lakes and ponds lacking significant stream inflows were included in this category. Drainage lakes lose water by stream flow from an outlet. In the context of this study, they include those lakes with relatively large watersheds receiving water from both surface influents and subsurface seepage. Influx of suspended particulate matter, both mineral and organic, in stream waters into drainage lakes is a major difference between these and seepage lakes. There is a certain amount of overlap between the two lake types, however, as ground waters play a major role in transporting metals to all lake basins (Hoffman and Fletcher, 1981). For example, Boyle (1994) has further subdivided lakes into six varieties on the basis of varying ground water and surface water input. The case studies include:

- Four small seepage lakes and ponds.

- Two large drainage lakes (Kuyakuz Lake; Cow Lake).

- Three lakes and ponds, near the CH porphyry copper-molybdenum prospect (MINFILE 093F 004). These were surveyed to complement earlier orientation studies (Cook, 1993a) and ongoing joint glacial dispersal studies of the Geological Survey Branch (Giles *et al.*, 1995) and the University of New Brunswick (O'Brien *et al.*, 1995; Weary *et al.*, 1995).

- Seepage and drainage lakes were chosen on the basis of apparent flow type and regional lake sediment geochemistry results (Cook and Jackaman, 1994b). All six contain elevated concentrations of gold and associated elements such as arsenic, antimony and/or molybdenum in centre-lake or centre-basin sediments. The four seepage lakes span a range of physiographic environments and include both eutrophic and unstratified variants; their identifiers (Table 1, Figure 1) are their site location numbers from Cook and Jackaman (1994b).

SAMPLE COLLECTION

SEDIMENTS AND WATERS

Orientation and Case Studies

Systematic collection of lake sediments and waters, and measurement of temperature and dissolved oxygen content of the water column, were conducted at each lake surveyed during orientation and follow-up case studies (Table 1). Sediments were sampled from a zodiac or canoe with a Hornbrook-type torpedo sampler (Photo 3). Standard sampling procedures, as discussed by Friske (1991), were used. Samples were placed in large (5" x 6") 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 1) ranged from a minimum of seven in small ponds, to a maximum of 69 in larger lakes such as Kuyakuz Lake, in order to evaluate the relationship between trace element patterns and bathymetry, organic matter content, drainage inflow and outflow, sediment texture and mineral prospect location.

An unbalanced nested sampling design, similar to that described by Garrett (1979), was used to assess case study sampling and analytical variation. A modified version of the Regional Geochemical Survey sampling scheme, devised for this purpose, has been described by Cook (1993a). Each block of twenty samples comprises twelve routine samples, five field duplicate samples to assess sampling variability, two blind duplicate samples to determine analytical precision, and one control reference standard to monitor analytical accuracy.

Regional Geochemical Surveys

Samples collected during the regional lake sediment surveys were obtained with a Hornbrook-type torpedo sampler (Photos 3 and 4). On the basis of results of the orientation studies, the regional lake sediment surveys incorporate some departures from standard lake sediment sampling strategies used elsewhere in Canada for the National Geochemical Reconnaissance (NGR) program (Friske, 1991; Friske and Hornbrook, 1991), particularly pertaining to overall site density and the number of sites sampled in each lake.

First, every lake in the survey areas was sampled, rather than sampling only a selection of lakes at a fixed density (*i.e.*, one site per 13 km^2). Even sediment in small ponds may contain anomalous metal concentrations revealing the presence of nearby mineralization, as at the Wolf prospect (Cook, 1995). In practice, some small ponds were not sampled due to unfavourable landing conditions. Samples were not collected from the centres of very large and deep lakes (10 km^2, 40 m deep) such as Tsacha, Uncha, Binta and Lucas lakes in the Nechako River map area, nor from reservoir areas such as Ootsa or Cheslatta lakes, which have been altered by the creation of the Nechako Reservoir. Organic soils from swamps and bogs were also avoided.

Secondly, centre-lake sediment samples were collected following standard NGR procedure, but sediment from the centres of all major known or inferred sub-basins was also collected to investigate the considerable trace element variations which may exist among sub-basins of the same lake. Consequently, up to five sites were sampled in some of the larger lakes in the Fawnie and Ootsa surveys. Lake bathymetry maps in unpublished reports of the Fisheries Branch, B.C. Ministry of Environment, Lands and Parks (Balkwill, 1991) were consulted prior to sampling several of the larger lakes, to assist in site selection.

Centre-lake water samples were collected from near the surface of all regional survey lakes, and from near the surface and bottom of all case study lakes. Surface water samples were, in both cases, collected in 250-millilitre polyethylene bottles from approximately 15 centimetres beneath the surface. Bottom waters were collected with a Van Dorn sampler 1 to 2 metres above the sediment-water interface. Complete details of bottle preparation and water collection procedures are given by Cook and Jackaman (1994b) for regional surveys, and by Cook (1993a) and Cook and Luscombe (1995) for orientation and case studies.

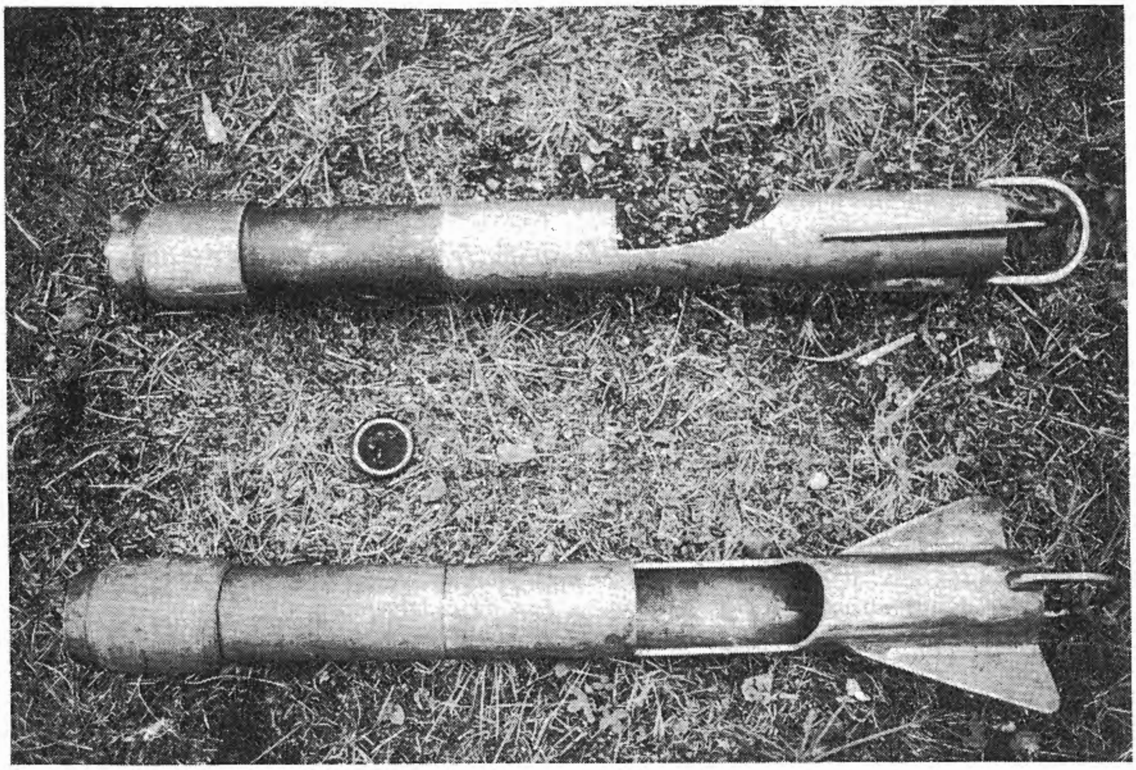


Photo 3. Hornbrook-type lake sediment samplers.

Photo 4. Regional lake sediment sampling in the Fawnie survey area.

Dissolved Oxygen and Temperature Measurements

Water column profiles of dissolved oxygen content (ppm) and temperature (°C) were measured as part of each case study to verify pre-existing Fisheries Branch data (*i.e.*, Burns, 1978), 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. No dissolved oxygen or temperature measurements were conducted during regional geochemical surveys.

Dissolved oxygen and temperature profiles 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 to a maximum depth of 29 metres, and at two near-shore sites. The instrument was calibrated for elevation and air temperature prior to measurement at each lake, and data collected only during the afternoon period so as to standardize measurement conditions. A total of 66 profiles comprising 822 pairs of measurements were surveyed; 49 profiles in 1992 and a further 27 profiles in 1994 (Table 1). Measurements generally corroborated prior Fisheries Branch data at most lakes, although considerable within-lake variations were encountered between separate sub-basins and channels. Results from a few lakes surveyed in late 1992 (*e.g.*, Clisbako, Wasp) were inconclusive due to the onset of cold weather in early fall. No profile data are given here; readers should consult Cook (1995) for selected profile data from some lakes adjacent to epithermal prospects.

SAMPLE PREPARATION AND ANALYSIS

Lake sediment samples were initially field dried and, when sufficiently dry to transport, shipped to a commercial laboratory for final drying at 40ºC. Complete details of sample preparation procedures and analytical methods are outlined by Cook (1993) and Cook and Luscombe (1995) for orientation and case studies, and by Cook and Jackaman (1994b) for regional surveys. Briefly, the entire dry sediment sample, to a maximum of 250 grams, was pulverized to approximately -150 mesh in a ceramic ring mill. Two analytical splits were taken from the pulverized material. The first 30-gram subsample was submitted to Activation Laboratories, Ancaster, Ontario for determination of gold and 34 additional elements by instrumental neutron activation analysis (INAA).

The second subsample, in the case of orientation and case studies, was submitted to Acme Analytical Laboratories, Vancouver, for determination of zinc, copper, lead, silver, arsenic, molybdenum, iron, manganese and 22 additional elements, plus loss on ignition, by inductively coupled plasma - atomic emission spectrometry (ICP-AES) following an aqua regia digestion. In the case of 1993 regional surveys, the second subsample was submitted to Can-Tech (formerly Barringer Magenta) Laboratories Inc., Calgary, for analysis for zinc, copper, lead, nickel, cobalt, silver, manganese, arsenic, molybdenum, iron, mercury, antimony, cadmium, bismuth and vanadium by atomic absorption spectroscopy (AAS) as per standard RGS procedures. Loss on ignition (LOI) was also determined. Blind duplicates and appropriate ranges of copper and gold-bearing standards were inserted into each of the analytical suites as part of a rigourous quality control program to monitor analytical precision and accuracy.

Lake waters obtained during orientation and case studies were filtered through 0.45-micron filters and analyzed for a variety of trace and major element suites by inductively coupled plasma - atomic emission spectrometry (ICP-AES) and inductively coupled plasma - mass spectrometry (ICP-MS) techniques (Cook, 1993; Cook and Luscombe, 1995). Sulphate and pH were also determined. Fawnie area regional lake waters, sampled as a pilot study to determine the usefulness of multi-element regional lake water geochemistry, were filtered through 0.45-micron MSI filters and analyzed for trace and major elements by inductively coupled plasma - atomic emission spectrometry (ICP-AES). Sulphate and pH were also determined. In contrast, unfiltered Ootsa area regional lake waters were analyzed for the standard RGS water analytical suite (pH, uranium, fluoride, sulphate) only.

RESULTS AND DISCUSSION

Highlights of results of orientation studies, regional surveys, and follow-up case studies are presented here. These represent only part of the work done, and additional results will be presented in future papers.

ORIENTATION STUDIES

Summary statistics for selected elements from all orientation lakes surveyed (Table 1) are provided in Table 3. Lakes in seven areas are immediately adjacent to known mineral prospects (Table 1). Elevated metal concentrations in sediments from each of these lakes reflect the presence of epithermal gold and porphyry molybdenum or copper-molybdenum mineralization. Selected results for four lakes are shown here: the Wolf and Clisbako epithermal precious metal prospects, and the Ken and Hanson Lake porphyry molybdenum prospects. Cook (1995) and Cook and Jackaman (1994b) should be consulted for further details.

EPITHERMAL PRECIOUS METAL PROSPECTS

The Wolf pond, located about 100 kilometres south-southwest of Fraser Lake, is a small eutrophic pond (max. depth: 4.5 m), approximately 60 by 35 metres in dimension. It is situated within a narrow intermontane bog in the rugged uplands of the Entiako Spur of the Fawnie Range. There is no stream input into the pond, inferring a groundwater source for contained metals. Clisbako Lake, located about 100 kilometres west of Quesnel, is a small single-basin lake (max. depth: 9 m) of unknown trophic status about 700 metres long. Two streams drain into the lake from the west and the south, defining a watershed of about 14 square kilometres.

TABLE 3
SUMMARY STATISTICS FOR SELECTED ELEMENTS: ORIENTATION STUDIES

		Mo (ppm)	Cu (ppm)	Pb (ppm)	Zn (ppm)	Ag (ppm)	Ni (ppm)	Co (ppm)	Cr (ppm)	Mn (ppm)	Fe (%)	As (ppm)	Cd (ppm)	Au (ppb) INAA	As (ppm) INAA	Sb (ppm) INAA	Fe (%) INAA	La (ppm) INAA	Ce (ppm) INAA	LOI (%)
Plutonic Rocks																				
HANSON LAKE (N=44)	Mean	8.36	60.48	9.20	117.18	0.40	30.75	9.64	37.52	584.05	3.55	13.41	0.52	3.11	14.29	0.78	3.89	32.30	51.73	26.5
	Median	7	65.5	9	122	0.35	32	10	40	601.5	3.78	13	0.5	3	14	0.8	3.925	32.5	53.5	27.5
	S.D.	8.08	15.19	3.02	24.27	0.22	6.97	1.82	8.78	136.56	0.81	7.76	0.18	2.53	8.25	0.14	0.81	6.09	9.85	5.9
	Variance	65.21	230.86	9.10	589.27	0.05	48.56	3.31	77.09	18649.72	0.66	60.20	0.03	6.38	68.01	0.02	0.66	37.05	97.04	34.5
	C.V.	96.55	25.12	32.77	20.72	54.63	22.66	18.87	23.40	23.38	22.83	57.86	33.88	81.14	57.70	18.69	20.95	18.85	19.04	22.2
	Minimum	1	25	2	60	0.1	13	4	11	274	1.46	2	0.2	1	6.2	0.4	1.93	17	29	5.4
	Maximum	55	83	15	158	0.8	44	13	51	985	4.92	57	0.9	14	62	1.1	5.4	44	70	33.8
TATIN LAKE (N=38)	Mean	8.63	33.71	5.08	70.03	0.14	15.50	5.39	21.61	770.42	2.20	2.58	0.30	1.71	4.50	0.66	2.31	42.95	49.97	32.0
	Median	8	35	4.5	77.5	0.1	17	6	22.5	697.5	2.02	2	0.3	1	4.4	0.65	2.12	47	54.5	34.1
	S.D.	4.19	10.84	2.31	22.81	0.06	4.42	1.92	7.50	326.90	1.18	0.92	0.16	1.21	1.76	0.16	1.12	14.35	15.84	9.8
	Variance	17.59	117.40	5.32	520.40	0.00	19.55	3.70	56.25	106863.28	1.38	0.84	0.03	1.45	3.11	0.03	1.26	205.89	250.84	95.6
	C.V.	48.59	32.14	45.40	32.58	45.20	28.53	35.68	34.71	42.43	53.44	35.64	54.44	70.51	39.19	24.25	48.51	33.41	31.69	30.5
	Minimum	1	1	2	17	0.1	4	1	4	195	0.44	2	0.2	1	1.6	0.2	0.53	12	14	3.4
	Maximum	23	49	11	98	0.3	22	11	44	2198	5.16	5	1	5	9.6	1	4.94	63	76	45.6
COUNTS LAKES (5) (N=63)	Mean	48.59	46.29	14.54	114.54	0.27	17.67	7.65	23.29	259.54	1.94	4.24	0.71	2.11	5.57	1.09	2.09	24.11	39.40	19.7
	Median	42	44	10	109	0.2	17	7	23	244	1.65	3	0.6	1	4.1	1.1	1.9	22	38	18.3
	S.D.	41.08	22.45	21.92	37.23	0.26	4.80	2.30	5.28	78.39	0.89	2.69	0.54	1.63	3.57	0.19	0.84	7.74	8.93	9.2
	Variance	1687.86	503.92	480.35	1386.32	0.07	23.03	5.30	27.85	6145.64	0.79	7.25	0.29	2.65	12.72	0.04	0.70	59.84	79.76	85.2
	C.V.	84.56	48.50	150.74	32.51	96.83	27.17	30.08	22.66	30.21	45.97	63.53	75.61	77.09	64.02	17.26	39.96	32.08	22.67	47.0
	Minimum	4	12	4	56	0.1	10	4	11	130	1.1	2	0.2	1	2.3	0.7	1.22	13	24	5.4
	Maximum	165	94	167	236	1.2	28	12	36	586	6.7	12	2.8	9	22	1.5	6.97	44	65	48.7
HILL-TOUT LAKE (N=52)	Mean	2.27	102.90	11.15	295.79	1.07	26.00	28.83	14.54	2436.42	3.91	7.23	2.02	4.65	9.68	1.41	3.86	17.79	27.94	33.1
	Median	2	101.5	10	317	0.8	25	26.5	14	625	2.83	5	1.95	4.5	9.4	1.5	2.665	18.5	28	34.1
	S.D.	1.25	27.20	4.75	90.14	0.59	7.72	16.48	3.11	8380.23	2.55	6.46	1.07	2.64	4.62	0.38	2.64	3.95	6.92	5.8
	Variance	1.57	739.85	22.56	8124.60	0.35	59.53	271.64	9.67	70228226.13	6.51	41.79	1.14	6.98	21.32	0.14	6.95	15.58	47.90	33.8
	C.V.	55.27	26.43	42.59	30.47	55.23	29.68	57.17	21.38	343.96	65.20	89.40	53.07	56.75	47.73	26.58	68.37	22.19	24.77	17.5
	Minimum	1	22	2	146	0.3	12	8	10	140	1.3	2	0.2	1	2.7	0.6	1.39	10	15	12.8
	Maximum	8	151	24	462	3	65	73	24	59655	10.96	31	5.3	12	23	2.3	12	25	44	42.1
Ootsa Lake Volcanics																				
BINTA LAKE (N=37)	Mean	6.46	30.68	12.68	85.62	0.10	20.89	8.14	22.27	777.86	2.11	14.19	0.26	2.59	12.55	2.12	2.28	30.11	52.97	26.0
	Median	7	34	8	87	0.1	21	8	23	690	2.16	13	0.2	2	12	1.6	2.35	30	54	29.4
	S.D.	2.65	8.74	30.93	17.59	0.02	4.89	2.03	4.51	326.74	0.66	7.03	0.10	1.85	5.74	2.86	0.58	6.01	10.33	8.8
	Variance	7.03	76.39	956.61	309.52	0.00	23.93	4.12	20.37	106759.34	0.44	49.44	0.01	3.41	32.93	8.20	0.34	36.15	106.64	77.4
	C.V.	41.06	28.49	244.00	20.55	16.01	23.42	24.95	20.27	42.00	31.47	49.55	39.01	71.22	45.71	135.01	25.46	19.97	19.49	33.8
	Minimum	1	6	2	48	0.1	11	5	13	243	1.2	5	0.2	1	5.3	1.2	1.38	19	37	3.7
	Maximum	11	43	195	135	0.2	31	14	32	1594	4.53	39	0.5	7	34	19	4.22	48	88	36.5
LAURIE LAKE (N=25)	Mean	2.84	16.44	6.76	57.72	0.20	7.32	4.60	10.36	291.60	1.20	6.56	0.22	2.04	7.52	1.46	1.31	22.48	36.84	25.2
	Median	3	21	7	64	0.2	8	5	11	272	1.03	6	0.2	1	7.2	1.5	1.15	22	37	31.2
	S.D.	1.84	9.30	1.45	16.27	0.09	2.70	0.87	2.51	81.01	0.39	2.93	0.05	2.34	2.38	0.33	0.34	1.29	3.06	15.4
	Variance	3.39	86.51	2.11	264.79	0.01	7.31	0.75	6.32	6563.00	0.15	8.59	0.00	5.46	5.67	0.11	0.11	1.68	9.39	235.8
	C.V.	64.83	56.57	21.47	28.19	47.68	36.94	18.83	24.27	27.78	32.71	44.68	23.34	114.51	31.64	22.46	25.76	5.76	8.32	61.0
	Minimum	1	2	3	31	0.1	2	3	6	189	0.77	2	0.2	1	4.3	0.9	0.88	21	31	2.6
	Maximum	10	32	9	90	0.4	12	6	15	484	2.19	12	0.4	12	14	2.2	2.05	26	45	41.5

TABLE 3 CONTINUED

BENTZI LAKE (N=58)	Mean	3.41	51.31	4.16	96.86	0.21	14.26	9.34	16.31	1561.81	2.83	10.10	0.28	2.59	12.70	1.77	3.08	21.78	41.66	31.4
	Median	4	53	4	93.5	0.2	14.5	9	17.5	549.5	2.17	8.5	0.2	1	12	1.7	2.635	22	43	35.9
	S.D.	1.88	25.13	1.71	25.21	0.13	4.46	2.22	4.01	3527.71	2.27	7.92	0.18	2.08	5.26	0.55	2.04	3.95	8.08	13.2
	Variance	3.55	631.38	2.94	635.56	0.02	19.91	4.93	16.08	12444715.03	5.17	62.80	0.03	4.32	27.65	0.30	4.15	15.58	65.28	175.5
	C.V.	55.15	48.97	41.27	26.03	60.64	31.30	23.76	24.58	225.87	80.28	78.43	63.68	80.34	41.41	30.96	66.10	18.13	19.40	42.2
	Minimum	1	9	2	39	0.1	5	5	5	257	1.56	2	0.2	1	2.5	0.5	1.42	12	22	4.2
	Maximum	8	100	7	143	0.6	23	15	23	18752	11.64	35	1.3	9	27	3.4	11.8	28	54	49.2
UNNAMED LAKE (N=8) (Bentzi Lake Area)	Mean	7.88	41.38	3.13	63.38	0.10	15.38	5.00	13.50	659.00	1.17	3.50	0.24	1.75	4.50	1.83	1.25	9.50	15.25	71.2
	Median	7.5	46.5	3	67.5	0.1	15	4.5	9.5	606.5	1.02	2.5	0.2	1	4.5	1.95	1.06	7.5	10	80.1
	S.D.	4.02	13.02	0.99	16.28	0.00	5.32	2.73	10.52	224.39	0.47	1.85	0.11	1.49	0.84	0.40	0.60	6.37	12.76	24.8
	Variance	16.13	169.41	0.98	265.13	0.00	28.27	7.43	110.57	50351.43	0.22	3.43	0.01	2.21	0.71	0.16	0.36	40.57	162.79	613.7
	C.V.	50.99	31.46	31.71	25.69	0.00	34.58	54.51	77.89	34.05	39.66	52.90	44.66	85.03	18.74	21.87	47.93	67.05	83.66	34.8
	Minimum	1	21	2	32	0.1	8	2	6	325	0.71	2	0.2	1	3.5	1	0.81	5	8	10.3
	Maximum	15	53	5	82	0.1	27	11	38	1033	1.9	6	0.5	5	6	2.2	2.6	25	46	83.2
WOLF POND (N=7)	Mean	15.86	54.29	7.86	230.43	1.61	15.71	9.43	16.29	262.71	2.41	35.57	0.53	32.57	37.31	1.60	2.26	27.29	53.86	51.1
	Median	18	71	8	306	2.2	21	14	21	302	3.37	47	0.5	43	47	2	2.91	37	75	52.3
	S.D.	5.27	26.48	4.91	131.18	0.99	10.24	7.35	8.44	157.28	1.83	31.68	0.26	18.55	30.58	0.99	1.66	17.70	33.26	7.7
	Variance	27.81	701.24	24.14	17208.29	0.98	104.90	53.95	71.24	24735.90	3.34	1003.62	0.07	344.29	935.09	0.99	2.75	313.24	1106.14	59.2
	C.V.	33.26	48.78	62.54	56.93	61.26	65.18	77.90	51.83	59.87	75.97	89.06	48.50	56.97	81.95	62.08	73.48	64.86	61.75	15.1
	Minimum	9	22	2	90	0.5	2	1	7	87	0.4	2	0.2	11	6.1	0.4	0.44	8	16	40.7
	Maximum	23	81	16	372	2.6	26	17	24	511	4.73	83	0.9	56	80	2.7	4.12	46	88	64.1
CLISBAKO LAKE (N=40)	Mean	3.03	33.55	3.63	89.20	0.12	50.50	11.43	26.05	785.80	2.64	24.45	0.25	8.88	25.63	3.47	2.89	16.73	30.18	46.0
	Median	3	35.5	2	99.5	0.1	52	12	27.5	745	2.69	24	0.2	9	25.5	3.1	3.15	17	30	50.3
	S.D.	1.35	11.76	3.18	22.24	0.06	13.37	2.53	6.14	279.26	0.89	7.21	0.10	3.77	8.00	1.18	0.86	4.21	7.51	16.9
	Variance	1.82	138.41	10.14	494.52	0.00	178.77	6.40	37.69	77986.73	0.79	51.95	0.01	14.21	63.94	1.38	0.74	17.69	56.35	286.6
	C.V.	44.60	35.07	87.83	24.93	50.58	26.48	22.15	23.57	35.54	33.72	29.48	39.87	42.48	31.19	33.96	29.89	25.15	24.88	36.8
	Minimum	1	8	2	54	0.1	22	6	16	369	0.95	7	0.2	1	9.3	2.1	1.14	8	15	7.1
	Maximum	6	59	20	130	0.4	74	16	35	1745	4.86	46	0.6	16	49	6.2	4.72	24	44	70.5
WASP LAKE (N=8)	Mean	1.00	33.50	5.50	118.13	0.20	21.13	6.13	16.38	204.50	1.54	4.63	0.40	3.13	6.05	1.90	1.96	23.75	44.00	45.8
	Median	1	32.5	5.5	119	0.15	21.5	6	17	195.5	1.62	4.5	0.35	3	5.95	1.75	1.865	22	42	42.2
	S.D.	0.00	3.78	1.93	7.06	0.12	3.00	0.99	2.62	23.83	0.27	2.45	0.16	1.96	1.41	0.26	0.58	2.43	5.53	12.2
	Variance	0.00	14.29	3.71	49.84	0.01	8.98	0.98	6.84	567.71	0.07	5.98	0.03	3.84	2.00	0.07	0.33	5.93	30.57	148.7
	C.V.	0.00	11.28	35.04	5.98	59.76	14.19	16.18	15.97	11.65	17.50	52.88	40.09	62.70	23.36	13.49	29.40	10.25	12.57	26.6
	Minimum	1	29	3	107	0.1	15	4	10	181	0.92	2	0.2	1	3.6	1.7	0.91	22	38	33.7
	Maximum	1	42	9	127	0.4	25	7	18	243	1.74	10	0.7	7	7.8	2.3	2.56	27	51	74.2
UNNAMED POND (N=5) (Wasp Lake Area)	Mean	1.00	32.80	2.60	111.80	0.14	23.00	4.20	10.60	102.00	0.86	2.00	0.66	3.20	3.26	1.02	0.90	16.80	25.40	58.1
	Median	1	34	2	110	0.1	24	4	10	86	0.85	2	0.6	4	3.3	1	0.89	18	26	56.3
	S.D.	0.00	4.09	0.89	6.02	0.05	4.12	0.45	1.52	36.65	0.08	0.00	0.13	1.64	0.38	0.11	0.13	2.17	3.91	3.9
	Variance	0.00	16.70	0.80	36.20	0.00	17.00	0.20	2.30	1343.50	0.01	0.00	0.02	2.70	0.15	0.01	0.02	4.70	15.30	15.1
	C.V.	0.00	12.46	34.40	5.38	39.12	17.93	10.65	14.31	35.94	9.07	0.00	20.33	51.35	11.80	10.74	13.98	12.90	15.40	6.7
	Minimum	1	28	2	107	0.1	16	4	9	79	0.77	2	0.5	1	2.7	0.9	0.74	14	20	54.1
	Maximum	1	37	4	122	0.2	27	5	13	166	0.98	2	0.8	5	3.7	1.2	1.09	19	29	63.2
Chilcotin Volcanics LAVOIE LAKE (N=52)	Mean	2.54	25.21	3.23	86.48	0.14	42.60	9.25	25.25	310.69	1.79	3.35	0.24	1.96	5.32	0.80	2.08	10.06	19.62	43.2
	Median	2	24	3	85	0.1	45	9	26	294.5	1.85	2	0.2	1	5.1	0.75	2.14	9	17.5	46.7
	S.D.	1.72	11.69	1.42	30.06	0.08	15.86	2.46	7.09	105.95	0.63	2.17	0.08	1.49	2.05	0.26	0.53	3.87	7.32	17.0
	Variance	2.96	136.72	2.02	903.55	0.01	251.50	6.07	50.31	11225.04	0.40	4.70	0.01	2.23	4.19	0.07	0.29	15.00	53.61	288.3
	C.V.	67.77	46.38	44.04	34.76	58.60	37.23	26.64	28.09	34.10	35.12	64.80	34.39	76.19	38.49	32.04	25.72	38.50	37.33	39.3
	Minimum	1	7	2	35	0.1	17	4	11	150	0.73	2	0.2	1	2.3	0.3	0.91	4	9	9.7
	Maximum	12	51	7	163	0.4	67	13	37	848	3.16	14	0.5	5	12	1.7	3.29	20	38	73.6

The Wolf (MINFILE 093F 045) and Clisbako (093C 016) gold-silver prospects are both in Eocene volcanic rocks of the Ootsa Lake Group. The Wolf prospect, a low sulphidation adularia-sericite epithermal deposit, is hosted by rhyolite flows, tuffs and subvolcanic rhyolite porphyry (Andrew, 1988; Schroeter and Lane, 1994). It comprises five mineralized zones, one of which (the Lookout zone) lies within the Wolf pond watershed. Here, mineralization occurs in northerly trending quartz-carbonate veins; other zones occur as siliceous stockworks and hydrothermal breccias (Schroeter and Lane, 1994), which are typically bordered by zones of argillic or sericitic alteration. The Clisbako prospect is a low-sulphidation adularia-sericite epithermal prospect in basaltic to rhyolitic tuffs and flows exhibiting intense silicification and argillic alteration. Gold occurs in quartz stockwork and silicified breccia zones. Several alteration zones have been identified (Dawson, 1991), although not all lie within the Clisbako Lake watershed. The largest, the South, Central and North zones, have exposed strike lengths of up to 450 metres (Schroeter and Lane, 1992). Gold concentrations up to 1076 ppb, as well as elevated concentrations of mercury, arsenic and antimony were reported by Dawson (1991).

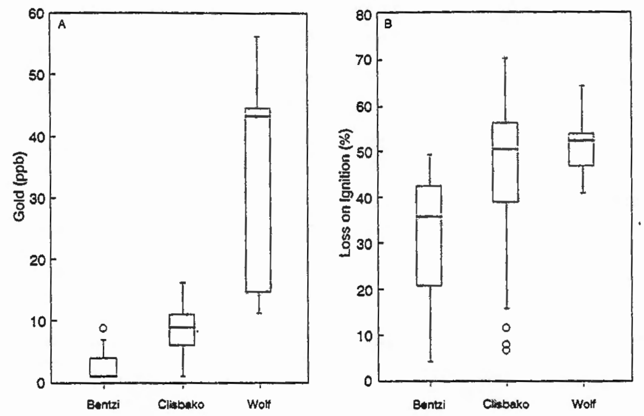


Figure 2. Boxplots showing variations in (A) gold (ppb); and (B) loss on ignition (%) in sediments of Bentzi Lake (n=58), Clisbako Lake (n=40) and Wolf pond (n=7). Median concentrations are denoted by the bold line in each box; 50% of the data for each lake lies within the box.

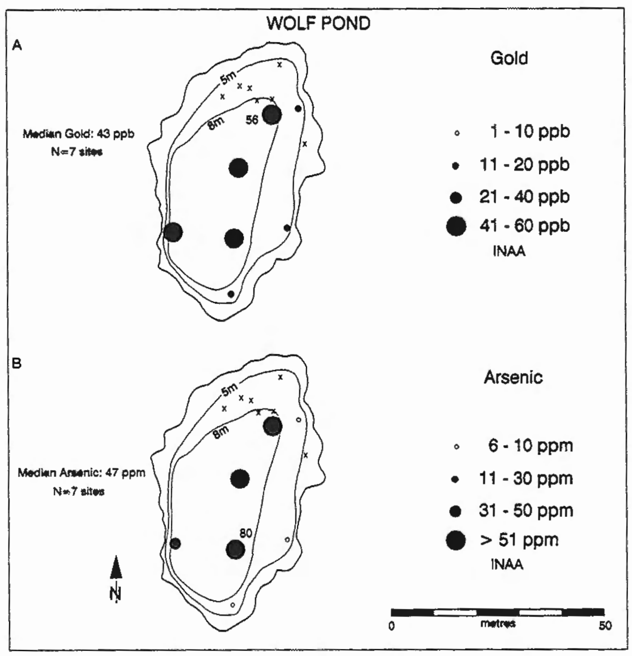


Figure 3. Distribution of (A) gold (ppb) and (B) arsenic (ppm) in Wolf pond sediment. Contours denote sample depth (metres), not lake depth. Sites where no sample could be obtained are denoted by an 'x'. Refer to Cook (1995) for local geology and locations of mineralized zones.

Abundance of Gold and Other Elements

Elevated concentrations of gold, arsenic and other elements occur in sediments of Wolf pond and Clisbako Lake. Relative gold distributions are shown by the boxplots in Figure 2. Maximum gold concentrations in Wolf pond and Clisbako Lake are 56 ppb and 16 ppb, respectively; median gold concentrations are 43 ppb and 9 ppb. Maximum arsenic concentrations are 83 ppm (median: 47 ppm) in Wolf pond, and 46 ppm (median: 24 ppm) in Clisbako lake. These concentrations are considerably greater than the regional background of 1 ppb gold and 2-4 ppm arsenic, as determined from results of nearby regional lake sediment surveys (*i.e.*, Cook and Jackaman, 1994b). Wolf pond also contains elevated concentrations of zinc (median: 306 ppm), molybdenum (median: 18 ppm) and silver (median: 2.2 ppm). It exhibits a much more diverse multi-element geochemical signature than Clisbako Lake sediment, which contains elevated concentrations of only antimony (median: 3.1 ppm) in addition to gold and arsenic. Analytical data for selected elements from sites within these lakes has been given by Cook (1995).

Spatial Distribution of Gold

Centre-lake sediments may, but do not necessarily, contain the highest gold concentrations in Interior Plateau lakes. Evidence from this and other studies (Coker *et al.*, 1982; Fox *et al.*, 1987) suggests that gold may also be concentrated in near-shore organic-rich sediments, particularly near drainage inflows. Gold distribution patterns in these sediments may, if present, not only reflect the presence of mineralization, but also indicate the general direction to it relative to the lake. Distribution of gold, arsenic and other elements in tiny Wolf pond is relatively uniform, with greatest concentrations occurring in the central, deepest, part of the small basin (Figure 3). The restricted size of the watershed (km^2) makes the source area relatively easy to discern. In Clisbako Lake, however, the locations of known altered and mineralized zones are revealed by gold distribution patterns present in sediment at stream and groundwater inflows (Figure 4A). Here, gold distribution patterns are more strongly influenced by possible source areas and high organic matter content (Figure 4B) than simply by basin depth. Three groupings of sediment sites contain at least 10 ppb gold. Two of these, at stream inflows, indicate the presence of up-drainage argillic alteration and/or mineralized zones; the third, on the southwest side of the lake, has an unknown

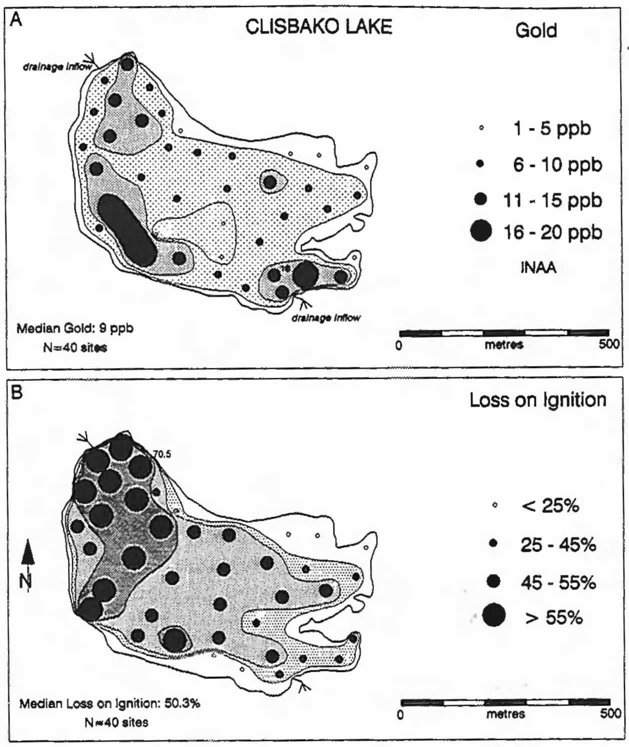


Figure 4. Distribution of (A) gold (ppb) and (B) loss on ignition (%) in Clisbako Lake sediment. Creeks entering the lake from both the south and northwest drain epithermal alteration and/or mineralized zones of Dawson (1991).

source. Gold concentrations in centre-lake sediments of Clisbako Lake (4-8 ppb) are relatively low, but are nevertheless regionally anomalous relative to a 1 ppb background.

Implications for Exploration

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

PORPHYRY MOLYBDENUM PROSPECTS

Tatin Lake, located approximately 6 kilometres north of Endako village and Highway 16, is a large (4-5 km long) east-trending lake with a maximum depth of about 19 metres. A wide range of limnological conditions exist in its component sub-basins, ranging from eutrophic regimes in the eastern and western sub-basins to mesotrophic-oligotrophic regimes in the main basin and channel. The lake receives weak stream drainage from the north and northwest. Hanson Lake, about 12 kilometres north of Tatin Lake, is 3 kilometres long and unstratified, with a single basin (max. depth: 7 m). It is part of the Shovel Creek drainage system, and receives only seasonal stream drainage from the north and south. Walsh (1977) and Burns and Philip (1977) should be consulted for additional bathymetric information on Tatin and Hanson Lake, respectively.

Tatin and Hanson lakes are situated within and adjacent to units of the Francois Lake intrusive suite which host porphyry molybdenum mineralization. The Ken molybdenum-copper prospect (MINFILE 093K 002), on the northwest side of Tatin Lake, comprises quartz-molybdenite stockwork mineralization associated with potassic and argillic alteration of the Casey quartz monzonite (Lodder and Godfrey, 1969). The Hanson Lake showing (MINFILE 093K 081), located on a ridge about 2.5 kilometres south of Hanson Lake, is a poorly developed molybdenite-pyrite-chalcopyrite stockwork associated with weak chlorite, kaolinite and sericite alteration (Kimura, 1978). A second mineralized area, the Han prospect (MINFILE 093K 078) and associated properties, is located to the north and northwest of Hanson Lake. Here, pyrite, chalcopyrite, sphalerite and minor galena occur in disseminations and veins within a breccia zone along the contact of two phases of the Francois Lake suite. Extensive polymetallic soil geochemical anomalies have been reported from this area (Kimura, 1972; Chapman, 1989).

Abundance of Molybdenum and Other Elements

Elevated molybdenum concentrations occur in sediments of both Tatin (max: 23 ppm) and Hanson (max: 55 ppm) lakes. Median molybdenum concentrations are 8 ppm and 7 ppm, respectively. These concentrations exceed the regional background of, in most cases, 1 to 2 ppm molybdenum in lake sediments from parts of adjacent NTS map areas 93E (Whitesail Lake; Johnson *et al.*, 1987a), 93L (Smithers; Johnson *et al.*, 1987b) and 93F (Nechako River; Cook and Jackaman, 1994b; Table 4). Significantly, molybdenum concentrations in Tatin and Hanson lakes also exceed the mean molybdenum content (1 ppm) of lake sediments reported for a portion of the Francois Lake intrusions by Hoffman and Fletcher (1976).

Although median molybdenum concentrations are similar, concentrations of several other elements are considerably greater in Hanson than Tatin Lake. Relative to Tatin Lake, Hanson Lake sediment contains approximately two times the copper (median: 65.5 ppm), chromium (median: 40 ppm) and nickel (median: 32 ppm), more than three times

TABLE 4
MEDIAN AND RANGE OF SELECTED ELEMENTS IN RGS CENTRE-LAKE SEDIMENTS: FAWNIE AND OOTSA SURVEY AREAS
(NTS 93F - NECHAKO RIVER)

Survey		Au (ppb) *INAA*	As (ppm) *INAA*	Sb (ppm) *INAA*	Mo (ppm) *INAA*	Cu (ppm) *AAS*	Zn (ppm) *AAS*
FAWNIE	**Median**	**1**	**5.8**	**0.8**	**2**	**27**	**80**
237 sites	Range	(1-256)	(0.5-57)	(0.1-3.5)	(1-17)	(7-397)	(15-366)
OOTSA	**Median**	**1**	**8.1**	**1.4**	**1**	**29**	**85**
224 sites	Range	(1-13)	(1.3-110)	(0.3-12)	(1-20)	(11-57)	(16-1036)

Survey		Fe (%) *AAS*	As (ppm) *AAS*	Ag (ppm) *AAS*	Mo (ppm) *AAS*	Mn (ppm) *AAS*	L.O.I. (%)
FAWNIE	**Median**	**1.40**	**2.1**	**0.2**	**5**	**260**	**50.6**
237 sites	Range	(0.10-8.50)	(0.2-35)	(0.1-1.8)	(1-22)	(34-4150)	(4.7-96.1)
OOTSA	**Median**	**1.40**	**2.7**	**0.2**	**5**	**285**	**47**
224 sites	Range	(0.20-8.20)	(0.3-73)	(0.1-0.6)	(1-34)	(50-3050)	(10.7-90.2)

the silver (median: 0.35 ppm), and four to six times the arsenic (median: 13 ppm). Median iron (3.78%) and zinc concentrations (122 ppm) are also greater than those of Tatin lake; in the case of iron, this is probably due to the unstratified water column and more oxygen-rich conditions prevailing in Hanson sediment. In contrast, uranium (INAA; median: 67 ppm) and thorium (INAA; median: 18 ppm) are enriched in Tatin Lake sediments, where they far exceed regional background. Median organic matter content, expressed as percent loss on ignition (LOI), is also greatest in Tatin Lake sediment (median: 34.1%).

Spatial Distribution of Molybdenum

Median molybdenum concentrations in Tatin and Hanson lakes are relatively similar, but there are considerable differences in its spatial distribution within sediments of the two lakes. Patterns vary with limnological variations between basins, organic matter content, and basin morphometry. For example, molybdenum is concentrated in centre-basin sediments of unstratified Hanson Lake, and in eutrophic sub-basins and some near-shore sediments of predominately mesotrophic-oligotrophic Tatin Lake. Tatin Lake, with the widest range of limnological environments, also has the most complex molybdenum geochemical patterns (Figure 5A) and the widest range of LOI, iron and manganese values.

Tatin Lake molybdenum distribution patterns are zoned, with the highest concentrations occurring in the western end of the lake near the Ken occurrence rather than in sediment of the main centre-lake basin. The most significant molybdenum concentrations occur in three areas: (1) near-shore shallow-water organic sediments (12-14 ppm) at the mouth of a small bay near the prospect, (2) western sub-basin gyttja (up to 14 ppm), and (3) eastern sub-basin gyttja, where the highest molybdenum concentration in the lake (23 ppm) was obtained, although its source is unknown. The considerable between-basin molybdenum variations in Tatin Lake sediments are particularly pronounced in profundal centre-basin sediments. For example, centre-basin sediment of the western sub-basin contains 12 ppm molybdenum versus 7 ppm and 23 ppm in the main basin and eastern sub-basin, respectively.

There is a close association between distribution of molybdenum and LOI (organic matter), particularly in the western end of the lake where high molybdenum concentrations occur in both near-shore organic sediments and centre-basin gyttjas (Figure 5A). In the former case, sediment from four shallow-water sites (1-1.5 m of water) largely comprises immature, poorly decomposed organic matter with the highest LOI values (43.1-45.6%) in Tatin lake. Distribution of molybdenum is roughly inverse to that of iron and manganese. Molybdenum exhibits an inverse relationship with the two, regardless of LOI values. For example, elevated iron (max: 5.16%) and manganese (max: 2198 ppm) values are concentrated in profundal sediments of the relatively oxygen-rich mesotrophic centre basin and oligotrophic channel, and at some near-shore sites, where molybdenum concentrations are relatively low. Conversely, iron and manganese are least common in the relatively oxygen-poor eutrophic sub-basins and near-shore organic sediments where elevated molybdenum values predominate. Nevertheless, there is little difference in sediment LOI values between the two basins (Figure 5B). Iron and manganese have similar distribution patterns in Tatin Lake sediment, but manganese is the more uniformly distributed; manganese concentrations of 500 to 1000 ppm vary little between sub-basins, regardless of trophic regime.

In Hanson Lake, metal distributions are relatively uniform and typically within narrow ranges. Molybdenum concentrations of at least 6 ppm are, for example, widely distributed throughout most of Hanson Lake sediment beneath the 4-metre depth contour (Figure 6A). Manganese in particular shows little variation, with nearly all sediment beneath the 4-metre contour containing 501 to 750 ppm. There are distinct differences, however, between (1) molybdenum, copper and LOI distributions in Hanson Lake sediment, and (2) those for iron and zinc. Elevated molybdenum, copper and LOI values are associated with centre-lake sediments. Elevated molybdenum concentrations of 11 to 18 ppm are particularly closely associated with profundal sediments in central and south-central Hanson Lake, where they closely correspond with elevated organic matter content (LOI 30%). Isolated sites with elevated concentrations of 16 ppm and 55 ppm molybdenum occur along the southwest and northeast margins of the lake, respectively, but no lake-margin zonation patterns are apparent. In contrast, zinc (Figure 6B) and iron exhibit distinct lake- margin zonation patterns. Elevated iron concentrations greater than 3%, and rather undistinguished zinc values greater than 110 ppm, are widely distributed beneath the 4 metre contour. However, zones of elevated iron (4%) and zinc (130 ppm) rim the northwest side of Hanson Lake, forming similar shaped zonation patterns within the sediment. These near-shore zones have no apparent association with sediment organic matter or the profundal basin. They are, however, located immediately down slope from extensive soil zinc anomalies

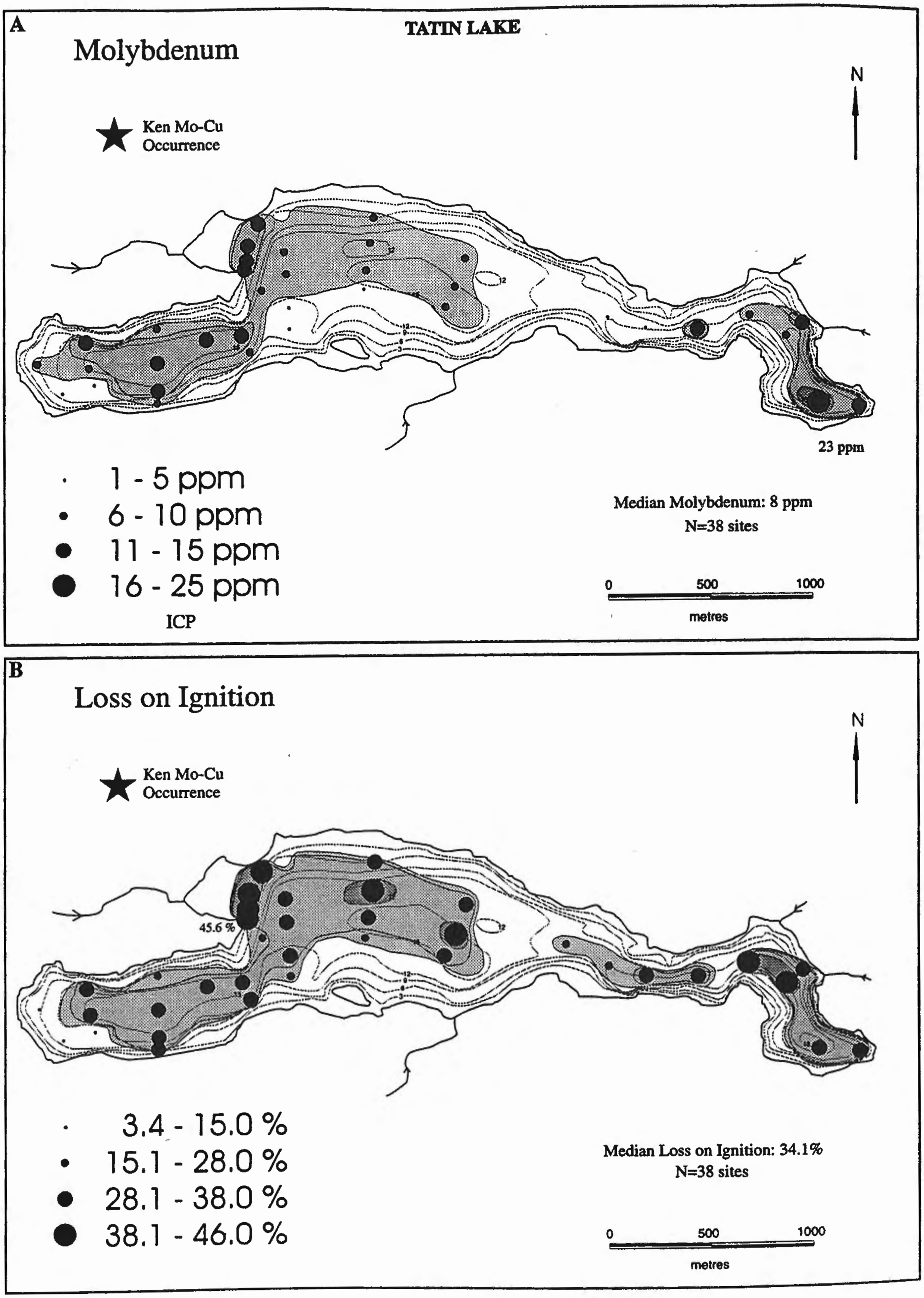


Figure 5. Distribution of (A) molybdenum (ppm) and (B) loss on ignition (%) in Tatin Lake sediment. Bathymetry after Walsh (1977).

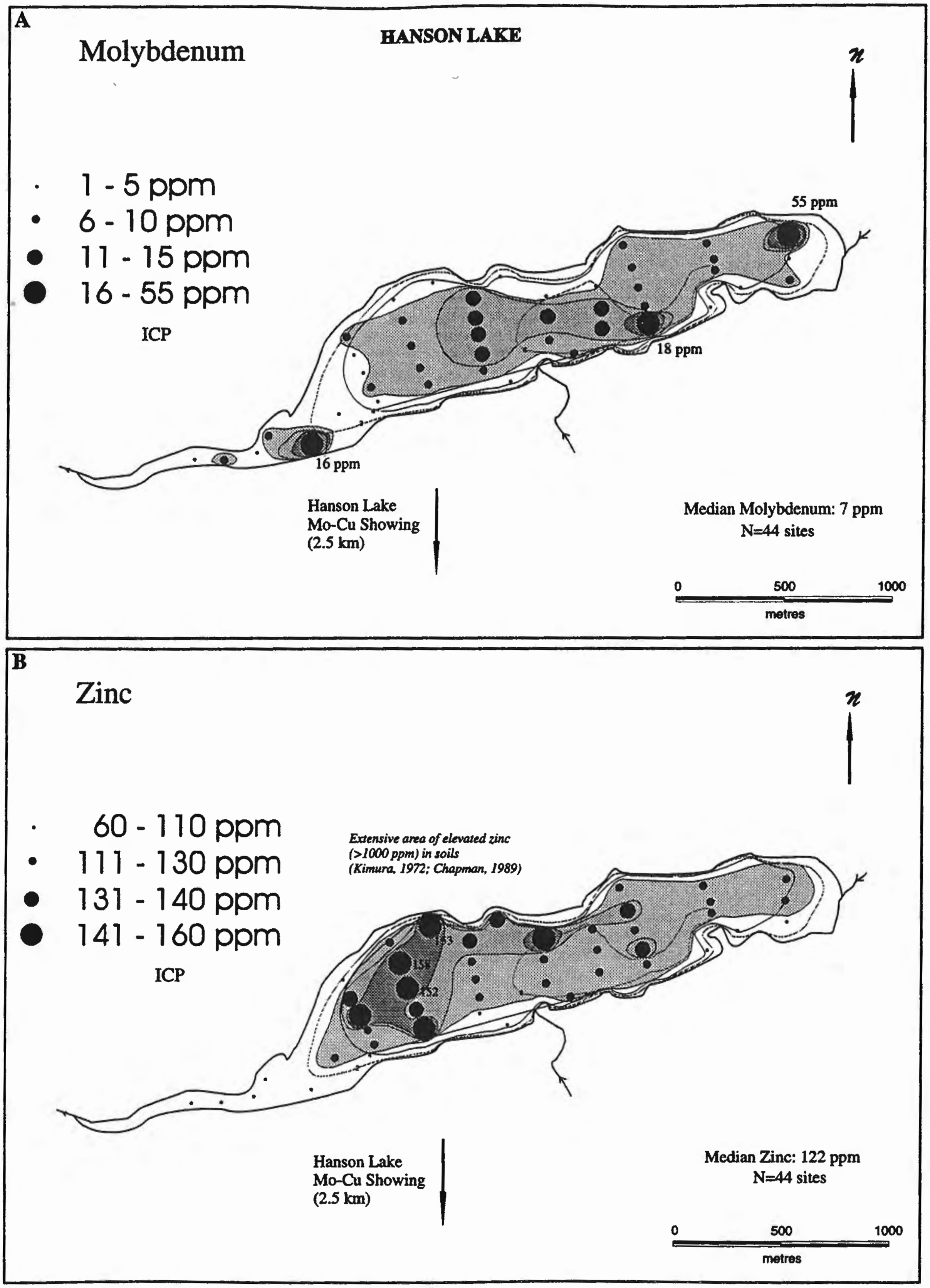


Figure 6. Distribution of (A) molybdenum (ppm) and (B) zinc (ppm) in Hanson Lake sediment. Bathymetry after Burns and Philip (1977).

(Kimura, 1972; Chapman, 1989), suggesting that these metals are of local hydromorphic origin and overprint the dominant geochemical pattern of Hanson Lake sediment.

Limnology, basin morphometry and organic matter content (as expressed by LOI) all appear to play roles in controlling the distribution of molybdenum and related elements in sediments. Friske (1995), in a study of Tatin Lake sediment cores, similarly concluded that limnological variations are an important factor in the accumulation of certain trace elements, particularly iron and manganese.

Implications for Exploration

Results here show that molybdenum concentrations of at least 12 ppm in centre-basin sediments reflect the presence of adjacent porphyry molybdenum prospects. In the case of Tatin Lake, only 6 ppm molybdenum is present in the main centre-lake basin. Among other examples, data reported by Mehrtens (1975) and Mehrtens *et al.* (1972) indicate that 25 ppm molybdenum in sediment of a small hilltop pond, and only 9 ppm in a small base-of-slope lake, outlined the location of stockwork molybdenum mineralization and associated soil anomalies at the Chutanli prospect in the Nechako Range. Mehrtens *et al.* (1972) also stated that, in this particular example, lake sediment geochemistry was a more cost-effective method of geochemical exploration than detailed stream sediment sampling. Molybdenum concentrations of 16 ppm and 24 ppm in two small lakes led to the discovery of the Mac porphyry molybdenum prospect (Cope and Spence, 1995). At the Gibraltar porphyry copper-molybdenum deposit south of the Nechako Plateau, sediment of lakes directly down slope and down drainage from the ore zones contain 10 to 32 ppm molybdenum (Coker *et al.*, 1979); a lake above one of the ore zones contains 42 ppm molybdenum.

The existence of near-shore, in addition to centre-lake and centre-basin, molybdenum anomalies in sediment of large lakes (*e.g.*, Tatin Lake) has important implications for the implementation of both regional and property-scale lake sediment geochemical surveys in the Nechako Plateau. Previous recommendations for gold exploration (Cook, 1995; Cook and Jackaman, 1994b), regarding regional sampling of all sub-basins and follow-up sampling of near-shore organic sediments at drainage inflows, are equally applicable to molybdenum exploration. Near-shore sampling is impractical for regional surveys covering large areas. It is, however, an effective property-scale exploration method, and will be discussed later in the paper.

REGIONAL GEOCHEMICAL SURVEYS

Studies elsewhere in Canada (Fox *et al.*, 1987; Davenport and McConnell, 1988; Rogers, 1988; Chapman *et al.*, 1990) have shown lake sediment geochemistry to be an effective gold exploration method. However, results of some studies in the Canadian Shield (Fox *et al.*, 1987; Coker *et al.*, 1982) concluded reconnaissance-scale (one site per 6 to 13 km^2) lake sediment exploration for gold to be inadequate for locating anomalous areas, and suggested that one to three samples per lake be collected. In Newfoundland, Davenport and Nolan (1991) considered a density of at least one site per 4 square kilometres to be necessary to ensure the detection of all significant near-surface gold mineralization. Exploration recommendations for the use of lake sediment geochemistry in the search for epithermal gold deposits in the northern Interior of British Columbia (Cook and Jackaman, 1994b) will not be repeated here. However, orientation study results support the detailed sampling approach. Regional lake sediment geochemistry is most effective if every lake in the survey area is sampled, a strategy used in the Fawnie, Ootsa and recently completed Pinchi Lake surveys. The high concentrations of gold and other elements in Wolf pond sediment, which led to the discovery of the Wolf prospect (Dawson, 1988), illustrate the importance of sampling even very small lakes.

Regional lake sediment geochemistry results for the Fawnie and Ootsa survey areas have been given by Cook and Jackaman (1994b), and summary statistics for selected elements are shown in Table 4. Briefly, survey results corroborate previously known lake sediment anomalies (*e.g.*, Wolf and Fawn/Gran prospects), enlarge potential target areas adjacent to currently known prospects (*e.g.*, Wolf), and outline new areas for further exploration (*e.g.*, Tsacha prospect). Gold and arsenic results for the Fawnie and Ootsa survey areas are shown in Figures 7 and 8, respectively, and are briefly summarized here to highlight geochemical patterns of interest to explorationists. Further details on these and other elements are given by Cook and Jackaman (1994b). Where applicable, unit designations of Diakow *et al.* (1994, 1995a) are used to identify geological units in the Fawnie survey area.

FAWNIE SURVEY

Background gold concentrations, as expressed by the median value, are 1 ppb for both Fawnie and Ootsa survey areas. In the Fawnie area, elevated gold concentrations (90th percentile: 6 ppb; maximum: 256 ppb) are associated with watersheds underlain by Middle Jurassic Hazelton Group rocks of the Naglico formation and, to a lesser extent, Eocene Ootsa Lake Group volcanics. Gold concentrations of at least 6 ppb occur at 33 sites (Figure 7), and particular attention is directed toward two areas where groupings of sites with high gold concentrations occur, (1) the Wolf Prospect - Johnny Lake area, and (2) the Tommy Lakes area:

In the Wolf prospect - Johnny Lake area in the northwest part of the survey area, elevated gold values in lake sediments draining both Eocene and Jurassic rocks considerably enlarge the potential target area for epithermal gold deposits. High gold concentrations occur in lake sediments on the northeast and northwest margins of the Eocene rhyolitic extrusive and intrusive rocks mapped by Diakow *et al.* (1994), and in sediment of Wolf pond (45 ppb) adjacent to the Wolf prospect as previously documented by Cook (1995). However, elevated gold concentrations also occur in parts of Cow Lake (69 ppb) and Johnny Lake (51 ppb) south of the Eocene volcanic centre, and in small lakes to the southeast (up to 256 ppb) where watersheds are under-

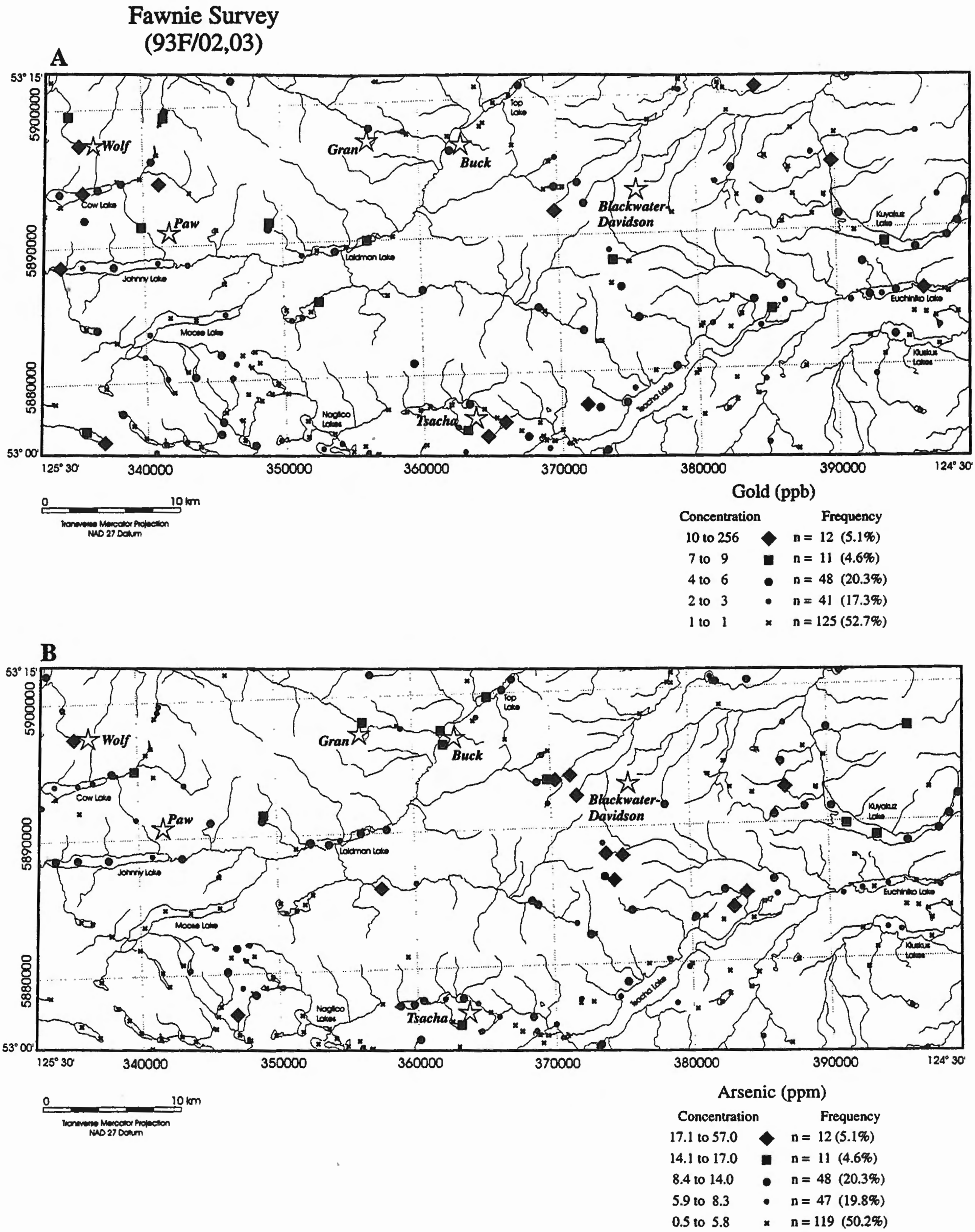


Figure 7. Regional distribution of (A) gold (ppb) and (B) arsenic (ppm) in lake sediments of the Fawnie survey area (237 sites). Significant mineral prospects are shown in italics. Refer to Diakow *et al.* (1994, 1995a, 1996) for geology of the survey area. Distribution maps of additional elements are given by Cook and Jackaman (1994b).

lain predominantly by poorly exposed basalt flows of the Naglico formation (map unit Nb).

In the Tommy Lakes area, located west of Tsacha Lake and immediately north of the Blackwater River in the southeast corner of NTS 93F/3, elevated sediment gold values occur in lakes floored by Early to Middle Jurassic rhyolitic rocks. Three small adjacent lakes southeast of the Tommy Lakes contain high gold values of 8 to 256 ppb. They pinpoint the location of the Tsacha gold prospect (MINFILE 093F 055), first reported (as the Tommy prospect) by Diakow *et al.* (1994) and subsequently staked by Teck Corporation. Watersheds of these lakes are underlain predominantly by Naglico formation volcanic sandstone, siltstone and conglomerate (Ns1) and rhyolitic lithic and ash flow tuffs (Nr) along the northern margin of Tertiary felsite sills and dikes. Elevated gold concentrations in bedrock and till from this area have been reported by Diakow *et al.* (1994) and Levson *et al.* (1994), respectively Lane and Schroeter (1997-2, this volume) should be consulted for further details on the Tsacha prospect.

The median arsenic (INAA) concentration in Fawnie lake sediments is 5.8 ppm. Elevated arsenic concentrations (90th percentile: 14.1 ppm; maximum: 57 ppm) are most common in lakes within the Fawnie Range, where several sites delineate a northwest-trending zone extending from Top Lake to the eastern end of Tsacha Lake. This zone is underlain predominantly by Ootsa Lake Group and lesser Hazelton Group rocks, and by a buried plutonic body inferred from aeromagnetic data (Diakow *et al.,* 1995a). Coincident elevated antimony concentrations are also present. Elsewhere, elevated arsenic concentrations also occur at, among other areas, Wolf pond adjacent to the Wolf prospect (site 1142), one of the lakes adjacent to the Tsacha property (site 1215), and in central Kuyakuz Lake (site 1170); coincident elevated gold concentrations (>90th percentile; at least 7 ppb) are also present at each of these sites. Sediment at Wolf pond is distinguished by a multi-element gold-arsenic-silver-zinc-molybdenum-mercury geochemical signature, but sediment in the four lakes encircling the Tsacha prospect has few similarities other than elevated gold and, to a lesser extent, copper concentrations. Elevated arsenic, zinc and lead concentrations occur in one lake (site 1215) near the Tsacha prospect, and elevated mercury in another, but the area lacks an overall multi-element geochemical signature of what are generally known as pathfinder elements.

Cook *et al.* (1995) provide a comparative case study of regional lake sediment and till geochemistry results from the Fawnie Creek map area (NTS 93F/3), in the western part of the Fawnie survey area. Here, five of seven known mineral prospects were outlined by regional lake sediment geochemistry data of Cook and Jackaman (1994b), using combinations of seven elements (Au, As, Sb, Zn, Cu, Pb and/or Mo >95th percentile). Geochemical data for these lakes are shown in Table 5. The five prospects are the Wolf, Fawn (Gran), Buck, Paw and Tsacha (Tommy) occurrences. Only the relatively minor Malaput and Fawn-5 prospects, neither of which is located near a lake, were undetected by the regional lake sediment geochemistry survey. Till and lake sediment geochemistry also outlined several additional potential targets in the area.

OOTSA SURVEY

Median gold concentrations in the Ootsa survey, as in the Fawnie area, are 1 ppb. There are far fewer lakes in the Ootsa survey area with high gold concentrations (90th percentile: 5 ppb; maximum: 13 ppb), but many with moderately elevated gold values; more than 25% of the sites contain at least 4 ppb gold (Figure 8). These are concentrated in two general areas, both of which are in the southern part of the survey area between Cheslatta Lake and the Nechako Reservoir: (1) the Yellow Moose Lake area, and (2) the Bird - Davidson lakes area.

The Yellow Moose Lake region, where a zone of elevated gold concentrations extends west-northwesterly along the north side of the Nechako Reservoir from roughly Yellow Moose Lake to the Saunders Hill area, encompasses the most extensive grouping of elevated gold values in the Ootsa survey area. Anomalous and roughly coincident concentrations of arsenic, antimony, molybdenum, mercury, copper, zinc, sulphate (water) and fluoride (water) are also present. Among these sites is the lake (site 3031) with the highest gold (13 ppb) and arsenic (110 ppm) concentrations detected in the Ootsa survey area; this is also the only site with coincident gold, arsenic and antimony concentrations above the 90th percentile. Bedrock in the southern part of this area (Diakow *et al.,* 1993) consists primarily of rhyolite and dacite flows of the Ootsa Lake Group, and rare exposures of the Hazelton Group.

Elevated gold and arsenic concentrations up to 10 ppb and 21 ppm, respectively, occur in a series of lakes within an east-trending valley, extending from the west end of Bird Lake to Davidson Lake. These lakes receive drainage from both the north and south.

FOLLOW-UP CASE STUDIES

Summary statistics for selected elements from all follow-up case study lakes (Table 1) are shown in Table 6. Interpretation of case study results is preliminary. Some relationships are nevertheless evident in drainage lake (*e.g.,* Kuyakuz Lake) and seepage lake (*e.g.,* lakes 3031 and 3087) geochemistry which should prove useful in designing more effective geochemical follow-up programs to regional survey results in the northern Interior.

DRAINAGE LAKES

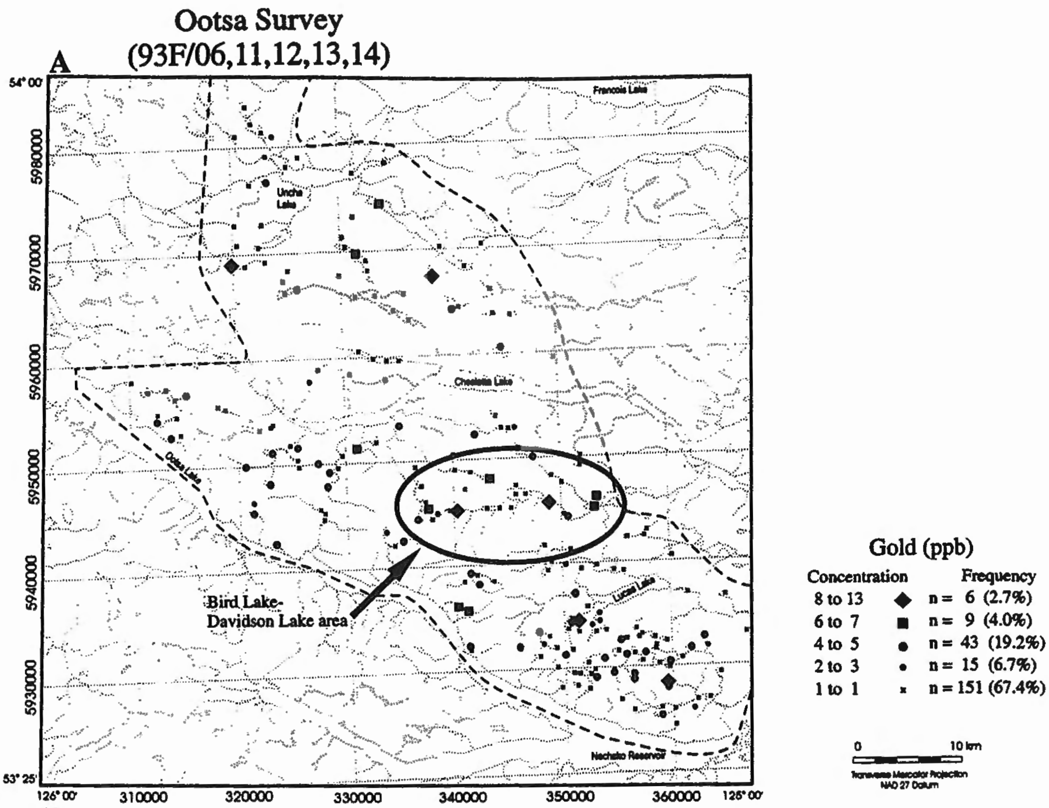
Kuyakuz Lake is a large, relatively shallow (max. depth: 14 m) unstratified lake. Molybdenum (median: 4.5 ppm) and arsenic (median: 9.2 ppm) zonation patterns in the sediment may indicate a possible direction to buried mineralization within the lake watershed. These patterns occur in the western end of the main lake basin, adjacent to a stream inflow draining an area west of the lake (Figure 9). Molybdenum and arsenic concentrations here reach 12 and 20 ppm, respectively. Gold (median: 1 ppb) and zinc (median:

TABLE 5
TRACE ELEMENT GEOCHEMICAL SIGNATURES OF LAKE SEDIMENTS ADJACENT TO KNOWN MINERAL PROSPECTS, FAWNIE SURVEY AREA.

Mineral Prospe	MINFILE	Lake or Area	NTS	*RGS Identifier*	Au (ppb) *INAA*	As (ppm) *INAA*	As (ppm) *AAS*	Sb (ppm) *INAA*	Sb (ppm) *AAS*	Mo (ppm) *INAA*	Mo (ppm) *AAS*	Cu (ppm) *AAS*	Zn (ppm) *AAS*	Pb (ppm) *AAS*	Ag (ppm) *AAS*	Hg (ppb) *AAS*	Fe (%) *AAS*	Mn (ppm) *AAS*	Ce (ppm) *INAA*	La (ppm) *INAA*	LOI (%)	Sulfate in water (ppm)	pH	Reference
Epithermal Gold																								
1) Wolf	93F045	Wolf Pond	93F/03	*931143*	**45**	**44**	**26.0**	**2.3**	**1.6**	**13**	**15**	**66**	**324**	6	**1.8**	**270**	2.70	338	**85**	**37.0**	51.5	12	7.10	Dawson (1991)
2) Tsacha	93F055	Tommy Lakes	93F/03	*931083*	4	10	5.3	1.0	0.5	2	7	**66**	84	5	0.2	**170**	1.90	495	24	14.0	46.0	3	7.92	Cook *et al.*
(Tommy)		area	93F/02	*931084*	**256 (970)**	7.8	5.9	0.8	0.3	4	5	36	66	4	0.1	40	1.70	510	15	7.2	49.3	3	8.00	(1995)
		(4 lakes)	93F/03	*931089*	**44 (26)**	7.7	1.5	1.1	0.4	7	9	50	90	1	0.1	50	1.60	309	9	4.9	73.1	7	8.14	
			93F/03	*931215*	8 (7)	15	5.5	1.4	0.6	5	6	43	**159**	**9**	0.2	40	2.30	836	28	12.0	66.3	5	8.27	
3) Fawn (Gran)	93F043	Square Lake	93F/03	*931158*	5	17	8.2	**2.5**	**1.8**	1	3	**67**	**366**	**61**	0.2	10	**3.70**	646	51	26.0	15.7	11	7.79	Hoffman & Smith (1982)
Base Metals																								
4) Buck	93F050	South of Top Lake	93F/03	*931112*	5	17	**8.6**	1.3	0.7	1	4	21	86	7	0.1	20	3.10	362	40	21.0	9.8	8	7.92	Cook *et al.* (1995)
5) Paw	93F052	East of Cow	93F/03	*931127*	9 (7)	8	3.6	0.9	0.4	3	6	**77**	109	2	0.2	50	1.90	224	13	9.5	57.1	15	7.89	Cook *et al.*
		Lake	93F/03	*931138*	256 (1)	5.1	1.8	0.8	0.3	**17**	**20**	**95**	**198**	8	0.2	80	1.70	185	14	6.6	52.0	**44**	7.82	(1995)
		(2 lakes)																						
Fawnie Survey				Median:	1	5.8	2.1	0.8	0.3	2	5	27	80	2	0.2	80	1.40	260	20	11	50.6	4	7.91	Cook &
(NTS 93F/02, 03)				x:	6.4	7.7	3.3	0.9	0.4	3.6	6.1	30.6	87.5	3.1	0.2	84.8	1.62	387	23.8	12.7	47.9	7.2	7.91	Jackaman
				±1s:	*24.9*	*6.6*	*3.8*	*0.5*	*0.4*	*3.2*	*3.8*	*27.5*	*47.2*	*4.9*	*0.1*	*45.4*	*1.16*	*439*	*17.4*	*9.0*	*19.5*	*15.0*	*0.30*	(1994)
				95th pct:	9	17	8.5	1.8	0.9	10	14	56	155	8	0.4	160	3.60	1140	53	28	78.2	20		
				99th pct:	69	43	22.0	2.7	1.8	15	19	77	324	20	0.5	210	5.30	2020	85	39	86.9	62		

Trace element geochemistry signatures in lake sediments adjacent to known mineral prospects, Fawnie survey area, central British Columbia

Analytical results of gold re-runs are given in brackets.
Highlighted values indicate that analytical result for that element is > 95th percentile for the entire Fawnie survey area (n=237 sites); LOI, pH and gold which does not re-run are excluded.



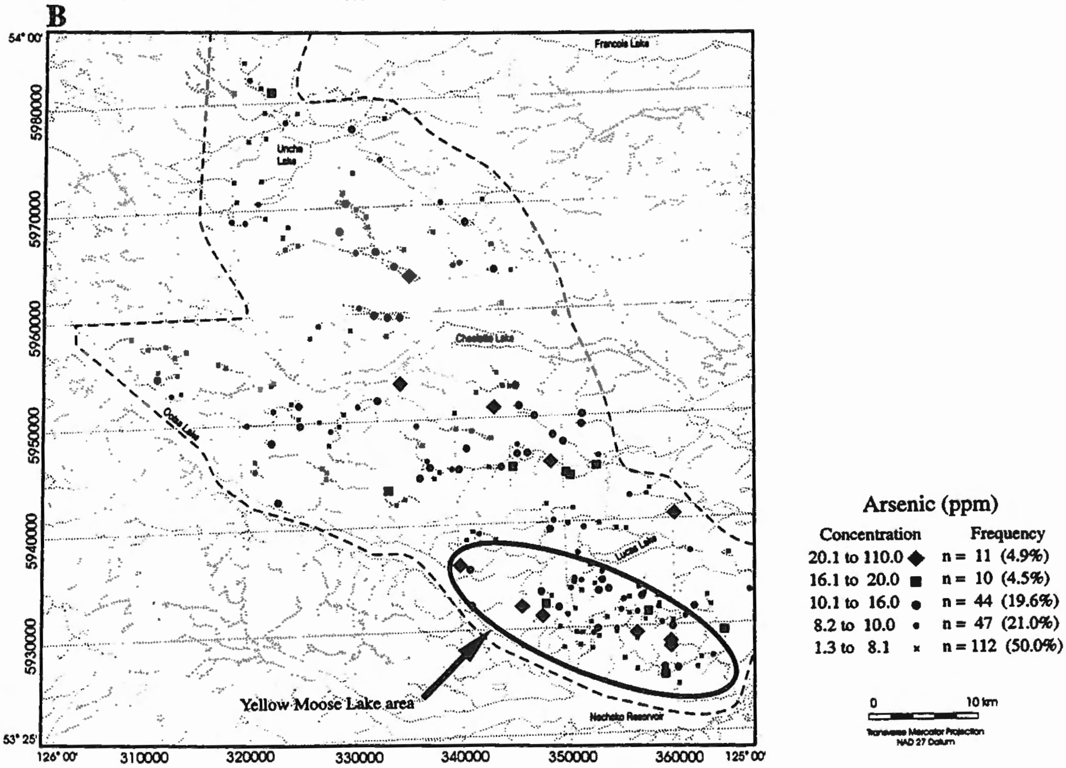


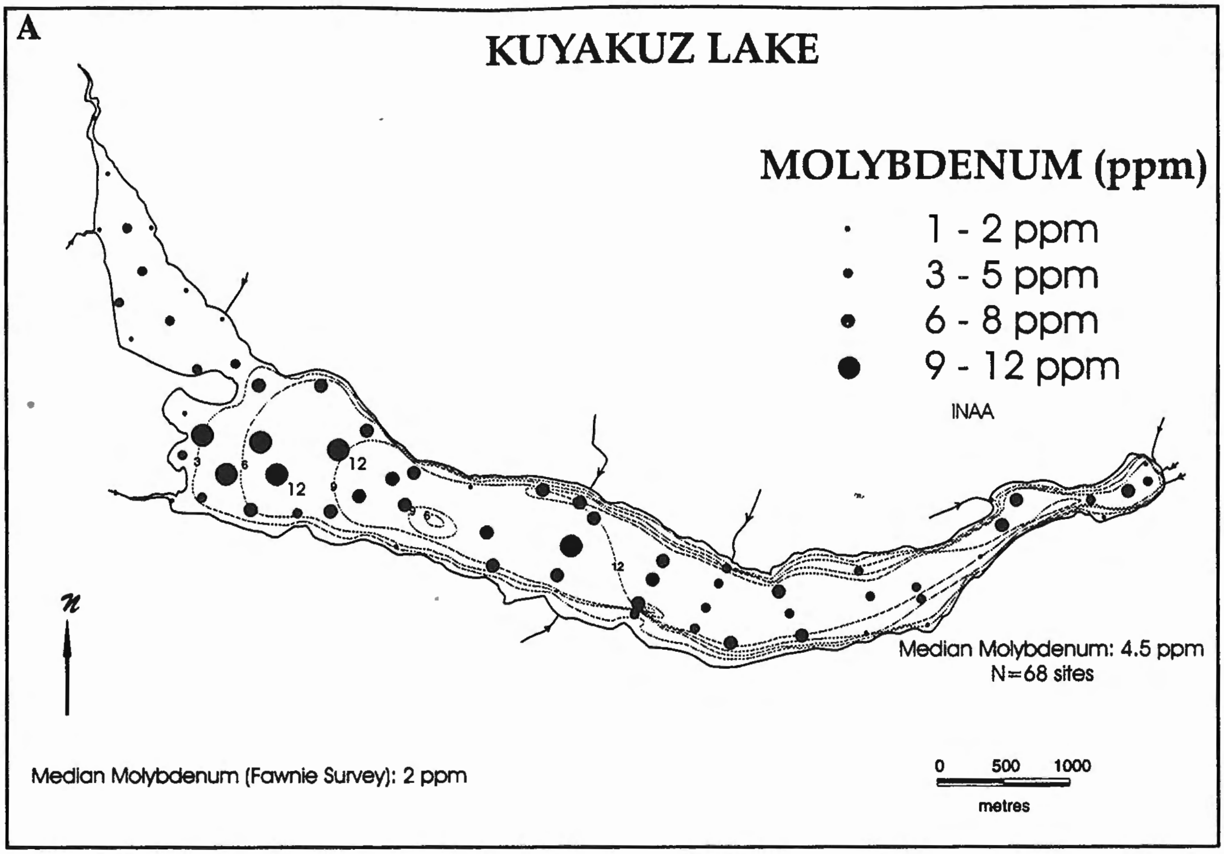
Figure 8. Regional distribution of (A) gold (ppb) and (B) arsenic (ppm) in lake sediments of the Ootsa survey area (224 sites). Refer to Cook and Jackaman (1994b) for generalized geology and distribution maps of additional elements.

TABLE 6
FOLLOW-UP CASE STUDIES: SUMMARY STATISTICS FOR SELECTED ELEMENTS

		Mo (ppm)	Cu (ppm)	Pb (ppm)	Zn (ppm)	Ag (ppm)	Ni (ppm)	Co (ppm)	Cr (ppm)	Mn (ppm)	Fe (ppm)	As (ppm)	Cd (ppm)	Au (ppb) INAA	As (ppm) INAA	Sb (ppm) INAA	Fe (%) INAA	La (ppm) INAA	Ce (ppm) INAA	LOI (%)
Drainage Lakes																				
KUYAKUZ	Mean	7.56	19.59	4.63	88.65	0.16	17.90	4.31	13.99	381.97	1.85	6.09	0.26	1.75	9.17	0.91	2.15	11.41	20.76	47.3
LAKE	Median	7	21.5	5	93.5	0.1	19	4	15	337	1.90	6	0.2	1	9.15	1	2.2	11	21	46.9
(N=68)	S.D.	4.34	9.08	2.18	29.70	0.08	4.49	1.92	4.63	130.36	0.56	2.68	0.09	1.41	2.97	0.34	0.71	4.13	7.83	19.7
	Variance	18.85	82.37	4.77	881.96	0.01	20.12	3.68	21.45	16994.72	0.32	7.19	0.01	1.98	8.81	0.11	0.50	17.05	61.38	387.6
	C.V.	57.43	46.33	47.16	33.50	49.49	25.07	44.52	33.11	34.13	30.53	44.03	35.21	80.43	32.37	37.37	32.96	36.19	37.73	41.6
	Minimum	1	1	2	39	0.1	7	1	5	201	0.51	2	0.2	1	3.3	0.2	0.63	5	7	3.0
	Maximum	19	36	10	156	0.4	25	9	22	800	3.69	15	0.5	7	20	1.6	3.93	20	36	84.1
COW LAKE	Mean	7.66	26.42	5.46	82.16	0.24	11.66	5.42	14.98	457.20	2.16	2.84	0.32	2.74	6.25	0.68	2.58	17.38	35.58	30.6
(N=50)	Median	8	31.5	5	88.5	0.25	12	5	16	461	2.20	2	0.3	1	6.5	0.7	2.565	17	34.5	35.1
	S.D.	4.06	14.41	2.14	21.68	0.10	3.19	1.33	3.91	67.68	0.46	1.13	0.13	2.58	1.54	0.16	0.52	3.36	7.26	13.2
	Variance	16.47	207.60	4.58	470.10	0.01	10.15	1.76	15.33	4579.92	0.21	1.28	0.02	6.65	2.38	0.03	0.27	11.26	52.78	175.2
	C.V.	52.99	54.54	39.20	26.39	42.35	27.32	24.47	26.13	14.80	21.16	39.84	41.62	94.08	24.72	24.01	20.10	19.31	20.42	43.3
	Minimum	1	1	2	22	0.1	6	3	5	299	0.93	2	0.2	1	2.4	0.1	1.1	7	17	3.3
	Maximum	13	47	13	120	0.5	17	11	21	607	3.25	7	0.7	12	9.3	0.9	3.94	30	59	56.8
Seepage Lakes																				
LAKE 3031	Mean	9.85	23.23	11.92	158.23	0.35	13.54	5.77	12.08	523.15	1.94	79.77	0.46	5.46	76.62	5.38	2.00	55.31	105.46	53.6
(N=13)	Median	10	24	8	166	0.3	14	6	13	559	2.07	74	0.5	5	72	5.6	1.99	57	110	52.6
	S.D.	1.21	3.96	13.71	28.27	0.12	1.98	1.42	2.22	144.37	0.88	36.60	0.17	2.22	33.88	0.79	0.91	12.72	23.43	5.2
	Variance	1.47	15.69	188.08	799.03	0.01	3.94	2.03	4.91	20843.64	0.78	1339.53	0.03	4.94	1148.09	0.62	0.83	161.73	548.77	26.6
	C.V.	12.33	17.05	115.02	17.86	33.86	14.65	24.67	18.35	27.60	45.38	45.88	37.04	40.68	44.23	14.61	45.38	22.99	22.21	9.6
	Minimum	7	16	3	103	0.2	8	3	7	233	0.69	34	0.2	1	36	3.1	0.75	30	61	47.6
	Maximum	11	28	56	197	0.7	16	8	15	683	3.11	142	0.7	9	130	6.1	3.19	70	130	62.8
LAKE 3087	Mean	6.21	31.00	5.88	49.54	0.31	19.38	4.04	16.29	137.54	1.17	8.50	0.29	2.92	9.85	5.29	1.46	30.88	52.00	50.4
(N=24)	Median	6	32	6	45.5	0.3	20.5	4	16	142	1.11	8	0.3	1.5	9.7	5.15	1.42	31	52	51.6
	S.D.	2.59	7.49	1.23	16.68	0.12	4.03	1.04	3.59	22.90	0.29	3.64	0.09	2.41	3.38	1.36	0.32	3.63	5.65	10.4
	Variance	6.69	56.17	1.51	278.09	0.01	16.24	1.09	12.91	524.26	0.09	13.22	0.01	5.82	11.42	1.85	0.10	13.16	31.91	107.4
	C.V.	41.67	24.18	20.88	33.66	36.93	20.80	25.77	22.06	16.65	24.95	42.77	31.30	82.70	34.32	25.72	21.81	11.75	10.86	20.6
	Minimum	2	16	4	26	0.1	12	3	11	98	0.8	4	0.2	1	5.1	3.2	0.98	23	39	33.8
	Maximum	12	44	8	78	0.5	26	6	27	173	1.74	16	0.5	8	17	8.9	2.12	38	64	70.5
LAKE 1138	Mean	18.33	33.40	2.80	140.13	0.22	13.27	2.33	4.67	206.87	1.38	2.00	1.71	1.87	4.33	0.81	1.45	6.07	12.33	60.1
(N=15)	Median	20	32	3	141	0.2	14	2	4	194	1.25	2	1.5	1	4.2	0.8	1.29	5	12	59.8
	S.D.	4.61	9.63	0.86	17.47	0.13	2.40	0.72	1.54	72.09	0.49	0.00	1.02	1.41	0.59	0.25	0.59	2.28	4.82	8.9
	Variance	21.24	92.83	0.74	305.12	0.02	5.78	0.52	2.38	5196.27	0.24	0.00	1.03	1.98	0.34	0.06	0.34	5.21	23.24	78.8
	C.V.	25.14	28.85	30.78	12.47	60.01	18.12	31.02	33.07	34.85	35.76	0.00	59.53	75.40	13.50	30.89	40.50	37.62	39.09	14.8
	Minimum	10	23	2	106	0.1	9	1	3	101	0.76	2	1	1	3.2	0.6	0.82	3	6	45.5
	Maximum	24	62	5	169	0.5	18	3	8	325	2.48	2	5	5	5.1	1.6	2.73	10	21	75.5
LAKE 1259	Mean	34.06	26.88	6.71	101.47	0.44	18.82	2.88	11.65	101.18	1.77	59.82	1.66	2.35	58.49	2.69	1.81	22.94	19.06	37.8
(N=17)	Median	12	25	6	101	0.4	18	2	11	97	0.67	11	1.5	1	14	2	0.77	20	17	36.1
	S.D.	90.19	10.21	3.96	28.61	0.24	5.82	3.02	4.70	34.39	4.53	188.33	0.41	2.40	175.77	2.68	4.39	14.11	9.72	8.6
	Variance	8133.56	104.24	15.72	818.51	0.06	33.90	9.11	22.12	1182.65	20.53	35467.90	0.17	5.74	30894.54	7.19	19.26	199.06	94.43	74.5
	C.V.	264.80	37.98	59.13	28.20	56.24	30.93	104.72	40.38	33.99	256.05	314.81	24.68	101.85	300.52	99.56	241.86	61.50	50.99	22.8
	Minimum	9	18	3	73	0.2	11	1	6	55	0.29	8	1.3	1	9.3	1.6	0.38	10	10	30.6
	Maximum	384	58	18	197	1.2	37	14	27	191	19.31	790	2.8	9	740	13	18.8	73	52	65.8

TABLE 6 CONTINUED

		Mo (ppm)	Cu (ppm)	Pb (ppm)	Zn (ppm)	Ag (ppm)	Ni (ppm)	Co (ppm)	Cr (ppm)	Mn (ppm)	Fe (%)	As (ppm)	Cd (ppm)	Au (ppb) INAA	As (ppm) INAA	Sb (ppm) INAA	Fe (%) INAA	La (ppm) INAA	Ce (ppm) INAA	LOI (%)
CH Study Area																				
CHUTANLI	Mean	5.58	27.42	7.10	74.10	0.17	13.42	4.50	14.80	446.66	1.86	41.20	0.35	4.14	36.92	1.56	1.81	11.42	24.36	34.4
LAKE	Median	4	26	7	75.5	0.1	13	4.5	15	446.5	1.86	39.5	0.3	3	30	1.4	1.535	11	23.5	39.7
(N=50)	S.D.	4.09	11.22	2.53	24.39	0.10	4.66	1.59	7.07	150.05	0.67	24.70	0.17	6.11	22.32	0.64	0.84	5.26	10.29	11.8
	Variance	16.70	125.88	6.38	594.66	0.01	21.76	2.54	49.92	22514.15	0.45	609.92	0.03	37.35	498.31	0.41	0.71	27.64	105.91	139.1
	C.V.	73.23	40.92	35.57	32.91	56.66	34.76	35.42	47.74	33.59	35.99	59.94	48.78	147.61	60.46	41.01	46.62	46.03	42.25	34.3
	Minimum	1	8	2	11	0.1	5	1	2	200	0.31	8	0.2	1	8.2	0.6	0.33	2	6	3.3
	Maximum	22	44	13	109	0.4	22	7	30	969	3.48	150	0.8	34	130	2.8	3.6	21	40	47.3
LAKE CH-1	Mean	1.58	34.05	3.32	235.47	0.23	9.95	3.32	10.58	142.26	0.91	2.00	0.62	2.89	2.39	0.73	0.94	8.05	16.63	59.4
(N=19)	Median	2	34	3	239	0.2	10	3	11	129	0.93	2	0.6	3	2.4	0.7	0.93	7	15	61.7
	S.D.	0.51	3.26	1.25	17.61	0.10	0.71	0.67	1.35	40.22	0.15	0.00	0.17	1.73	0.47	0.14	0.17	1.87	4.06	9.0
	Variance	0.26	10.61	1.56	310.15	0.01	0.50	0.45	1.81	1617.65	0.02	0.00	0.03	2.99	0.22	0.02	0.03	3.50	16.47	80.9
	C.V.	32.13	9.56	37.69	7.48	43.80	7.09	20.24	12.73	28.27	16.15	0.00	27.74	59.72	19.52	18.82	17.69	23.22	24.40	15.2
	Minimum	1	29	2	207	0.1	9	2	8	94	0.68	2	0.4	1	1.2	0.5	0.67	6	12	34.2
	Maximum	2	39	6	264	0.4	11	5	13	249	1.2	2	1	6	3.4	1.1	1.23	12	25	68.7
LAKE CH-2	Mean	11.67	22.33	3.33	79.33	0.12	9.67	2.67	7.56	366.22	1.07	27.56	0.44	2.89	28.00	0.77	1.08	5.56	13.33	71.6
(N=9)	Median	9	22	3	76	0.1	10	3	8	303	1.1	14	0.5	1	16	0.7	1.09	5	12	76.7
	S.D.	6.80	2.74	1.58	17.10	0.04	1.66	0.71	1.42	128.10	0.26	21.16	0.18	2.62	18.03	0.20	0.28	2.55	6.00	11.0
	Variance	46.25	7.50	2.50	292.50	0.00	2.75	0.50	2.03	16410.19	0.07	447.78	0.03	6.86	325.25	0.04	0.08	6.53	36.00	121.8
	C.V.	58.29	12.26	47.43	21.56	36.08	17.15	26.52	18.85	34.98	24.38	76.79	40.74	90.67	64.41	26.09	25.86	45.99	45.00	15.4
	Minimum	6	19	2	56	0.1	7	2	6	226	0.73	10	0.2	1	13	0.5	0.72	3	6	51.2
	Maximum	26	27	7	106	0.2	12	4	10	555	1.49	58	0.8	8	55	1.1	1.51	10	23	80.0



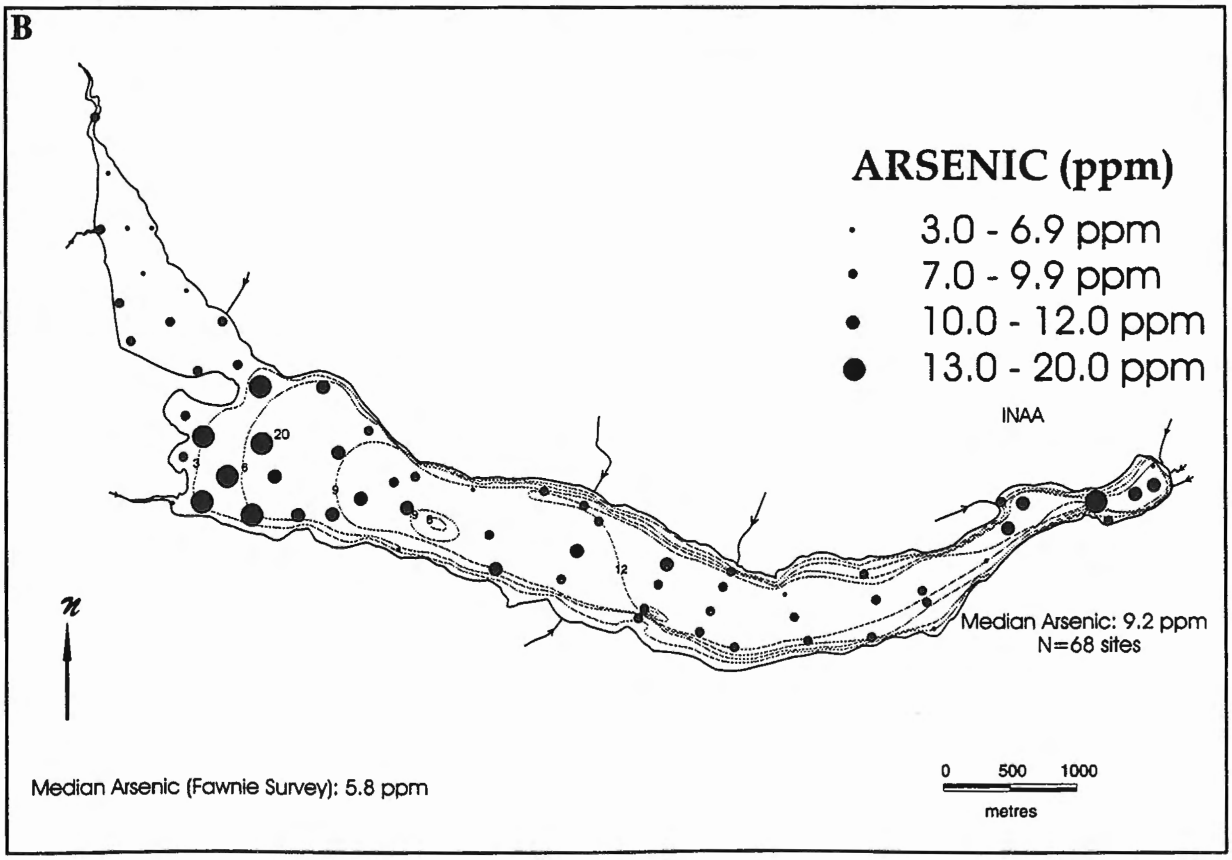


Figure 9. Distribution of (A) molybdenum (ppm) and (B)arsenic (ppm) in Kuyakuz Lake sediment. Bathymetry after Burns (1978).

93.5 ppm) have similar, if less pronounced, geochemical zonations, suggesting that the bedrock source of these metals lies to the west of the inflow. Drainage lakes, surveyed earlier during orientation studies, exhibit similar zoning patterns. They are interpreted here to represent the local accumulation of metals originating from down slope and down drainage hydromorphic dispersion from adjacent mineralization. Some examples include near-shore sediment zoning patterns in both single-basin lakes (*e.g.*, gold in Clisbako Lake; molybdenum in Hanson Lake) and multi-basin lakes (*e.g.*, molybdenum in Tatin Lake). As well, significant between-basin variations within multi-basin lakes (*e.g.*, molybdenum in Tatin Lake; gold in Bentzi Lake; copper in Hill-Tout Lake) are likely to be at least partly caused by the location of the mineralized area within the lake watershed.

SEEPAGE LAKES

Seepage lakes 3031 and 3087 are single-basin ponds and lakes lacking any significant stream inflows. They exhibit elevated gold (medians: 5 ppb and 1.5 ppb, respectively), arsenic (medians: 72 and 9.7 ppm) and antimony (medians: 5.6 ppm and 5.2 ppm) distributions (Figures 10 and 11) that are generally more homogenous than those in sediment of drainage lakes.

Conversely, lake 1259, near Tsacha Mountain in the Fawnie Range, exhibits characteristics of both seepage and drainage lakes. Although nominally a high-elevation seepage pond, it receives local stream drainage from the north and the sediment shows considerable variability for several elements (Table 6). For example, elevated concentrations of gold (median: 1 ppb), arsenic (median: 14 ppm), antimony (median: 2.0 ppm), silver (median: 0.4 ppm), zinc (median: 101 ppm) and lead (median: 6 ppm) are present in sediment at the mouth of the main stream inflow, possibly indicating the presence of up-stream mineralization. Extremely high concentrations of molybdenum (384 ppm), arsenic (740 ppm) and iron (18.8%) are also present locally at another site, perhaps denoting a spot where groundwater enters the oxygen-rich lake basin.

In general, regional geochemical results from a single site in seepage lakes are likely to be more representative of the sediment geochemistry, and that of the surrounding watershed, than a single site within drainage lakes. To illustrate, the coefficient of variation (C.V.) may be used as a measure of the relative variability of elements within each lake. Garrett *et al.* (1980) state that C.V. values of greater than 70% are indicative of non-normally distributed data. A perusal of C.V. data from most seepage lakes (lakes 3031, 3087, 1138; Table 6), and from small ponds and lakes (*e.g.*, Bentzi 2, Wasp) surveyed during orientation studies (Table 3) confirms that, for many elements, C.V. values are generally lower than those for either single-basin or multi-basin drainage lakes (*e.g.*, Clisbako, Bentzi and Kuyakuz Lakes). Results here are somewhat influenced by the number of near-shore samples, and are not entirely comparable to regional surveys where only centre-lake sediment is collected. Nevertheless, the greater geochemical heterogeneity of drainage lake sediment suggests that detailed sampling of these lakes may be more useful in determining a general direction toward mineralization during property-scale geochemical exploration surveys.

SUGGESTIONS FOR GEOCHEMICAL EXPLORATION

REGIONAL SURVEYS

Regional lake sediment geochemical surveys are most effective for precious and base metal exploration if every lake in the survey area is sampled. The presence, for exam-

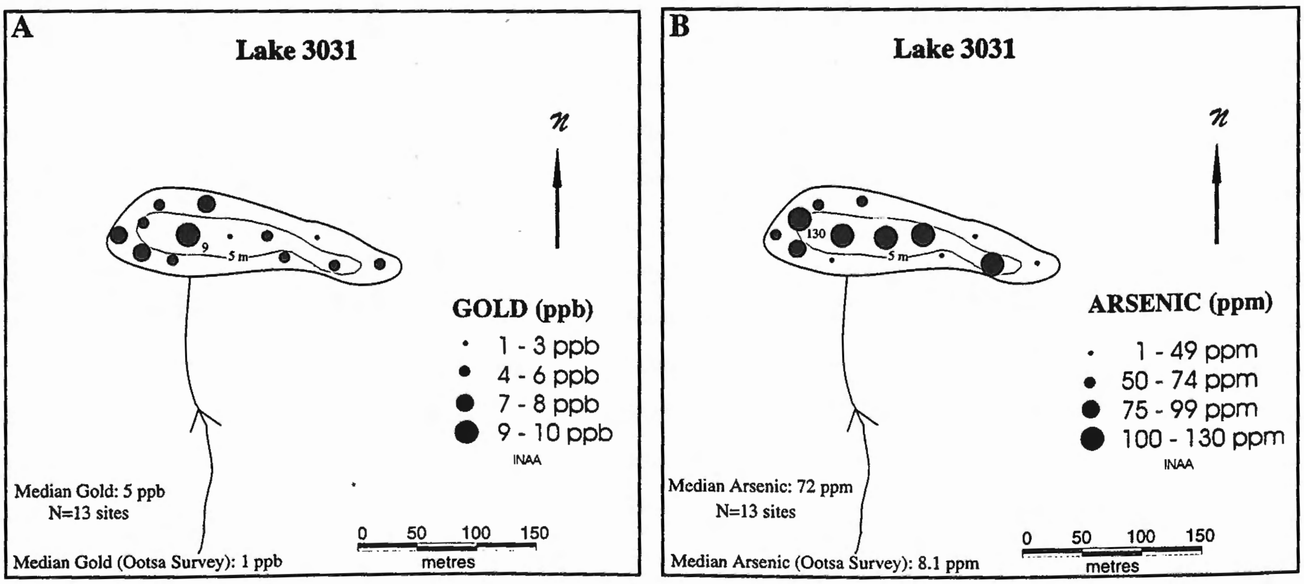


Figure 10. Distribution of (A) gold (ppb) and (B) arsenic (ppm) in lake 3031 sediment. The 5-metre contour denotes sample depth, not lake depth.

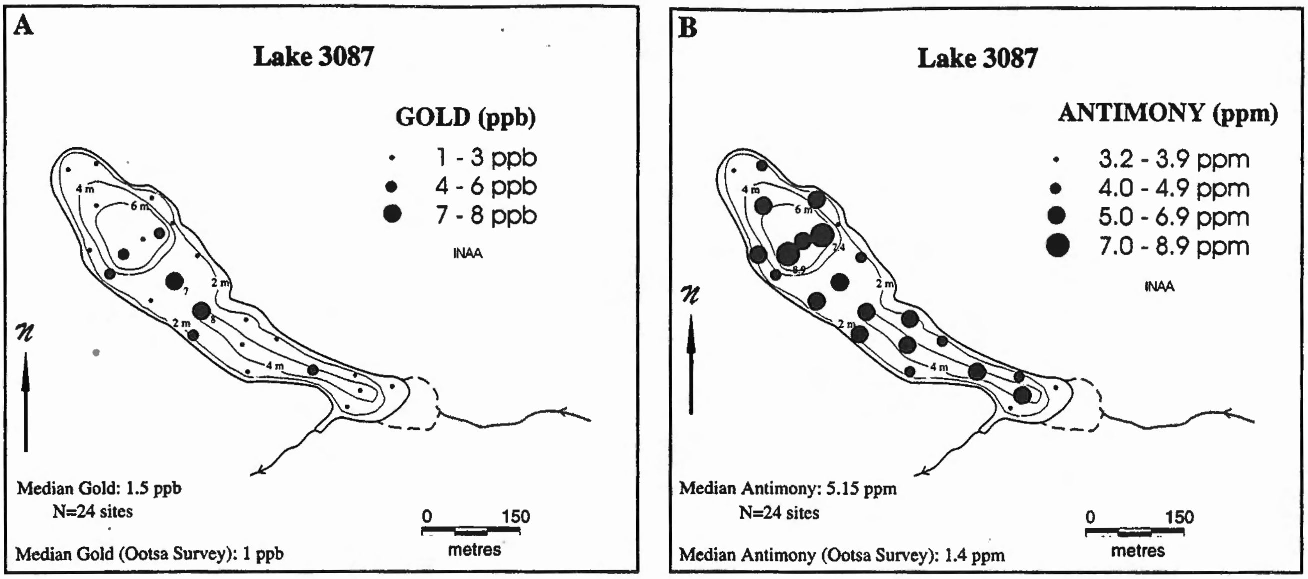


Figure 11. Distribution of (A) gold (ppb) and (B) antimony (ppm) in lake 3087 sediment. Contours denote sample depth (metres).

ple, of elevated molybdenum values in basins other than the main centre-lake basin of some lakes has important implications for the success of regional geochemical surveys, and sampling designs should be modified to accommodate this. Accordingly, a single centre-lake sample should be collected from the profundal basin of small lakes and ponds, and additional samples should be taken from the centres of major sub-basins. Cook and Jackaman (1994b) should be consulted for additional recommendations.

FOLLOW-UP SURVEYS

For property-scale exploration, different types of anomalous lakes (*i.e.*, drainage lakes *vs.* seepage lakes) require different follow-up exploration strategies. At a minimum, the original centre-basin site should always be resampled to verify the anomaly in the case of gold and other elements which are susceptible to the 'nugget effect'. Subsequently, detailed sediment sampling of anomalous drainage lakes should be conducted to map the presence of any metal zoning patterns. This should include the sampling of near-shore organic sediment from all sides of the lake and from near all stream inflows. General directions toward potential areas of buried mineralization within the watersheds of these lakes may be inferred from the orientation of any zoning patterns, as shown here for Clisbako, Tatin and Hanson lakes.

For seepage lakes, detailed sediment sampling may be a less useful tool for property-scale follow-up of regional geochemical anomalies, because of the more uniform distribution of metals within the sediment. Each case will be different, but centre-basin geochemical results here are likely to be more representative of the entire lake and watershed than any similar site within drainage lakes. Delineation of watershed boundaries, followed by surface prospecting and till geochemistry surveys, may be a more useful procedure in locating the possible source of the metals.

SUMMARY

Lake sediment geochemistry is an effective mineral exploration tool at several levels, from regional reconnaissance surveys to property-scale follow-up. Orientation studies show that trace and precious elements in lake sediments confirm the presence of adjacent mineral prospects in the northern Interior Plateau. Sediments at Wolf, Clisbako and other lakes, for example, reflect the presence of nearby epithermal precious metal deposits, containing maximum gold concentrations of 56 ppb and 16 ppb, respectively. These concentrations are far in excess of the regional background of 1 ppb gold in lake sediments. Similarly, lake sediments at Tatin and Hanson lakes, among others, reflect the presence of nearby porphyry molybdenum occurrences, containing maximum molybdenum concentrations of 23 ppm and 55 ppm, respectively. These concentrations also exceed regional background of 1 to 2 ppm molybdenum in lake sediments of adjacent map areas.

Bedrock geology influences regional geochemical patterns. On a more detailed scale within lakes adjacent to known prospects, orientation studies indicate that centre-lake sediments may, but do not necessarily, contain the highest gold and molybdenum concentrations. Shapes and locations of metal distribution patterns in lake sediment appear to be influenced by four closely related factors: (1) the location, within the watershed, of the mineral deposit relative to active ground water and stream water flow into the lake basin; variations in the organic matter content of the sediment; limnological factors, particularly in regard to limnological variations between basins; and basin morphometry. Notably, results here echo findings of Hoffman and Fletcher (1976) that limnological variability of Interior Plateau lakes does not obscure the existence of high metal values in sediments adjacent to known mineralization.

On the basis of orientation study results, two regional lake sediment geochemistry surveys were conducted in the Nechako River (NTS 93F) map area, and a third recently completed in the Fort Fraser (NTS 93K) map area. These surveys are ongoing contributions to the objective of completing RGS lake sediment coverage of the northern Interior Plateau. Results clearly demonstrate that regional lake sediment surveys are useful for detecting areas of prospective precious and base metal mineralization. They corroborate earlier lake sediment anomalies adjacent to known mineral prospects, enlarge target areas around known prospects, and outline new areas for further exploration. In addition, there is excellent potential for the use of lake sediment sampling in the follow-up of regional geochemical anomalies at a property scale. Results from several drainage lakes adjacent to epithermal and porphyry prospects show that some metal zoning patterns, in near-shore sediments and near drainage inflows, indicate general directions toward mineralization and alteration zones. Accordingly, detailed sediment sampling to map metal zoning patterns may be a useful tool in the follow-up of regional geochemical anomalies.

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BIOGEOCHEMICAL SURVEYS IN THE INTERIOR PLATEAU OF BRITISH COLUMBIA

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Geological Survey of Canada Contribution 1996167

KEYWORDS: Biogeochemistry, exploration, gold, copper, Clisbako, Fish Lake, lodgepole pine, alder, willow, Douglas fir, baseline data.

INTRODUCTION

Exploration for mineral deposits in the Interior Plateau is hampered by extensive forest cover, by glacial drift which blankets much of the bedrock, and by extensive plateau basalt. In this biogeoclimatic regime, tree roots penetrate to a depth of several metres and extract metals from the soil, glacial drift, locally the bedrock, and the waters contained within these media. The roots extract elements required by the trees, together with others not required for plant growth, but which the trees can tolerate. Many of the latter group of elements are stored in the outer bark, twig ends and tree tops. Thus, the extensive root system of a tree is able to integrate the geochemical signature of many cubic metres of the substrate, and amplify this signature by accumulating elements (notably many heavy metals) in the tree extremities. Surveys to collect and analyze tree and shrub tissues can, therefore, provide valuable information on the chemistry of the substrate and assist in defining areas of good mineral exploration potential.

With these principles in mind, biogeochemical surveys were conducted in two areas of the Interior (Chilcotin) Plateau: around epithermal mineralization near the Clisbako River, and near the Fish Lake porphyry copper-gold deposit (Figure 1). In both survey areas the dominant tree species is lodgepole pine (*Pinus contorta*), therefore this species was selected as the prime sample medium. Locally, other species were collected in order to characterize their biogeochemical signatures, and assess their relative abilities to detect concealed mineral deposits in this environment. There were no known biogeochemical data from the survey areas, or even from the Interior Plateau in general. Given this situation it was necessary to first conduct orientation surveys.

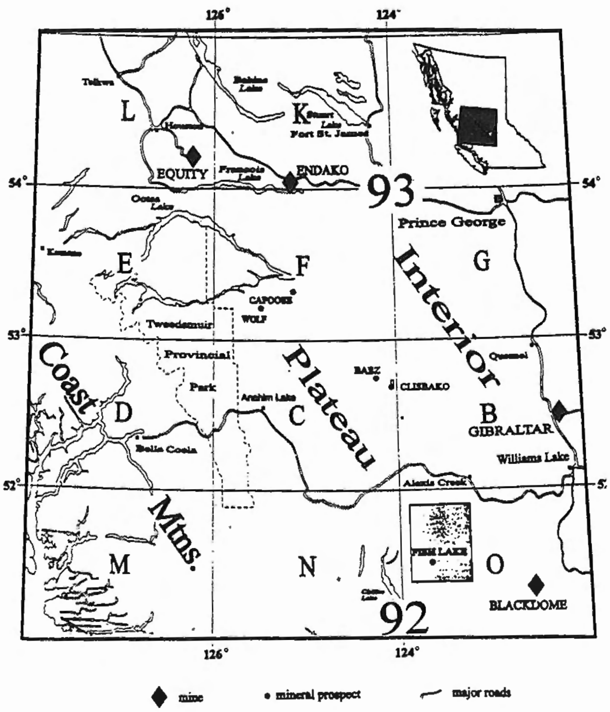


Figure 1. Location map.

GEOLOGY AND MINERALIZATION

CLISBAKO

Exposure in the Clisbako area is poor, with less than 4% rock outcrop which is restricted to gullies, incised drainages and road cuts (Schroeter and Lane, 1992). Figure 2 shows the general geology and the locations of mineralized showings within the Clisbako group of mineral claims. Schroeter and Lane (1992) note that three well developed hydrothermal alteration centres (North, Central and South zones), and subordinate alteration zones have been identified within a suite of Eocene Ootsa Lake Group volcanic rocks (Tipper, 1978) that range in composition from basalt to rhyolite. Hostrocks are rhyolitic breccias and tuffs that have been pervasively silicified, argillized and bleached by hydrothermal fluids. Sulphide concentrations are low (1 - 5%), and dominated by pyrite with local enrichment of marcasite, arsenopyrite and pyrargyrite as the main silver-bearing mineral (Dawson, 1991). No visible gold has been reported.

FISH LAKE

A geological map of the Fish Lake area (NTS 92O) published by Tipper (1978) has recently been revised. The southern part of the present survey area was mapped by Riddell *et al.* (1993), and the adjacent area to the north by Hickson and Higman (1993). The geological contacts shown on Figure 3 are based upon the published results, and comments by C.J. Hickson (personal communication). The region is largely drift covered and thick glaciofluvial deposits occupy the valleys (Plouffe, 1997, this volume). Laterally extensive flows of Miocene to Pleistocene basalt (Chilcotin Group), mostly less than 30 metres thick, cover large tracts of the survey area. These overlie Eocene volcanic rocks that range in composition from picritic basalt to rhyolite. Small Cretaceous to Tertiary granodioritic plutons occur at Cone Hill, Vedan Mountain and Newton Hill.

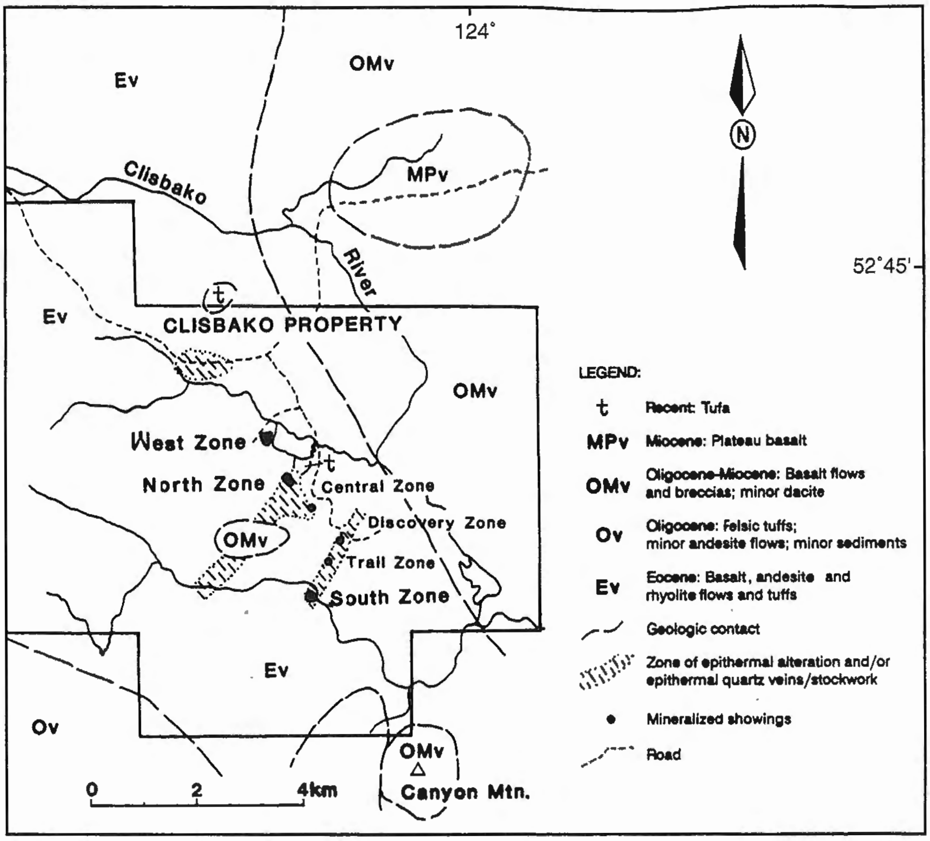
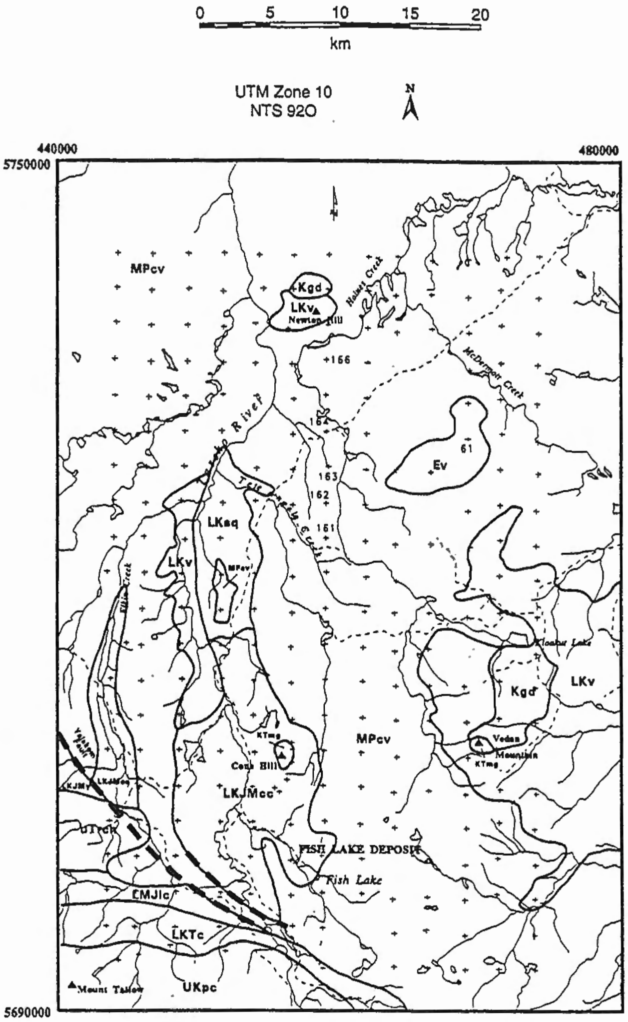


Figure 2. Geology of the Clisbako area with mineral showings (modified after Dawson, 1991 and Schroeter and Lane, 1992).

Photo 1. Lodgepole pine top - portion above where it is being held is the typical amount collected for analysis of the stem and branches, less the needles and cones.



LEGEND

MIOCENE AND PLIOCENE

Mpcv Basalt (olivine ± plagioclase)

EOCENE

Ev Picritic basalt; andesite; rhyolite

CRETACEOUS TO TERTIARY

KTmg Granodiorite and tonalite

CRETACEOUS

Kgd Granodiorite and diorite (porphyritic)

UKpc *(Powell Ck. Fm)* Volcanic flows and tuffs (andesitic)

LKtc *(Taylor Ck. Gp)* Clastic sediments

LKsq *(Silverquick Fm)* Sandstone and conglomerate

LKv Volcanic lavas and tuffs (rhyolite to andesite)

Jackass Mtn. Gp.

LKJMy *(Yalakom Mtn. Facies)* Clastic sediments

LKJMcc *(Churn Ck. Facies)* Marine sediments and conglom.

LMJlc *(Last Ck. Fm)* Clastic sediments

TRIASSIC

UTrch *(Hurley Fm)* Clastic and carbonate sediments

Figure 3. Simplified geology of the Fish Lake area, compiled from Tipper (1978), Hickson and Higman (1993) and Riddell *et al.* (1993). Lodgepole pine sample sites are marked as '+'; numbers by sample sites are those referred to in text.

Cretaceous strata are mostly clastic sediments with some felsic volcanic rocks. Clastic sedimentary rocks of Jurassic age crop out in the southwestern corner of the survey area, overlying Upper Triassic calcareous clastic beds of the Hurley Formation.

A major, steeply dipping fault system, named the Yalakom fault (Figure 3) by Leech (1953), has brought Triassic to Cretaceous strata in the southwest into juxtaposition with rocks ranging in age from Cretaceous to Pleistocene. Northeast of this fault the flood basalts and glacial deposits obscure the structure, but north and northeasterly striking faults have been recognized (*e.g.* Elkin Creek and Taseko Valley).

Mineralization has been found at Fish Lake, Newton Hill and Cone Hill. The Fish Lake deposit is by the far the largest known in the survey area. Preliminary engineering studies indicate a possible mineable reserve of 747 million tonnes grading 0.23% Cu and 0.446 g/t Au per ton at a strip ratio of 1.57:1 (Caira *et al.*, 1995). The deposit is oval in plan, 1.5 kilometres long, up to 800 metres wide, and extends to a maximum depth of 880 metres. Mineralization is disseminated chalcopyrite with bornite associated with potassic metasomatism, and has a halo of pyrite to the north and east that coincides with a zone of phyllic alteration.

ORIENTATION SURVEYS

SAMPLE COLLECTION, PREPARATION AND ANALYSIS

In the summer of 1992 a short visit was made to the Clisbako and Fish Lake areas to examine the distribution of tree and shrub species, and to collect a suite of representative tissues from common species in both areas. Twig and foliage samples were collected from dwarf birch (*Betula glandulosa*), Sitka alder (*Alnus sitchensis*), two species of willow (*Salix bebbiana* and *Salix barratiana*), Canada buffaloberry (*Shepherdia canadensis*) and lodgepole pine (*Pinus contorta*). Outer bark was scraped from the pines, and the latest three years growth from the top of the pines (Photo 1) was collected by climbing trees. The tops were required to determine if their inter-site chemical signatures were sufficiently varied to warrant conducting a helicopter-borne survey to obtain pine tops over a large area the following year. At Clisbako, 48 samples were collected from 27 sites; in the Fish Lake area 73 samples were collected from 37 sites.

All samples were sent to the Geological Survey of Canada laboratory in Ottawa for air drying. Samples were either macerated in preparation for analysis of dry tissue, or reduced to ash by controlled ignition in a kiln at 470°C. Unless otherwise stated, the data presented here are concentrations in ash; the main exception is mercury for which concentrations were determined on dry tissue, because it volatilizes during the ashing process. Determinations on ash were made for 35 elements by instrumental neutron activation analysis (INAA) at Activation Laboratories Ltd., Ancaster, Ontario, and for 32 elements by inductively coupled plasma emission spectrometry (ICP-ES) at Acme Laboratories Ltd., Vancouver, B.C. Mercury determinations were by cold vapour atomic absorption on tissue that was macerated but not ashed.

RESULTS OF ORIENTATION STUDIES

In general, trace element concentrations in the vegetation of the Interior Plateau are quite low, being mostly close to usual background levels for each species tested. However, metal enrichment occurs in tissues of several species growing close to zones of mineralization. Table 1 shows common background levels of selected elements in the species tested, and some examples of enrichment over mineralization in the survey areas.

CLISBAKO

From Table 1 it is evident that there are unusually high concentrations of gold in twigs of Sitka alder (300 ppb Au) and Bebb willow (123 ppb Au) in the Clisbako area. These samples were collected in a valley adjacent to the North zone (Figure 2). Glandular birch from the same location yielded 35 ppb gold in twig ash. Thallium, not reported in Table 1 because of some uncertainty with the accuracy of the analytical data, appears to be enriched in twigs of birch and the two species of willow. A lodgepole pine on argillized sinter flanking the valley, 100 metres to the east, yielded 54 ppb gold and 57 ppm arsenic in its outer bark. The top stems of the pines near the North zone are not enriched in gold but contain levels of other elements commonly enriched in epithermal systems, that are an order of magnitude above background for pine tops: up to 4 ppm silver, 11 ppm arsenic, 16 ppm cesium and 1000 ppm rubidium.

At the South zone, alder is enriched in molybdenum (162 ppm) and tungsten (18 ppm), whereas there are only subtle enrichments of metals in the pines. Near the West zone there are few metal enrichments in the vegetation, with 45 ppb gold in pine bark being the most notable exception.

Four kilometres northwest of the North zone there is a boggy area with whitish mud which has been interpreted as a hot-spring tufa deposit (Figure 2). Birch twigs from this site are strongly enriched in lithium (138 ppm) and strontium (6000 ppm) with moderately high concentrations of boron (966 ppm) and magnesium (5.9%). Background concentrations of these elements in birch are 2 ppm (Li),

TABLE 1
EXAMPLES OF METAL ENRICHMENT IN ASH OF TREES AND SHRUBS FROM THE CLISBAKO AND FISH LAKE AREAS

	Background*	Examples of Enrichments
Au ppb	5 - 10	300 ppb in alder twigs: Clisbako, N. zone 123 ppb in willow twigs: " N. zone 67 ppb in pine bark: Fish Lake (nr. trench) 57 ppb in pine bark: Fish Lake 54 ppb in pine bark: Clisbako, N. zone 45 ppb in pine bark: Clisbako, W.zone
Ag ppm	0.2	6 ppm in pine twigs: Fish Lake 4 ppm in pine tops: Clisbako, N. Zone
As ppm	2	57 ppm in pine bark: Clisbako, N. zone 37 ppm in birch twigs: " N. zone 32 ppm in pine bark: Fish Lake
Cd ppm	1	13 ppm in pine twigs: Fish Lake 10 ppm in pine tops: Clisbako, S. zone
Cs ppm	1	27 ppm in pine tops: Clisbako, S. zone
Cu ppm	80	431 ppm in alder twigs: Fish Lake 400 ppm in pine twigs: Fish Lake 367 ppm in pine bark: Fish Lake 330 ppm in pine tops: Clisbako, S. zone
Mo ppm	2	162 ppm in alder twigs: Clisbako, S. zone 127 ppm in alder twigs: Fish Lake 68 ppm in alder twigs: Clisbako, road cutting
Ni ppm	30	355 ppm in pine tops: Clisbako, road cutting 226 ppm in pine tops: Clisbako, S. zone
Sb ppm	0.2	6 ppm in pine bark: Clisbako, N. zone
W ppm	<1	18 ppm in alder twigs: Clisbako, S. zone

*Typical concentrations of metals in plants within the survey area from locations remote from known mineralization.

1500 ppm (Sr), 500 ppm (B), and 3% (Mg). A top stem of lodgepole pine from this site is similarly enriched in lithium and strontium. These analyses reflect the alkaline nature of the area and an association of element enrichments characteristic of ancient hot springs.

FISH LAKE

In the Taseko River valley (Figure 3), close to the main zone of mineralization at Fish Lake, the pine top stems show weak enrichment of gold, molybdenum, copper, cesium, nickel and sodium. Strongest biogeochemical contrast occurs a few hundred metres to the east of the Fish Lake valley. On the west-facing slope of the hill, pine bark is enriched in gold (up to 67 ppb in ash), copper (367 ppm), arsenic (32 ppm) and selenium (6 ppm), and an alder yielded 127 ppm molybdenum and 431 ppm copper. Trees growing over the surrounding plateau basalt were relatively enriched in chromium, iron, sodium, scandium and rare-earth elements.

SUMMARY OF RESULTS FROM THE ORIENTATION STUDY

The chemistry of the common trees and shrubs in the Clisbako area provides a clear indication of element enrichments typical of modern epithermal systems. Highest concentrations of gold, molybdenum, lithium and thallium occur in the twigs of the shrub alder, birch and willow. However, these species are not evenly distributed throughout the survey area, and they are therefore only of use in differentiating metalliferous valleys from those that are metal deficient. As such, they provide a powerful means for locating near-surface zones of mineralization, and can be used to focus exploration efforts. As a reconnaissance biogeochemical medium, the lodgepole pine is the optimum species because of its widespread occurrence. There is weak enrichment of gold, molybdenum, arsenic, cesium and nickel in the pine tops from sites close to the North and South zones of epithermal precious metal mineralization. The pine bark samples from the same sites yielded slightly higher concentrations of gold, silver, arsenic and cadmium, and confirmed the elevated background levels of molybdenum.

At Fish Lake the porphyry copper-gold deposit has generated mostly weak biogeochemical signatures, with the exception of molybdenum, copper and, locally, gold to the east of the deposit. From these data it was concluded that in the Fish Lake area, a reconnaissance-level biogeochemical survey making use of lodgepole pine top stems was likely to generate a subtle response to underlying porphyry-style mineralization, and therefore a second phase of study involving biogeochemical mapping was planned for the following year.

HELICOPTER-MOUNTED RECONNAISSANCE-LEVEL SURVEY

Pacific Phytometric Consultants (Surrey, B.C.) was contracted to collect tree-top samples from a helicopter at sites identified on 1:50 000-scale topographic maps. The contract specified that, wherever possible, a tree top should be sampled within a 200-metre radius of the preferred site. The only departures from the preassigned grid were due to recent burns, pine beetle kill, bogs and complex multi-storied, multi-species stands where pines were lower in the forest canopy and therefore could not be sampled with safety.

During a three-day period in early May, 1993, a 1625 square kilometre area was surveyed along 715 kilometres of grid lines at a spacing of 2.5 kilometres between sample sites (Figure 3). The top 0.5 metre, mostly comprising three years of growth, was snipped from a lodgepole pine at each of 276 sites. A single top (stem, branches, needles and cones - see Photo 1) from a healthy tree was collected at each sample station. Rounded-top lodgepole pines have thick branches and abundant cones making them difficult to cut with hand shears. In some cases it was possible to break the top of the tree by bending it and then cutting. The fresh weight of each sample varied from 500 grams to 1 kilogram. The total flying time was 15.9 hours to provide an overall productivity of 17.5 samples/hour (3.4 minutes/sample). Production was 22 sites/hour (2.75 minutes/sample) when flying along a predetermined line.

The survey crew consisted of the pilot, a navigator (who also bagged the samples), and a sampler, secured by a safety belt with two lanyards, who leaned out of the hovering helicopter to snip off the tree tops. Once the helicopter was positioned, the actual sample retrieval time was usually 5 to 10 seconds. Constant intercom communication between the flight crew is essential for safety and efficiency of sampling. More details of the sampling methods are given in Dunn and Scagel (1989), with modifications described in a second paper (Scagel and Dunn, in preparation). Site locations were located with an accuracy of 15 metres using a GARMON GPS-100 global positioning system receiving signals from at least five satellites.

RESULTS OF RECONNAISSANCE SURVEY

A detailed account of the sample preparation, the analytical program and the results are given in Dunn *et al.*, 1994. At the low sample density (1 site per 6 km^2) it was considered unlikely that any undiscovered zones of mineralization might be located: the objective of the survey was to define regional trends in geochemical patterns and spatial relationships of the elements which might provide focus for future exploration efforts. The data are summarized in Tables 2 and 3. Table 2 lists elements determined by INAA and represents total content of elements in ash. Table 3 lists elements determined by ICP-ES following an aqua regia digestion of the ash. This digestion provides total content of most elements, but only a partial digestion of a few elements (*e.g.*, Ba and probably Sr and B). The 50th percentile can be considered representative of the 'background' concentration of each element.

In addition to providing baseline data on the elemental content of the pine tops, the principal geochemical information to emerge from the reconnaissance survey is:

- Sample density was too low to outline the low-grade copper-gold mineralization at Fish Lake. However, there are several areas of relative enrich-

TABLE 2
CONCENTRATIONS OF ELEMENTS DETERMINED BY INAA IN ASH OF LODGEPOLE PINE TOPS FROM THE FISH LAKE RECONNAISSANCE SURVEY AREA (N = 276)

	Percentile Values		
	50th	90th	100th
Au ppb	8	18	40
As ppm	0.9	2.0	4.1
Br ppm	4	7	18
Ca %	8.8	13.1	25.8
Ce ppm	< 3	5	16
Co ppm	7	12	23
Cr ppm	8	66	190
Cs ppm	0.3	3.7	29
Eu ppm	< 0.01	< 0.01	0.52
Fe %	0.35	0.59	1.86
Hf ppm	0.7	1.5	2.8
K %	29	34.5	43.5
La ppm	1.1	2.3	6.1
Lu ppm	<0.05	0.06	0.19
Mo ppm	< 2	10	34
Na %	0.12	0.28	0.86
Nd ppm	<5	6	33
Rb ppm	110	390	1300
Sb ppm	0.1	0.3	9
Sc ppm	1.1	2.0	5.5
Se ppm	< 2	< 2	9
Sm ppm	0.2	0.4	1.7
Ta ppm	< 0.5	< 0.5	2.3
Th ppm	< 0.1	0.4	0.9
U ppm	< 0.1	< 0.1	1.3
W ppm	< 1	< 1	8
Yb ppm	< 0.05	0.27	0.93
Zn ppm	2100	2800	3500

TABLE 3
CONCENTRATIONS OF ELEMENTS DETERMINED BY ICP-EX (AQUA REGIA DIGESTION) IN ASH OF LODGEPOLE PINE TOPS FROM THE FISH LAKE RECONNAISSANCE SURVEY AREA (N = 276)

	Percentile Values		
	50th	90th	100th
Ag ppm	0.6	1.2	1.9
Al %	0.77	1.70	2.89
B ppm	558	739	1228
Ba ppm	22	56	152
Be ppm	< 0.3	0.4	0.9
Cd ppm	3.3	6.4	10.8
Cu ppm	244	333	446
Li ppm	2	4	21
Mg %	7.4	10.3	13.2
Mn %	0.53	0.95	1.86
Ni ppm	73	169	435
P %	3.63	5.52	9.25
Pb ppm	7	15	89
Sr ppm	214	415	715
Ti %	< 0.02	0.02	0.07
V ppm	< 2	< 2	16

ment of gold, and there is a weak northerly trend to some zones of enrichment (Figure 4).

- Chromium is the element most strongly concentrated over the zones of gold mineralization at Fish Lake and Cone Hill (Figure 5). However, this may reflect the underlying lithology (marine sediments of the Cretaceous Jackass Mountain Group) rather than the zones of mineralization.
- In the eastern part of the survey area, near Vedan Mountain, there is relative enrichment of gold, cesium (Figure 6), rubidium, tungsten and, to a lesser degree cadmium. Mercury in dry pine needles is also weakly enriched in this area (Figure 7). It is noteworthy that these elements are among those enriched in vegetation from zones of recent epithermal gold mineralization in New Zealand (Dunn, 1995). A similar pattern is exhibited by aluminum, possibly reflecting an increased level of alteration in the rocks in this area.
- Copper (Figure 8), molybdenum, lithium, nickel, phosphorus and silver are more enriched in the western part of the study area than in the east.

ANALYSES OF PINE CONES

Most of the tree top samples included cones. These were removed from the stems and set aside for further study. According to their state of maturity, they have different morphologies. New cones (1 year old) are small and dense and have a high ash yield. Two year old cones are closed, have a lower ash yield, and range in colour from green to brown. Cones that are three years or older are brown, suberized and mostly open, having shed their seeds. Comparison of open, closed and immature (small 1st year) cones from three trees indicates that the immature cones are enriched in potassium and rubidium with respect to the older cones, but are depleted in most other elements, or have similar concentrations. Nine trees yielded sufficient numbers of both open and closed cones to provide a preliminary indication of differences in their chemical compositions. Table 4 summarizes these differences for elements sufficiently concentrated to provide a comparison.

The data in Table 4 show that a biogeochemical survey using lodgepole pine cones must take their ages into the account. For some elements (*e.g.* Cr, Cs, Mo, Ni, Rb, Zn and possibly Au) the differences in cone age are not significant. For other elements, notably arsenic and antimony, the differences are substantial.

Given these observations, the analytical data obtained from the cones could be used to augment the data from the pine top stems and substantiate some of the sites indicating element enrichment. South of Newton Hill (site 166, Figure 3) cones yielded 110 ppb gold and 1100 ppm nickel. Twelve kilometres to the southeast (site 61) the concentrations were 48 ppb gold and 540 ppm nickel. This site yielded a relatively high gold concentration (31 ppb Au, 98th percentile value) in the pine top study (Dunn *et al.*, 1994). Many sites in the southeastern part of the survey area yielded anomalous enrichments of cesium (up to 57 ppm), substantiating the data from the pine top study.

TABLE 4
COMPARISON OF RELATIVE ENRICHMENTS OF ELEMENTS IN OLD (OPEN) AND YOUNG (CLOSED) CONES FROM NINE LODGEPOLE PINES IN THE INTERIOR PLATEAU

	No. of trees with element enriched in **open cones**	No. of trees with element enriched in **closed cones**	No. of trees with **similar enrichment** in both open and closed cones	Significant differences in composition
Au	5	1	3	no
As	9	-	-	yes
Br	5	3	1	no
Ca	8	-	1	yes
Co	6	-	3	no
Cr	4	-	5	no
Cs	1	1	7	no
Fe	7	2	-	yes
K	-	5	4	yes
La	6	-	3	yes
Mo	1	1	7	no
Na	7	-	2	yes
Ni	3	4	2	no
Rb	-	1	8	no
Sb	9	-	-	yes
Zn	1	-	8	no

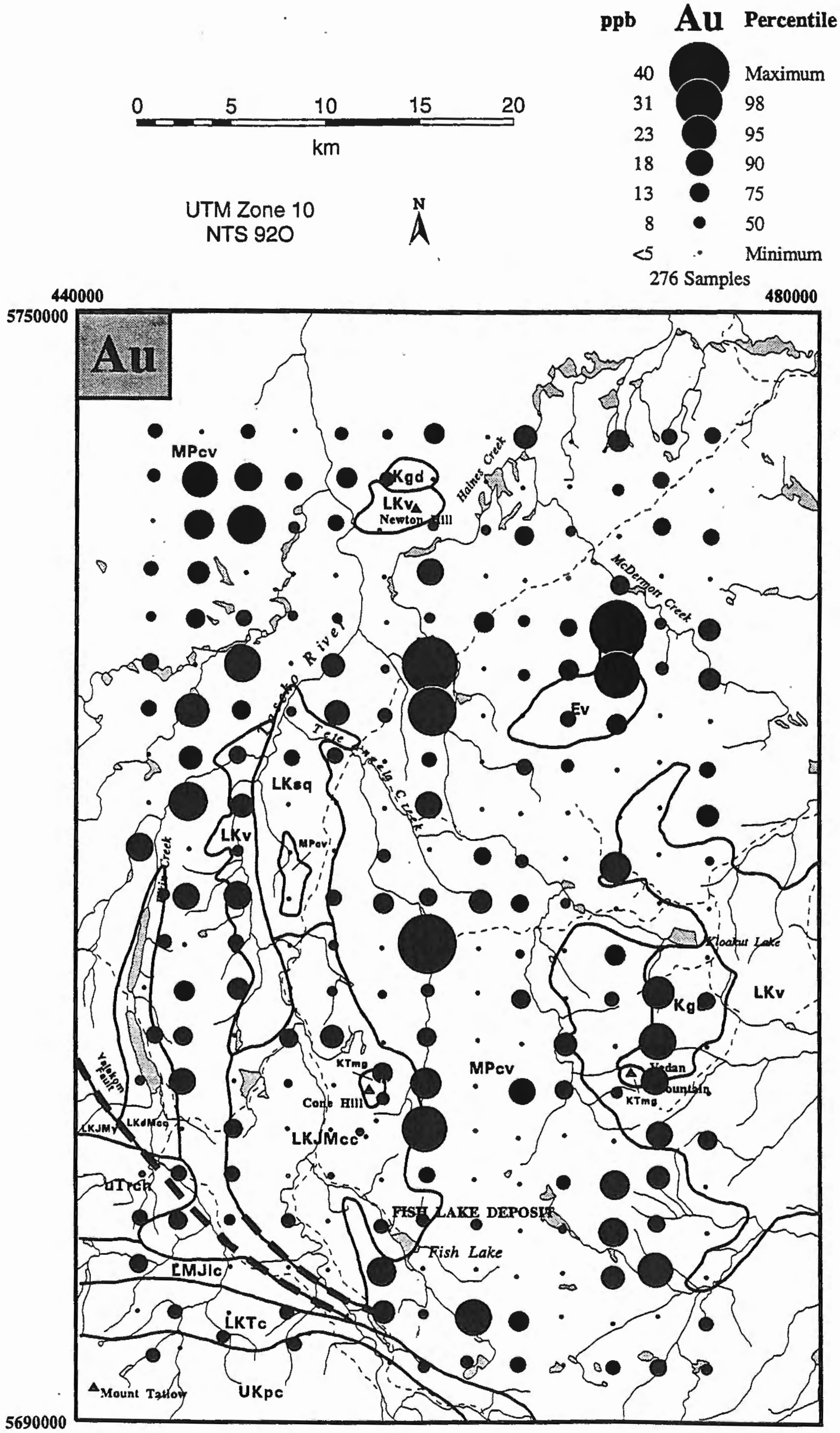


Figure 4. Gold in the ash of lodgepole pine top stems - Fish Lake area.

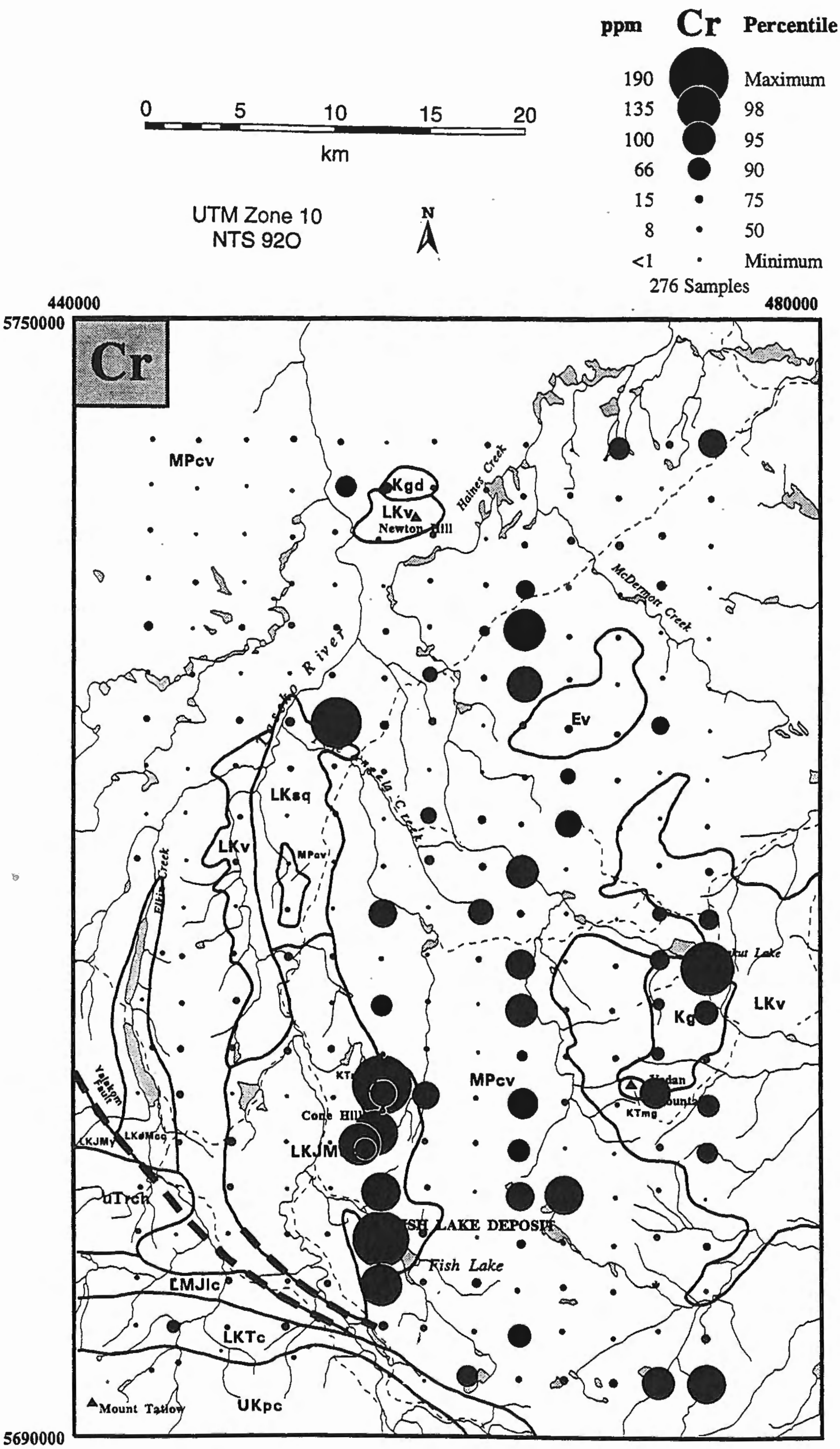


Figure 5. Chromium in the ash of lodgepole pne top stems - Fish Lake area.

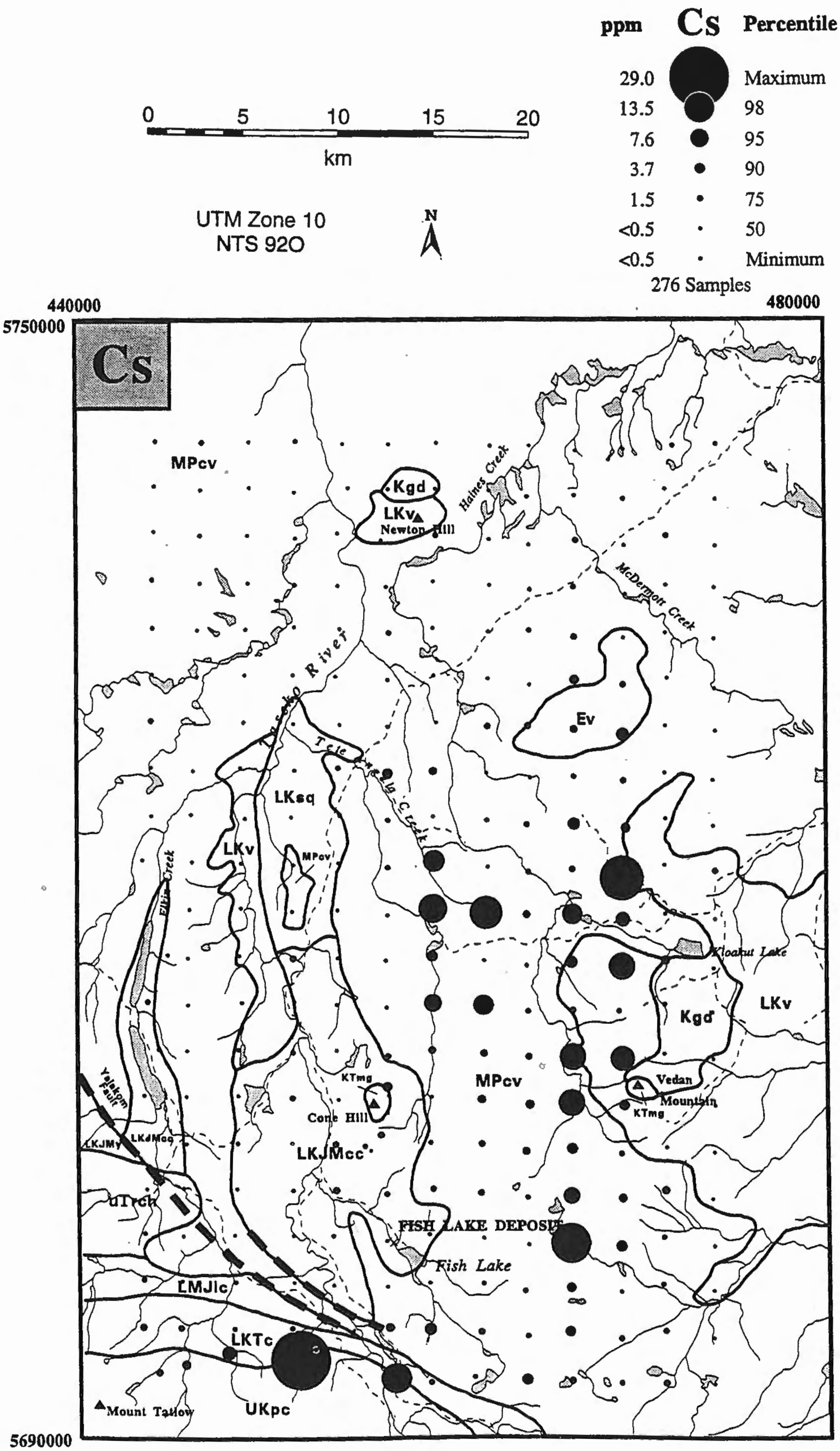


Figure 6. Cesium in the ash of lodgepole pine top stems - Fish Lake area.

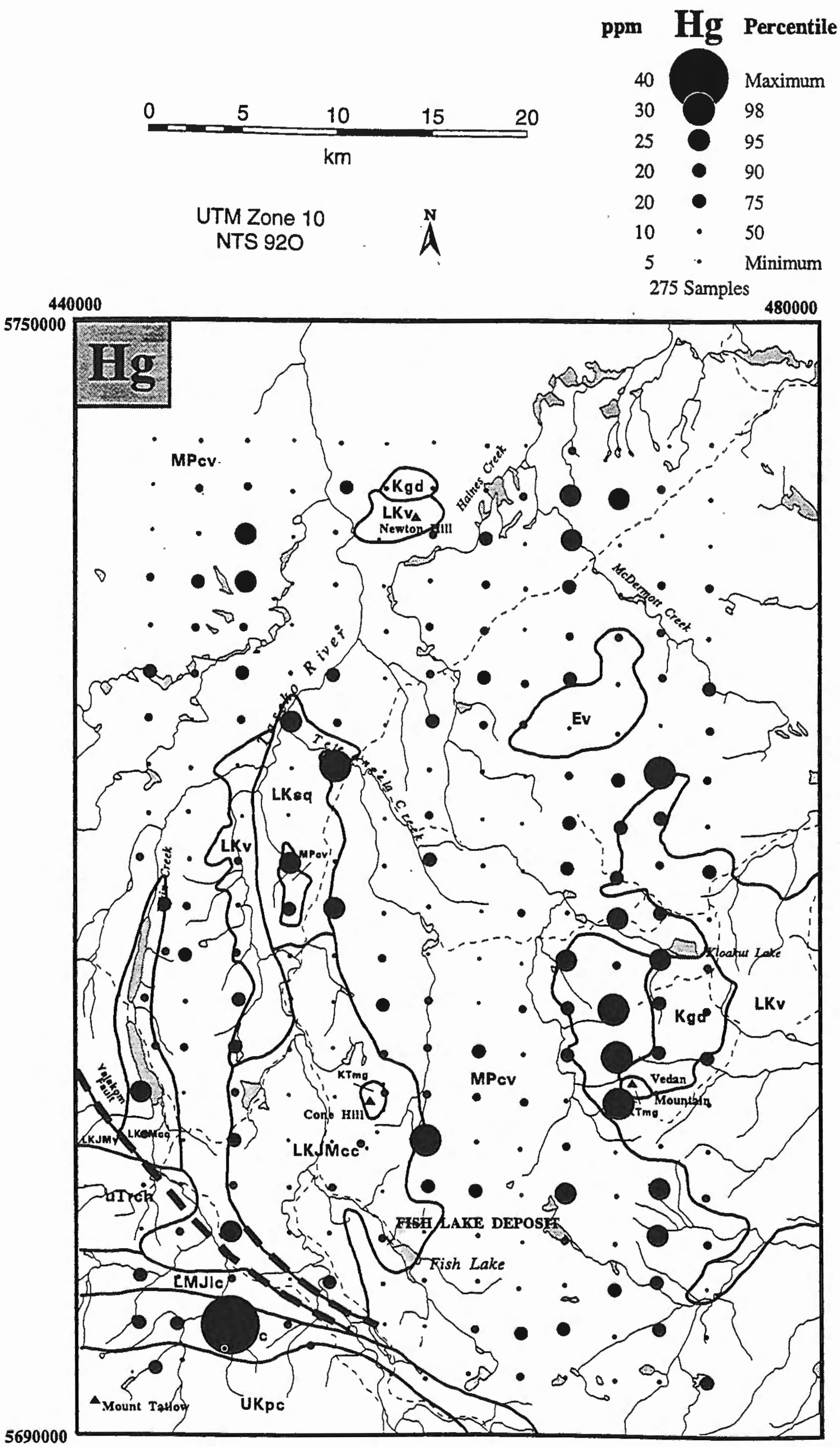


Figure 7. Mercury in dry lodgepole pine top stems - Fish Lake area.

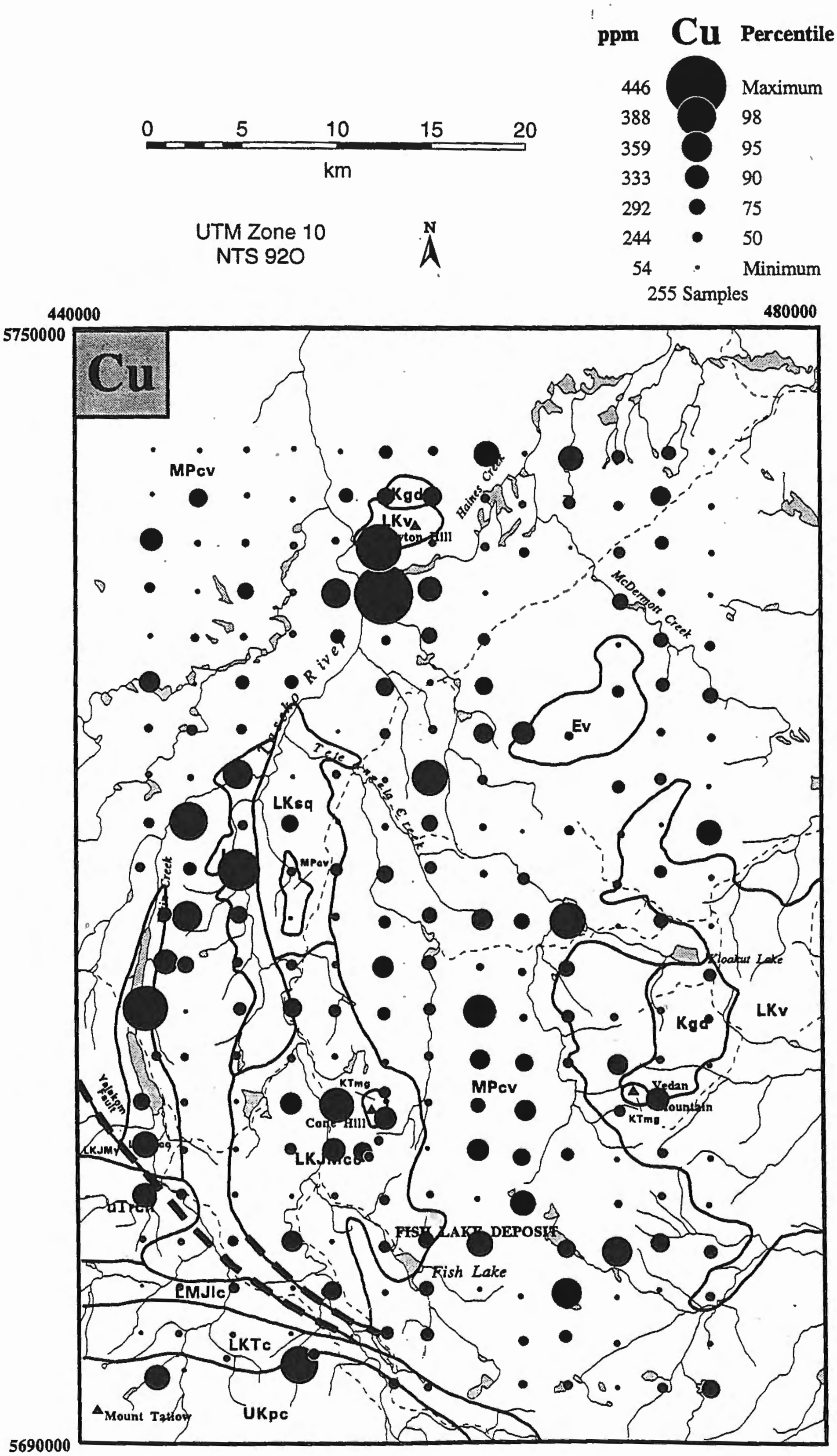


Figure 8. Copper in the ash of lodgepole pine top stems - Fish Lake area.

DETAILED STUDIES

A final phase of study involved detailed sampling at several locations within the area covered by the helicopter survey:

Cone Hill (Figure 3). Lodgepole pine bark samples were collected along three west-east traverses, 200 metres apart, across the southern flank of Cone Hill where gold enrichment in soils had been noted by Valerie Gold Resources Ltd. (A. G. Troup, personal communication, 1993). Along one line (L2300) sampled previously for B-horizon soils at 100-metre intervals, samples of pine bark were collected at a spacing of 200 metres (Figure 9). A plot of gold data indicates similar north-northeasterly trends of gold distribution in the two sample media at the eastern end of the traverses. There is a second zone of weak gold enrichment at the western end of line 2300 in an area not covered by the soil survey. This survey shows that, although the absolute concentrations of gold are different in the two sample media, the patterns of gold distribution are similar.

Newton Hill (Figure 3). In 1992, Verdstone Gold Corporation's annual report included results from trenching at Newton Hill. The most enriched section reported was 0.86 g/t Au (857 ppb Au) over 48 metres. Samples from the pine top reconnaissance survey did not detect the zone of known gold mineralization, because Douglas fir is the dominant species on Newton Hill. Lodgepole pine tops are lower in the forest canopy than those of the fir, and it would have been unsafe to sample them from a helicopter. The ground-based survey involved the collection of bark from lodgepole pine and/or Douglas fir at 31 sites, along two 800-metre lines 300 metres apart, according to availability. Both species from sites near the top of the hill were weakly enriched in gold (up to 40 ppb; background 5 ppb). On the northern flank of the hill the lodgepole pine indicated unusual enrichment of zinc (up to 6000 ppm; background 2000 ppm); and at several sites over the hill selenium was enriched in Douglas fir bark (up to 21 ppm; background 1 ppm). *Phacelia heterophylla*, a herbaceous perennial, yielded a high concentration of 15 ppb gold in fine, dry stems from one site. Also of note, was the enrichment of mercury in dry tissue of the epiphytic yellow lichen *Letharia vulpina* (235 ppb) and to a lesser degree in the red-stemmed feathermoss *Pleurozium schreberi* (100 ppb). In this area background concentrations in dry plant tissue are less than 30 ppb mercury. From the survey it was concluded that although the gold signature of the vegetation was more subtle than that in the soils (locally >50 ppb Au with up to 2120 ppb Au, Verdstone Gold Corporation, personal communication, 1993), judicious sampling and INA analysis of the vegetation revealed a mineral system enriched in gold, zinc, selenium and mercury, with weak enrichment of arsenic, barium and molybdenum. Copper, known to be associated with the gold, was not included in the analytical programme.

Other Areas. Several other areas that yielded weakly anomalous concentrations of elements were visited to determine if there was any obvious source for the metal enrichment. These included the area between Kloakut Lake and Vedan Mountain (Figure 3), and a zone of weak gold enrichment (up to 38 ppb Au) between Newton Hill and Tête Angela Creek [site Nos. 161-164 (Figure 3)]. Neither area yielded anomalous concentrations of gold in lodgepole pine bark, but both showed some enrichment of silver. Subsequent biogeochemical work by Better Resources (C.C. Rennie, Better Resources Limited, personal communication, 1994) in the Tête Angela Creek area found enrichment of gold in willow (140 ppb in ash: similar to that at Clisbako North zone), and mercury (up to 150 ppb in dry pine bark). To date no mineralization has been found.

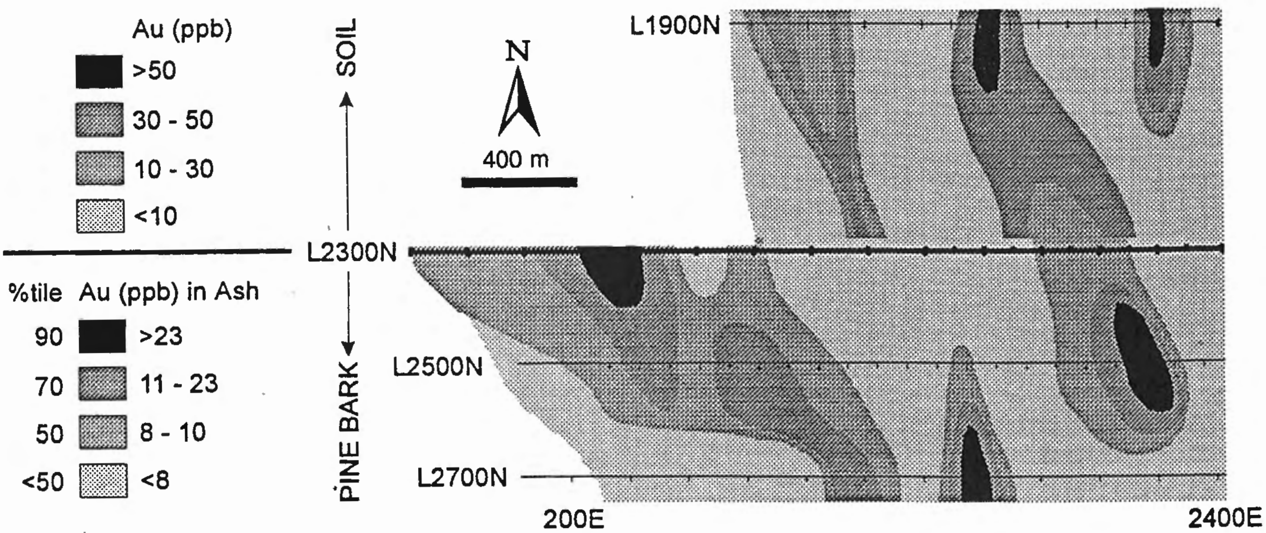


Figure 9. Distribution of gold in lodgepole pine bark and B-horizon soils. Samples from cut lines on the southern flank of Cone Hill (Figure 3). Soil data courtesy of A.G. Troup, Valerie Gold Resources Ltd. Contoured soil values (upper half) and bark values (lower half) indicate continuity of zones with relative gold enrichment.

CONCLUSIONS

Helicopter-borne tree-top sampling programs at a reconnaissance level provide an extremely rapid means of conducting geochemical surveys in forested terrain, regardless of topography and access. At a between-site spacing of 2.5 kilometres, an area of 100 square kilometres can be sampled in an hour of flying. This sample density allows recognition of major geochemical trends in the substrate, and the spatial relationships of zones of relative metal enrichment which may reflect lithogeochemical zonation of metals. Data should be viewed together with those of other data sets (*e.g.* gamma-ray spectrometry and Quaternary studies: Plouffe, 1997 this volume) to help in determining their significance. Some comparisons are discussed by Plouffe. The biogeochemical technique is a method of quickly screening an area to provide focus for more detailed ground studies.

Detailed studies have shown there to be a significant biogeochemical response to the mineralization at Clisbako with enrichment in gold, arsenic, molybdenum, tungsten, cesium and rubidium. Gold enrichment is particularly pronounced in twigs of shrub alder and willow. At Fish Lake there is weak enrichment of gold, molybdenum, copper, cesium, nickel and sodium, in pine tops and strong enrichment in chromium throughout the Fish Lake and Cone Hill area. Bark samples are locally enriched in gold, arsenic, copper and selenium, and alder is enriched in molybdenum and copper. Enrichment of gold, silver, selenium and mercury is noted elsewhere in the survey area.

It is concluded that the collection and analysis of plant tissues can provide information that can assist in focusing exploration efforts. By including biogeochemical methods in an exploration program, valuable primary information (*i.e.*, indications of mineralization not immediately apparent from other sample media) and secondary information (*i.e.*, substantiation of gamma ray signatures and/or enrichments found in till, soil or other sample media) can be obtained.

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I gratefully acknowledge the many people who have provided assistance and information to help in conducting these surveys. In particular: Rob Scagel (Pacific Phytometric Consultants) for sample collection, field assistance and for providing in-depth knowledge of the forests; Wendy Spirito, Robin Balma and Steve Adcock (GSC) for data compilation and map production; Tina Hearty, Alice MacLaurin and Alex Fitzpatrick for their assistance in preparing the samples for analysis; Nadia Caira and Ross Banner (Taseko Mines Ltd.) for information, their generous hospitality at the Fish Lake camp and for trucking the samples to Williams Lake; Rob Owens (Alpen Helicopters) for his skills at flying the helicopter to collect the samples.

I thank the following for many useful discussions and information: Cliff Rennie (Better Resources Limited, Vancouver); Art Troup and Frank Lang (Valerie Gold Resources Ltd., Vancouver); David Dunn and Steve Sorensen (Pioneer Metals Corporation, Vancouver); Herb Pickner (Panther Mines Ltd., Vancouver); Rudy Durfeld (Durfeld Geological Management, Williams Lake); Larry Reaugh (Verdstone Gold Corporation, Vancouver); and colleagues at the GSC in Ottawa and Vancouver.

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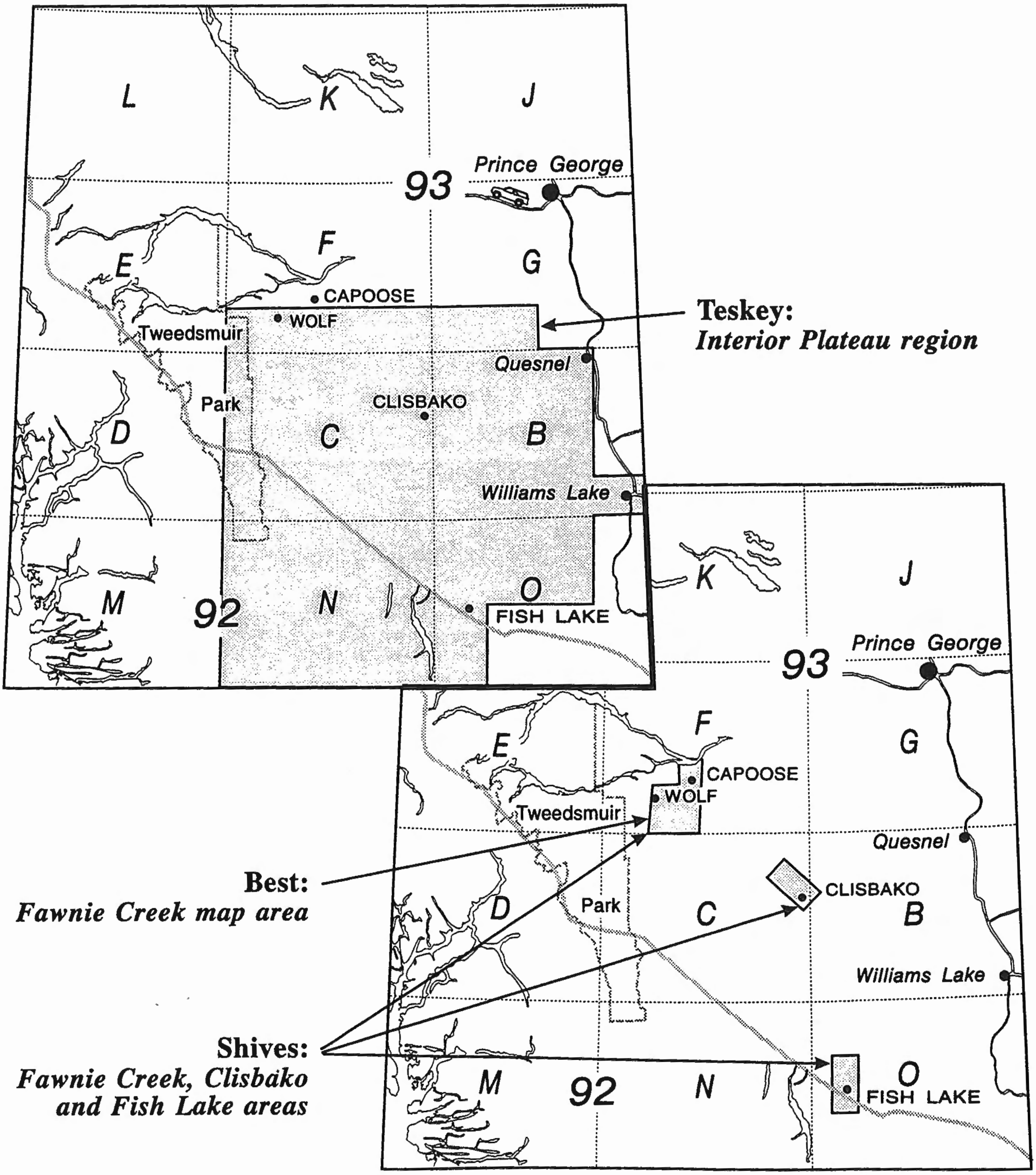
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HIGH-RESOLUTION REGIONAL AEROMAGNETIC SURVEY - INTERIOR PLATEAU BRITISH COLUMBIA

By Dennis Teskey, Peter Stone, Peter S. Mustard and Paul Metcalfe
Geological Survey of Canada

Geological Survey of Canada Contribution 1996161

KEYWORDS: Aeromagnetic survey, Interior Plateau, Yalakom fault, Tchaikazan fault, Tatla Lake Complex, Anahim volcanic belt, Eocene volcanic rocks, Chilcotin Group.

INTRODUCTION

Exploration in the Interior Plateau of British Columbia has been inhibited by extensive glacial drift and recent (Miocene) lava flows (Diakow and van der Heyden, 1995). Accordingly, a high-resolution regional aeromagnetic survey was included as part of the Canada - Bristish Columbia Mineral Development Agreement 1991-1995. Additional funding was obtained from the Geological Survey of Canada and the private sector, allowing the survey to be extended to include all of NTS 92N and 93C and parts of 93F, 93G, 93A and 92O quadrants (Figure 1). The survey area includes part of the Coast Mountains in the southwest quadrant. The objectives of the survey were to map faults and boundaries between major lithological units at regional scales and, at larger scales, to help define intrusive and volcanic boundaries, faults and alteration zones. There was concern that the latter objective would require extensive processing to reduce the masking effect of the extensive Miocene cover.

METHODOLOGY

To meet the objective of acquiring a data set suitable for mapping at 1:50 000 scale, east-west flight lines were flown at 800-metre spacing, with north-south control lines at 5-kilometre intervals in a 'smooth-drape' mode, that is on a smooth surface nominally 305 metres above mean terrain clearance but limited by the safe climb and descent capacity of the aircraft. The contract was awarded to Geonex/Aerodat Ltd. in March, 1993, and the survey was flown during the late summer and early fall of 1993, with some reflights in the spring of 1994, from a base at Williams Lake. Geomagnetic diurnal monitors were located at Williams Lake, Anahim Lake and Vanderhoof. Three aircraft were utilized in the survey - a Cessna 404, Cessna 310

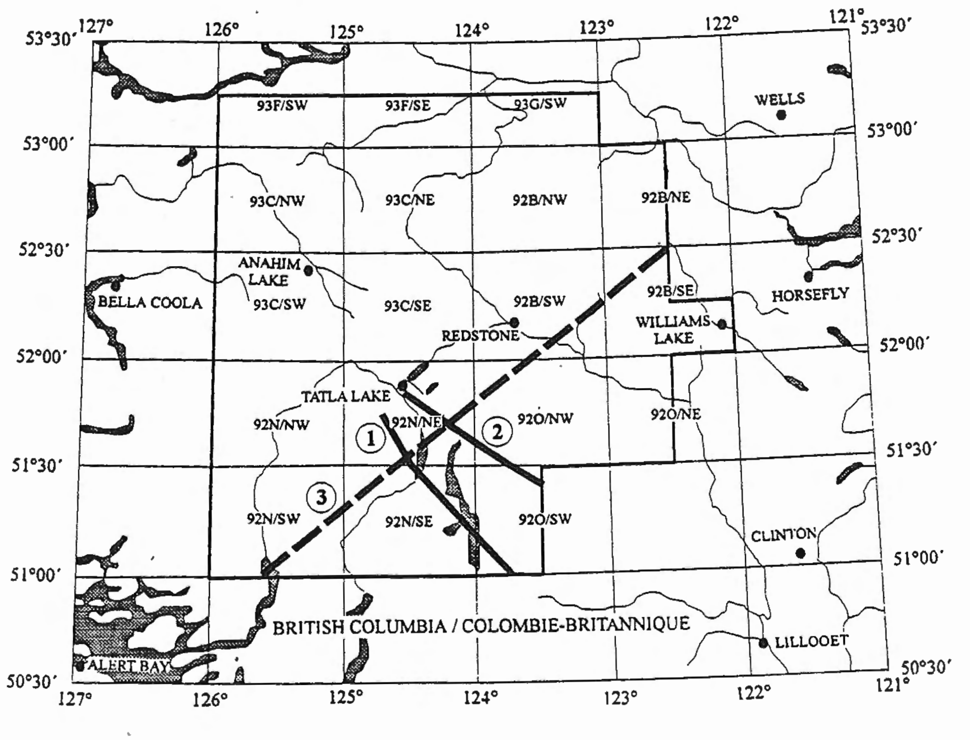

Figure 1. Area covered by high-resolution regional aeromagnetic survey. Approximate locations of 1-Tchaikazan fault, 2-Yalakom fault, 3-possible northeast-trending fault, as interpreted from the aeromagnetic data.

and Rockwell Aerocommander, each equipped with a stinger-mounted 0.005-nanotesla sensitivity split-beam cesium vapour magnetometer, together with radar and barometric altimeters and digital recording systems. Navigation was achieved by Global Positioning System (GPS), with differential corrections applied to determine final XYZ positions accurate to within 25 metres. An initial colour, residual total-field map at a scale of 1:250 000 was released as Geological Survey of Canada Open File 2785 in November, 1994 (GSC, 1994) while 1:100 000 total-field contour maps were released under the same Open File in June, 1995. The digital data are available from the GSC's Geophysical Data Centre (613-995-5326). Although the survey parameters were considered to be appropriate for 1:50 000 mapping, publication was limited to 1:100 000 in order that as much as possible of the available funding could be directed to the acquisition of high-resolution magnetic data. Larger scale maps, enhanced maps and derived products can, however, be obtained for the Geophysical Data Centre and can be generated from the digital data.

PROCESSING AND INTERPRETATION

Routine techniques that have been applied to the data set include: vertical gradient to delineate near-surface vertical contacts; shaded relief (illumination by an artificial light source at arbitrary inclination and declination), to emphasize linears and contacts perpendicular to the direction of the light source; and upward continuation to identify and map the extent of major units and intrusions. The actual interpretation of the original and derived data sets, combined with other available data sets (*i.e.* Radarsat), can often be carried out most effectively by geoscientists most familiar with a specific area. Further analytical interpretation that could be carried out includes modelling of individual profiles or anomalies; however, a careful selection of anomalies and integration of available geological and physical properties (*e.g.*, magnetization) is required for this approach to be effective. More automated procedures such as Euler (Reid *et al.*, 1990) or Werner (Hartman *et al.*, 1971) deconvolution techniques can be used to extract useful information on particular simple-source geometrics such as contacts, dikes and small intrusion on a more routine basis, however the results must be carefully interpreted.

PRELIMINARY RESULTS

The aeromagnetic total field maps and derived products reveal a wealth of information relevant to the structure of the area, a short and incomplete list of which are noted below.

Major fault systems are defined and/or redefined by the aeromagnetic data. Examples are:

- The Yalakom and Tchaikazan faults (Wheeler and McFeely, 1991), which merge on the southwestern boundary of the Tatla Lake Metamorphic Complex 10 to 15 kilometres west of the town of Tatla Lake. This confirms fault relationships shown on new geologic maps of the area (Mustard *et al.*, 1994; Mustard and van der Heyden, 1997, this volume). It also appears that the Yalakom fault system continues to the northwest into the Charlotte Lake map area (93C/3), although the structure becomes less well defined and cannot be confidently continued along trend through the entire Charlotte Lake area.
- A lineation, possibly the location of a major fault which can be traced across the survey area from southwest (51°, 125°50'W) to northeast (52°30'N, 122°30'W) (*see* Figure 1 for approximate location). The anomaly also has a signature on the residual gravity map corrected for isostasy (P. Keating, personal communication).

The general trend of magnetic patterns through the central part of the map area, northeast of the Yalakom fault, is north and northwest. This pattern is particularly evident along and parallel to the Fraser fault, which is seen as a dominant magnetic low, and its continuation north-northwest to the northern Fraser Plateau region, evident as parallel patterns of magnetic highs and lows.

Major features evident at the 1:250 000 scale include the Tatla Lake Metamorphic Complex (Mustard and van der Heyden, 1994) and major plutonic complexes of the Mount Waddington (NTS 92N; Tipper, 1969) and the southwest part of the Anahim Lake (NTS 93C) map areas. The latter areas contain complex aeromagnetic patterns, probably reflecting the presence of an intrusive complex comprising plutons of different compositions. Evidence to support this interpretation comes from new mapping and geochronologic studies in parts of these areas (van der Heyden *et al.*, 1994; Mustard *et al.*, 1994; Mustard and van der Heyden, 1997, this volume) and predicts there is similar complexity exists in the rest of the Mount Waddington area, which on regional-scale geologic maps has been shown as a few large plutonic bodies of similar general age (*e.g*, ,Klinaklini pluton of Tipper, 1969).

In addition to the confirmation of the main trends of the Yalakom and Tchaikazan fault systems, major plutonic bodies mapped by Mustard *et al.* (1994), Mustard and van der Heyden (1997, this volume) in NTS 92N/15 and N/14 (east half) are clearly delineated by the aeromagnetic data. The Wilderness Mountain and Klinaklini plutons are well defined, as are the Sapeye Creek pluton and an unnamed large plutonic body at the north end of the Niut Range. New geochronological data for these plutons demonstrate that they are Late Triassic in age rather than Cretaceous, as previously believed, and that the eastern pluton intrudes Middle Triassic volcanic rocks which host several zones of porphyry copper-gold mineralization probably related to pluton intrusion (*e.g.*, New Mac claim group, Mustard *et al.*, 1994). Several smaller aeromagnetic anomalies do not correspond to any mapped plutonic bodies or other indentified features. These may represent unexposed extensions of the known plutonic bodies or small unknown buried plutons.

Anomaly patterns can be identified and used to extend mapped Eocene volcanics on the tectonic assemblage map of Wheeler and McFeely (1991). The broad positive magnetic anomaly, slightly to the northeast of the Clisbako River study area (*ca.* 52°46'N, 124°10'W), is interpreted as the signature of a subvolcanic intrusion or stock underlying an Eocene volcanic centre interpreted by Metcalfe and Hickson (1995). The anomaly lies at the intersection of two linear magnetic discontinuities. The first was identified (P. Read, personal communication, 1995) as cospatial with the Chilcotin fault, whose trace is exposed to the southeast of the Clisbako River area. This anomaly extends northwest across the Clisbako volcanics from approximately 52°30'N, 123°30'W to 53°00'N, 124°15'W. Other magnetic discontinuities in this area are subparallel to the Chilcotin structure.

A second magnetic discontinuity crosses the area trending slighly south of due east, parallel to the trend of the Anahim volcanic belt. The intersection of the two discontinuities occurs at approximately 52°50'N, 124°05'W. If the east-west discontinuity is also interpreted as a significant structure in the basement, the implication is that the location of the Clisbako volcanic centre is controlled by such structures. Also implicit in this a hypothesis is the interpretation that such basement structures, being pre-Eocene, predate the Anahim belt volcanism. This does not disprove a proposed hot-spot origin for the Anahim belt volcanism, but suggests an additional structural control.

The Clisbako River area is also transected by numerous high-frequency north-bending trending anomalies, usually associated with areas underlain by Neogene Chilcotin Group basalts due to the abundance of magnetite in these rocks. The anomalies persist in areas which are not underlain by Chilcotin basalts but where scarcity of outcrop may conceal the presence of dikes. This interpretation does not, however, explain why these anomalies do not cut the large anomaly interpreted as an Eocene stock.

An interesting, and as yet unexplained feature, is the dominant north-westerly trending magnetic low in the southwest part of the study area; over part of the Coast Mountains. It may be the expression of a deeply buried source with reversed magnetization.

At 1:50 000-scale, the new data provide information of the extent and boundary contacts of mapped and possibly unmapped features which may be important loci for mineral deposits. Examples include:

- In the Fawnie Creek area (93F/3) mapped by Diakow and Webster (1994), several known (Wolf, Fawn and Buck) and new (Malaput and Tommy) epithermal occurrences have been explored in Eocene and Jurassic rocks. Mineralization in Jurassic rocks may be related to contacts with the Late Jurassic Capoose batholith exposed in the northern part of the sheet. The aeromagnetic data can play an important role in this area by mapping contact zones between the Jurassic, Cretaceous and Eocene rocks, faults and alteration zones within units, and different phases within the batholith. In some cases, the data could be used to plan more detailed geophysical surveys in areas of particular interest.
- In the Clisbako River area, mapped by Metcalfe and Hickson (1995), magnetic Eocene volcanics, occurring in a possible eroded caldera, host potetially economic epithermal mineralization. Two known deposits, Baez and Clisbako (Metcalfe and Hickson, 1995) occur on the flank of a magnetic anomaly associated with an eroded caldera and an outlier to the southeast, respectively.
- In the Mount Tatlow area (92O/5), the Fish Lake porphyry deposit occurs near the Yalkom fault and on the flank of a major magnetic anomaly associated with mapped Eocene volcanics. The deposit appears to lie on a faulted contact which may act as a conduit for mineralizing fluids. Plouffe (1997, this volume) has also noted the presence of a significant gold anomaly in till which is also located on the flank of an aeromagnetic anomaly in this area.

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ELECTROMAGNETIC MAPPING IN DRIFT COVERED REGIONS OF THE NECHAKO PLATEAU, BRITISH COLUMBIA

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V.M. Levson and L. J. Diakow, British Columbia Geological Survey

Geological Survey of Canada Contribution 1996179

KEYWORDS: Time-domain electromagnetic survey, Fawnie Creek, Capoose batholith, drift thickness, resistivity mapping, buried contacts.

INTRODUCTION

The southern Nechako Plateau of British Columbia (Figure 1) is a region of low relief, covered with glacial drift of variable thickness and composition. The drift limits bedrock mapping to regions of outcrop or to specific areas where bedrock can be inferred indirectly from topographic features. Geological mapping must therefore be supplemented by geochemical and geophysical surveys.

With this in mind, a Geonics EM-47 time-domain electromagnetic (TDEM) survey was carried out to investigate whether EM can map bedrock lithology and structure, as well as thickness and lithology of the drift (Best, 1995; Best *et al.*, 1995). As the contact between the Capoose batholith and the surrounding volcanic rocks is associated with known mineralization (Lane and Schroeter, 1995) a major objective of the surveys was to locate this contact beneath the drift cover.

Bedrock consists of resistive intrusives and volcanics. The eddy current generated within these bodies decays quickly, thus generating a low S/N ratio at long times (greater than 0.5 ms). Resistive drift overlies the resistive bedrock. Such environments are a challenge for EM methods.

Two sites were selected close to the expected location of the contact (Figure 2) and EM surveys were conducted across the proposed contact. Soundings in a third site investigated the ability of TDEM to map variations in drift thickness and lithology.

DESCRIPTION OF STUDY AREA

BEDROCK GEOLOGY AND MINERAL POTENTIAL

The bedrock geology of the Fawnie Creek map area was first mapped by Tipper (1954, 1963) and recently by Diakow *et al.* (1994). The area is part of a broad, structurally uplifted zone that includes the Fawnie Range and the Nechako Range to the east. The oldest strata, of probable Early Jurassic age, consist mainly of felsic volcaniclastic rocks. These in turn are conformable with stratigraphically overlying basaltic flows with interlayered fossil-bearing sediments of Middle Jurassic age. The Late Jurassic Capoose batholith, composed of quartz monzonite and granodiorite, projects southwest beneath the Entiako Spur and a relatively thin cap of Jurassic rocks that are variably altered to a propylitic assemblage. Eocene volcanic rocks of the Ootsa Lake Group form scattered, relatively thin outliers that rest unconformably on the Jurassic rocks. Miocene and younger basalts of the Chilcotin Group underlie mainly topographically subdued areas south and northwest of the Naglico Hills.

Anticipated mineral potential of the Fawnie Creek map area is high, based on the recent discovery of new precious metal prospects (Diakow and Webster, 1994), encouraging till and lake sediment geochemical results (Levson *et al.*, 1994; Cook and Jackaman, 1994) and geological mapping that shows a close spatial and possible genetic association between the Capoose batholith and a variety of known mineralized prospects (Lane and Schroeter, 1995). Mineralization in the Fawnie Creek and adjoining areas consists mainly of deposits found within or along the margin of subvolcanic and larger epizonal calcalkaline plutons. Three magmatic mineralizing events are inferred from recent 1:50 000 scale geological mapping and new radiometric dates. The oldest event, represented by the Late Jurassic Capoose batholith, is spatially associated with skarn, base metal veins and precious metal epithermal prospects. Latest Cretaceous felsic hypabyssal plutons at the Capoose prospect, contain either porphyry copper or disseminated silver mineralization, and Eocene rhyolitic volcanic rocks host epithermal precious metal stockwork veins at the Wolf prospect (Andrew, 1988).

QUATERNARY GEOLOGY

During the late Wisconsnian Fraser glaciation, ice moved into this part of the Nechako Plateau from the Coast Mountains (Tipper, 1971). Ice-flow studies indicate there was one dominant flow-direction towards the east-northeast, modified by topographic control during both early and late stages of glaciation (Giles and Levson, 1994; Levson and Giles, 1994). At the last glacial maximum, ice covered the highest peaks in the region suggesting an ice thickness in excess of 1000 metres. Glacial deposits are of variable thickness and include: compact, matrix-supported, silty diamictons interpreted as basal melt-out and lodgement tills (Photo 1), and loose, massive to stratified, sandy diamictons of inferred debris-flow origin. Typically, basal tills unconformably overlie bedrock and are overlain by glacigenic debris-flow deposits, glaciofluvial sediments or colluvium. Thick (10 m or more) sequences of till occur both in main valleys and smaller valleys oriented oblique to the regional ice-flow direction, such as the van Tine Creek valley.

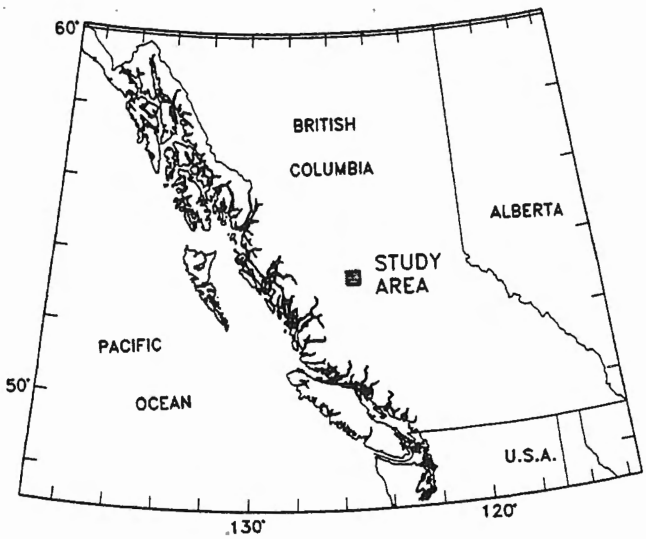

Figure 1. Location map of the Interior Plateau electromagnetic survey.

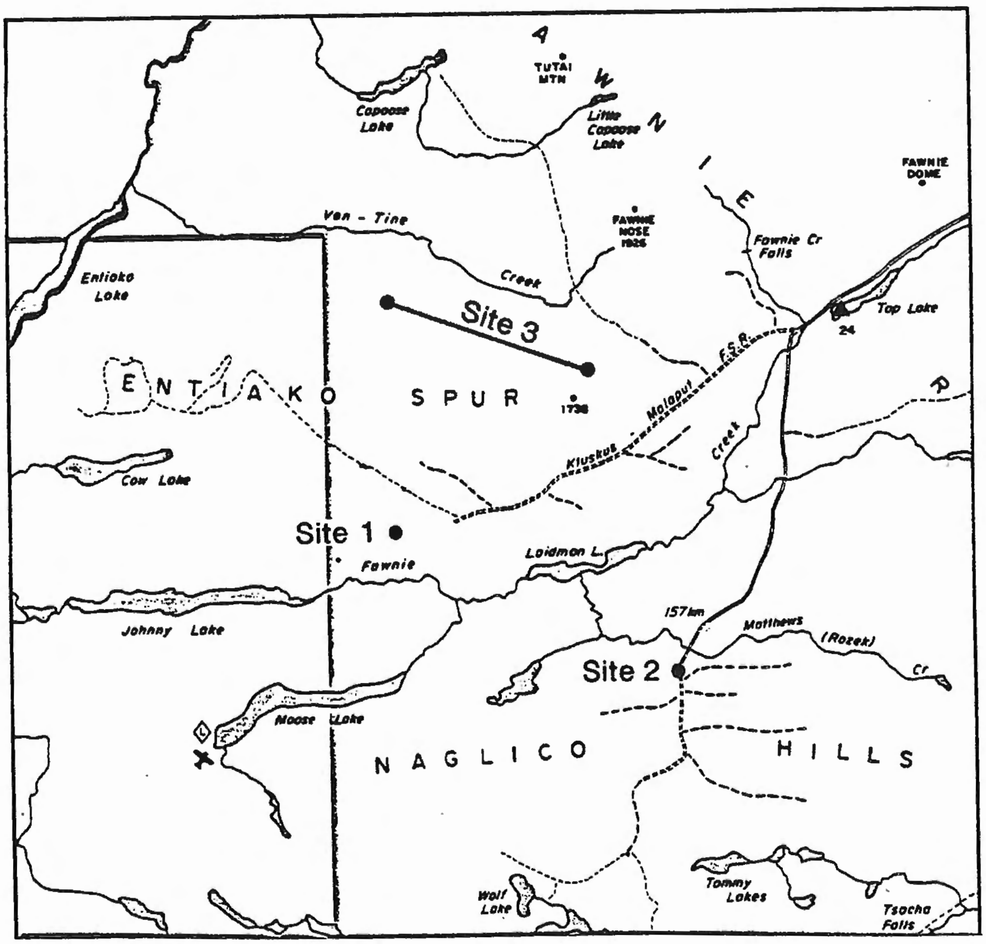

Figure 2. Vanderhoof Forest District recreational map showing the three EM-47 survey sites.

Photo 1. Till and glacigenic debris-flow deposits overlying bedrock exposed in a trench at the Wolf epithermal gold prospect.

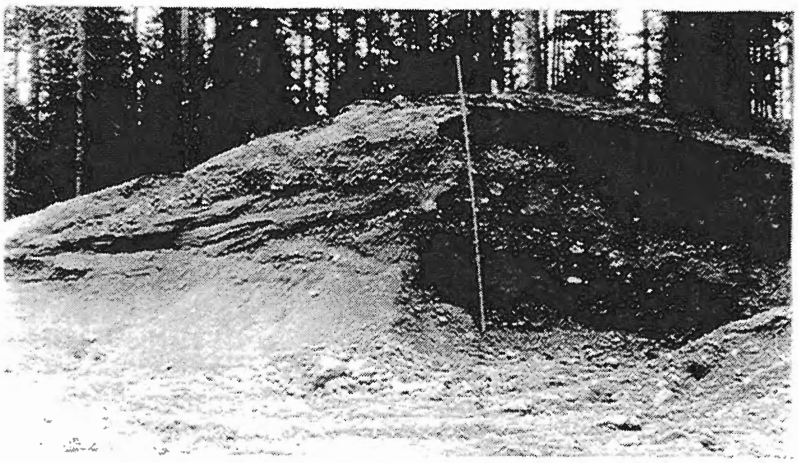

Photo.2. Exposure of glaciofluvial gravels and sands in a small esker in the van Tine Creek valley near site 3. Measuring rod is 4 metres long.

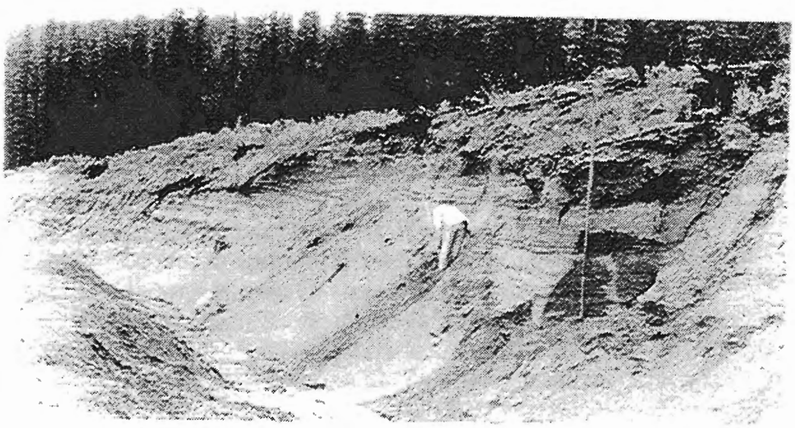

Photo 3. Exposure at site 1, of well-sorted, ripple-bedded, fine to coarse sand in a coarsening upward sequence interpreted as a glaciofluvial fan-delta deposit. Measuring rod is 3 metres long.

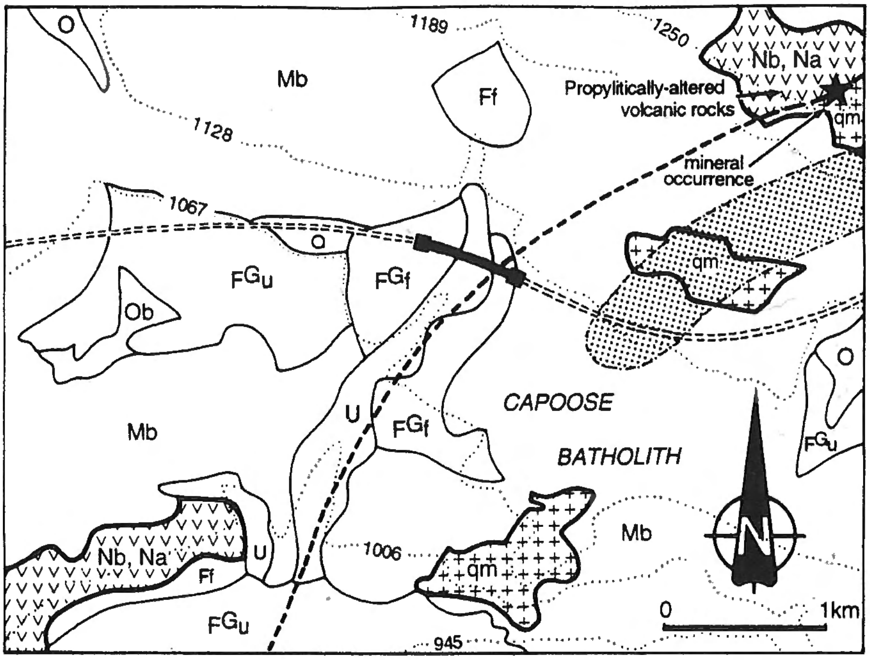

Figure 3. Bedrock and surficial geology of the region around EM survey site 1. The location of the EM survey (thick bar) along the Kluskus-Malaput forestry road (double dashed line), the inferred contact of the Capoose batholith with volcanic country rocks (thick dashed line) and an area of anomalous (10-80 ppb) gold in tills (shaded) are shown. Abbreviations: qm - quartz monzonite; Nb, Na - basalt and andesite; F^{G}f - glaciofluvial fan-delta, F^{G}u - glaciofluvial outwash; Ff - alluvial fan Mb - morained blanket; O, Ob - organics; U - undifferentiated (steep gullies).

During deglaciation, glaciofluvial and glaciolacustrine sediments were deposited in many parts of the region on or near the ablating glaciers. Glaciofluvial sediments consist mainly of poor to well sorted, stratified gravels and sands and commonly occur as eskers, kames, terraces, fans and outwash plains in valley bottoms and along valley flanks. Several small eskers formed under down-wasting ice in van Tine Creek (Photo 2) and Fawnie Creek valleys. Gravelly outwash plains covered the main valley bottoms as large volumes of sediment and water were removed from the ice margin. Glacial lakes formed locally along the margins of the retreating ice. One such lake, on the south side of the Entiako Spur (near site 1), probably was dammed by stagnant ice in Fawnie valley, A coarsening-upward sequence of well sorted, ripple-bedded, sands (Photo 3; see also section 9.5 in Levson and Giles, 1994) at this site is interpreted as a prograding fan-delta (Figure 3) that formed along the margin of the lake. Glacial lake sediments have also been mapped in the northern part of the region and may extend into the van Tine Creek valley near EM survey site 3.

During postglacial times, the surficial geology of the area was modified mainly by fluvial activity and the local development of alluvial fans in valley bottoms (Figure 3), as well as by colluvial reworking of glacial deposits along the valley sides. Holocene fluvial sediments in the map area are dominated by floodplain silts, fine sands and organics. Low areas in valleys are characterized by marshes and shallow lakes filled with organic sediments (Figure 3).

SITE DESCRIPTIONS

Figure 2 shows the location of the EM sites. Sites 1 and 3 are situated well down on the south and north sides of the Entiako Spur respectively, in areas where bedrock is generally poorly exposed. Site 2 is situated at a low elevation on the gentle north slope of the Naglico Hills, in an area where glacial deposits, presumed to be thick, mantle bedrock. The sites are located approximately 150 to 160 kilometres southwest of Vanderhoof in the Fawnie Creek map sheet (NTS 93F/3).

SITE 1 (CAP)

Regionally anomalous concentrations of gold, silver, arsenic and antimony in tills (Levson *et al.*, 1994) and gold and arsenic in sediments (Cook and Jackaman, 1994) occur at site 1 and, although the surficial sediment cover is extensive, silicified and mineralized country rock crops out nearby along the margin of the Capoose batholith (Diakow *et al.*, 1994). These data point to an area of potentially significant mineralization, along the west-central margin of the Capoose batholith. Due to the thick overburden in this area, Levson *et al.* (1994) suggested that geophysical prospecting was required to locate the sources of the gold anomalies. The EM survey reported here was initiated in part to investigate the thickness of the overburden and to help identify the western margin of the Capoose batholith in this area of high mineral potential.

Site 1 (Figure 2) consists of nine, 80 x 80 metre loop soundings along the Kluskus-Malaput forestry road in the Vanderhoof Forestry District, approximately 160 kilometres southwest of Vanderhoof. Sounding 0W was located on the north side of the road with the centre of the loop about 25 metres east of Kilometre 19 (Best, 1995).

SITE 2 (CAP2)

The main purposes of the EM survey at site 2 were to better locate the buried southern contact of the Capoose batholith and to determine the drift thickness in the area. Results of lithologic analysis of pebbles from tills in this area show a consistent northward increase in the percentage of quartz monzonite clasts derived from the batholith. Percentages of quartz monzonites range from 0% a few kilometres south of the inferred contact of the batholith, to 5% near the contact, and 10-23% over the batholith. Conversely, Jurassic andesite percentages decrease from a high of 45%, a few kilometres south of the inferred contact, to 17-24% north of the contact.

Site 2 consists of seven, 40 x 40 metre loop soundings and one 80 x 80 metre loop sounding (OS) along the Kluskus-Ootsa forestry road in the Vanderhoof Forestry District, approximately 150 kilometres southwest of Vanderhoof (Figure 2). Sounding 0S was located on the west side of the road about 1.4 kilometres south of the bridge crossing Matthews (Rozek) Creek (Best, 1995).

SITE 3 (CLVAN)

Anomalous gold concentrations in tills throughout this area (soundings CLVAN-1 to CLVAN-5 inclusive) were documented by Levson *et al.*, 1994 and are associated with a belt of thermally altered Hazelton rocks (Diakow *et al.*, 1994). This area is believed to be near the edge of the northern part of the Capoose batholith. Anomalously high copper values also occur in till near soundings CLVAN-2 (64 ppm) and CLVAN-5 (43 ppm) (Levson *et al.*, 1994). Mineral occurrences known in the area southeast of sounding CLVAN-5 include a magnetite skarn and epithermal-style mineralization (Lane and Schroeter, 1995). The main purposes of the EM survey at this site were to determine the depth to the top of the Capoose batholith, in other words drift thickness, and drift lithology in the area.

Site 3 consists of five 80 x 80 metre loop soundings along the van Tine road, approximately 150 kilometres southwest of Vanderhoof (Figure 2). The five soundings were spaced about 1.5 kilometres apart (Best, 1995).

ELECTROMAGNETIC METHODS

The time-domain electromagnetic survey used a Geonics EM-47 (Geonics, 1991) leased from the Ontario Geological Survey. Best (1995), Best *et al.* (1995), and the references therein contain a description of this system and a summary of electromagnetic methods.

The central sounding mode was used for all soundings. The period T of the transmitter current consists of a positive square wave of duration T/4, followed by an off-time of duration T/4 (receiver measurement time). These are then reversed to give a total period equal to T. The frequency of the transmitted square wave is the reciprocal of the period T. Three frequencies are available with the EM-47 system (UH = ultra high frequency = 285 Hz, VH = very high frequency = 75 Hz and H = high frequency = 30 Hz).

The receiver voltage in the EM-47 unit is measured in millivolts and then converted to the time derivative of the vertical magnetic field. This derivative, also called the normalized voltage, is measured in nV/m^2. The TEMIXGL software (Interpex Limited, 1994) can plot this voltage as a function of time.

The voltages can also be converted to apparent resistivity values (r_a) using the late time normalized voltage (Kaufmann and Keller, 1983; Fitterman and Stewart, 1986; Spies and Eggers, 1986). The apparent resistivity is defined as the ratio of the measured voltage to the voltage that would be measured over a half-space of constant resistivity.

Once the apparent resistivity versus time curves are computed, the data can be interpreted in terms of multi-layered earth models using standard forward and inverse mathematical modelling programs. A number of assumptions are required to ensure the data can be meaningfully represented by a layered earth model. We used the TEMIXGL software package for modelling the data from the Fawnie Creek map area.

FIELD PROCEDURES

Three data sets were collected at the high and very high frequency ranges at each sounding. A single data set was collected for the ultra-high range at most soundings.

Two transmitter loop sizes were used; 80 by 80 metres (area = 6400 m^2) and 40 by 40 metres (1600 m^2). The current in the wire was approximately 2.3 amps.

There were no cultural noise problems in the area, such as those caused by grounded pipes, electric transmission lines and electric fences. Several electrical storms occurred during the survey but did not interfere with the EM measurements.

The EM 47 system proved to be very reliable and robust in the field. There was no down time due to instrument problems.

The data for each site and/or sounding were transferred to a personal computer using software provided by Geonics. The files created by this software were subsequently translated into a form compatible with the Interpex software package TEMIXGL.

EDITING THE DATA

The data were first edited to remove noisy or bad data from the files. Examples of the noise encountered are given in Best (1995). The TEMIXGL software permitted the rapid removal of this noise using an interactive mouse. The results can quickly be displayed to ensure that all the noise is removed.

INTERPRETATION OF THE DATA

The edited apparent resistivity data formed the basis of the interpretation. Details on interpretation procedures can be found in Best (1995) and Best *et al.* (1995).

When an apparent resistivity curve does not fit a layered-earth model the voltage data can only be interpreted by forward modelling. In this case type curves and other available models are compared with the data (McNeill *et al.*, 1984; Spies and Parker, 1984; West *et al.*, 1984). Fortunately all the data from this survey, with the exception of five soundings from site 2 and sounding 330 at site 1, fit a one-dimensional earth model.

SITE 1

Examples of apparent resistivity versus time plots for site 1 are illustrated in Figure 4a. The data fit a model consisting of a layer of drift overlying resistive bedrock (Figure 5a). The overburden resistivity is relatively constant (68 to 157 ohm-metres "Ω-m"), but its thickness varies from 30 to 120 metres. The bedrock resistivity changes from about 8400, Ω-m on the east end of the traverse to about 10 000 Ω-m on the west end. The overburden was thickest, about 80 metres, to the east of the gully. Sounding 330 in the gully is difficult to fit to a one-dimensional model because the three-dimensional gully completely distorts the layering.

The interpretation of the EM results for this site, that is a generally thick overburden section, is supported by results of geology mapping (Levson and Giles, 1994). A large Late Pleistocene glaciofluvial fan (Photo 3) delta (Figure 3) occurs at this site and it is an obvious feature on air photos and on the ground. Exposures of the fan-delta sediments reveal up to several metres of ripple-bedded and troughs crossbedded sands (Photo 3; see Section 93-5, Levson and Giles, 1994). The fan delta sediments overlie till which is exposed in a modern gully that has incised the fan delta. Several tens of metres of till are exposed in cuts along the gully below the fan delta, further supporting the interpretation for thick overburden in this area. The EM results, however, provide the best estimate of the variations in drift thickness.

The bedrock depression between soundings 80W and 330W, and the lower bedrock resistivities associated with the depression, occur at the inferred location of the contact between granite to the east and volcanics to the west. The contact is extrapolated through this area from rock exposures to the north and south (Figure 3; *see* Diakow *et al.*, 1994). The lower resistivities across the contact may be a result of increased porosity (increased water content) due to fracturing or alteration of minerals in the contact zone to clay. The bedrock resistivity at the two ends of the line 8400 Ω-m to the east and 10 000 Ω-m to the west) are consistent with unaltered granite and basalt respectively. Considering the high resistivity of overburden and bedrock (low signal-to-noise ratio at large times) the information gleaned from the TDEM data is quite impressive.

A linear gold anomaly extending eastward for over 5 kilometres from near Site 1 (Figure 3) is documented by Levson *et al.* (1994). It contains the highest gold concentration recovered from regional till samples in the map area (77 ppb). Anomalous gold values occur at sample sites throughout this zone which is about 1 kilometre wide and several kilometres long. The shape of the zone is suggestive of a well developed, glacial dispersal train, comparable with or even larger than other dispersal trains in the region, including, for example, that developed down-ice of the Wolf property (Levson and Giles, 1995). This interpretation is further supported by the orientation of the anomalous zone parallel to the glacial paleoflow direction in the area. The up-ice end of the gold anomaly (Figure 3) also coincides with an area of regionally anomalous arsenic (25 to 46 ppm), antimony (2.2 to 2.8 ppm) and silver (0.4 ppm) concentrations in till (Levson *et al.*, 1994) and with anomalous gold and arsenic concentrations in lake sediments (Cook and Jackaman, 1994). Pervasively silicified and veined country rock adjacent to the intrusion, chip sampled directly north of this area (asterisk on Figure 3), yield gold, arsenic and antimony concentrations of 101 ppb, 12 730 ppm and 79 ppm, respectively, as well as anomalous silver (6 ppm), copper (186 ppm), lead (321 ppm), zinc (675 ppm) and molybdenum concentrations (14 ppm; Diakow *et al.*, 1994). These data further suggest that the area west of the anomalous zone, along the western edge of the Capoose batholith, is a prime target for exploration.

SITE 2

Three of the seven apparent resistivity versus time plots for site 2 are illustrated in Figure 4b. The five northern soundings (CAP2-0 to CAP2-320) have approximately the same shape as the two southern soundings (CAP2-400 and CAP2-480) but have a finite conductor response superimposed on them (see CAP-801 and CAP2-240). Finite conductors have a cross-over time, the time when the voltage changes sign, that is related to the depth to the top of the conductor.

The character of the voltage versus time curves changes going from north (CAP2-0) to south (CAP2-480). For example, the cross-over time decreases going north to south, indicating the conductor axis (top of the conductor) is shallower at the southern end. Sounding CAP2-320 is unique (Figure 4c) as the voltage decays very slowly at times greater than 0.4 millisecond. Indeed, the conductor axis must be very shallow at this sounding because the cross-over time is between 42 and 69 microseconds. There is a possibility that the conductor may be a culvert, although none was obvious in the area. Further field investigation is warranted to define the nature of this conductor.

The conductor is not present on the two southern soundings. Indeed, a one-layer model fitted to the data indicates that the drift is around 10 to 12 metres thick and that the bedrock has a resistivity of 3500 Ω-m. An overburden thickness on the order of 10 metres is compatible with estimates from surficial and bedrock geology mapping. A similar drift thickness is obtained from the five northern soundings when the finite conductor response is ignored (Figure 7b). The depth to the finite conductor current axis is consistent with the drift thickness.

The bedrock resistivity beneath the northern soundings is about three times larger than beneath the southern values. This change may be related to the granite-volcanic contact. An inferred contact between granitic and volcanic rocks has been mapped in the vicinity of this EM survey site (Diakow *et al.*, 1994) but no bedrock exposures are present.

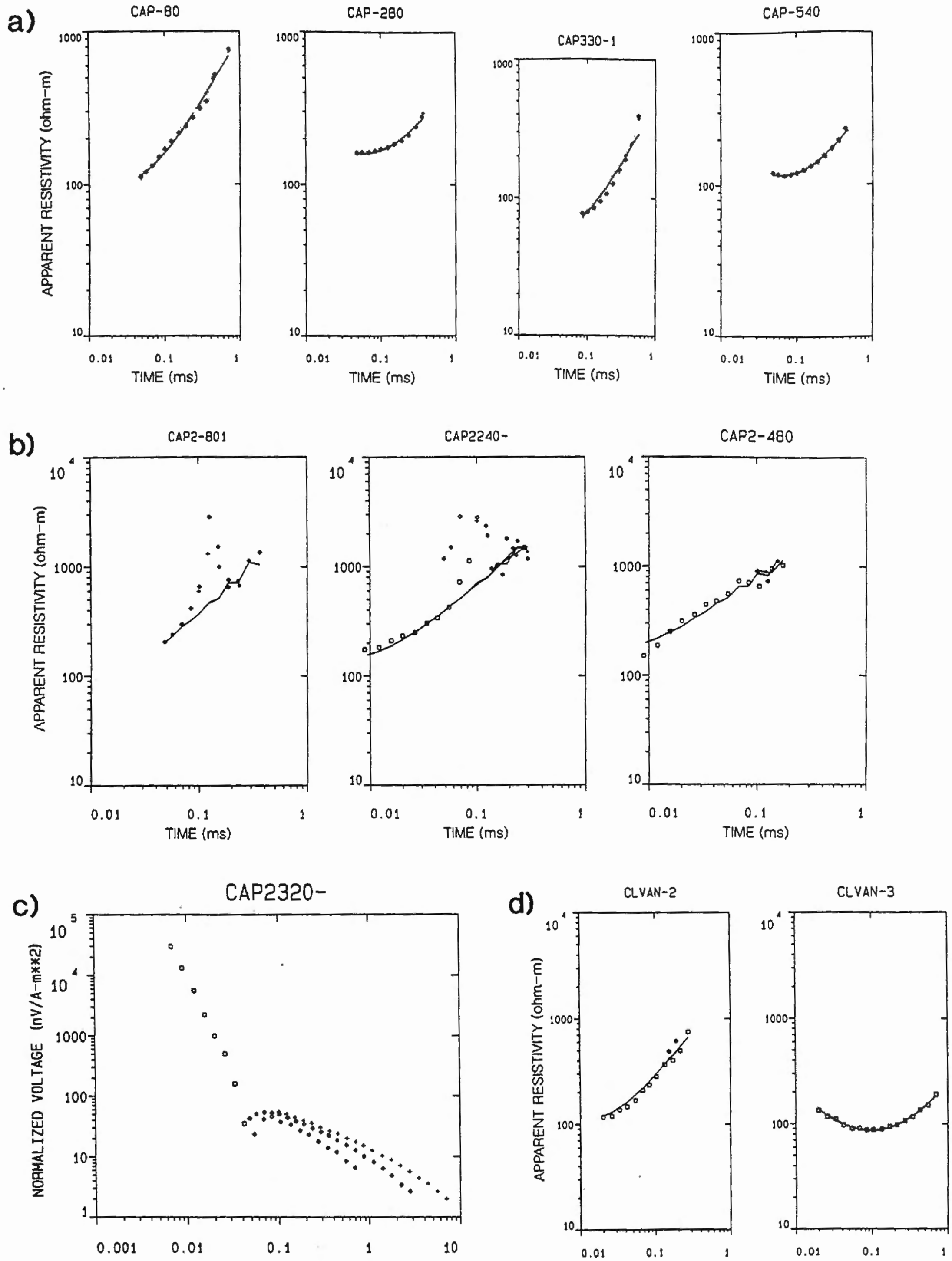

Figure 4. (a) Edited apparent resistivity versus time (log-log) plots for several soundings at site 1. (b) Edited apparent resistivity versus time (log-log) plots for several soundings at Site 2. (c) Example of cross-over time for one of the soundings at site 2 (the squares are positive voltages and the plusses are negative voltages). (d) Edited apparent resistivity versus time (log-log) plots for several soundings at site 3.

However, tills immediately south of this area contain abundant basaltic boulders whereas those to the north contain numerous granitic clasts. This supports the EM interpretation of a bedrock contact between the Capoose batholith and volcanic rocks at site 2. More fieldwork is needed to verify this and explain the nature of the conductor.

SITE 3

Two of the five apparent resistivity versus time plots for site 3 are illustrated in Figure 4d. The voltage (apparent resistivity) for CLVAN-1 is very noisy, but nevertheless fits a homogeneous half-space model that is very resistive. See Best (1995) for further details.

The other four soundings along the van Tine road are quite different and suggest the drift consists of two layers; one more resistive than the other (Figure 4d). The one-dimensional models for soundings CLVAN-3 to CLVAN-5, at the east end of the site 3 traverse (Figure 2), have the conductive layer overlying bedrock while CLVAN-2, near the west end of the traverse, has the resistive layer overlying bedrock (Best, 1995). The drift resistivities are greater than 60 Ω-m, and bedrock resistivities are several thousand ohm-metres. No drill holes or other information on the depth to bedrock are available, however, glaciolacustrine sediments have been mapped northwest of this region. These clay-rich sediments generally have a lower resistivity than sands and gravels. Regional stratigraphic studies indicate that ice damming prior to the last glaciation was common (Levson and Giles, 1995) and it is quite plausible that a glaciolacustrine unit may be present in the subsurface of this region. Tills in the area contain an unusually high proportion of clay, further suggesting that they may overlie a clay-rich unit. The till near site CLVAN-3 is especially clay rich, has an unusual yellow-brown colour (possibly indicating a high iron content) and is overlain by a spruce bog (see Site 93114, Levson *et al.*, 1994). The conductive layer at the surface at CLVAN-2 may therefore represent a small late-glacial clay unit.

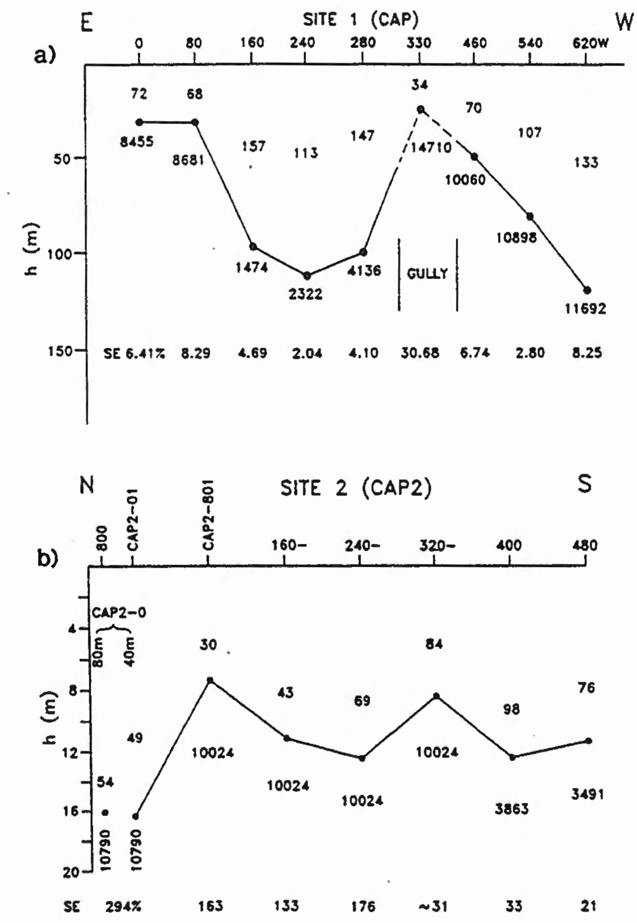

Figure 7. (a) Resistivity section based on the layered earth interpretation of the apparent resistivity plots for Site 1. (b) Resistivity section based on the layered earth interpretation of the apparent resistivity plots for Site 2. The values of standard error of fit from the inversion (labelled SE in the diagrams) are shown along the bottom of the 2 sections. The high SE values for CAP2-0 to CAP2-240 are caused by the finite conductor response superimposed on the layered earth responses.

SUMMARY AND OUTLOOK

The results of this survey indicate that useful electromagnetic data can be obtained in drift covered areas in the Nechako Plateau. The signal-to-noise (S/N) ratio is low at measurement times greater than 0.5 millisecond; thus little information is gleaned from the data at long times. Differences in bedrock resistivity of 2 or more can be resolved and, the drift thickness can easily be measured.

The contact between the granitic pluton and the volcanics at site 1 appears to be associated with thicker drift and more conductive bedrock, perhaps a result of (clay?) alteration or fracturing along the contact. One of the most pronounced multi-element till geochemical anomalies in the Fawnie Creek map area occurs directly east of EM survey site 1, adjacent to the western margin of the Capoose batholith. Here anomalous gold values occur in an east-trending zone that is about a kilometre wide and several kilometres long which parallels the local ice-flow direction. Till samples at several sites in this zone also contain anomalous arsenic, antimony and silver. The geochemical anomaly indicates an up-ice source in the vicinity of the EM survey, along the western margin of the batholith. Elsewhere, along the batholith margin, variably silicified country rock, sometimes associated with barite (see Malaput prospect *in* Diakow and Webster, 1994), suggests that near-surface hydrothermal activity locally accompanied the emplacement of the Capoose batholith. Further research, including drilling, is required to verify this concept.

A finite bedrock(?) conductor was located at site 2. The drift here is quite thin (less than 15 m) with resistivity values similar to those at site 1. The bedrock resistivity near the conductor differs from the resistivity further south, but it is not clear if it is associated with the granite-volcanic contact. Further field examination of the area is needed to verify that the conductor is real and not associated with a man-made object such as a culvert.

The resistivity character of the drift at Site 3, soundings CLVAN-2 to CLVAN-4, is different from the drift at the other two sites and is most likely due to the presence of glaciolacustrine sediments. Further investigations are needed to verify these results as there are no drill holes in this area.

Although the signal-to-noise ratio is low for times greater that 500 microseconds, that is 0.5 millisecond, the drift and bedrock material is resistive enough to permit eddy currents to diffuse into the ground rapidly. The depth of penetration at 500 microsecond can therefore be quite large. This is evident from depths to bedrock of more than 100 metres, obtained near the contact between the Capoose batholith and the volcanic country rock at site 1. This is quite different from conductive environments. For example, the signal-to-noise ratio at 7 milliseconds is very large for soundings near the dike by the Roberts Bank causeway in Delta (Best *et al.*, 1995). The shallow subsurface has saline water in the pores, producing a bulk resistivity of 1 to 1.5 ohm-metres. The underlying formation contains fresher water that produces a bulk resistivity of more than 100 ohm-metres. This contact can not be observed on the soundings if it is more than 70 metres deep. In other words, the eddy currents take more than 7 milliseconds to diffuse to this contact when it is deeper than 70 metres. The eddy current diffusion rate must be at least 12 times slower in the conductive sediments along the Fraser delta than in the glacial till in the Nechako region.

The central sounding configuration can generate a layered earth interpretation that is unique when the earth closely approximates horizontal layers of fixed resistivity. Significant topography, for example the gulley at site 1 can distort the one-dimensionality of the soundings because of the two or three dimensional topography. This is also true for bedrock topography. In such situations the depth and resistivity estimates for the layers will be incorrect. As a rule of thumb, the relief, either surface or bedrock, within one transmitter loop should be less than 25% of the length of one side of the loop. In other words if the loop sides have a length of 40 metres, the maximum relief should be less than 10 metres. Significant lateral variations in resistivity can also distort the soundings.

Where finite bedrock conductors are present, large-loop time-domain soundings are often difficult to interpret (*e.g.*, site 2). Consequently, a frequency-domain electromagnetic system such as the Apex MaxMin system is preferable over the large-loop systems. This is particularly true in this area as the drift does not appear to be that thick or conductive.

In conclusion, the results of the EM-47 survey in this region of the Interior Plateau are encouraging, in that the method successfully resolved till thickness, multiple Quaternary stratigraphic units, bedrock contacts, possible alteration zones as well as bedrock conductors. The potential contribution of electromagnetic techniques to regional geoscience programs is significant and we recommend and encourage its use.

ACKNOWLEDGMENTS

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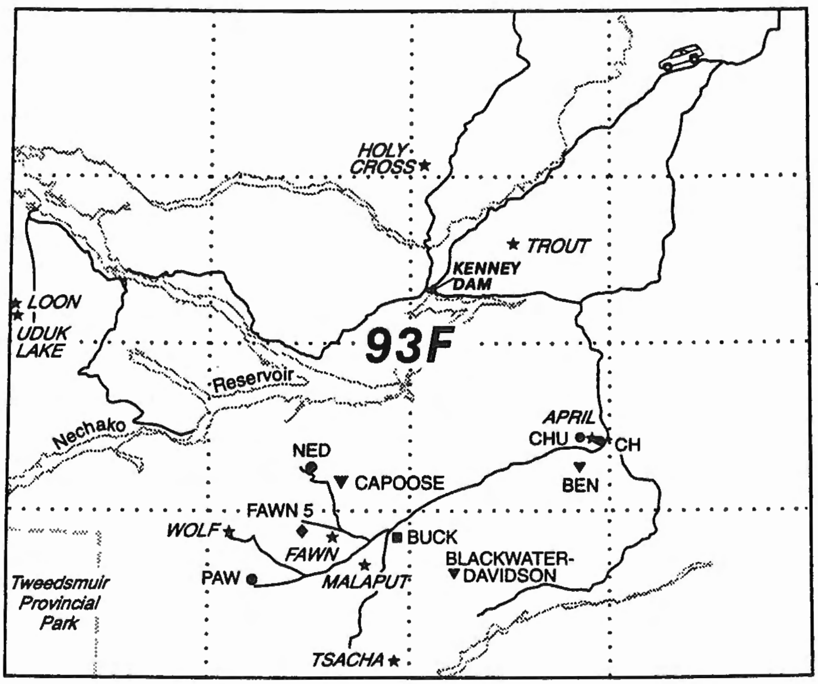
Mineral Deposits



Lane:
Southern Nechako Plateau

A REVIEW OF METALLIC MINERALIZATION IN THE INTERIOR PLATEAU, CENTRAL BRITISH COLUMBIA (PARTS OF 93B, C AND F)

By R.A. Lane and T.G. Schroeter
British Columbia Geological Survey

KEYWORDS: Economic geology, Interior Plateau, Ootsa Lake Group, Hazelton Group, Capoose batholith, epithermal, porphyry, porphyry-related, gold, silver, copper, molybdenum, zinc, lead.

INTRODUCTION

The mineral deposits component of the Interior Plateau project was conducted in parts of the Fraser and Nechako plateaus between 1992 and 1995. This report summarizes investigations of twenty mineral occurrences that were visited during the project. Field investigations of mineral occurrences, together with property-scale mapping, were conducted at seventeen occurrences located in the Nechako River map area (93F), two in the Anahim Lake map area (93C) and one in the Quesnel map area (93B; Figure 1). Although the project area has no producing mines, the operating Endako molybdenum mine and the recently decommissioned Equity Silver silver-gold-copper mine lie to the north, the closed Blackdome gold mine is located to the south, and the Gibraltar porphyry copper mine is in operation to the east. Also, the Huckleberry porphyry copper deposit is in the mine development stage (Figure 1).

Since its inception, this project has raised the mining industry's awareness of the Nechako Plateau as an area that is under explored. The potential of the region to host different styles of mineral deposits derives from its favourable geology, characterized mainly by Jurassic Hazelton Group and Eocene Ootsa Lake Group volcanic rocks, their coeval intrusions and locally intensive extensional faulting. However, much of the most prospective bedrock is concealed beneath the low, rolling, forested topography, as well as a veneer of glacial till, that is typical of the area.

Until recently only limited exploration had been conducted in the region as it was hampered by poor road access, a lack of significant bedrock exposure and an antiquated geoscience database. The release of data from surveys (*i.e.*, bedrock mapping: Diakow and Webster, 1994; lake sediment geochemistry: Cook and Jackaman, 1994; till geochemistry: Levson and Giles, 1994; and mineral occurrence studies: Schroeter and Lane, 1994), conducted in 1993 by the British Columbia Geological Survey Branch, resulted in a significant increase in staking and exploration in the southern Nechako River map area.

OBJECTIVES

A regional metallogenic synthesis of the Interior Plateau area was initiated by Schroeter and Lane in 1991 and continued under the auspices of the Interior Plateau project. The objectives were to:

- Characterize, classify and compare mineral deposits in the Interior Plateau.
- Promote exploration in the area by developing ore deposit models and exploration criteria.

METHODS

The mineral deposits component of the Interior Plateau project consisted of investigations of more than twenty metallic mineral occurrences. These investigations consisted of the following:

Literature research and compilation: mineral exploration assessment report files, petroleum geology assessment report files and government regional geology maps and reports were compiled for parts of NTS map sheets 93B, 93C and 93F. Lineaments and other structural features were interpreted from a Landsat image of part of NTS 93F and added to the compilation.

Regional geology framework: regional mapping of four 1:50 000-scale map sheets (NTS 93F/02, 03, 06 and 07), conducted by by the British Columbia Geological Survey Branch (Diakow *et al.*, 1997, this volume), provided a regional geologic framework for the area. Specific sections of Eocene stratigraphy were mapped at 1:10 000 scale on the Wolf and Holy Cross epithermal gold prospects.

Mineral occurrence investigations and exploration monitoring: this work consisted of preliminary and follow-up investigations of the styles of mineralization and alteration that characterize the metallic mineral occurrences in the Interior Plateau region. A summary of the occurrences studied is in Table 1. Each occurrence was briefly described based on examination of bedrock showings, trenches, diamond-drill core, regional geologic setting and discussions with company project geologists. Table 2 lists the analyses of grab samples from most of the prospects visited.

Deposit modeling, interpretation and future work: a schematic section depicting the spatial and possible genetic relationships between intrusions and mineralization discussed is shown in Figure 2. Lead isotope "fingerprinting" will be conducted on main phase sulphide-bearing mineralization from most of the prospects and may provide significant new information to aid exploration in the region. Uranium-lead zircon dating of felsic rocks at the Tsacha and Capoose prospects is in progress and will provide additional constraints on the age of mineralization.

EXPLORATION HISTORY

The earliest recorded exploration (1927) in the region resulted in the discovery of several large quartz-molybde-

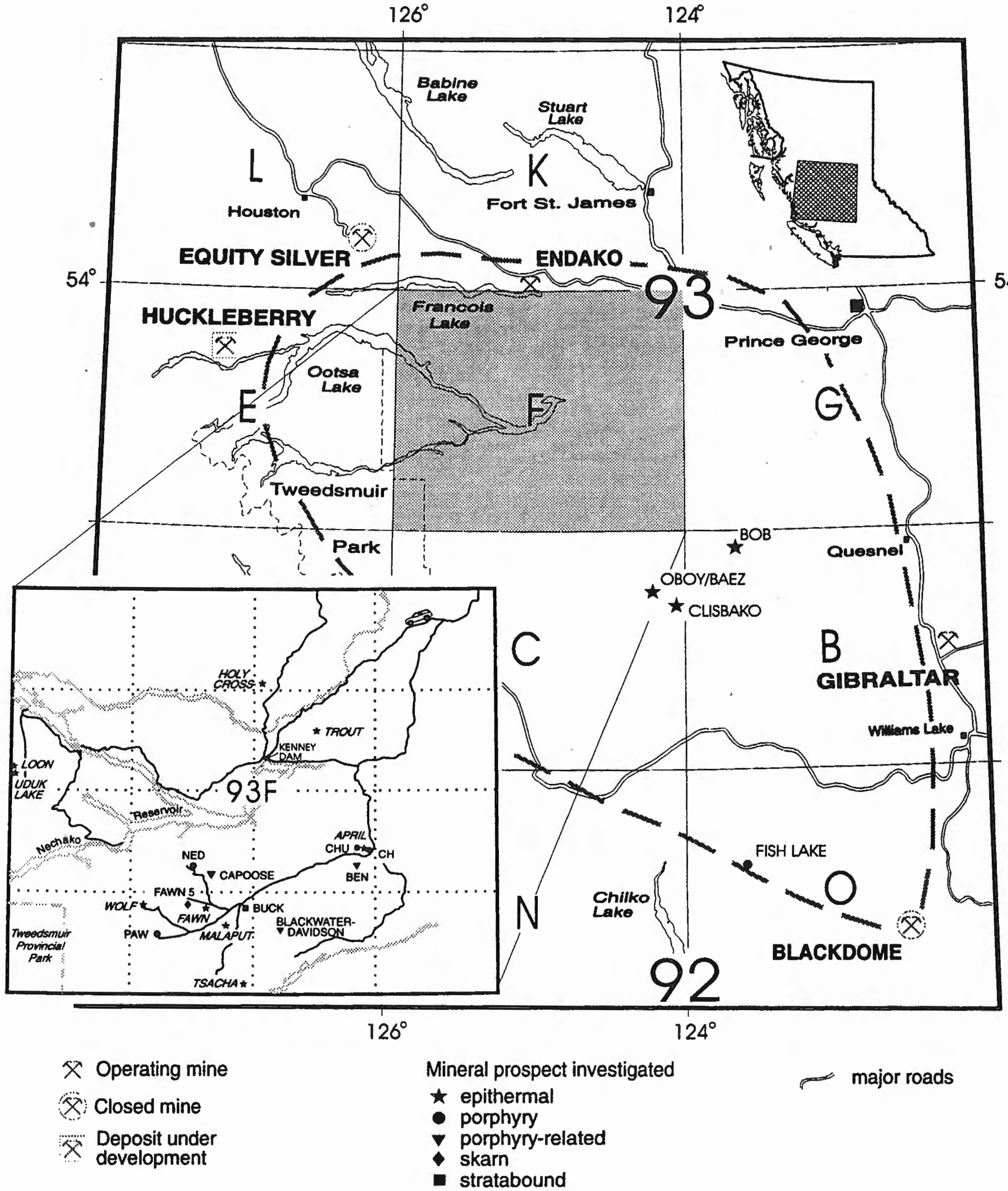


Figure 1. Location of mineralized prospects in central British Columbia investigated during this study.

TABLE 1
CHARACTERISTIC FEATURES OF MINERAL OCCURRENCES IN THE INTERIOR PLATEAU

Deposit Type Occurrence (Minfile)	Ag:Au	Metallic Minerals	Gangue Minerals	Style of Mineralization	Alteration	Age of Mineralization	Hostrock Group: lithologies
Epithermal Au-Ag							
Baez (Oboy - 093C 015)	4 to 100	py,aspy	K-fld,ser,qtz,calc,chl	f-gr. disseminations in and peripheral to veinlets and breccias	potassic, phyllic, silicic, argillic	Eocene	Ootsa Lake: rhyolitic flows, breccias
Bob (093B 054)	1 to 6	py,aspy,sb	qtz,K-fld,clay,chl,calc	disseminations in altered horizons	silicic, argillic, potassic, propylitic	Eocene	Skeena: sandstone, conglomerate, siltstone and argillite cut by qfp dikes
Clisbako (093C 016)	20 to 110	py,marc,aspy	qtz,chal	f-gr. whisps and disseminations in stockwork and breccia zones	silicic	Eocene	Ootsa Lake: rhyolite flows, tuffs, breccias; andesite flows and breccias
Holy Cross (093F 029)	4 to 10	py	qtz,ba	sparsely disseminated in intensely silicified zones	silicic, argillic, hematitic	Eocene	Ootsa Lake: rhyolite dome complexes
Loon (093F 061)	n/a	py	qtz,chal	disseminated, drusy infillings in stockwork and breccia zones	silicic	Eocene	Ootsa Lake: felsic and intermediate flows, tuffs and breccias
Trout (093F 044)	4 to 20	py,Au,el	qtz,ad	rythmically banded quartz-adularia veins and silica-flooded zones	silicic	Eocene	Kasalka(?): polymictic conglomerate and andesitic breccia
Uduk Lake (093F 057)	2 to 60	py	qtz,chal	f-gr. and c-gr. disseminations in stockwork and breccia zones	silicic, argillic	Eocene	Ootsa Lake: rhyolite flows, tuffs and breccias
Wolf (093F 045)	1 to 20	Au,Ag,el,py,cpy	qtz,calc,chal	diss. in banded and bladed veins; microscopic inclusions of Au in py	silicic, argillic	Eocene	Ootsa Lake: rhyolite and high-level intrusions
Yellow Moose (093F 058)	2 to 60	sb,aspy,py,marc,cnb,Au	qtz,chal	f-gr. disseminations and blebs in stockworks and breccias	silicic, argillic	Eocene	Ootsa Lake: rhyolite tuffs, breccia, sandstone
Tsacha (093F 055)	<1 to 50	py,cpy,agl,Au,gln,el,stef	qtz,calc,chal,amth,hem	f-gr. disseminations, colloform banded and bladed veins	silicic, argillic, phyllic	pre-Late Cretaceous	Hazelton: rhyolite flows, ash-flow tuffs
Fawn (093F 043)	7 to 13	py,aspy,pyg	qtz,chal,ba,dol,calc,ser	disseminated in silica flooded breccia and stockwork zones	silicic, argillic	Jurassic (?)	Hazelton: andesitic flows; limy ash, lapilli and block tuffs
Malaput (no Minfile)	n/a	py,sph,gln	qtz,ser,calc	weakly developed stockworks in broad alteration zone	silicic, phyllic	Jurassic (?)	Hazelton: felsic tuffs and/or flows
Au-Ag Base Metal							
April (093F 060)	1 to 400	sph,gln,py,po,aspy,cpy	qtz,chl,calc	c-gr. disseminations to semimassive, crudely banded veins/shears	phyllic, propylitic	Jurassic (?)	Hazelton: tuffaceous/limy siltstones
Ben (093F 059)	15 to 120	aspy,py,po,cpy,gln,sph,mo	qtz,bio	semimassive veins, layered to laminated or foliated	phyllic, potassic	Jurassic (?)	Hazelton: intermediate flows, tuffs
Blackwater-Davidson (093F 037)	15 to 120	sph,py,po,gln,aspy, cpy,tet,bou,marc	qtz,ser,bio	disseminated and fracture controlled and replacements	phyllic, potassic	Late Cretaceous (?)	Hazelton: felsic and intermediate flows and tuffs; siltstone and argillite
Buck-Xmas Cake (093F 050)	>150	sp,py,po,ga,cp	qtz,carb	massive to semimassive sulphide breccia	argillic	Late Cretaceous (?)	Hazelton: rhyolite flows, breccias
Buck-Rutt (093F 050)	>150	sph,py,po	qtz,ser,chl,clay	disseminated, laminated to layered, stratabound	argillic, phyllic, silicic	Late Cretaceous (?)	Hazelton: tuffaceous siltstones, argillites
Capoose (093F 040)	70	sph,gln,py,aspy,cpy, tet,po,pyg,el,Au	qtz,gnt,mus	disseminated, replacement and fracture controlled	phyllic, hornfels	Late Cretaceous	Hazelton: garnetiferous rhyolite sills, hornfels
Au-Cu (-Fe) Skarn							
Fawn 5 (093F 053)	~50	mag,po,py,cpy,aspy,gln	bio,chal,ep,dp,calc	massive to semimassive magnetite disseminated sulphides in metasomatized andesite tuffs	hornfels, calc-silicate metasomatism	Jurassic	Hazelton: andesitic flows, tuffs, fragmentals
Porphyry Mo-Cu							
CH, C (093F 004)	n/a	py,cpy,po,mo	qtz,K-fld,bio,mag	disseminated in veinlets and weakly developed stockworks	silicic, hornfels, potassic, propylitic, phyllic	Eocene (?)	Hazelton: andesite flows, siltstones crowded feldspar porphyry, granodiorite and diorite
Paw (093F 052)	n/a	py,mo,cpy		disseminated and fracture controlled	silicic	Jurassic	Capoose batholith: diorite to granodiorite
Chu (093F 001)	n/a	mo,py,po,cpy	qtz,bio	disseminated and fracture controlled	hornfels, potassic	Jurassic (?)	Hazelton: pyroclastic andesite and siltstone; granodiorite dikes related to the Capoose batholith (?)
Ned (093F 039)	n/a	mo,py,cpy	qtz	disseminated and fracture controlled	silicic	Late Cretaceous (?)	Late Cretaceous (?) quartz monzonite

TABLE 2
ROCK GEOCHEMISTRY OF SELECTED SAMPLES FROM MINERAL OCCURRENCES IN THE INTERIOR PLATEAU

MINERAL OCCURRENCE Sample No.	Au ppb	Ag ppm	Mo ppm	Cu ppm	Pb ppm	Zn ppm	As ppm	Sb ppm	Ba ppm	Fe %
HOLY CROSS										
94BLA-HC1-2	5	0.3	5	7	21	11	4.8	14	2200	
94BLA-HC1-TR4	42	4	6	305	41	10	6.2	12	4200	
94BLA-HC3-3	<2	0.3	<1	207	16	51	4.5	2.5	2500	
94BLA-HC5-1a	140	16.5	3	3704	25	124	10	15	960	
94BLA-HC6-2	<2	1.3	9	3	32	15	19	100	1700	
94BLA-HC6-6	2730	3.7	19	22	10	4	2.6	7.3	<50	
94BLA-HC7-1	<2	0.3	21	2	8	5	5.8	9.2	1700	
94BLA-HC7-TR7	5	0.6	4	16	61	48	31	23	3100	
94BLA-HC12-8	10	0.9	59	25	343	42	23	23	2200	
TOMMY										
LDI27-1A	2	0.2	<1	5	8	44	9	3	32	
LDI27-1B	461	12.1	1	14	17	27	16	5	25	
LDI27-1C	3740	2	<1	27	156	125	30	3	81	
LDI27-1C	2935	1.4	1	28	164	128	30	<2	82	
LDI27-1D	52	0.4	<1	9	13	34	17	3	87	
LDI27-11A	3342	34.8	<1	25	56	22	8	7	31	
LDI27-11B	2716	34	1	43	126	19	5	6	30	
LDI27-11C	660	26.3	<1	7	6	17	13	3	46	
LDI27-11D	976	11.2	1	9	10	15	30	2	87	
LDI27-11D	952	11.6	1	10	13	16	31	4	91	
LDI27-12	2449	41.8	<1	3	7	7	3	2	54	
MALAPUT										
IWE 8-1A	2	0.2	3	1	92	120	7	2	1326	
IWE 8-1B	6	0.1	<1	121	2	51	10	<2	24	
IWE 8-1C	1	0.3	2	1	90	55	2	4	89	
IWE 8-1	3	0.1	2	3	13	22	<2	3	426	
IWE 3I-5	1	0.1	1	9	6	16	6	4	130	
LDI 22-4	2	0.2	<1	4	<2	77	9	<2	22	
LDI 6-1A	1	0.2	7	107	15	41	<2	<2	60	
LDI 6-1B	1	0.3	9	119	<2	35	<2	2	47	
LDI 6-2	1	0.1	51	101	5	20	<2	<2	33	
LDI 8-5	1	0.1	1	10	3	9	2	5	54	
LDI 8-6	4	0.7	1	5	105	39	<2	5	76	
LDI 12-3	6	0.3	3	36	80	787	18	4	18	
LDI 26-4	20	1.1	<1	13	7	51	<2	3	259	
LDI 37-1	2	0.2	3	10	7	62	4	<2	87	
IWE 3-5	101	6	14	186	321	675	12730	79	14	
TGI 256	1	<0.1	1	4	13	3	<2	<2	11	
IWE 25-2	29	21.3	6	6202	12	294	<2	<2	186	
APRIL										
94BLA-A3	2030	2.9	15	1319	17	54600	22000	24	<50	
BEN										
94BLA-B3	2320	145.9	4	164	2320	379	1600	440	450	
BUCK										
94BLA-BK-1	130	721*	<1	1899	3.8*	12.1*	100	48	-	
TSACHA										
TS94-TO-1	0.93*	46.2	3	412	750	1208	9	16	28	
TS94-TO-2	3.99*	90.5*	3	9	10	18	2	2	163	
TROUT										
TS94-CT-1	2.33*	40.46*	2	11	7	64	5	2	15	
TS94-CT-3	173.45*	591.42*	3	66	18	80	12	4	160	
TS94-CT-7	8.40*	54.17*	2	17	6	36	78	4	20	

TABLE 2 *continued*

UDUK LAKE										
TS94-UL-2	240	2.2	29	5	9	5	336	11	107	
TS94-UL-3	11	0.1	12	6	9	41	244	3	49	
TS94-UL-5	55	9.8	3	10	7	6	80	7	51	
TS94-UL-8	58	3.1	5	6	10	8	93	7	165	
TS94-UL-15	220	2.9	5	2	18	8	224	3	56	
TS94-UL-16	41	0.1	8	2	15	1	85	2	57	
TS94-UL-4	8	0.5	12	28	46	20	10	2	57	
TS94-UL-17	75	2.2	93	4	15	7	100	5	93	
TS94-UL-19	320	3.7	82	7	14	7	410	7	155	
TS94-UL-20	650	8	80	9	14	1	868	26	81	
TS94-UL-23	38	0.7	10	34	27	33	19	2	19	
TS94-UL-25	97	70	27	5	6	1	40	2	212	
94BLA-UL-1	290	8.1	134	9	73	173	847	17	56	
WOLF										
WO-BL93-4	273	0.7	<1	<1	7	4	3	<2	7	
WO-BL93-18	14637	513.5	18	11	12	24	16	<2	8	
WO-BL93-21	255	44.2	1157	5	22	82	780	29	18	
WO-BL93-42	1178	16.9	5	16	254	19	17	48	14	
WO-BL93-47	355	0.6	12	9	15	24	15	2	24	
BLACKWATER-DAVIDSON										
BD-BL93-1	150	0.4	1	86	11	7366	28	6	124	
BD-BL93-2	313	16.5	6	155	35180	3704	<2	18	28	
BD-BL93-10	8	0.8	<1	212	42	62	15	<2	68	
BD-BL93-10B	4	<0.1	1	10	7	7	8	<2	14	
FAWN 5										
FA-BL93-15	411	19.2	19	5972	7	275	37	4	6	
FA-BL93-18	5	0.3	<1	259	4	118	18	<2	116	
FA-BL93-20	3	0.1	<1	2	22	30	10	4	28	44.00

Analysis by instrumental neutron activation or inductively coupled plasma (values are in ppm unless otherwise shown), except where denoted by an asterix(*) which indicates analysis by fire assay with AA or gravimetric finish. For the latter, values are in g/t for gold and silver, and in percent for base metals.

num veins on the Stella property, 10 kilometres southwest of Endako village, 160 kilometres west of Prince George. In 1965, after a lengthy exploration interval, the Endako molybdenum mine opened and continues to operate today. Ore reserves (proven and probable) as of December 31, 1995, were 104 843 000 tonnes averaging 0.077% Mo (Placer Dome Inc., 1995 Annual Report).

The first published regional mapping in the area was conducted by Dr. H.W. Tipper with the Geological Survey of Canada between 1949 and 1952 (Tipper, 1963).

During the 1960s, (in the search for porphyry copper±molybdenum targets) several major mining companies conducted regional reconnaissance stream-sediment sampling programs and/or airborne magnetic surveys over the northern parts of the region. The existing regional geological base map (Tipper, 1963) showed the distribution of intrusions which became the early targets for porphyry exploration programs. By 1969, Rio Tinto Canadian Exploration Limited (Riocanex) and American Smelting and Refining Company (ASARCO) had identified soil geochemical (Cu-Pb-Zn-Mo) and induced polarization anomalies in the area of Chutanli Lake (now CH and Chu occurrences). Riocanex also outlined multi-element geochemical anomalies towards the north end of the Fawnie Range (Capoose prospect). Between 1970 and 1972 Riocanex completed a regional lake-sediment sampling program and identified several multi-element anomalies that were not followed up until 1982. Also, in the early 1970s, Noranda Exploration Company Limited conducted regional stream-sediment surveys and several follow-up induced polarization surveys on claims in the Tetachuck Lake and Chelaslie Arm areas, Nechako Reservoir (iIn the search for porphyry targets). In addition, from the late 1950s to the mid 1980s, several major companies evaluated the region for its hydrocarbon potential (Hickson, (1990). Regional reconnaissance programs for uranium were undertaken from 1970 to the early 1980s.

Exploration waned between 1974 and 1979; only a few programs (*e.g.* by Cities Services Minerals Corporation, Granges Exploration (Canada) Ab. and ASARCO) were undertaken. Access to the area was greatly improved by the completion of the Kluskus-Ootsa forestry road in 1977. In the late 1970s Granges carried out regional geochemical, geological and geophysical surveys, culminating with stak-

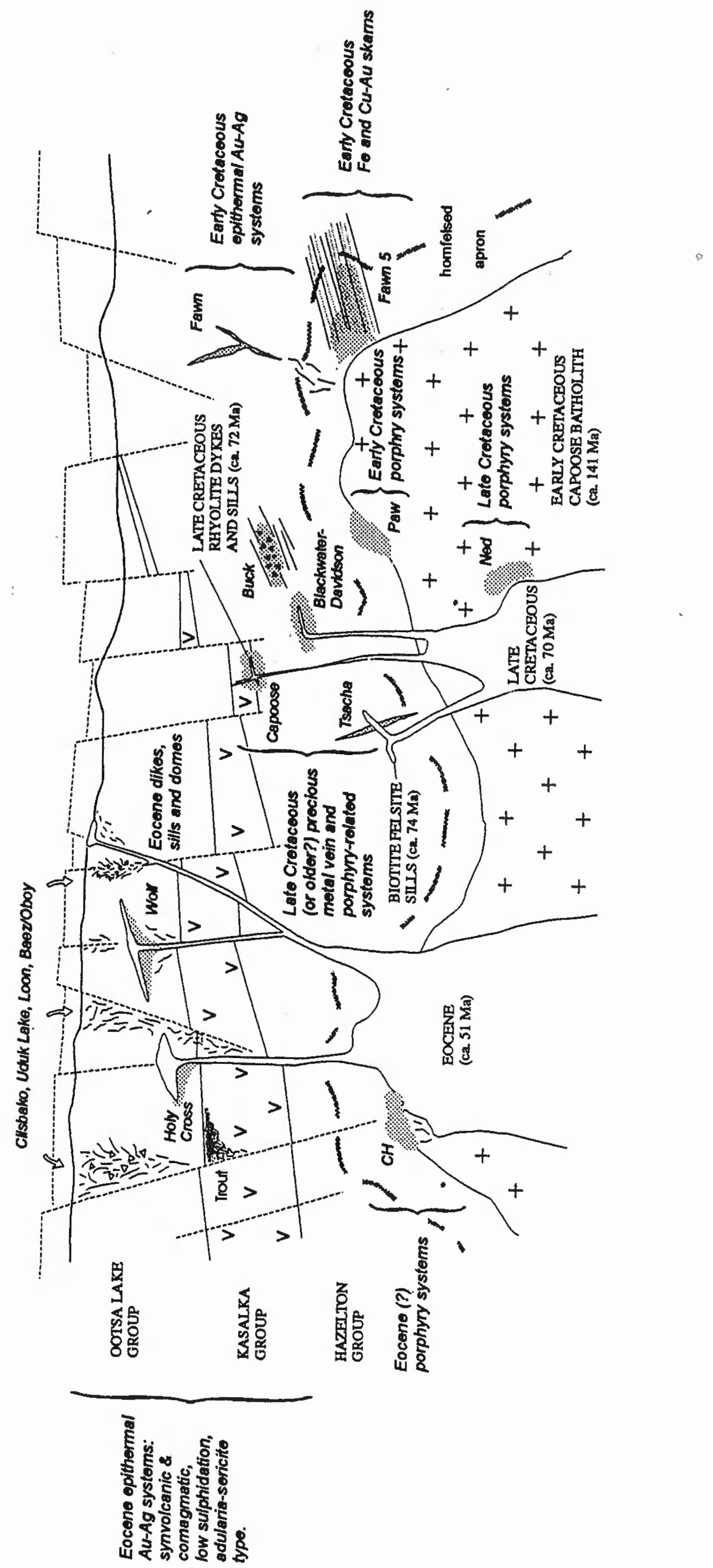


Figure 2. Schematic section showing the location of mineral occurrences and spatially and/or genetically related intrusions. Refer to Table 1 for mineral occurrence characteristics.

ing of the Capoose and Pem (Blackwater-Davidson) polymetallic prospects, and the Ned porphyry copper-molybdenum prospect, in the Fawnie Range.

By 1979 Granges had identified a significant multi-element Ag-Pb-Zn-Au geochemical anomaly on the Capoose property. Subsequent drilling programs over the next four years (1979-1983) resulted in the assessment of a drill-indicated resource of 28 million tonnes grading 37.7 g/t Ag and 0.51 g/t Au (Granges Inc., 1994 Annual Report). In the southern Interior Plateau, Barrier Reef Resources Ltd. discovered the Blackdome gold-silver epithermal bonanza vein deposit in 1979. It was brought into production in 1986 and produced approximately 6955 kilograms (223 600 oz) of gold and 23 640 kilograms (760 000 oz) of silver from 306 000 tonnes of ore milled (Schroeter and Lane, 1991). The mine closed in 1991; however, exploration for additional reserves has resumed.

During the late 1970s Equity Mining Corporation, bought out by Placer Development Ltd. in 1978, outlined a mineable reserve at the Equity Silver polymetallic deposit southeast of Houston. Between 1980 and 1994, the mine produced approximately 80 900 tonnes (178.2 million lb) of copper, 2 075 000 kilograms (66.7 million oz) of silver and 15 903 kilograms (511 296 oz) of gold from more than 32 million tonnes of ore mined at an average grade of 0.34% Cu , 101 g/t Ag and 1.01 g/t Au (Giancola, 1994).

Between 1979 and 1983 Canadian Hunter Exploration Limited, and others, conducted oil and gas exploration programs in the region west of Quesnel. Several deep (3000 m) holes were drilled, primarily on seismic targets, to test for favourable structures.

The very high price of molybdenum at the end of the 1970s was a factor in a few porphyry programs (*e.g.*, Chutanli Lake and Tetachuk Lake areas) in 1980; however, a dramatic fall in the molybdenum price in the early 1980s resulted in a 3-year mine shutdown at Endako, from 1983 to 1985 inclusive, at Endako and essentially terminated exploration for porphyry molybdenum targets, until recently. At the beginning of the 1980s the focus of exploration turned to gold. Several regional stream-sediment surveys were conducted within the project area early in the decade; however, the only significant follow-up property work consisted of diamond drilling programs carried out between 1980 and 1983 on the Capoose polymetallic deposit. Companies with regional and/or property programs in the 1980s included E & B Explorations, Amax Exploration, Dome Exploration, Hudson Bay Exploration and Development, Selco, Long Lac Minerals, JMT Services, Riocanex, BP Minerals, Placer Dome, Abo Oil, Colassal, Cominco, Newmont, Kerr Addison, Mingold, Imperial Metals and Noranda Exploration. The main exploration target was epithermal gold-silver deposits with either bonanza-vein or bulk-mineable potential. The discovery of several such deposits, particularly in Nevada, and the refinement of the epithermal model, provided the impetus for similar exploration in British Columbia. Geochemical programs identified anomalies with gold±mercury±arsenic±antimony±silver, particularly associated with silicification in felsic volcanic rocks of the Eocene Ootsa Lake Group. The most significant prospect, discovered as a result of these regional surveys, is the Wolf epithermal gold-silver deposit. In 1983 Riocanex discovered epithermal mineralization by prospecting around a regional lake-sediment silver-zinc-arsenic-molybdenum anomaly. Riocanex and BP Canada Ltd. also identified several multi-element geochemical anomalies in the Capoose Lake area, similar to those associated with the Capoose prospect.

Follow-up drilling on the Trout, Wolf, Bob, Oboy, Uduk Lake and Rhub-Barb properties in the late 1980s targeted epithermal gold mineralization. An M.Sc. thesis completed at the University of British Columbia by Andrew (1988) describes the Capoose and Wolf deposits in detail.

By the beginning of the 1990s logging activity had provided (and continues to provide) road access into the southern part of the region (to approximately Kilometre 160 along the Kluskus-Ootsa forest service road), south of Vanderhoof. The area south of the West Road (Blackwater) River is accessible from logging roads that extend west from Quesnel and northwest from Williams Lake.

In 1990, Eighty-Eight Resources Ltd. discovered abundant epithermal quartz float in glacial outwash deposits (locally 10 m thick), to the east-southeast of the Oboy epithermal prospect, in an area with no previously recorded staking. This potentially significant new gold-silver discovery, Clisbako, soon caught the attention of a few major companies. At the same time, with the end of operations at the Equity Silver mine to the northwest scheduled for the early 1990s, Equity Silver Mines Ltd. tested the previously explored Chu/CH porphyry prospect, this time for its gold content. In 1991-1992, Placer Dome Inc. tested the CH property for its copper-gold content. In 1991 Metall Mining Corporation optioned the Clisbako property and conducted an airborne geophysical survey. Using the geophysical data together with available satellite imagery, Metall identified what it believed to be a caldera. Subsequent relatively shallow drilling (*e.g.*, 100 m) over the next two years located several zones of epithermal mineralization; however, they were only weakly anomalous and the option was terminated.

To the north of the West Road River, drilling on the Wolf epithermal prospect by Metall in 1992 demonstrated that the majority of silicified 'lenses' at the Ridge and Pond zones are part of an extensive, gently west-dipping body (2-30 m thick) of silicified hydrothermal breccia with banded and bladed quartz veins containing gold (*i.e.*, bulk mineable potential).

Biogeochemical surveys, principally bark sampling of lodgepole pine, conducted by Metall in 1992 at the Clisbako and Wolf projects, gave encouraging results; other such surveys carried out by the Geological Survey of Canada (Dunn, 1997; this volume) corroborate the usefulness of these surveys in specific areas. Metall also experimented with an induced polarization survey on both properties, apparently with good success.

In 1992, Cogema Resources Inc. carried out reconnaissance mapping (including 1:50 000 scale) in the Interior Plateau region and identified several gold targets. Western Keltic Mines Inc. acquired the Fawn (Gran) and Buck properties. Homestake Canada Inc. explored the Uduk

Lake property in the northwest. During 1992-1993, Granges Inc. drilled its Blackwater-Davidson (Pem) property; results suggest a similar style to the Capoose prospect.

Between 1992 and 1993 Fox Geological Consultants Ltd. conducted regional stream-sediment sampling programs, on behalf of Phelps Dodge Corporation of Canada Ltd., primarily in the area west of Quesnel and northwest of Williams Lake, and staked several claims.

In 1993-1994 Cogema drilled several targets. It closed its office in Vancouver in January, 1995 and its holdings in the Interior Plateau region were subsequently acquired by Phelps Dodge. Regional mapping (1:50 000 scale) by the British Columbia Geological Survey Branch in 1993 (Diakow and Webster, 1994) identified potentially significant gold mineralization at the Tommy showing which was later acquired by Teck Corporation as part of the Tsacha property. Results of regional lake sediment (average density of 1 site per 7.7 km^2) and till geochemical surveys, carried out by the Geological Survey Branch (Cook and Jackaman, 1994; Levson and Giles, 1994), were released in June 1994. Several anomalies were identified which led to a heavy staking in the area. It is estimated that over 700 units were staked over a two month period by eleven companies and individuals. In addition, results of the Geological Survey of Canada airborne radiometric and magnetic survey over much of the area were released in early 1994 (Teskey *et al.*, 1997; this volume). Exploration reached its peak during 1994 with several reconnaissance and drilling programs, all targeted on precious metals.

Table 3 lists the exploration methods that led to the discovery of mineral occurrences in the study area.

REGIONAL GEOLOGIC SETTING

The Nechako and Fraser plateaus encompass an area that extends southward from the Skeena Arch and westward from the structural contact of Stikine Terrane with the Cache Creek Terrane. They are bounded to the west and south by the Coast Plutonic Complex. The region is underlain by rocks of the Stikine Terrane comprised of remnants of superposed island arcs and associated marine sequences that are assigned to the Lower Permian Asitka, the Upper Triassic Stuhini and the Lower and Middle Jurassic Hazelton groups.

During Middle Jurassic (Bajocian) time, terrane accretion caused structural onlap of the Cache Creek Terrane onto Stikinia and led to formation of the Bowser Basin. This event also coincided with the abrupt end of widespread volcanism associated with the development of the Hazelton arc. In Callovian time, uplift of the Skeena Arch separated the Bowser Basin in the north from its counterpart, the Nechako Basin in the south (Tipper and Richards, 1976). Initial deposits in these basins consisted primarily of shale, indicative of starved basin conditions. Succeeding chert-dominated coarse clastic deposits mark a marine regression and fluvial-deltaic sedimentation that apparently ended locally in Kimmeridgian time.

During Early Cretaceous time, shallow-marine sediments of the Skeena Group were deposited. Upper Cretaceous calcalkaline volcanic rocks, represented in central Stikinia by the Kasalka Group, stratigraphically overlie the Skeena Group and mark the construction of a continental margin arc. This volcanism remained active until latest Late Cretaceous time.

Robust continental arc magmatism was re-established during Middle and Late Eocene time with eruption of the Ootsa Lake and Endako groups. The Miocene and Pliocene Chilcotin Group is stratigraphically above the Endako Group. It forms a broad lava plateau, covering much of south-central British Columbia, dominated by alkali olivine basalt.

LITHOSTRATIGRAPHY

Recent bedrock geological mapping has focused on the southern half of the Nechako River map area (NTS 93F), and much of the following discussion applies specifically to the geology and mineral occurrences in this region. However, several mineral occurrences (*i.e.*, Eocene epithermal gold-silver deposits that are similar to Eocene occurrences studied in the Nechako River map area) were investigated farther to the south (NTS 93C) and brief descriptions of the rocks that host those occurrences are included here.

The Fawnie and Nechako ranges in the southern Nechako River map area are tectonically uplifted blocks in which Mesozoic rock units predominate. They include mainly volcanic and sedimentary strata that broadly correlate with parts of the Stuhini, Hazelton, Bowser Lake, Skeena and Kasalka groups (*see* Table 1 in Diakow *et al.*, 1997, this volume). Stratigraphy in the southern Nechako River map area comprises rare Upper Triassic marine sedimentary rocks at the base, succeeded by two sequences of interlayered volcanic and volcaniclastic sedimentary rocks containing fossils that range in age from early Toarcian to early Bajocian. Early Jurassic volcanism (Toarcian to Aalenian?) is exclusively rhyolitic in composition; it contrasts with a younger (Bajocian), dominantly basaltic event. Both sequences record island arc volcanism and associated intra-arc clastic sedimentation. Early Callovian marine siltstone and shale are sporadically exposed, and contain chert-bearing conglomerate interbeds that become more prevalent eastward from the Fawnie Range towards the Nechako Range. These deposits are interpreted to record initial transport of chert-rich detritus shed into the Nechako basin from highstanding Cache Creek Terrane to the east. Widely separated exposures of andesitic and dacitic volcanic rocks in the study area yield radiometric dates suggestive of eruptive episodes during Late Jurassic (*ca.* 152 Ma), Jura-Cretaceous (*ca.* 144 Ma) and Late Cretaceous time (*ca.* 65 to 70 Ma). With the exception of the youngest event, which may represent waning Kasalka Group volcanism, contemporaneous magmatism corresponding with the older events is sporadically preserved in central Stikinia, recorded locally by the Netalzul volcanics of the Bowser Lake Group, and the Francois Lake intrusions, respectively.

Strata of Cenozoic age in the study area include the Ootsa Lake, Endako and Chilcotin groups. During Early Eocene time the Ootsa Lake Group, characterized by

TABLE 3
DISCOVERY METHODS FOR SELECTED PROSPECTS IN THE INTERIOR PLATEAU PROJECT AREA

Property	Deposit Type	Discovered By:	Year	Discovery Method	Current Owner
April	Mesothermal vein?	Granges Expl. Ab.	1982	Regional geochemical stream sediment sampling: Zn-Ag anomalies followed by prospecting and grid-based soil sampling	Placer Dome
Baez	Epithermal Au	Phelps Dodge	1992	Reconnaissance stream sediment and soil sampling, rock sampling, geophysics, diamond drilling	Phelps Dodge
Ben	Mesothermal vein	BHP-Utah		Reconnaissance exploration for volcanogenic massive sulphide mineralization in Hazelton Group rocks	BHP - Utah
Blackwater-Davidson (Pem)	Porphyry-related Au-Ag	Granges Expl. Ab.	1973	Reconnaissance silt sampling: Pb-Zn-Ag stream sediment anomalies led to subsequent soil sampling & staking of the Pem claim	Granges
Buck (Range)	Mesothermal vein?	BP Minerals Ltd.	1981	Reconnaissance geochemical sampling and prospecting outlined several base metal - silver anomalies; trenching and rock sampling followed	Western Keltic Mines
Capoose	Porphyry-related Ag-Au	Rio Tinto Canadian Expl. Ltd.	<1969	Reconnaissance stream and lake sediment sampling; follow-up prospecting, soil and rock sampling, trenching and diamond drilling	Granges
CH (C)	Porphyry Cu-Au	Rio Tinto Canadian Expl. Ltd.	<1969	Reconnaissance lake sediment sampling (and interpretation of federal government regional aeromagnetic survey); follow-up I.P. and magnetometer surveys in conjunction with bedrock mapping over favourable geology of Jurassic Hazelton Group intruded by Chutanli Lake monzonitic stocks	Placer Dome
Chu	Porphyry Cu	ASARCO Inc.	1969	Reconnaissance stream sediment anomalies led to the discovery of copper and molybdenum mineralization in outcrop	Orvana
Clisbako	Epithermal Au	Eighty-Eight Res.	1990	Prospecting and rock sampling; trenching and diamond drilling; biogeochemistry	Eighty-Eight
Fawn (Gran)	Epithermal Au-Ag	BP Minerals Ltd.	1982	Reconnaissance geochemical sampling and prospecting in an area of favourable garnet alteration, and Pb lake sediment anomaly, outlined a broad base metal-silver anomaly; trenching, geophysics and diamond drilling confirmed orientation and width	Western Keltic Mines
Fawn 5	Skarn Fe, Skarn Cu-Au	BP Minerals Ltd. B.C. Geological Survey	1983 1993	Reconnaissance mapping and sampling on the margin of the Capoose batholith	Western Keltic Mines Ltd.
Holy Cross	Epithermal Au	Noranda	1987	Prospecting and rock chip sampling of silica-flooded rhyolite followed by trenching	Kennecott
Loon	Epithermal Au	Mingold Resources Inc.	1988	Reconnaissance exploration; prospecting; traced mineralized float boulders up- ice to their source	Hudson Bay
Ned	Porphyry Mo-Cu	Granges Expl. Ab.	1975	Reconnaissance stream and lake sediment sampling; follow-up soil sampling outlined an area of anomalous Mo-Cu	none
Oboy	Epithermal Au	Rio Algom Exploration Inc.	1985	Reconnaissance soil and stream sediment Ag-As anomalies	Phelps Dodge
Paw	Porphyry Mo-Cu	Perry Grunenberg	1993	Prospecting new logging roads	Perry Grunenberg
Tsacha (Tommy)	Epithermal Au	B.C. Geological Survey	1993	Regional mapping crew discovered and sampled auriferous epithermal quartz vein and stockwork mineralization	Teck
Trout	Epithermal Au	Kerr Addison Mines Ltd.	1984	Reconnaissance exploration; prospecting, mapping & sampling	Phelps Dodge
Uduk Lake	Epithermal Au	Amax Exploration	1980	Reconnaissance mapping; soil and rock geochemistry, geophysics and trenching	Pacific Comox / Pioneer Metals
Wolf	Epithermal Au	Rio Algom Expl. Inc.	1983	Anomalous silver lake-sediment anomaly followed by soil and rock sampling, biogeochemistry, geophysics, trenching and diamond drilling.	Lucero
Yellow Moose	Epithermal Au	Newmont Expl. of Canada Ltd.	1987	Structural interpretation of Landsat image data followed by reconnaissance prospecting; traced stibnite-bearing float up-ice to its bedrock source	Phelps Dodge

subaerial high-potassium, calcalkaline rhyolitic and less voluminous andesitic rocks, formed an extensive volcanic province in south and central British Columbia. The Endako Group is also a sequence of high-potassium andesitic flows that have compositional continuity with volcanic rocks of the Ootsa Lake Group. Their source is believed to be volcanic centres that lay to the north of the uplifted region, as they thin dramatically southward, overlying progressively older rocks along the northern flank of the ranges. During the Neogene, alkaline shield volcanoes erupted extensive sheets of basaltic flows assigned to the Chilcotin Group.

Three main plutonic suites are recognized cutting layered rocks in the study area. They include Jura-Cretaceous quartz monzonite of the Capoose batholith, Late Cretaceous felsic sills and dikes, and Eocene granodiorite and dioritic stocks.

DEPOSIT DESCRIPTIONS AND CLASSIFICATION

Many of the following mineral prospects have previously been discussed (Diakow and Webster, 1994; Schroeter and Lane, 1992, 1994; Lane and Schroeter, 1995). Prospects are grouped, firstly, by deposit type and, secondly, by assumed age of mineralization. In most cases the age of mineralization is uncertain and an interpreted age, based on field relationships, is reported. Prospect locations are shown on Figure 1 and the information in the text is summarized in Table 1.

EPITHERMAL GOLD OCCURRENCES

Epithermal precious metal mineralization has been documented in many localities throughout the Interior Plateau. Of the twelve epithermal occurrences studied and summarized in this report, nine (Bob, Clisbako, Holy Cross, Loon, Oboy, Trout, Uduk Lake, Wolf and Yellow Moose) occur in Eocene (or younger) strata and three (Fawn, Malaput and Tsacha) are hosted by Lower or Middle Jurassic volcanic rocks. Seven of the Eocene occurrences are hosted by felsic volcanic rocks assigned to the Eocene Ootsa Lake Group, one is in polymictic conglomerate and andesitic breccia, found locally at the base of the Ootsa Lake Group or Upper Cretaceous Kasalka Group, and one is hosted by Lower Cretaceous Skeena Group clastic rocks. The three older deposits are hosted by intermediate to felsic volcanic rocks of the Hazelton Group. A lack of geochronology data for a large majority of the deposits hinders a more exact interpretation of their ages.

Hostrocks for the Eocene prospects generally consist of quartz-phyric flow-banded rhyolite and associated fragmental rocks. Spatially and genetically related hypabyssal intrusions crop out at the Wolf occurrence. Structures, both regional and local, are commonly subvertical and northerly trending, although they vary in orientation from northwest to northeast and are probably related to east-west Eocene extension (Diakow and Webster, 1994). Veins and breccia zones typically have northerly trends. In areas of limited exposure, coincident geophysical (I.P., magnetic and EM) and multi-element geochemical (soil and till) anomalies also commonly have northerly trending patterns.

Mineralization is predominantly structurally controlled and is characterized by broad zones of generally weak to moderate argillic alteration within which quartz and/or chalcedony (±adularia) comprise intensely silicified zones, banded veins, stockworks and breccias. Illite and montmorillonite comprise the clay mineralogy at one prospect (Clisbako) and are indicative of low-temperature epithermal systems. Other common gangue minerals include barite, potassium feldspar, sericite, calcite and chlorite.

The epithermal mineral occurrences are typically of the sulphide-poor, adularia-sericite type. Pyrite is the most common sulphide, but is not always present, and locally ranges up to several volume percent. Locally it is accompanied by trace amounts of marcasite, arsenopyrite, stibnite and/or cinnabar. Native gold, electrum and argentite have been identified at several of the prospects.

Hostrocks for suspected Early Cretaceous epithermal precious metal occurrences are Hazelton Group andesitic flows and pyroclastic rocks. Two of the three occurrences are within the thermal aureole of the *circa* 148 Ma Capoose batholith. Mineralization at the Fawn and Malaput prospects is confined to east-trending siliceous and/or sericite and clay-altered zones that contain chalcedonic quartz and traces of pyrite±arsenopyrite±sphalerite±galena±pyrargyrite. The Tsacha prospect consists of northerly trending auriferous, banded quartz-calcite veins that are cut by Late Cretaceous felsite sills.

Prospects discovered to date have both bulk-mineable and bonanza-vein potential.

EOCENE EPITHERMAL GOLD-SILVER OCCURRENCES

Uduk Lake (MINFILE 93F 057) - 93F/12W

The Uduk Lake epithermal gold-silver prospect is located approximately 70 kilometres south-southwest of Burns Lake. The Duk claims cover a broad (2 km wide) area of hydrothermally altered rhyolitic to dacitic rocks of the Ootsa Lake Group. Outcrop on the property is sparse, however, bedrock is commonly within 1 or 2 metres of the surface. A zone of clay and silica-altered rhyolite, in angular float and outcrop, measuring about 600 by 200 metres, occurs in the southwestern part of the property.

Several junior companies explored the ground during the middle and late 1980s. A few modest diamond drilling programs tested silica stockwork zones with gold values in the range of 0.02 to 1.45 g/t (Allen and MacQuarrie, 1985). Soil and rock geochemical surveys, carried out in 1993, outlined six gold-silver-arsenic anomalies (Dunn, 1993) that were trenched in 1994. The trenches exposed moderately to intensely clay-altered rhyolite flows and tuffs. Weak silicification is accompanied by a quartz-chalcedony±sulphide stockwork that locally grades into a more sulphide-rich, black-matrix breccia containing angular rhyolite clasts that are rimmed with thin layers of chalcedony. Pyrite is the only sulphide mineral observed and occurs mainly in vein, stockwork and breccia zones and less commonly as weak disseminations in altered rhyolite. It is present in trace amounts ranging up to 5% locally. Five of the six trenches sampled were anomalous in gold. Results included a 6-metre section grading 1.4 g/t Au and an entire 42-metre trench averaging 0.41 g/t Au. Grab samples typically grade over 1 g/t Au and assays as high as 5.7 g/t Au have been recorded (Tupper and Dunn, 1994).

Loon (MINFILE 93F 061) - 93F/12W

The Loon epithermal gold prospect is located immediately north of the Uduk Lake prospect. It was discovered by prospecting which located mineralized boulders that were traced up-ice to their source. Subsequent soil sampling outlined a strong silver anomaly oriented at 020º with a strike length of more than 300 metres. Trenching of the anomaly yielded results grading up to 0.2 g/t Au and 4.5 g/t Ag (Taylor, 1990). Coincident induced polarization and resistivity anomalies were drill tested in 1994; intervals of chalcedonic breccia in variably clay and silica-altered Ootsa Lake volcanics were intersected, but were barren or only weakly anomalous (Gal, 1994).

The hostrocks and mineralization are similar to the Uduk Lake property (*i.e.*, pyritic quartz veins, stockworks and chalcedonic breccia zones within broader zones of intensely clay-altered, quartz-phyric and flow-banded rhyolite to dacite flows, tuffs and breccias of the Ootsa Lake Group). Pyrite occurs as very fine to fine-grained rims on clasts and in veinlets within chalcedonic breccias, and as fine to medium-grained subhedral crystals in vuggy cavities.

Clisbako (MINFILE 93C 016) - 93C/09E

The Clisbako epithermal gold-silver prospect has been previously described by Schroeter and Lane (1992). Its work history has been documented in assessment reports by Dawson (1991) and Heberlein (1992a, b). The area was recently mapped in some detail by the Geological Survey of Canada (Metcalfe and Hickson, 1994 and 1995).

Epithermal mineralization is hosted by several north to northeast-trending structures that cut a sequence of Eocene volcanic rocks. They consist mainly of rhyolite flows and breccias, amygdaloidal andesite flows, and rhyolitic and dacitic tuffs. These rocks form an arcuate highland that have been interpreted to be the remnants of a caldera (Metcalfe *et al.*, 1997, this volume).

In 1991, airborne radiometric, magnetic and electromagnetic surveys were flown over the area, and a field program consisting of trenching, mapping and sampling was conducted over the altered zones. A nineteen-hole, 3020-metre diamond drilling program followed (Heberlein, 1992a). In 1992, an induced polarization survey identified several chargeability and resistivity anomalies; these were tested by an eleven-hole, 1360-metre diamond drilling program. Assays of core samples exceeding 1.0 g/t Au were uncommon (Heberlein, 1992b).

Alteration is characterized by broad zones of moderately to intensely clay-altered rock that is cut by silica±pyrite (marcasite) stockworks. Near structures, zones of pervasive silicification predominate. Banded drusy quartz and dark grey chalcedony (±pyrite and/or marcasite) veins and silicified zones contain the highest gold and silver values. Assays of selected grab samples range from 0.05 to 0.76 g/t Au and 5.0 to 15.8 g/t Ag and all have anomalous arsenic, mercury and, to a lesser extent, antimony. Illite and montmorillonite comprise the clay mineralogy (Schroeter and Lane, 1992) and are indicative of a low-temperature regime that is consistent with an epithemal setting.

Baez (Oboy - MINFILE 93C 015, 016) - 93C/9E, 16E

The Baez property, including the Oboy prospect, is 125 kilometres west of Quesnel. It adjoins the western boundary of the Clisbako property (Schroeter and Lane, 1992). The property is underlain by a sequence of poorly exposed rhyolites, dacites, andesites and basalts of the Eocene Ootsa Lake Group. Rhyolitic tuffs, flows and breccias are the main hostrocks for mineralization (Goodall, 1994).

The Baez claims were staked in 1992 and 1993 as a result of reconnaissance stream-sediment sampling (Goodall, 1994). In 1993, soil sampling on four grids outlined several multi-element (Ag-As-Sb-Au-Hg) anomalies. In 1994 approximately 50 line-kilometres each of soil sampling and induced polarization surveys were carried out. Prospecting, mapping and diamond drilling followed. One of the targets is a north-trending multi-element soil geochemical anomaly 800 metres wide by 1800 metres long, coincident with airborne electromagnetic and resistivity anomalies and a pronounced magnetic lineament. Mineralized sections of core from the 1994 drilling program consist of bleached and clay-altered, fractured dacite and andesite. The fractures are filled with fine-grained silica and cored by fine-grained subhedral pyrite and/or marcasite. Pyrite, as 2-millimetre and smaller euhedral cubes, is also disseminated throughout the wallrock. The total pyrite content is estimated at 1 to 2%. Pervasive chlorite-calcite alteration, typical of the Baezeko River area, is widespread. Drilling has shown oxidation extends to depths of approximately 30 metres.

The Oboy epithermal gold prospect is about 8 kilometres west of the main target area on the Baez property. Outcrop is sparse in this area, however core from 1987 drilling on the Camp zone (Cann, 1987) displays hostrock lithologies comprising pale green (bleached) flow-banded andesite and green and purple mottled felsic to intermediate pyroclastic breccia of the Ootsa Lake Group. Argillic alteration is moderate to intense and imparts a chalky texture to the rocks. Mineralization consists of 2% to 5% fracture-controlled, fine-grained pyrite in a gangue of drusy quartz, calcite and chlorite. Disseminated, epigenetic pyrite cubes up to 2 millimetres across are present throughout.

Bob (MINFILE 93B 054) - 93B/13E

Mineralized rocks at the Bob prospect are silica and potassium feldspar altered and consist of three pyrite-bearing auriferous zones, with or without arsenopyrite. These mineralized horizons are in Lower Cretaceous Skeena Group clastic sedimentary rocks, above, in and below a low-angle, sheared contact between conglomerate and sandstone. The sedimentary rocks generally trend north-northeast and dip 20° to 50° to the southeast. They are cut by north and west-trending steeply dipping fracture systems and intruded by narrow clay and sericite-altered quartz feldspar porphyry dikes and/or sills. Potassium-argon whole-rock analysis from one of these intrusions yielded a date of 54.9±2.0 Ma (Brown, 1986). A whole rock K-Ar date of 64.8±2 Ma was derived from sandstone that hosts the mineralization (Brown, 1986). The genetic relationship of the porphyry dikes and sills to mineralization is unknown. The mineralized zones are 3 to 30 metres thick and assays typically average about 0.3 g/t Au (Brown, 1985). The zones are also anomalous in mercury, arsenic, antimony and silver. They are overlain by, or in fault contact with, basaltic and rhyolitic breccia of probable Eocene age.

Wolf (MINFILE 93F 045) - 93F/03W

The Wolf prospect, located approximately 130 kilometres southwest of Vanderhoof, is a low sulphidation, adularia-sericite epithermal gold-silver deposit with potential for bonanza and bulk-mineable mineralization.

Hostrocks are flow-banded and quartz-phyric rhyolitic flows and tuffs of the Ootsa Lake Group and a genetically related feldspar porphyry sill (Figure 3). Whole-rock K-Ar dates of 47 to 49 Ma from rhyolite and the sill suggest they may be comagmatic (Andrew, 1988). The rhyolites locally overlie polymictic conglomerate that is interpreted to locally mark the base of the Ootsa Lake Group. Elsewhere, the rhyolites unconformably overlie andesitic flows and epiclastic rocks of the Hazelton Group. Minor west-side-down movement along northerly trending structures that dissect exposures of the Ootsa Lake Group probably took place post-Early Eocene and are manifestations of the extensional tectonic regime that existed during that time. Hypabyssal sills and dikes preserved at Wolf, but not found elsewhere in the vicinity, suggest that the prospect may have been a small volcanic centre.

Extensive areas of silicification, brecciation and veining occur in three topographic highs. Alteration and mineralization are characterized by banded and bladed quartz-chalcedony veins and hydrothermal breccias within variably silicified and clay-altered sulphide-poor zones. At the main area (Ridge and Pond zones), silicification, veining and brecciation are concentrated at the base of a gently west-dipping hypabyssal feldspar porphyry sill. Veins are typically oriented north or northeast, parallel to small-displacement block faults. Two continuous chip samples from trenches on the Ridge zone averaged 8.49 g/t Au and 42.2 g/t Ag over 7.5 metres (Cann, 1984) and 2.69 g/t Au and 14.0 g/t Ag over 26.5 metres (Heberlein, 1992c). Selected grab samples yielded assays up to 78 g/t Au. The planar zone, defined by drilling in 1992, has a minimum strike length of 300 metres, extends down dip for more than 240 metres, and averages 7.6 metres in thickness (Dawson, 1995). The layer averages between 1 and 2 g/t Au over its thickness.

In 1994, a nine-hole, 1333-metre diamond drilling program, designed to test several induced polarization and biogeochemical anomalies identified during 1993 surveys (Love, 1994), peripheral to known mineralization, produced disappointing results.

Trout (MINFILE 93F 044) - 93F/10W

The Trout epithermal precious metal occurrence is located 60 kilometres southwest of Vanderhoof. The Discovery or Main zone crops out in a swampy valley bottom southwest of Swanson Creek. The area is underlain by mottled maroon and green polymictic conglomerate overlying volcanic breccia of either Late Cretaceous (Kasalka Group?), or Eocene (basal Ootsa Lake Group) age. The cobble-sized clasts consist of locally derived rounded sedimentary, volcanic and intrusive lithologies. They are cemented by finely banded chalcedonic quartz-adularia veins up to 8 centimetres wide. The banded chalcedonic quartz occurs in shades of pale brown to cream to clear. Many veins also contain drusy cavities and bladed textures (quartz pseudomorphs after barite or calcite).

Visible sulphides are rare in the veins, but traces of disseminated pyrite are common in the hostrocks. Very fine grained to microscopic pyrite, gold and argentite occur in distinct grey bands less than 1 millimetre thick, and within tabular lead-grey features, 0.5 millimetre wide by up to 2 millimetres long within bands of white translucent fine-grained quartz, that are perpendicular to clast margins. Sampling in trenches across the Discovery zone returned assays of up to 19.5 g/t Au over 5 metres (Schmidt, 1987). Selected grab samples assayed over 170 g/t Au (*see* Table 2).

Hydrothermal fluids were apparently channeled along a gently southwest-dipping contact between underlying volcanic breccia and overlying conglomerate. The hangingwall of the zone is flooded with silica and quartz-adularia veins while the footwall is pervasively silicified to about 1 metre below the contact. Distinct veinlets in the underlying volcanic breccia are dominantly oriented 050/80°SE.

Yellow Moose (MINFILE 093F 058) - 93F/06E

The Yellow Moose property is located south of Arrow Lake, approximately 20 kilometres west of Kenney Dam.

The Arrow showing is on the southeast shore of the lake and was not examined. It is reported to consist of drusy quartz veins and chalcedonic quartz flooding in siliceous rhyolite and arkosic sandstone that are cut by coarse-grained stibnite veins with accessory pyrite, marcasite and cinnabar (Bohme, 1988). The showing carries negligible gold or silver values.

The Gus zone consists of diffuse silicification and minor quartz-chalcedony veining in brecciated rhyolite and crystal to crystal-lapilli tuff. Northeast-trending mineralized zones, consisting of narrow veins, stockworks and breccias contain 1 to 2% fine-grained disseminated arsenopyrite, stibnite and pyrite. Assays up to 0.8 g/t Au have been reported (Bohme, 1988). Clay alteration of hostrocks is pervasive. Late fractures are coated with iron and manganese oxides.

A third zone, an induced polarization anomaly designated the IPA zone, and the Gus showing, were evaluated by a six-hole, 626-metre diamond drilling program in 1994. Drilling outlined a northeast-trending, weakly mineralized zone that dips moderately to the east (K. Schimann, personal communication, 1994).

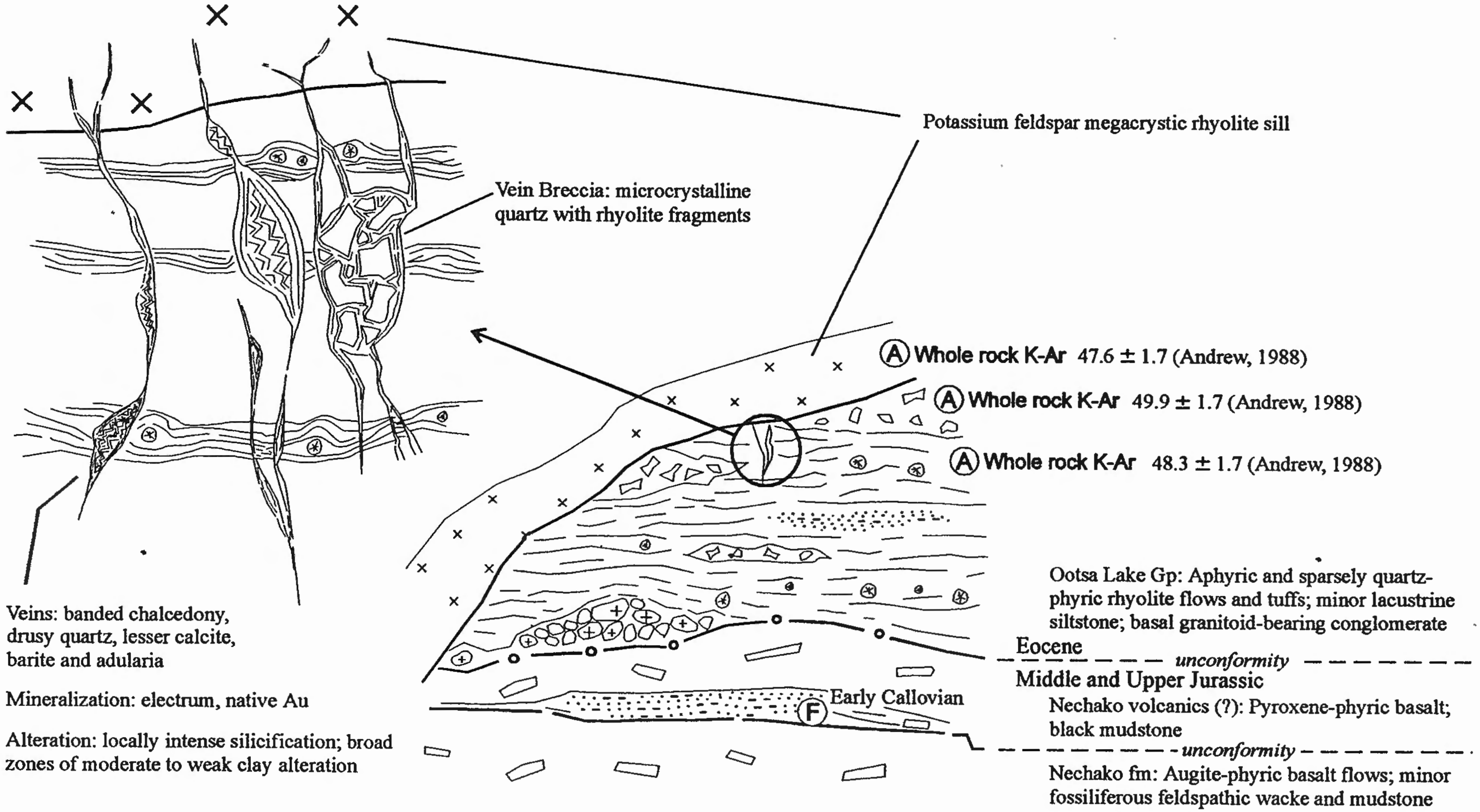


Figure 3. Schematic stratigraphic section of the wolf volcanic-hosted epithermal precious metal vein deposit (after original sketch by L.J Diakow).

Holy Cross (MINFILE 93F 029) - 93F/15W

The Holy Cross epithermal gold prospect is located about 33 kilometres south of Fraser Lake. Prospecting and chip sampling of silica-flooded rhyolite, exposed in a series of northwest-trending knotts, led to the discovery of several zones anomalous in gold. Subsequent exploration included geochemical, magnetometer and induced polarization surveys, geological mapping and the excavation of 26 trenches (Donaldson, 1988; Barber, 1989).

The oldest rocks are Hazelton Group andesitic crystal tuffs and plagioclase-phyric flows which are metasomatically altered to a fine-grained, mottled pale pink and green rock. They are intruded by a biotite quartz monzonite plug that has yielded a U-Pb zircon date of 169.3±0.3 Ma (Lane, 1995). Upper Cretaceous and younger strata unconformably overlie rocks of the Hazelton Group. Chert-pebble conglomerates, tentatively assigned to the Lower Cretaceous Skeena Group, are conformably overlain by hornblende-phyric andesite flows. These flows have yielded a preliminary K-Ar date, on hornblende, of 70.3±3.0 Ma (R.M. Friedman, personal communication, 1995). Maroon to purple andesitic volcanic flows, possibly from the base of the Eocene Ootsa Lake Group, unconformably overlie the Cretaceous rocks. These are in turn overlain by maroon to pale-coloured rhyolite flows and breccias assigned to the mid-Eocene Ootsa Lake Group. Andesite to basalt flows of the Late Eocene Endako Group and related diorite to gabbro plugs and necks form resistant knobs.

Two styles of mineralization have been recognized on the property. Zones of brecciated and intensely silicified rhyolite locally contain up to 1% fine-grained, disseminated pyrite; a zone of massive grey crystalline silica in trench 88-1 averaged 2.64 g/t Au and 9.7 g/t Ag across 2 metres (Donaldson, 1988). Zones of banded hematitic quartz veins and clear drusy quartz stockwork are weakly anomalous or barren. The veins and pervasively silicified zones are commonly enveloped by weakly to moderately clay-altered and bleached wallrock. Manganese oxides limonite and hematite commonly coat fractures. Pervasive hematitic alteration has stained andesites and rhyolites dark maroon or purple peripheral to the bleached zones. Sulphidization appears to be a post-hematite event and has resulted in the development of up to 4% disseminated cubic pyrite with bleached envelopes.

EARLY CRETACEOUS OR OLDER EPITHERMAL GOLD-SILVER OCCURRENCES

Fawn (MINFILE 93F 043) - 93F/03E

Epithermal gold-silver mineralization at the Fawn prospect consists of silicified breccia with sulphide-bearing stockworks and veins within a zone of iron carbonate and sericite alteration. Hostrocks are andesitic flows, lapilli tuffs, ash tuffs and argillaceous sedimentary rocks of the Hazelton Group. Locally intense metasomatism overprints the sub-greenschist grade regional metamorphic minerals in the volcanic rocks, resulting in zones of biotite hornfels and skarnification. Sulphide-bearing felsic dikes, of suspected Eocene age, cut the Hazelton stratigraphy.

Diamond-drill holes intersected silicified breccia within zones of clay, sericite and iron carbonate altered wallrock. One intersection graded 2.02 g/t Au and 25.2 g/t Ag over 8.1 metres (Baknes and Awmack, 1994a). The breccia zone has a true thickness of about 7 metres, strikes east and dips 60º to the north. Breccia zones consist of grey, silicified and brecciated lapilli tuff. Sulphide content is about 1% consisting mostly of pyrite. Fine-grained needles of arsenopyrite, possible sphalerite and an unknown steel-grey mineral (pyrargyrite?) occur in trace amounts. Dominant gangue minerals are quartz, chalcedony, calcite (late-stage post-sulphide). Quartz-lined drusy cavities are common and contain rhombs of white dolomite and euhedral blades of barite.

Tsacha (MINFILE 93F 055) - 93F/03E

In 1993 a Geological Survey Branch regional mapping party discovered an auriferous epithermal quartz vein system in the Tommy Lakes area (Diakow and Webster, 1994). The area is underlain primarily by rhyolitic ash flows and variably welded tuffs. They are intruded by felsic to intermediate dikes and sills. The veins crop out on hummocky, moss-covered knobs.

In 1994 a program consisting of soil geochemistry, prospecting, trenching and rock chip sampling was conducted. In 1995, a 35-hole, 5200-metre diamond drilling program, focused on the main or Tommy vein, tested the vein system over a strike length of 650 metres and 150 metres down dip (J. Pautler, personal communication, 1995). The Tommy vein trends north, dips vertically and is up to 8 metres wide. It is intruded by a biotite-phyric felsite sill that has yielded a preliminary U-Pb zircon date of 73.8+2.9/-0.1 Ma (R.M. Friedman, personal communication, 1995). Surface sampling across the vein has returned assays up to 61.9 g/t Au and 292.5 g/t Ag over 1.5 m (Pautler, 1995).

The Tommy vein consists of massive clear to milky white crystalline quartz and subordinate calcite with locally developed colloform bands of pale grey chalcedonic quartz, adularia and rare amethyst. Metallic mineral content of the vein system is typically less than 1% and includes traces of chalcopyrite, pyrite, stephanite, argentite, galena, native gold (and/or electrum), specularite and magnetite (J. Pautler, personal communication, 1995). Vague bands of earthy hematite and sparse malachite are minor vein constituents. Vein textures include brecciation, banding and drusy cavities. Massive vein quartz-carbonate is commonly flanked by stringer, stockwork and/or breccia zones. Wallrock alteration is inconsistent and patchy. Narrow, locally intense zones of silicification abruptly give way to broad zones of weak clay alteration that may be stained a brick-red colour due to pervasive earthy hematite. Clay and sericite alteration is sporadic.

Several other quartz veins and stockwork zones parallel the Tommy vein. Potential for discovery of additional veins is excellent.

Malaput - 93F/03E

The Malaput showing, discovered by Geological Survey Branch mappers in 1993 (Diakow and Webster, 1994), consists of weak sulphide mineralization (traces of pyrite, sphalerite and galena) in an east-trending zone of quartz and sericite-altered felsic bedded tuffs. The rock is pale greenish white and displays rare primary textures including lapilli-sized lithic fragments, quartz eyes and an east-trending weakly developed fabric that may be relict flow banding. Locally the rock exhibits a well developed silica stockwork locally with crystalline barite. Sphalerite and galena are associated with crosscutting calcite veinlets. Fractures are coated with earthy hematite and/or pyrolusite. Pyritic tuffs, fine-grained sedimentary rocks and pyroxene-bearing volcanic flows crop out to the north.

SKARN MINERALIZATION

Fawn 5 (MINFILE 93F 053) - 93F/03E

Two types of skarn mineralization were identified along the western margin, and within the thermal aureole, of the Jura - Cretaceous Capoose batholith. Both occur on the Fawn 5 claim.

Andesitic pyroclastics and limy tuffs of the Hazelton Group locally exhibit extensive hornfelsing and local development of garnet-pyroxene-epidote (±wollastonite±actinolite) infiltration skarn. These effects extend more than 5 kilometres from the western edge of the batholith. Iron skarn consists of massive to semimassive magnetite in a gangue consisting mainly of garnet, pyroxene and epidote. A grab sample from the iron skarn occurrence graded 44% Fe with negligible precious and base metal values. Copper-gold skarn consists of 1% finely disseminated pyrite and traces of disseminated chalcopyrite, pyrrhotite and arsenopyrite in strongly epidote-altered andesitic tuffs. A grab sample from this new occurrence graded 0.6% Cu, 0.4 g/t Au and 19 g/t Ag.

The potential for future discoveries of skarn mineralization, within the metasomatically altered envelope surrounding the batholith, is excellent.

VEIN AND PORPHYRY-RELATED DEPOSITS

Several prospects studied are classified here as either "subvolcanic", as described by Panteleyev (1992), or peripheral veins. They are hosted, all or in part, by Jurassic Hazelton Group strata. They exhibit fracture-controlled, disseminated, semimassive to massive and/or replacement styles of mineralization. The principle sulphides are pyrite, arsenopyrite, sphalerite, chalcopyrite and galena. Mineralization is spatially, and perhaps, genetically associated with felsic sills, dikes or plugs of at least Late Cretaceous age. At two of the prospects (April and Ben), mineralized veins are parallel to the fabric in foliated tuffaceous felsic volcanic hostrocks. These rocks are truncated by an Eocene granitic body (the CH pluton).

Capoose (MINFILE 93F 040) - 93F/06

The Capoose precious and base metal prospect is located 2 kilometres north of Fawnie Nose in the Fawnie Range, approximately 110 kilometres southeast of Burns Lake. The deposit is just east of the Capoose batholith (Figure 4) within and adjacent to garnet-bearing rhyolite dikes and sills that intrude thermally altered Middle and Upper Jurassic volcanic and sedimentary rocks. The hostrocks are pervasively kaolinized and sericitized, defining broad zones of moderate to intense phyllic alteration. Sulphide minerals, mainly pyrite, sphalerite, galena, chalcopyrite and arsenopyrite, occur as disseminations and as aggregates adjacent to, or intergrown with, garnet (Andrew, 1988). Sulphide veinlets and fracture fillings are also present. Tetrahedrite, pyrrhotite, pyrargyrite, electrum, native gold and cubanite occur as inclusions within the more common sulphides (Schroeter, 1981). Sulphide-garnet aggregates are commonly enveloped by quartz and fine-grained muscovite (Andrew, 1988). Diamond drilling outlined a geological resource of 28.3 million tonnes grading 36 g/t silver and 0.3 g/t Au (Granges Exploration Ltd., 1987).

The Capoose prospect resembles a low-grade porphyry-style deposit; however, the age of mineralization is equivocal. The mineralized and phyllically altered rhyolite sills were originally assigned a Late Cretaceous age based on whole-rock K-Ar dates (Andrew, 1988). However, new preliminary U-Pb zircon dates (R.M. Friedman, personal communication, 1995), from samples collected in 1995, suggest that there were two distinct ages of sill emplacement. A rhyolite sill, containing 3 to 5% metasomatic garnet, yielded a date of 140.7±0.6 Ma, suggesting that it may be related to the emplacement of the Capoose batholith. A locally mineralized, garnet-bearing rhyolite sill and dike complex (and contemporaneous rhyolitic extrusives), that cuts the former, yielded Late Cretaceous ages (*ca.* 72 Ma). We consider mineralization to be associated with this Late Cretaceous intrusive event.

Blackwater-Davidson (Pem - MINFILE 93F 037) - 93F/02W

The Blackwater-Davidson prospect is located approximately 7 kilometres northeast of Mount Davidson, about 160 kilometres south of Vanderhoof. Outcrop on the property is sparse and most of the information has been obtained from diamond drilling and geophysical surveys.

Stream sediment lead-zinc-silver anomalies, from a survey conducted in 1973, led to staking. Follow-up geochemical and geophysical surveys were conducted intermittently from 1977 to 1984. Diamond drilling between 1985 and 1987 identified two areas of mineralization, the Silver and Gold zones in an area of high resistivity, flanked by a zone of high chargeability that is coincident with a base metal - silver soil anomaly. Additional diamond drilling was carried out in 1992 and 1994.

Hostrocks are Hazelton Group felsic (rhyolitic to dacitic) and mafic (andesitic to trachyandesitic) volcanics as well as argillites, greywackes, sandstones and siltstones. A series of block faults may explain the repetition of rock units observed in diamond-drill core.

The Gold zone is a structurally controlled east-trending, steeply dipping zone up to 70 metres wide with a strike length of 300 metres (Allen, 1992). Disseminated and shear-hosted sulphides, consisting mainly of pyrite and sphalerite, subordinate pyrrhotite and traces of galena, arsenopyrite and chalcopyrite, occur in felsic lapilli tuffs, breccias and flows that are affected primarily by phyllic

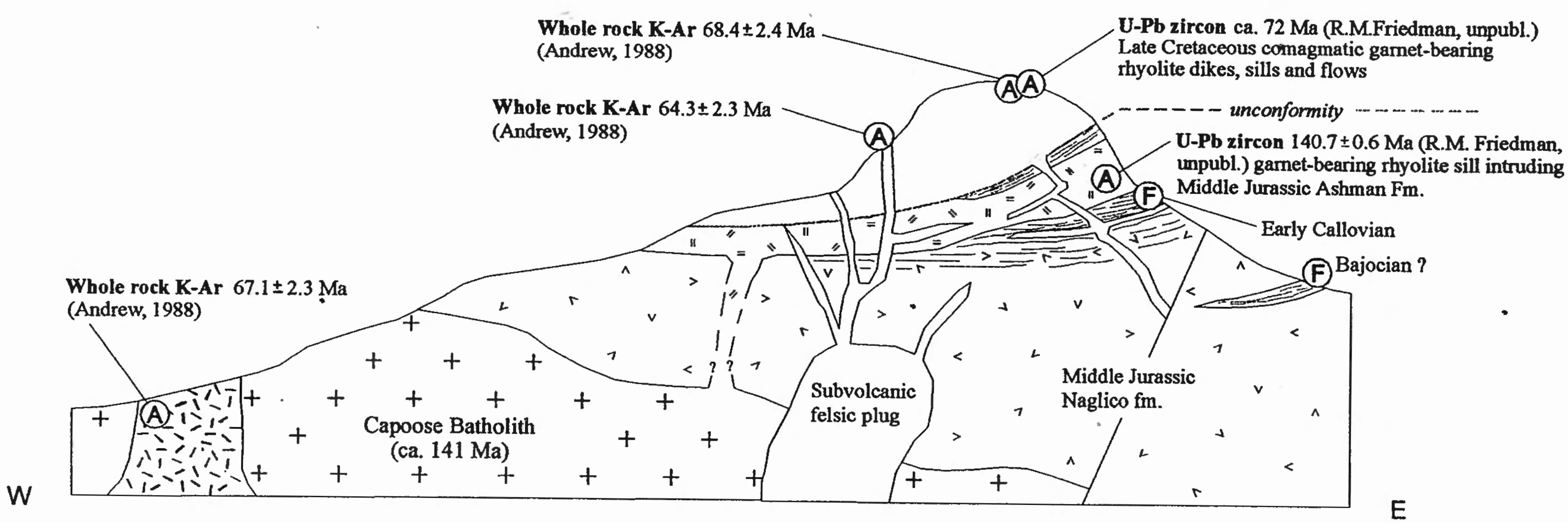


Figure 4. Diagramatic section of the Capoose porphyry-related bulk tonnage Ag (+/- Au) deposit. Mineralization is related to a series of Late Cretaceous rhyolitic dikes and sills that intrude Middle Jurassic rocks and an Early Cretaceous rhyolite sill (modified after original sketch by L.J.Diakow).

Figure 4. Diagramatic section of the Capoose porphyr-related bulk tonnage Ag(±Au) deposit. Mineralization is related to a series of Late Cretaceous rhyolitic dikes and sills that intrude Middle Jurassic rocks and an Early Cretaceous rhyolite sill (modified after original sketch by L.J. Diakow).

and argillic alteration. The best diamond-drill intersections from the Gold zone graded 14.28 g/t Au over 6.3 metres (Zbitnoff, 1988) and 0.72 g/t Au over 47.5 metres (Allen, 1993). The Silver zone is a relatively flat-lying body up to 70 metres thick that contains an estimated 6 million tonnes grading 37 g/t silver and 0.05 g/t gold (Allen, 1993).

Buck (MINFILE 93F 050) - 93F/03E

The Buck property, located about 120 kilometres southwest of Vanderhoof, covers two known mineralized showings (Baknes and Awmack, 1994b). The Rutt showing, a stratabound zone of sphalerite, pyrrhotite and pyrite is exposed in several hand-excavated trenches and outcrops along a northerly trend for about 400 metres. One trench exposes rusty weathering, carbonate and sericite-altered tuffaceous and argillaceous siltstones with 1 to 2% fine-grained disseminated and stratiform pyrite and less than 1% pyrrhotite and blackjack sphalerite. Bedded sedimentary rocks strike north-northeast and dip gently to the east. The Christmas Cake showing, exposed in two small hand-excavated trenches, is about 350 metres southeast of the Rutt zone. It occurs in a felsic volcanic breccia within 75 metres of a north-trending quartz feldspar porphyry dike, 200 to 300 metres wide. The showing consists of semimassive to massive sulphides in a breccia, where intergrowths of sulphide minerals (sphalerite+pyrite+chalcopyrite+galena) comprise the matrix for angular fragments of rhyolite. A grab sample from one of the trenches assayed 721 g/t Ag, 12.1% Zn and 3.8% Pb.

April (MINFILE 93F 060) - 93F/07E

The April showing is located approximately 100 kilometres southwest of Vanderhoof and 2 kilometres north of Chutanli Lake. It consists of a lens or vein of massive to semimassive sulphide hosted by Lower Jurassic tuffaceous siltstone near the contact with an Eocene granitic stock.

The sulphide lens is steeply dipping and trends 320°, subparallel to bedding. It is exposed over a 15-metre length and varies in width from 0.3 to 1.8 metres. Sulphides are mainly pyrite, pyrrhotite, sphalerite, arsenopyrite and galena. Assays from a three-hole diamond drilling program conducted in 1984 include 2.95 g/t Au, 4.0 g/t Ag and 0.77% Zn over 0.57 metre; and 1.4 g/t Au, 573.5 g/t Ag, 15.96% Zn and 15.83% Pb over 0.3 metre (Zbitnoff and Williams, 1985).

Ben (MINFILE 93F 059) - 93F/07E

The Ben precious metal occurrence is located about 105 kilometres southwest of Vanderhoof and 5 kilometres north of Tatelkuz Mountain. Mineralized outcrops were discovered during reconnaissance exploration for volcanogenic massive sulphide deposits in 1991 (Wesa and St. Pierre, 1992).

Precious and base metal mineralization occurs in three closely spaced showings (Hooter, Shawn and Creek) hosted by foliated intermediate flows, related pyroclastics and siltstones of the Hazelton Group. These rocks are intruded by plutons of at least two ages: a Jura-Cretaceous(?) monzonite that is locally hornfelsed and displays a crude foliation, and the CH stock, a 51.8±1.0 Ma (U-Pb zircon) biotite-hornblende granodiorite that truncates the older foliated rocks. The foliation trends northwesterly and dips steeply to the southwest. Hazelton rocks are commonly hornfelsed near contacts with the intrusions and contain up to several percent biotite which gives the rock a brown to purplish cast.

Mineralization appears to parallel foliation trending 140° to 150° and consists of disseminated to locally semimassive quartz-sulphide veins or seams containing arsenopyrite, pyrite and pyrrhotite, with or without chalcopyrite and galena. A 3.0-metre chip sample across one mineralized zone assayed 0.7 g/t Au, 95 g/t Ag and 0.2 % Pb (Wesa and St. Pierre, 1992). These zones are also anomalous in arsenic, zinc, antimony and bismuth.

PORPHYRY DEPOSITS

Bedrock exposure is very limited in the vicinity of known porphyry prospects and age data are limited. Despite this we consider the possibility for future discoveries of porphyry-style deposits to be excellent. Much more work is required in order to understand the three prospects that are summarized below.

CH (MINFILE 93F 004) - 93F/07E

The CH porphyry prospect is located 100 kilometres south-southwest of Vanderhoof and straddles the Kluskus-Ootsa forest service road. Exploration programs, carried out from 1969-1975, 1980-1985 and 1991-1992, identified porphyry copper-gold and peripheral precious-base metal vein mineralization (*see* under April occurrence). The CH prospect occurs at the margin of the mid-Eocene CH granodiorite stock: however, its genetic relationship to the intrusion is not known.

Early trenching programs uncovered fracture-controlled pyrite-chalcopyrite and magnetite in hornfelsed intermediate volcanic and fine-grained sedimentary rocks of the Hazelton Group. Later diamond drilling intersected hornfelsed volcanic and tuffaceous sedimentary rocks cut by crowded feldspar porphyry and monzonite to diorite plugs. Mineralization in drill core consists 1 to 2% disseminated and fracture-controlled pyrite, traces of chalcopyrite and molybdenum and magnetite in both intrusive and volcanic-sedimentary rocks near the contact.

Ned (MINFILE 93F 039) - 93F/06E

The Ned showing consists of several small exposures of quartz monzonite of the Capoose batholith, 2.5 kilometres southeast of Capoose Lake. It is close to a Late Cretaceous(?) granodiorite (Andrew, 1988) of unknown extent. A strong molybdenum-copper soil anomaly and coincident induced polarization anomalies overly an area that is, with the exception of the showing, entirely overburden covered.

Siliceous veins, up to 25 centimetres wide, cut the intrusion and contain coarse-grained molybdenite flakes, up to 10 millimetres across, concentrated along vein margins as a selvage. Traces of molybdenite and rare chalcopyrite are disseminated throughout the quartz monzonite. Pyrite is more abundant and occurs along fractures. A chip sample across 5 metres graded 0.046 % MoS_2 and 0.03 % Cu with negligible gold and silver (Shear, 1978).

Percussion drilling on the Ned, 'A' and 'J' claims, in 1978 and 1979, intersected weakly mineralized biotite quartz diorite of the Capoose batholith. Drill holes averaged up to 0.02% MoS_2 over their entire length. Individual assays graded as high as 0.091% MoS_2 over 3 metres, and 0.044% MoS_2 and 0.15% Cu over 3 metres (Shear, 1978, 1979).

Paw (MINFILE 93F 052) - 93F/03W

The Paw porphyry copper-molybdenum showing is located along the Kluskus-Malaput road about 5 kilometres southeast of the Wolf prospect. Sparse outcrops of granodiorite to diorite, presumably part of the Capoose batholith, host 3 to 4% fracture-controlled and disseminated pyrite with traces of molybdenite and chalcopyrite. Little work has been done on the prospect, but the showing suggests that more porphyry-style mineralization may occur in the area.

SUMMARY

Three ages of plutonism have been documented in the Interior Plateau. They are Jura-Cretaceous (*ca.* 148 to 141 Ma), Late Cretaceous (*ca.*74 - 65 Ma) and Eocene (*ca.* 51 Ma).

The oldest event is related to the emplacement of the Capoose batholith which is spatially associated with porphyry (Paw), skarn (Fawn 5) and epithermal vein (Fawn) showings. They occur in metasomatically altered Jurassic Hazelton Group volcanic rocks on the western margin of the batholith. The thermal aureole of the Capoose batholith locally extends more than 5 kilometres from the margin of the intrusion. The Ned porphyry Mo-Cu prospect is hosted by quartz monzonite of the batholith, but is also close to a probable Late Cretaceous(?) intrusion.

Late Cretaceous felsic dikes and sills, that intrude Middle and Upper Jurassic intermediate volcanic and sedimentary rocks, are interpreted to be the source of mineralization at the Capoose porphyry-related silver (±gold) deposit. Late Cretaceous intrusions may also be associated with similar mineralization at the Blackwater-Davidson precious and base metal prospect and with porphyry molybdenum-copper mineralization (*e.g.*, Ned). The Tsacha epithermal vein deposit is cut by a Late Cretaceous felsic sill, establishing a minimum age for the prospect.

Eocene (or younger) epithermal precious metal prospects (*e.g.*, Wolf) comprise the majority of known metallic mineral occurrences in the region. Most are hosted by Eocene Ootsa Lake Group felsic volcanic rocks and are related to east-west extensional tectonism.

Precious metal bearing quartz-chalcedony (± calcite, adularia and barite) veins, stockworks and breccia zones are typically low-sulphide systems (*e.g.*, Clisbako) and display classic epithermal textures such as banded veins and drusy cavities. Base metal content is generally low, suggesting that the systems developed near the paleosurface (at depths of *ca* 1 km). Hostrocks are typically intensely fractured and brecciated. Barren or weakly anomalous silica, sericite and clay-altered wallrocks typically envelope the mineralized zones.

Porphyry-style Cu-Au-Mo mineralization (CH) occurs close to the Eocene CH pluton.

The Miocene and younger plateau basalts of the Endako and Chilcotin groups, so far as we know, contain no metallic mineralization, but may have some potential for industrial minerals.

Most of the known mineral occurrences were discovered by prospecting areas with regional lake or stream-sediment geochemistry anomalies. Exploration in the Interior Plateau is hampered by extensive glacial till cover and till prospecting has proven to be an effective method for locating mineralization.

Information from regional mapping, regional and case study geochemical surveys and mineral deposit studies have encouraged mineral exploration in the Interior Plateau region. A metallogenic model has been proposed for the area and is continuing to evolve as more information is collected. A close liaison with industry geologists has resulted in a better understanding of the geological and mineralizing processes in the region.

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