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Ministry of Energy, Mines
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Geological Survey Branch

EXPLORATION IN BRITISH COLUMBIA 1992

Part A - Overview of Exploration Activity

Part B - Geological Descriptions of Properties

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FOREWORD

Mineral exploration in British Columbia declined in 1992, reflecting soft prices, particularly for precious metals; uncertainties with respect to land-use decisions and the regulatory climate; and steadily increasing competition for high-risk exploration capital, particularly from Latin American countries. Project expenditures, in the order of $50 to $60 million, were down more than 30% over 1991. However, a number of potentially significant advanced projects were actively pursued.

The value of total hard mineral production also declined for the fourth successive year. Labour disputes and declining demand for metallurgical coal both contributed to lower coal production. Three hardrock mines closed permanently in 1992: Bell Copper on Babine Lake, the Samatosum mine near Adams Lake and the McDame asbestos mine at Cassiar. In addition, open pit reserves were exhausted at the Equity Silver, Premier and Lawyers mines. Future production at Equity and Premier will be from underground; Cheni Gold Mines Ltd. the operator of the Lawyers mine, has acquired additional reserves on a nearby property.

Only one new mine was brought on stream in 1992, the small Dome Mountain gold mine near Smithers, shipping ore to the Equity Silver concentrator for custom milling. Two major projects, the Stronsay lead-zinc deposit in the northern Rocky Mountains and the Mount Polley porphyry copper-gold deposit in the Cariboo have cleared all the regulatory hurdles necessary for development, but arranging production financing is difficult in the current investment climate.

The British Columbia Geological Survey Branch maintained an active program of fieldwork in 1992, including projects in regional mapping, mineral deposit studies, surficial geology, drift prospecting and regional geochemistry. The results of the survey were published in *Geological Fieldwork 1992*, Paper 1992-1, released early February, 1992.

W.R. Smyth
Chief Geologist

PART A
OVERVIEW OF EXPLORATION ACTIVITIES

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PART A

OVERVIEW OF EXPLORATION ACTIVITIES

BRITISH COLUMBIA EXPLORATION and DEVELOPMENT HIGHLIGHTS and INITIATIVES - 1992

By Richard E. Meyers
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INTRODUCTION

The exploration industry in British Columbia has undergone a major transition during the past few years. An industry that normally thrives on operating in an aggressive high-risk environment has redirected exploration investment to more conservative ventures. The spectrum of exploration activities that normally covers grassroots projects to drill-testing of new targets has, in large part, been refocused toward those in the upper range of mature prospects; those having more available data, known resources in the ground and a potentially higher probability for development and production. These were the exploration targets for British Columbia in 1992.

As a result the major and junior exploration companies that operated in British Columbia this year have concentrated on classic mineral deposit models and targets that are the mainstay of the province's mining industry and known to yield the highest quality results.

EXPLORATION EXPENDITURES: NATIONAL AND REGIONAL PERSPECTIVES AND TRENDS

Preliminary estimates from industry sources indicate that total expenditures on exploration projects in British Columbia during 1992 were in the order of $50 to $60 million. This figure is consolidated from regional exploration data surveys, carried out by District Geologists on

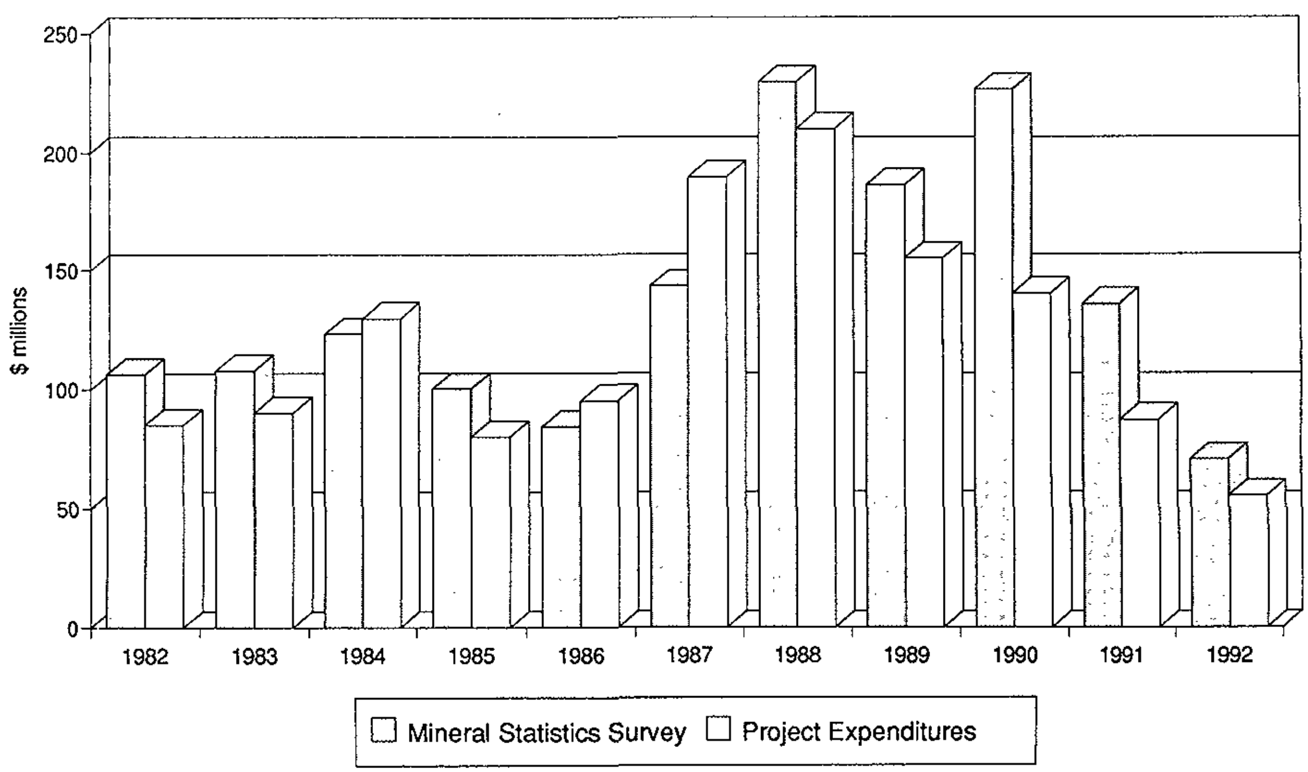

Figure A-1. Mineral exploration expenditures in B.C. 1982 to 1992.

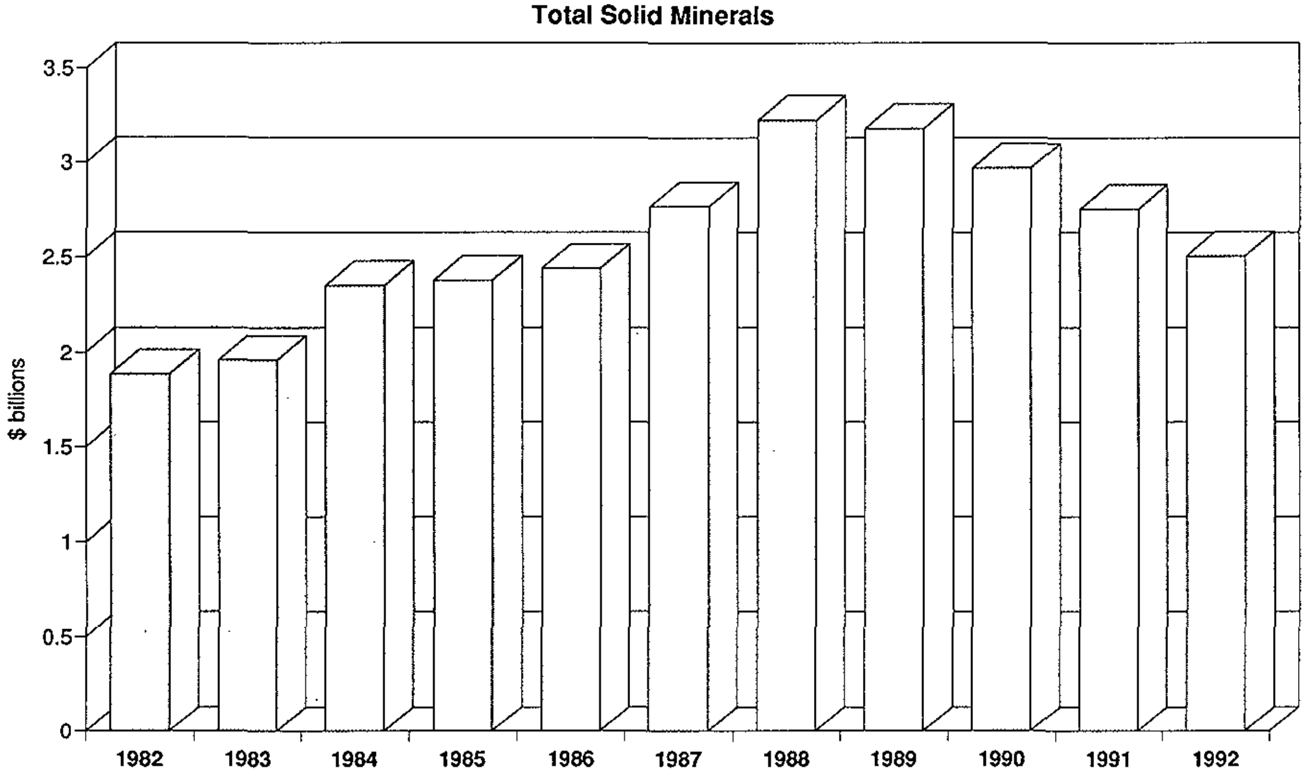

Figure A-2. Mineral production in B.C. 1982 to 1992.

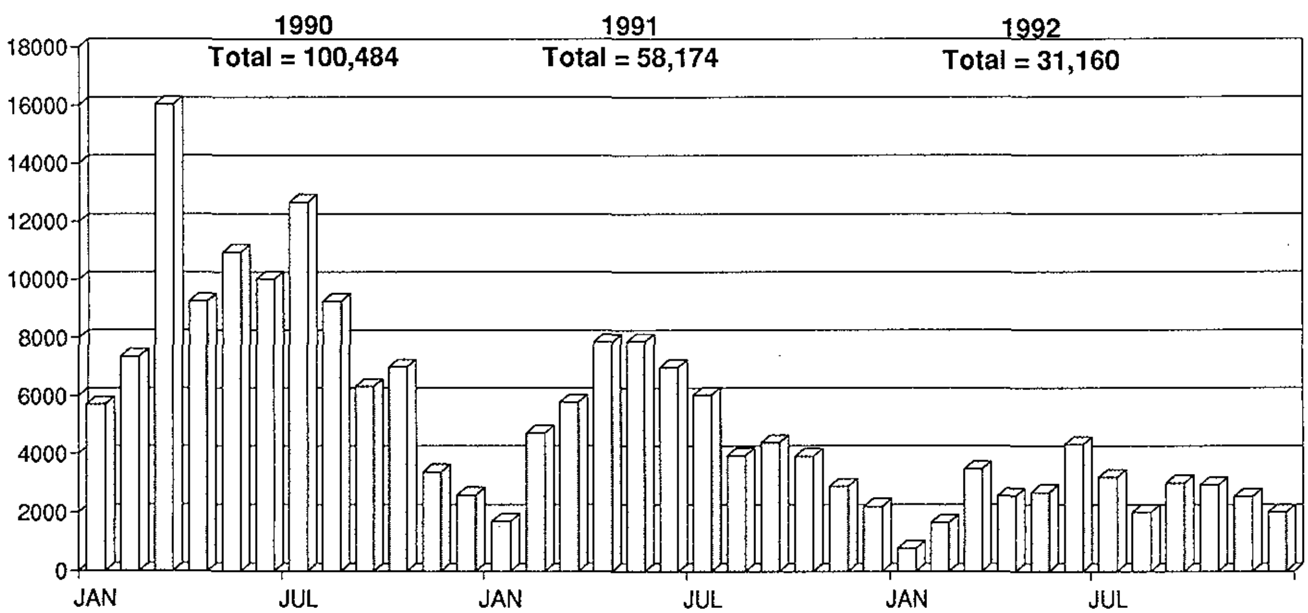

Figure A-3. Total mineral claim units recorded by month; 1990 to 1992.

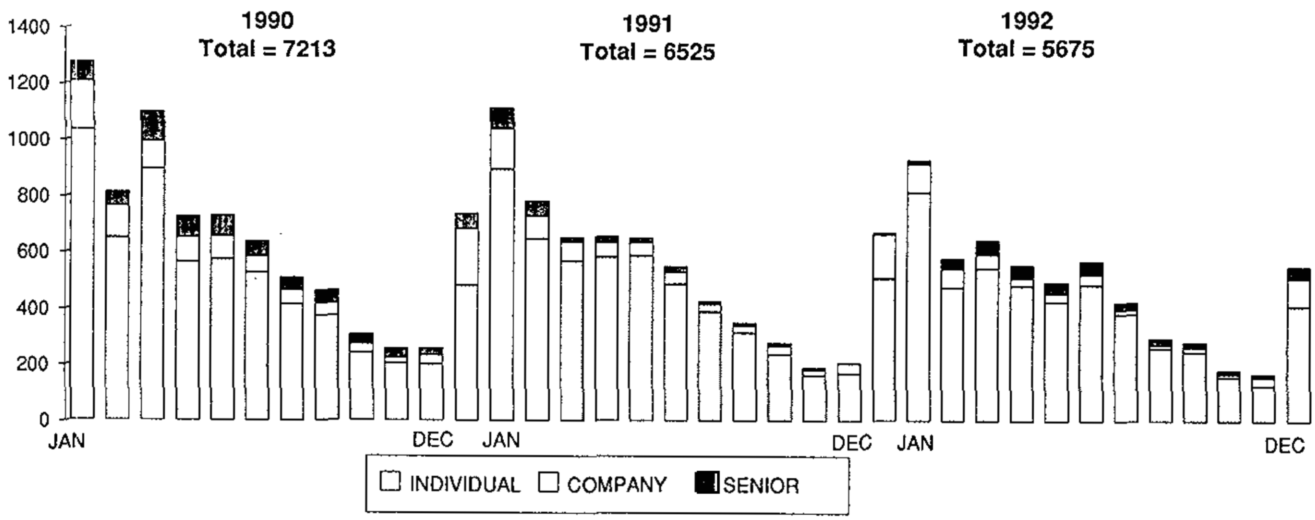

Figure A-4. Free miner certificates recorded by type and by month; 1990 to 1992.

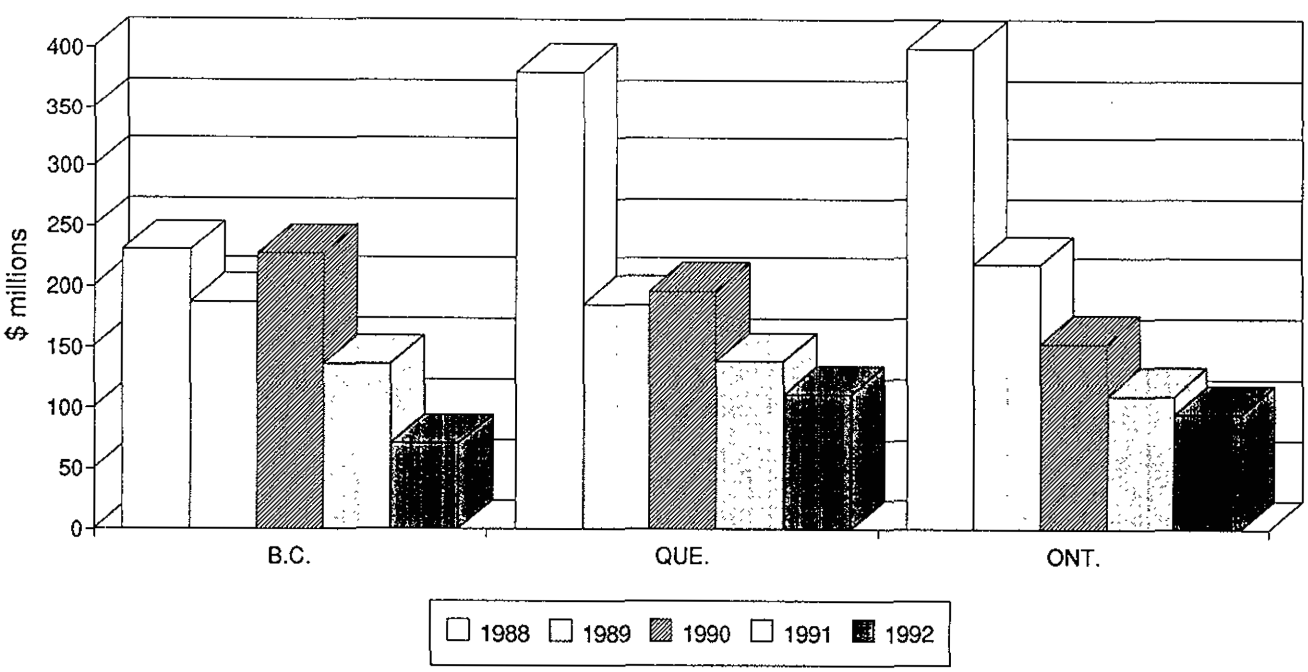

Figure A-5. Exploration expenditures.

a project-by-project basis throughout the province, and is an estimate of the actual total dollars spent on the ground. The province's Mineral Statistics survey estimates a total of $70.5 million. The latter figure includes project expenditures, but also incorporates a variety of general costs, including related overhead and head office expenses.

During the past decade, exploration expenditures in the province have fluctuated by more than $100 million (Figure A-1), peaking above $200 million in 1988, during the heyday of flow-through funding. The past four years have shown a steady decline. For the same ten-year period, the pattern of exploration spending is consistent with changes in the total value of solid mineral production (Figure A-2).

In the shorter term, since 1990, similar changes are apparent in the levels of new mineral titles recorded (Figure A-3) and in the number of Free Miner Certificates issued to explorationists operating in the province (Figure A-4). Both sets of figures illustrate significant and parallel declines during the past three years and are, themselves, indicators of the levels of exploration activity.

Figure A-5 implies that the trend is not unique to British Columbia. The patterns in industry expenditures for three Canadian provinces are similar and portray an analogous set of factors and results. Quebec, Ontario and British Columbia are traditionally the most actively explored regions in Canada and together account for an average of 73% of total Canadian exploration expenditures annually.

HIGHLIGHTS AT OPERATING MINES

PRODUCTION LEVELS

One new mine was opened in 1992, the **Dome Mountain gold mine** (Figure A-6). However, five operations were closed due to exhausted ore reserves, or technical and financial problems (*see* Operations). The forecast value of solid mineral production for 1992 in British Columbia is $2.50 billion, down from $2.75 billion in 1991 (Table A-1). Copper has moved to the top of the value list, displacing coal as the most economically important material mined in British Columbia. At a projected value for the year of approximately $898 million, down marginally from the 1991 value of $846 million, copper represents nearly 36% of the total value of all mine production.

Coal represents 29% of the total value of production, as output dropped by 28% from 1991. This is largely a result of shutdowns due to strikes and lockouts at two operations in the Kootenay coalfields. Total value is forecast at $721 million, down from $937 million last year.

The production of gold is also expected to be slightly lower, at a forecast level of 15.3 million grams (475 900 ounces), valued at $208 million, down from 17.4 million grams (541 200 ounces) last year.

The only metals showing a significant increase in value of production are lead and zinc. The quantity of lead produced is projected to be 23% higher at 64 million kilograms (141 million pounds), valued at $43 million. In contrast, zinc production is down by about 2.6%, at 109 million kilograms (240 million pounds), but due to strong prices, the value of zinc production has actually increased by $19 million to $171 million.

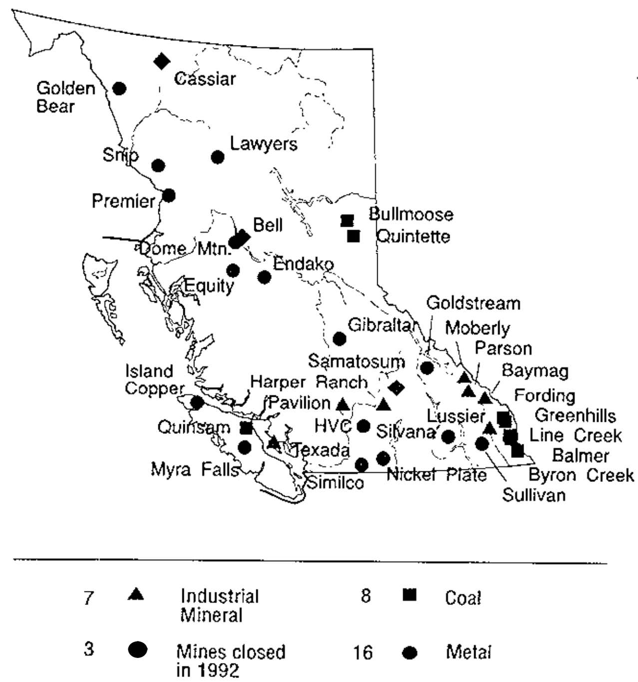

Figure A-6. Operating mines in B.C. - 1992.

TABLE A-1
VALUE OF MINERAL PRODUCTION IN B.C.

	Quantity (millions)	$ Value (millions)
Copper	314 kg	898
Gold	15 g	208
Zinc	109 kg	171
Lead	64 kg	43
Molybdenum	8 kg	52
Silver	321 g	50
Other metals		5
Coal		721
Industrial Minerals		40
Structural Materials		316
Total Solid Minerals		2 505

Source: MEMPR, Mineral Policy

Silver shows the greatest drop of all at 260 million grams (8.3 million ounces) valued at $40 million, down from 484 million grams (15.5 million ounces) in 1991, which represents a 46% decrease in production. The closure of the Equity Silver pit and Samatosum mine, and reduced production at the Lawyers and Premier operations are the main factors contributing to the substantial decrease in silver output.

OPERATIONS

METAL MINES

The **Snip** gold mine is certainly one of the recent mining success stories for both British Columbia and for Cominco Ltd. (60%) and Prime Resources Ltd. (40%). Snip operates at 450 tonnes per day, well above design capacity of 300 tonnes per day. At $130 to $160 per ounce of gold produced, production costs are by far the lowest in the province. On-going exploration drilling within the mine continues to replenish reserves and the operation produced its 200 000th ounce on September 15, 1992.

At the **Golden Bear** gold mine, Homestake Canada Ltd. has overcome enormous start-up problems to make the transition from major losses in 1991 to a modest profit in 1992. To complement the effort, the company has also had successful exploration programs at several prospects on the property, including the Bear Deep South and Fleece A and B zones.

Westmin Resources Limited's **Premier** gold mine ended open-pit mining during the year and continued with underground production. The company is looking at the option of custom milling ore from various sources including the Brucejack West zone (*see* Advanced and Development Projects), Chichagof and Greens Creek, Alaska, Mount Skinner and Westmin's own Debbie property. The company has applied to mine a 7500-tonne sample from the 900 zone at the Debbie property.

Reserves have been exhausted at the AGB and Cliff Creek zones at the **Lawyers** mine, operated by Cheni Gold Mines Ltd. In total, some 642 000 tonnes of ore grading 8.91 grams per tonne gold was produced. Cheni has optioned the **Mets** deposit from Golden Rule Resources Ltd. (50%) and Manson Creek Resources Ltd. (50%) and plans to begin production from this property in 1993. Reserves are 53 518 tonnes grading 11.62 grams per tonne gold. In the interim, a small high-grade gold deposit was delineated in the **Phoenix** zone and was mined late in the year, yielding approximately 310 kilograms of gold.

British Columbia's newest mining operation is the **Dome Mountain** gold mine, which opened in 1992 near Houston. The operation is a joint venture between Timmins Nickel Ltd. (operator) and Habsburg Resources Ltd. Start-up production of 100 to 200 tonnes per day is trucked to the Equity Silver mill. The deposit is a mesothermal quartz vein system containing gold and base metal sulphides, with reserves of 295 000 tonnes grading 12.34 grams per tonne gold.

Following 12 years of successful production at the **Equity Silver** mine of Placer Dome Inc. (55.8%), open pit mining is complete. Production totalled 32 391 000 tonnes grading 94.3 grams per tonne silver, 1.03 grams per tonne gold and 0.35% copper. Underground development is in progress on the North (Waterline) zone, which has reserves of 750 000 tonnes grading 0.68% copper, 209 grams silver and, 4.18 grams gold per tonne at a cut-off of 250 grams per tonne silver equivalent.

Gibraltar Mines Ltd. carried out two extensive drilling programs on the **Gibraltar North** copper deposit discovered in 1990-91. The new zone is northwest of the Gibraltar East pit. A potential geological resource is believed to be in the order of at least 50 million tonnes grading more than 0.4% copper, together with gold, silver and zinc values. The company planned to carry out detailed reserve and engineering evaluations by year-end.

The outlook has improved at the **Myra Falls** operation of Westmin Resources Limited following an extended period of high operating costs. The operation has switched to cheaper, long-hole stope mining at the **H-W** mine, with the objective of reducing costs to below $50 per tonne. During the same period, Westmin has had a particularly successful exploration program. Several new zones are now, or soon will be potentially available for development; the **Lynx "G", Ridge, Battle, Gap, H-W Extension, H-W 42** and **43** blocks and the newly discovered **Trumpeter Zone** on Thelwood Creek. Total geological reserves for the **Battle** lens are currently estimated at 3 018 400 tonnes, grading 2.9% copper, 0.4% lead, 14% zinc, 24 grams per tonne silver and 1.3 grams per tonne gold. Present mining reserves for this zone are 1 518 000 tonnes grading 2.3% copper, 0.3% lead, 10.7% zinc, 1.0 gram per tonne gold and 18.4 grams per tonne silver.

Since starting up its second life in May of 1991, the **Goldstream** copper-zinc mine of Bethlehem Resources Corporation has produced more than 600 000 tonnes of ore and has shipped about 19 000 tonnes of copper in concentrate to Nippon Mining Company in Japan. The operation's zinc circuit was brought on stream in early 1992. Zinc recovery is estimated at 22%, to produce a concentrate grade of 47% zinc.

COAL MINES

British Columbia's coal production was plagued with interruptions in 1992. Reduced demand for metallurgical coal by the Japanese steel industry and competition in international markets have also contributed significantly to lower production levels in this sector.

The Kootenay coalfields were the hardest hit. The **Fording River** operations of Fording Coal Ltd. went on strike in May with no resolution in sight near year-end. Westar Mining Ltd., operator of both the Balmer and Greenhills mines was forced into bankruptcy at the end of August and the two mines were offered for sale by the bankruptcy trustee. The Balmer mine had been shutdown by a lockout since May but the Greenhills mine remained in production until the end of October. By late December, the Balmer mine had been purchased by Teck Corporation and the Greenhills mine by Fording Coal Ltd. but neither mine had resumed production.

Elsewhere in the Kootenays, the **Line Creek** mine of Line Creek Resources Ltd. continued operations throughout the year. Successful exploration efforts there have expanded reserves. The company is currently developing a new pit on the MSA North zone and is evaluating other newly outlined zones for future production.

The **Byron Creek** thermal coal operation, formerly owned by Esso Resources Canada Limited, was recently sold to employee-owned Corbin Creek Resources Ltd. Most coal produced from this mine is purchased by Ontario Hydro.

On Vancouver Island, near Campbell River, Hillsborough Resources Ltd. recently acquired the **Quinsam** coal mine from Consolidated Brinco Ltd. and is proceeding with a major restructuring to increase profitability. The company plans to increase production four-fold to 1 million tonnes per year. Open-pit production has been cut back and the use of continuous miners underground has improved efficiency. Ore blending to customer specifications has been a key element of production planning. The company is also evaluating options of building new handling facilities at Campbell River, or expanding those at Texada Island, where it currently barges production to be transferred to ocean-going freighters.

MINE CLOSURES

In addition to the coal mine shutdowns in southeastern British Columbia, three mining operations were closed permanently during 1992. The Noranda Inc. **Bell Copper** mine was shut down in May after 18 years of operation. The mine produced 190 million tonnes of ore grading 0.463% copper. Although potential reserves remain at depth, a critical factor is the lack of tailings storage on Newman Peninsula in Babine Lake.

Near Adams Lake, operations at the **Samatosum** silver-zinc-lead-copper-gold mine of Minnova Inc. were suspended prematurely after only three years of production. This operation fell victim to steadily decreasing silver prices, which resulted in a drastic reduction in mineable reserves.

The Cassiar Mining Corporation **McDame asbestos mine** closed following less than two years of failing operations. Difficult ground conditions restricting the development of stopes was the primary problem. The Cassiar operation was placed in receivership in February following 40 years of production.

ADVANCED EXPLORATION AND DEVELOPMENT PROJECTS

At the beginning of the year a number of exploration projects had advanced to, or approached the development stage and throughout the year some have been undergoing various stages of review in the Mine Development Assessment Process. The projects described in this section are shown in Figure A-7 and listed with reserves in Table A-2.

The **Eskay Creek** project, now operated by Homestake Canada Ltd. (formerly by International Corona Corp.) continued with geophysical surveys and diamond drilling on the Eskay stratigraphic horizon. In addition, a 15-tonne bulk sample was taken from the 21B zone for metallurgical test work. Over-all geological resources are 4.75 million tonnes grading 26.13 grams per tonne gold and 932.17 grams per tonne silver; a recently recalculated mining reserve on the 21B Zone orebody is 1.19 million tonnes grading 59.41 grams per tonne gold and 2659.35 grams per tonne silver, together with significant base metal values, using a 12.44 grams per tonne

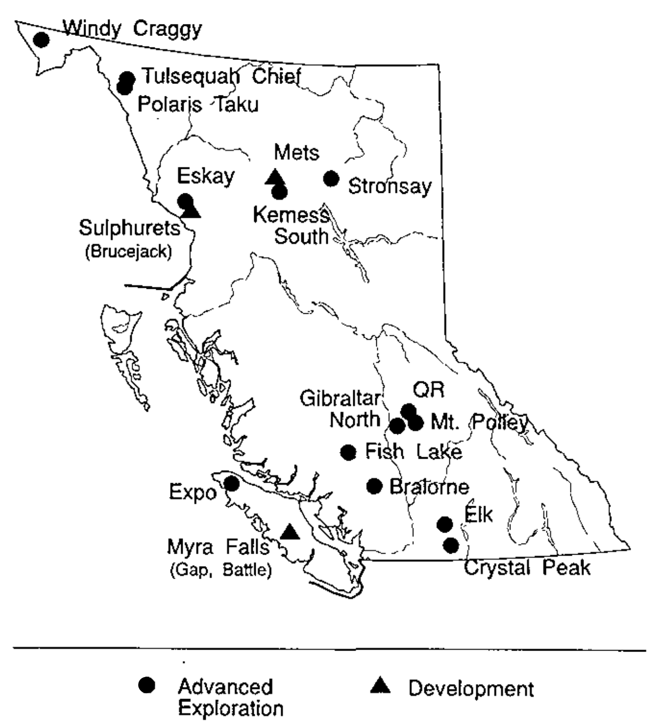

Figure A-7. Advanced exploration/development projects.

TABLE A-2
NEW MINES, DEVELOPMENT AND ADVANCED EXPLORATION PROJECTS

Company Name	Project Name	Commodity	Estimated Tonnes (000s)	Estimated Grade	Reference	Estimated Employment
New Mines						
Timmins Nickel Inc., Habsburg Resources Inc.	Dome Mountain	Au	295	12.34 g/t Au	Habsburg Resources Ltd. 1992	55
Development (Production Decision Announced)						
Westmin Resources Ltd.	Battle Zone/ Myra Falls	Cu, Pb, Zn, Ag, Au	3018	2.9% Cu, 0.4% Pb, 14.0% Zn, 24.0 g/t Ag, 1.0 g/t Au	Westmin Resources Ltd. Oct./92	568
Equity Silver Mines Ltd.	North Waterline Zone	Cu, Ag, Ag	750	0.68% Cu, 209 g/t Ag, 4.18 g/t Au	Equity Silver Mines Ltd. Sept./92	
Cheni Gold Mines Ltd. Golden Rule Resources Ltd. Manson Creek Resources Ltd.	Mets	Au	53.5	11.62 g/t Au	Cheni Gold Mines Ltd. 1992	
Advanced Exploration						
Geddes Resources Ltd.	Windy Craggy	Cu, Au, Ag, Co	297 440	1.38% Cu, 0.2 g/t Au, 3.83 g/t Ag, 0.069% Co	Geddes Resources Ltd. Annual Rept. 1991	600
Curragh Resources Ltd Asturiana de Zinc	Stronsay (Cirque)	Pb, Zn, Ag	22 080	2.8% Pb, 9.4% Zn, 60 g/t Ag	Curragh Resources Ltd. MDAP Stage I Report	300+
Homestake Canada Ltd.	Eskay Creek 21B	Au, Ag	1190	59.41 g/t Au, 2659.3 g/t Ag	Homestake Canada Ltd. Oct./92	200+
Gibraltar Mines Ltd.	Gibraltar North	Cu	50 000+	0.4% Cu	Gibraltar Mines Ltd.	
Redfern Resources Ltd.	Tulsequah Chief	Cu, Pb, Zn, Au, Ag	7800	1.6% Cu, 1.18% Pb, 6.47% Zn 2.74 g/t Au, 109.72 g/t Ag	Redfern Resources Ltd. Oct./92	
Canarc Resources Corp. Suntac Minerals Corp.	Polaris-Taku	Au	2590	14.74 g/t Au	Suntac Minerals Corp. Press Release, Oct./92	
Newhawk Gold Mines Ltd. Granduc Gold Mines Ltd.	Brucejack Lake (Bruceside)	Au, Ag	749.3 (West Zone)	15.43 g/t Au, 647.2 g/t Ag	Newhawk Gold Mines Ltd. Press Release Oct./92	50 - 60
Fairfield Minerals Ltd.	Elk	Au	308.4	22.18 g/t Au, 24.68 g/t Ag	Fairfield Minerals Ltd.	
Taseko Mines Ltd.	Fish Lake	Cu, Au	1 080 000	0.23% Cu, 0.41 g/t Au	Taseko Mines Ltd. Press Release, Oct./92	300+
El Condor Resources Ltd. St. Philips Resources Inc.	Kemess South	Cu, Au	207 000	0.23% Cu, 0.64 g/t Au	El Condor Resources Ltd. MDAP Prospectus 1992	300+
Jordex Resources Inc.	Expo/Hushamu	Cu, Au, Mo	173 260	0.25% Cu, 0.31 g/t Au 0.01% Mo	Jordex Resources Ltd. Oct-92	
Imperial Metals Corp.	*Mount Polley*	*Cu, Au*	*49000*	*0.38% Cu, 0.55 g/t Au*	*Imperial Metals Corp.* MDAP, Oct./92	
CMP Resources Ltd.	Q R	Au	1200	5.2 g/t Au	CMP Resources Ltd. N.Miner, Oct 5/92	

gold cut-off. Feasibility studies are currently in progress on the project and are expected to be completed to submit an application to the Mine Development Review Process by June of 1993.

One of the best known and controversial advanced exploration projects in British Columbia has been the **Windy Craggy** project, operated by Geddes Resources Ltd. In 1991 this project completed Stage I of the Mine Development Assessment Process. In 1992, however, review of the project was suspended in deference to a newly initiated land and water use evaluation of the area by the provincial Commission on Resources and the Environment (CORE, *see* New Initiatives). A re-evaluation of the overall reserves of the deposit now stands at approximately 300 million tonnes grading 1.38% copper, applying a 0.5% copper cut-off. Of additional importance to the project is the initiation by the BC Geological Survey of a regional mapping and mineral potential evaluation of the Tatsenshini area. This study discovered **a new high-grade copper massive sulphide zone** on the Geddes property about 5 kilometres southeast of the main deposit.

The **Tulsequah Chief** copper-lead-zinc-gold-silver project, operated by Redfern Resources Ltd., is located 75 kilometres northeast of Juneau, Alaska. Redfern continued underground drilling to test up-dip and down-dip extensions of the deposit, and is particularly encouraged that the H lens has been extended to depth. The deposit is a Kuroko-type volcanogenic massive sulphide deposit hosted by Devonian felsic volcanic rocks. It was mined from 1951 to 1957 by Cominco Ltd. Drilling since 1987 has delineated reserves of 7.8 million tonnes grading 1.6% copper, 1.2% lead, 6.5% zinc, 2.74 grams per tonne gold and 109.7 grams per tonne silver. The government of Alaska is evaluating the feasibility of building a road to the British Columbia border, close to the project.

A few kilometres southwest of the Tulsequah Chief property, Suntac Minerals Corporation and Rembrandt Gold Mines Ltd. are proceeding with drilling on the **Polaris-Taku** deposit. The companies hope to double reserves with infill and stepout drilling. Work has confirmed the extension of the C-vein. The property was operated before and after the Second World War and produced 690 000 tonnes averaging 10.28 grams per tonne gold. Gold mineralization occurs in a mesothermal quartz-carbonate vein system in Paleozoic or Triassic rocks. Suntac has explored the property since 1988. Recently published geological reserves are 2.59 million tonnes grading 14.74 grams per tonne gold, with a cut-off grade of 8.6 grams per tonne.

Prospecting and trenching on the Northair Mines Ltd. **Brucejack Lake** (Bruceside) gold project at Sulphurets Creek turned up several new gold prospects, the best known is the "**SG**" zone. The zone is 130 metres long, 3 metres wide, with an average surface sample grade of 20.71 grams per tonne gold and 38.39 grams per tonne silver. The company is currently evaluating the possibility of shipping ore from the **Brucejack West zone** to Westmin's Premier mill, north of Stewart. The West zone is a vein and stockwork system containing 750 000 tonnes averaging 15.4 grams per tonne gold and 678 grams per tonne silver.

At the **Kemess South** project, El Condor Resources Ltd. (60%) and St. Philips Resources Inc. (40%) have delineated a calcalkaline porphyry gold-copper deposit of approximately 207 million tonnes grading 0.23% copper and 0.64 gram per tonne gold. Much of the definition drilling and metallurgical testwork planned for 1992 was deferred. El Condor directed its 1992 efforts to the adjacent, wholly owned Kemess North property (*see* Exploration Highlights). The Kemess properties are located southeast of the Toodoggone district, close to the Omineca mine road. El Condor has submitted a prospectus to the Mine Development Assessment Process and has begun environmental impact studies. Estimated capital costs for development are $350 million.

The **Stronsay** (Cirque) lead-zinc-silver project of Curragh Resources Inc., north of Williston Lake, has experienced delays and uncertainties. However, issues related to the Mine Development Assessment Process (MDAP) have been resolved and a Mine Development Certificate was issued in December 1992. At Stage I of the MDAP, reserves were reported as 22.08 million tonnes of 2.8% lead, 9.4% zinc and 60 grams per tonne silver. Capital costs are estimated at approximately $155 million.

The **Telkwa** coal project was recently acquired by Manalta Coal Ltd. from Shell Canada Resources Ltd. and is in the Mine Development Assessment Process. Production of one million tonnes per year is planned, at a capital investment of $80 million. Reserves of 57 million tonnes occur in two zones. In 1992, Minalta completed a 5000-metre drilling program to upgrade reserves in the North Zone deposit.

In October of 1992 a Mine Development Certificate was issued to Imperial Metals Corporation to develop the **Mount Polley** porphyry copper-gold deposit, located 56 kilometres northeast of Williams Lake. The certificate allows the company to proceed with open-pit development and production at 13 700 tonnes per day, on an initial ten-year mining reserve of 49 million tonnes grading 0.38% copper and 0.55 gram per tonne gold. Capital costs are estimated at $150 million; production costs are projected to be $0.45 per pound of copper. Subject to successful financing, construction is tentatively scheduled to start in 1993 and production in 1995.

Elsewhere in the Cariboo region, CMP Resources Ltd. has recently bought the **QR** alkali porphyry gold deposit from Rea Gold Corporation. This project has an Approval-in-Principle in good standing until July 1995. Total reserves, in three separate and widely spaced gold zones, are in the order of 1.2 million tonnes averaging about 5.2 grams per tonne gold. CMP has announced that it intends to proceed with underground bulk sampling in preparation for development as soon as possible.

At the **Fish Lake** porphyry copper-gold project, Taseko Mines Limited has completed an extensive program of some 69 000 metres of diamond drilling. As a result of this program, Taseko has announced an over-all geological reserve of 1.08 billion tonnes grading 0.23% copper and 0.41 gram per tonne gold, applying a 0.52% copper equivalent cut-off grade. The deposit has been drilled off at 100-metre centres, which has effectively doubled the extent of known mineralization and geological data. At approximately $C7.0 million in exploration expenditures, this has been the largest single exploration project in the province during 1992. Taseko expects to complete pre-feasibility stage evaluation by mid-1993.

In the Bridge River camp, Avino Mines and Resources Ltd. has submitted a prospectus application for a Mine Development Certificate to re-open the **Bralorne mine**. Avino's program is the third attempt to bring the mine back into production since 1983. The deposit is a mesothermal gold-silver vein system that produced continuously from 1932 to 1971. Combined with the neighboring Pioneer deposit, it produced more than 127 metric tonnes of gold.

In the southern interior of the province, near Merritt, Fairfield Minerals Ltd. has submitted the **Elk** project for Mine Development Assessment. The Siwash North zone is a small, high-grade gold-silver vein deposit with current reserves of 308 400 tonnes grading 22.18 grams per tonne gold and 24.68 grams per tonne silver. During the year Fairfield initiated a bulk sampling program on the vein. The first sample of 517 tonnes had an estimated grade of 130.3 grams per tonne gold and 99.4 grams per tonne silver. A larger sample is to be shipped later in the year.

In the northern Vancouver Island copper belt Jordex Resources Ltd. continued work on the **Expo/Hushamu** porphyry copper-gold project. Established reserves in the deposit are in two zones totalling 173.3 million tonnes that grade 0.25% copper, 0.01% molybdenum and 0.31 gram per tonne gold. The current strategy is to increase reserves by outlining additional tonnages between the zones to facilitate the design of a larger pit. Ultimate production plans would probably see ore from this deposit shipped to the Island Copper operation for milling.

The **Crystal Peak garnet project**, operated by Polestar Exploration Ltd. near Hedley in southern British Columbia is still in the Mine Development Assessment Process. Concern was raised in 1991 over this project because of possible impacts on other land uses in the area, particularly on the adjacent Apex Mountain ski area. A report commissioned by government early in 1992 to examine marketing prospects, cost-benefit analysis and aboriginal concerns, determined that the project would, in general, not have major impacts on other activities in the area. A number of measures to harmonize land uses with the project were proposed. Further study on garnet marketability is currently in progress.

HIGHLIGHTS OF MAJOR EXPLORATION PROJECTS

Gold-enriched porphyries, polymetallic massive sulphide deposits and veins and transitional deposits remained the exploration targets of choice during 1992 in British Columbia. The inherent potential for discovering another Highland Valley Copper, Sullivan or Snip deposit in the diverse spectrum of metallogenic environments in the province continues to motivate explorationists. The properties mentioned below are shown in Figure A-8 and listed in Table A-3 with estimated preliminary reserves, when available.

PORPHYRY COPPER-GOLD DEPOSITS

In the Sulphurets Creek area, north of the Stewart camp, work by Placer Dome Inc. and predecessors in the area has established the existence of a complex area of porphyry mineralization several kilometres in diameter, that contains at least three major porphyry copper pros-

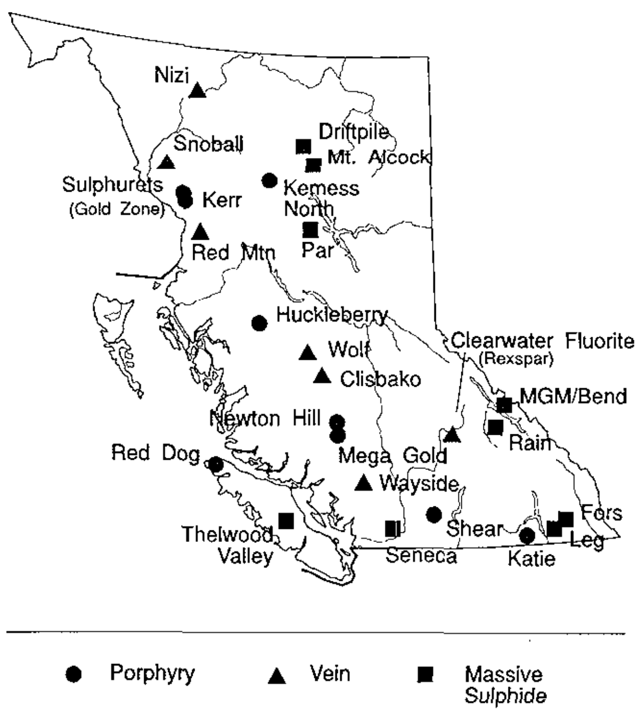

Figure A-8. Exploration highlight projects.

TABLE A-3
1992 EXPLORATION HIGHLIGHTS

Company Name	Project Name	Commodity	Estimated Tonnes (000s)	Estimated Grade	Reference	Exploration Expenditures ($ Millions)
Placer Dome Inc.	Kerr	Cu, Au	126 000	0.62% Cu, 0.274 g/t Au	Placer Dome Inc.	1.2
Placer Dome Inc.	Sulphurets Gold (Sulphside)	Au, Cu	18 000	0.35% Cu, 0.823 g/t Au	Placer Dome Inc.	1.3
New Canamin Res. Ltd.	Huckleberry	Cu, Au	78 000	0.401% Cu, 0.025% MoS2	CIM Spec Vol 15	0.55
El Condor Res. Ltd.	Kemess North	Cu, Au	116 109	0.19% Cu, 0.377 g/t Au	El Condor Res. Ltd.	1.0
Placer Dome Inc.	Shear	Cu, Au	n/a	n/a		0.3
Yellowjack Res. Ltd.	Katie	Cu, Au	n/a	n/a		0.385
Crew Natural Res. Ltd.	Red Dog	Cu, Au, Mo	25	0.35% Cu, 0.44g/t Au 0.006% Mo	Crew Natural Res.	n/a
Cominco Ltd.	Par	Pb, Zn,Ag,Ba	n/a	n/a		0.5
Teck Explorations Ltd. Cominco Ltd.	MGM/Bend	Zn, Pb, Ag	n/a	n/a		0.6
Kokanee Explorations Ltd., Chapleau Res. Ltd., Barkhor Res. Inc.	Fors	Ag, Pb, Zn	n/a	n/a		0.3
Kokanee Explorations Ltd., Legion Res. Ltd.	Leg	Zn, Ag, Ba	n/a	n/a		0.25
Minnova Inc., International Curator Res. Ltd.	Seneca	Zn, Cu, Au, Ag	533	0.91% Cu, 0.22% Pb, 7.06% Zn, 68.8 g/t Ag, 1.44 g/t Au	Minnova Inc.	0.25
Westmin Resources Ltd.	Thelwood Valley (Myra Falls)	Cu, Pb, Zn, Ag, Au	n/a	n/a		3.5 (includes Gap, Battle)
Lac Minerals Ltd.	Red Mountain (Marc Zone)	Au	840	12.68 g/t Au	Lac Minerals Ltd.	1.19
Gold Fields Canadian Mining Ltd.	Nizi	Au, Ag	n/a	n/a		0.6
Minnova Inc.	Wolf	Au	n/a	n/a		0.35

pects as well as the Brucejack Lake gold vein deposit. Placer Dome's main focus has been on two zones: the **Kerr** deposit and the **Sulphurets Gold zone**. The Kerr deposit is a deformed porphyry copper-gold deposit, hosted by Early Jurassic volcanic and sedimentary rocks. Previous drilling established a geological resource of 126 million tonnes grading 0.62% copper and 0.274 gram per tonne gold. Work in 1992 was directed to improving grade estimates in this zone through better core recoveries.

Two kilometres north of the Kerr deposit, Placer Dome Inc. also continued drilling on the **Sulphurets Gold zone** (Sulphside). Porphyry mineralization is associated with strongly silicified quartz monzonite dikes and sills that intrude altered epiclastics and tuffs. With a pre-1992 drill-indicated resource of 18 million tonnes grading 0.35% copper and 0.823 gram per tonne gold, this property offers potential support for the Kerr project.

In the Tahtsa Reach area, east of the Coast Mountains, New Canamin Resources Ltd. has undertaken a re-evaluation of the **Huckleberry** porphyry copper-molybdenum deposit, completing two phases of diamond drilling. This property was explored extensively in the 1960s and 1970s. Published reserves are in the order of 78 million tonnes grading 0.401% copper and 0.025% molybdenite. The current objective is to establish a higher grade "starter pit" of about 30 million tonnes averaging 0.5 to 0.6% copper. Copper zoning in the deposit appears to offer good potential for this to be accomplished.

At the **Kemess North** property, El Condor Resources Ltd. (100%) has delineated a geological reserve of 115 million tonnes grading 0.19% copper and 0.39 gram per tonne gold. At present this deposit is considered to be uneconomic and would be evaluated as a supplemental reserve when production from the main Kemess South deposit is achieved.

In the central Nicola volcanic belt in the southern interior, Placer Dome Inc. has had moderately encouraging drill results on the **Shear** copper-gold property, optioned from Northair Mines Ltd. The project covers several copper prospects associated with subvolcanic dioritic and monzonitic intrusive breccias in Upper Triassic Nicola volcanic rocks. The property is strategically located 25 kilometres southeast of the town of Merritt. It is crossed by a four-lane highway and a power transmission line.

Yellowjack Resources Ltd., in a joint venture with Hemlo Gold Mines Ltd. and Brenda Mines Ltd., continued with a major drilling program on the **Katie** porphyry copper-gold project. The property is located in the Salmo area of southeastern British Columbia. Mineralization is associated with Lower Jurassic Rossland Group volcanic rocks and comagmatic diorite intrusions. Of three zones tested by drilling, the Main zone so far shows the best continuity and size potential. Grades there range from 0.10 to 0.53% copper and from 0.1 to 1.15 grams per tonne gold. With the 1992 work, Yellowjack has increased its interest in the project to 57%.

In the northern Vancouver Island copper belt, Crew Natural Resources Ltd. has established mineable reserves on the **Red Dog** copper-gold deposit of 25 million tonnes grading 0.35% copper and 0.44 gram per tonne gold at a 0.2% copper cut-off grade. Crew Natural has submitted a prospectus to the Mine Development Assessment Branch. The production scenario is to convey 20 000 tonnes of ore per day to Holberg Inlet and barge it to the Island Copper mine of BHP-Utah for milling.

POLYMETALLIC MASSIVE SULPHIDE DEPOSITS

The returning exploration interest in base metals, particularly in the higher grade zinc-rich massive sulphide deposits, has developed in parallel with the recent porphyry programs. The success of projects such as Tulsequah Chief and the new discoveries at Myra Falls are indications of continued trends in short and intermediate term exploration programs for targets of this type.

In the **Gataga** district and adjacent areas in northeastern British Columbia several Devonian sedimentary exhalative barite-zinc-lead-silver prospects, explored extensively in the early 1980s, have been re-activated. As well, the recent advanced exploration and pre-development on the Stronsay (Cirque) deposit has contributed to the attraction of the area. Teck Explorations Ltd. carried out preliminary work on the **Mount Alcock** and **Bear** deposits and **Driftpile** prospects. In the same area, Minnova Inc. has acquired the **Pie, Akie** and **Yuen** prospects. Both companies plan more extensive programs in 1993.

Northeast of Germansen Landing, Cominco Ltd. has undertaken an aggressive drilling program on the **Par** lead-zinc-silver-barite project. This property covers a Paleozoic sequence of Cambrian to Devonian clastic and carbonate rocks. Within the section, stratiform horizons of galena, sphalerite and barite mineralization are hosted by shales and carbonate rocks. The 1992 work is follow-up to encouraging geochemical and trenching programs carried out in 1991.

On the northeast side of McNaughton Lake, in the Columbia River area, Teck Explorations Ltd. and Cominco Ltd. completed the second phase of an extensive drilling program on the **MGM/Bend** zinc-lead-silver project. Mineralization occurs in Cambrian Tzar Creek metapelites, near the contact with overlying Chancellor Group limestones. Massive and disseminated pyrrhotite, sphalerite and galena occur in thin horizons traced for approximately 7 kilometres by surface surveys and diamond drilling.

In the Purcell Mountains of southeastern British Columbia, a new sedimentary exhalative massive sulphide discovery has been made by the joint venture of Consolidated Ramrod Gold Corporation, Chapleau Resources Ltd. and Barkhor Resources Inc. on the Fors lead-zinc-silver prospect. The property is located southwest of Cranbrook near Munroe Lake. The discovery hole intersected 3.0 metres of crudely bedded massive sulphides grading 7.25% zinc, 6.47% lead and 66.9 grams silver per tonne and over 130 metres of "vent complex" rocks including albitic alteration and tourmalinized fragmentals with extensive low-grade lead and zinc mineralization. Hostrocks are siltstones and argillites of the Middle Proterozoic Aldridge Formation.

On Wilds Creek, north of Creston, Consolidated Ramrod Gold Corporation drilled the **Leg** prospect to further delineate bedded zinc-barite mineralization in clastic sediments high in the Purcell Supergroup stratigraphy. The 1992 work confirmed previous intersections of two such horizons.

East of Vancouver, Minnova Inc. continued work on the **Seneca** project. This property comprises Kuroko-type massive sulphide lenses hosted by felsic volcanic rocks of the mid-Jurassic Harrison Lake Formation. Minnova explored south of the Fleetwood zone under the Chehalis River valley. One encouraging intersection returned 3.2 metres of 1.83% copper, 23.3% zinc, 1.71% lead, 121.6 grams per tonne silver and 2.13 grams per tonne gold.

At the **Myra Falls** mine, near Buttle Lake, Westmin Resources Limited is exploring the extension of the H-W horizon in the **Thelwood valley** (*see* Operating Mines). The area of interest is in a faulted-off section of the mine stratigraphic sequence, where encouraging drill intersections early in the year have prompted a more aggressive program.

PRECIOUS METALS BEARING VEINS AND TRANSITIONAL DEPOSITS

Exploration targets in this category cover a broad spectrum of epigenetic mineral deposits. They include deeper level mesothermal veins, high-level epithermal deposits and those that form in transitional zones at intermediate depths.

Northeast of Stewart, near the eastern margin of the Coast Ranges, Lac Minerals Ltd. continued with a successful program on the **Red Mountain** project. Among several significant gold prospects on the property, the Marc and North zones are the most economically important to date. The Marc zone has a preliminary geological resource of approximately 840 000 tonnes grading 12.68 grams per tonne gold. Detailed geological work in 1992 refined the deposit model, and added additional potential reserves to the North zone. New mapping suggests that the volcanic rocks cut by the Goldslide intrusion may be older (Stuhini?) than previously believed.

On the **Nizi** property, northeast of Dease Lake, Gold Fields Canadian Mining Limited diamond drilled epithermal gold-silver-barite mineralization in the Devono-Mississippian Sylvester Group.

Minnova Inc. continued work on the **Wolf** gold project in Eocene Ootsa Lake volcanic rocks. Epithermal gold mineralization occurs as sulphide-bearing banded chalcedonic quartz veins and breccia matrix. A previous interpretation that the mineralization was cut off by thrust faulting was apparently invalidated by this season's drilling program.

INDUSTRIAL MINERALS

Exploration interest in industrial minerals has shown a significant increase recently, with the slow-down in metallic minerals activity. In southern British Columbia, particularly, applications to develop various types of construction stone products have been on the rise. Among these are projects to produce marble, limestone, granitic dimension stone, feldspar and silica sand. In the southern Fraser Canyon, Cromlech Ltd. has applied to recover unconsolidated silica and feldspar sand deposits at Scuzzy Creek; at Sumas Mountain, near Abbotsford, Quality Mineral and Industry Supply Co. Ltd. proposes to develop a sodic feldspar deposit.

The existing spectrum of successful industrial minerals operations has provided encouragement to potential developers, as the variety and availability of high quality commodities is recognized. Examples of such operations are the barite and silica operations of Mountain Minerals Ltd. near Golden. This company has been a long-established supplier of barite to the drilling industry and relatively pure quartz to glass producers. Elsewhere in the region, Baymag Mines Co. Ltd. produces magnesite; gypsum is mined at Lussier River and Windermere by Domtar Construction Materials Ltd. and Westrock Industries Ltd., respectively. Lime for cement and other industrial uses is produced by Lafarge Ltd. at Kamloops and Continental Lime Ltd. at Pavilion.

NEW INITIATIVES IN BRITISH COLUMBIA

Several new programs that will have a significant influence on future mineral resource development in British Columbia were initiated in 1992.

On July 13, 1992 the provincial government passed the *Commissioner on Resources and Environment Act*. The **Commission on Resources and Environment** (CORE) created by this act, is charged with developing a province-wide land-use strategy.

As land use and resource management are major factors that will influence future directions in the mineral resource industry, the government of British Columbia approved a multi-agency program entitled **Corporate Resource Inventory Initiative (CRII)** to establish the inventories of the major land based resources of the province. As a part of this initiative, the Geological Survey Branch of the Ministry of Energy, Mines and Petroleum Resources has undertaken a project to evaluate the mineral potential of British Columbia. The **Mineral Potential Project** will evaluate known and unknown resources, that will be expressed in a variety of themes and formats such as in-place value, industry activity, revenues and employment. The databases established will be used for the evaluation of current and future applications and will be maintained on a geographic information system (GIS) and updated as conditions and knowledge change.

During the first year of the project the priority areas evaluated are Vancouver Island, the Kootenays and parts of the Cariboo-Chilcotin region. The scheduled completion date for these three areas is April, 1993.

A third major initiative undertaken in British Columbia during 1992 is the development of a **Protected Area Strategy** for the province. This initiative was introduced as part of the new government's commitment to preserve 12% of the land base. The strategy incorporates previous programs including provincial and national parks, old-growth areas, wildlife habitats, ecological reserves and heritage sites. Under the program protected areas become part of a broad spectrum of land-use designations that will range from Special Management Lands, Multiple Resource Use areas, Major Development Projects to Settlement Lands.

SUMMARY AND OUTLOOK FOR 1993

In the current period of re-adjustment in the exploration industry in British Columbia, operators are evaluating many previously explored targets. A number of major mineral deposits discovered in the pre-1980 period are undergoing serious scrutiny in anticipation of improved metal markets and a potential upturn in the business cycle.

Sediment-hosted zinc-rich and volcanogenic copper-rich polymetallic massive sulphide deposits offer small to medium tonnage and high-grade potential, particularly those enriched in precious metals. The many copper-bearing porphyry deposits discovered during the 1970s continue to receive major exploration efforts, which may very well lead to the next new mine to be developed in the province.

Currently, there are several advanced projects that are potentially close to a pre-production development decision. The Mount Polley and QR projects have most approvals in place to go ahead. Imperial Metals is negotiating financing arrangements for Mount Polley and CMP Resources Ltd. plans to carry out bulk sampling and metallurgical work at QR. Approvals for the Curragh Resources' Stronsay project are expected in the near future. Here too, funding is expected to be an important hurdle to overcome. The option of custom milling is looking attractive to some operations such as the Premier mine. The viability of this approach will indoubtedly be considered for a number of small, high-grade deposits. Other major projects such as Kemess, Elk and Red Dog are at, or near, the entry stage of the permitting process.

ACKNOWLEDGMENTS

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TABLE A-4
ACTIVE EXPLORATION PROPERTIES IN B.C. 1992

Property (Operator)	MINFILE Number	Mining Division	NTS	Commodity	Deposit Type	Work Done
NORTHWESTERN DISTRICT						
Babs (Equity Silver Mines Ltd.)		Omineca	093L/16E	Cu, Au	Porphyry	7ddh, 322 m; geochem; IP; mag;EM; mapping; test pits
Bandit (North American Metals Corp.)	104K 086	Atlin	104K/1E	Au, Ag, Cu	Vein	trenching; geochem; IP; mapping
Bear Pass (Hugh/Pam/Ken) (Trev Corp.)	104A 028	Skeena	104A/4E	Au, Ag, Zn		1400 geochem samples
Brenda (Canasil Resources Inc.)	094E 107	Omineca	94E/7W	Au, Cu	Stockwork, breccia	13 ddh, 721 m
Dome Mountain (Timmins Nickel Inc.)	093L 276	Omineca	93L/10, 15	Au, Ag, Zn	Vein	13 ddh, 1045 m
Engineer (Ampex Mining)	104M 014	Atlin	104M/8E	Au, Ag, Sb, Te	Epithermal vein	203 t stoped
Equity Silver (Equity Silver Mines Ltd.)	093L 001	Omineca	93L/1W	Ag, Cu, Au		37 u/g ddh, 2922 m
Eric (Equity Silver Mines Ltd.)		Omineca	93L/2W	Ag, Cu		6 ddh, 440 m
Eskay Creek/GNC (Homestake Canada/Int. Corona)	104B 008	Skeena	104B/9W	Au, Ag	VMS/epithermal	15 t bulk sample; 8 ddh, 3658 m; IP; seismic; downhole EM
Foremore (Cominco Ltd.)		Liard	104G/2, 3	Zn, Pb, Ag, Au, Cu	Submarine exhalative	UTEM; mag; radar sounding
Freemont (Timmins Nickel Inc.)	093L 141	Omineca	93L/10E	Au, Ag, Cu, Pb, Zn	Vein	1 ddh, 198 m
GIM (Zappa Resources Ltd.)	104B 292	Liard	104B/10W	Au	Skarn	1 ddh, 60 m; mapping; geochem
Golden Bear (North American Metals Corp.)	104K 079	Atlin	104K/1W	Au	Epithermal	29 ddh, 5656 m; IP; geochem; recce mapping
Hank (Homestake Canada Ltd.)	104G 107	Liard	104G/1W, 2E	Au, Ag	Epithermal	IP; mapping; geochem
Huckleberry (New Canamin Resources Ltd.)	093E 037	Omineca	93E/11E	Cu, Mo	Porphyry	36 ddh, 4900 m
Kerr (Placer Dome Inc.)	104B 191	Skeena	104B/8, 9	Cu, Au	Porphyry	10 ddh, 1587 m; 125 ddh relogged; IP
Kutcho Creek (Cominco Ltd.)	104I 060	Liard	104I/1W	Cu, Zn, Au, Ag	VMS	UTEM; relogging; geochem
Lawyers (Cheni Gold Mines Inc.)	094E 066	Omineca	94E/6E	Au, Ag	Epithermal vein	24 ddh; trenching; prosp.
Limonite Creek (Cyprus Canada Inc.)	093L 075	Omineca	93K/12W	Cu		3 ddh, 395 m; EM; mapping; geochem
Louise Lake (Equity Silver Mines Ltd.)	093L 079	Omineca	93L/13E	Cu, Au, Mo	Porphyry	13 ddh, 2652 m
MR (Equity Silver Mines Ltd.)		Omineca	93M/2	Cu, Ag		8 ddh, 795 m
Mets (Cheni Gold Mines Inc.)	094E 093	Liard	94E/6W	Au, Ag	Epithermal vein	decline, crosscut, drifting

Property (Operator)	MINFILE Number	Mining Division	NTS	Commodity	Deposit Type	Work Done
Nizi (Gold Fields Canadian Mining Ltd.)	104I 032	Liard	104I/14, 15	Au, Ag, Pb, Zn	Epithermal vein	8 ddh, 1300 m; geophys; trenching
Pitt/Trinity (Inco Limited)	103H 066	Skeena	103H/12	Cu, Pb, Zn, Ag, Au	VMS	HLEM; VLFR; mag; air EM; geochem
Polaris Taku (Suntac Minerals Corporation)	104K 003	Atlin	104K/12E	Au	Mesothermal vein/rpl	22 ddh, 6340 m
Polo (American Fibre Corp.)		Skeena	104B/9W	Ag, Au	VMS/epithermal	Mag; VLF-EM; geochem; mapping
Premier Gold (Westmin Resources Ltd.)	104B 054	Skeena	104B/1E	Au, Ag, Pb, Zn	Epithermal vein	38 u/g ddh, 917 m
Red Mountain (Lac Minerals Ltd.)	103P 086	Skeena	103P/13	Au, Ag, Zn		13 ddh, 3998 m; mapping; EM, IP
Shure (Westmin Resources Limited)	104A 014	Skeena	104A/4	Au, Ag	Epithermal vein	7 ddh, 675 m; IP, VLF-EM, mag
Snip (Cominco Ltd.)	104B 250	Liard	104B/11E	Au, Ag	Shear-hosted vein	27 u/g ddh, 5000 m; 14 sfc ddh, 3208 m
Snoball (Noranda Exploration Co. Ltd.)		Liard	104G/1W	Au	Vein	12 ddh, 1505 m; trenching
Spectrum (Columbia Gold Mines Ltd.)	104G 036	Laird	104G/9W, 10	Au, Cu	Vein/porphyry/ breccia	6 ddh, 710 m
Strike (Navarre Resources Corp.)	104A 010	Skeena	104A/4W	Cu, Pb, Zn, Ag, Au	Vein	mapping; EM; geochem; trenching
Su (A. L'Orsa)	093L 303	Omineca	93L/15E	Zn, Ag, Pb	VMS?	1 ddh, 88 m; trenching
Sul/Nica (Placer Dome Inc.)		Skeena	104B/9	Au, Cu	Shear-hosted porphyry	4 ddh, 591 m
Sulphurets Gold (Placer Dome Inc.)	104B 182	Skeena	104B/9	Cu, Au	Porphyry	23 ddh, 5577 m
Sulphurets-Bruceside (Newhawk Gold Mines Ltd.)	104B 193	Skeena	104B/8E	Au, Ag	Vein	geochem; mapping; prosp.
Telkwa Coal (Manalta Coal Ltd.)	093L 152	Omineca	93L/11	coal	Coal	19 ddh, 2407 m; 24 rdh, 2380 m; mag; EM; DC profiling
Tennyson (Teuton Resources Corp.)	104B 167	Skeena	104B/8E	Au, Ag	Vein	5 ddh, 396 m
Treaty Creek (Tantalus Resources Ltd.)	104B 078	Skeena	104B/9W	Au, Ag	Vein	trenching; sampling; mapping
Tulsequah Chief (Redfern Resources Ltd.)	104K 002	Atlin	104K/12, 13	Cu, Pb, Zn, Au, Ag	VMS	13 u/g ddh, 5000 m; sfc mapping
CENTRAL DISTRICT						
Andy (Placer Dome Inc.)	93N 121	Omineca	92N/7	Au, Cu	Alkali porphyry	geochem; geophys
Att (Placer Dome Inc.)		Omineca	94D/15	Au, Cu	Porphyry	geochem; geophys
CH (Placer Dome Inc.)	93F 001	Omineca	93F/7E, 8W	Au, Ag	Porphyry/ epithermal	13 ddh, 1700 m

Property (Operator)	MINFILE Number	Mining Division	NTS	Commodity	Deposit Type	Work Done
Cas (Placer Dome Inc.)		Omineca	94E/2	Au, Cu	Porphyry	geochem; geophys
Cat (Placer Dome Inc.)	93C 069	Omineca	94C/3	Au, Cu	Alkali porphyry	VLF, IP, mag
Clisbako (Minnova Inc.)		Cariboo	93B/12, 93C/9	Au, Ag	Epithermal	15 ddh; geochem; geophys
Continental Jade (Jade West Res. Ltd.)	093N 165	Omineca	93N/13W	Jade	Replacement	100 pdh, 500 m; trenching
Darb (Swannell Minerals Corp.)		Omineca	94D/9E	Au, Cu	Porphyry	4 ddh, 800 m; geochem; geophys
Dominion Creek (Allan Raven)	93H 133	Cariboo	93H/6	Pb, Zn, Au, Ag	Vein/replacement	bulk sample; pilot mill test
Gibraltar North (Gibraltar Mines Ltd.)	93B 007	Cariboo	93B/9W	Cu	Porphyry/ shear hosted	67 ddh, 17 429 m
Hal (Swannell Minerals Corp.)		Omineca	93N/6	Au, Cu	Porphyry	4 ddh, 800 m; geochem; geophys
Jan (Placer Dome Inc.)		Omineca	93N/7	Au, Cu	Alkali porphyry	geochem; geophys
Jane - Plateau (Zwlon Enter. Ltd.)		Cariboo	93A/14W	Au	Vein	5 ddh, 250 m; geochem; geophys
Joh (Swannell Minerals Corp.)		Omineca	94D/9E	Au, Cu	Porphyry	4 ddh, 2400 m; geochem; geophys
Kemess North (El Condor Res. Ltd.)	94E 021	Omineca	94E/2	Au, Cu	Porphyry	90 ddh; geochem; geophys
Kemess South (El Condor Res. Ltd.)	94E 094	Omineca	94D/15, 94E/2	Au, Cu	Porphyry	36 ddh, 6000 m; prefeasibility
Lake (Placer Dome Inc.)		Omineca	93O/4W	Au, Cu	Alkali porphyry	4 ddh; geophys
Lustdust (Alpha Gold Corp.)	93N 009	Omineca	93N/11W	Zn, Ag	Replacement	10 ddh, 2500 m; trenching
Max (Rio Algom Expln., Inc.)	93K 020	Omineca	93K/16	Au, Cu	Alkali porphyry	6 ddh, 600 m; geochem
Mitzi (Noranda Expln. Co. Ltd.)	93N 096	Omineca	93N/1W	Au, Cu	Alkali porphyry	6 ddh; geophys
Mouse Mountain Teck Explorations Ltd.)	93G 005	Cariboo	93G/1W	Au, Cu	Porphyry	7 ddh, 951 m
Mt. Alcock (Teck Explorations Ltd.)	94F 015	Omineca	94F/11W	Pb, Zn, Ag	Sedex	geochem; gravity
Nor (Rio Algom Expln. Inc.)	94E 094	Omineca	94D/15 94E/2	Au, Cu	Porphyry	18 ddh, 4520 m
Pal (Swannell Minerals Corp.)		Omineca	94C/5E, 6W	Au, Cu	Porphyry	4 ddh, 800 m; geophys; geochem
Par (Cominco Ltd.)	95C 024	Omineca	94C/2, 3	Pb, Zn, Ag	Sedex	17 ddh, 3000 m; geophys; geochem
Prince (Cominco Ltd.)		Cariboo	93G/10	Au, Cu	Porphyry	2 ddh, 300 m

Property (Operator)	MINFILE Number	Mining Division	NTS	Commodity	Deposit Type	Work Done
South Gatage (Minnova Inc.)	94F 014	Omineca	94F/13	Pb, Zn, Ag	Sedex	geochem; mapping
Spanish Mountain (Eastfield Res. Ltd.)	93A 043	Cariboo	93A/11W	Au	Vein	geochem; bulk sample; pilot mill test
Sustut (Beauchamps Expln. Inc.)	94D 065	Omineca	94D/7, 10	Au, Cu	Porphyry, VMS	5 ddh; geochem; geophys
Tut (Swannell Minerals Corp.)		Omineca	94C/5E	Au, Cu	Alkali porphyry	4 ddh, 600 m; geochem; geophys
Wolf (Minnova Inc.)	093F 045	Omineca	93F/3W	Au, Ag	Epithermal	15 ddh, 2002 m; geochem; geophys

SOUTH CENTRAL DISTRICT

Property (Operator)	MINFILE Number	Mining Division	NTS	Commodity	Deposit Type	Work Done
Beaton (Lakewood Mining Co. Ltd.)	92INE119	Kamloops	92I/10E	Cu, Au	Porphyry	5 pcdh, 454 m
Bethsaida (Cominco Ltd.)	92ISW042	Kamloops	92I/6E	Cu, Au	Porphyry	11 ddh, 3300 m; geophys, IP, 18 km
Bonanza-Goldstripe (Dave Javorsky)	92JNE084	Lillooet	92J/9E	Au, Ag, Cu	Vein	6 pack-sack ddh
Bys 1-2 (CP Rail)	92INW013	Kamloops	92I/14E	Aggregate, RR balast	Industrial mineral	12 ddh, 1382 m
Calling Lk (Cominco Ltd.)	92ISW009	Kamloops	92I/6E	Cu, Au	Porphyry, Vein	3 ddh, 700 m; geophys, IP, 9.6 km
Carmi Moly (James Hinke)	82E 029	Greenwood	82E/3W	Au, Ag, Cu, Mo	Porphyry	3 ddh 311 m, 14 pcdh 1311 m; 4 trenches 1000 m; geophys, IP/VLF 300 m
Clearwater (American Bullion Minerals)	82M 034	Kamloops	82M/12W	Fluorite	Replacement, Massive Sulphide	geochem, baseline U-Th Survey
Clifton (Discovery Consultants)	82LNE041	Vernon	82L/10E	Marble, Dolomite	Industrial mineral	bulk sample
Dorothy (Dorothy Dennis)		Similkameen	92H/8W	Au, Pt, Pd		1 ddh; geophys, VLF/EM
Elk (Cordilleran Engineering Ltd.)	92HNE134	Similkameen	92H/16W	Au	Vein	pcdh 2683 m; 2 bulk samples, 2000 t, 258 assays
Fish Lk (Taseko Mines Ltd.)	92OSW041	Clinton	92O/5E	Cu, Au	Porphyry	121 ddh, 60 960 m
Flag (Core Enterprises Ltd.)	82M 058	Kamloops	82M/5W	Ag, Pb, Zn	Massive sulphide	1 ddh, 90 m
French Bar (Richard Clark)	92O 056	Clinton	92O/1W	Au, Cu	Vein	ddh, road construction
Gold Ridge (Highland Talc Minerals Ltd.)	92ISW063	Kamloops	92I/4E	Talc	Industrial mineral	2 km road, trench, sampling
Golden Loon (Placer Dome Inc.)	92P 106	Kamloops	92P/8W	Au, Ag, Cu	Porphyry	geochem, soil 4500, rock 100
Jessie, Sarah, Rio (Panther Mines Ltd.)		Clinton	92O/5E, 12E	Cu, Au	Porphyry	4 ddh, 1500 m; line cutting 8.5 km, grid, road
Jura (J.E. Christofferson)	92HNE024	Similkameen	92H/9W	Cu, Au	Porphyry	2 ddh, 200 m

Property (Operator)	MINFILE Number	Mining Division	NTS	Commodity	Deposit Type	Work Done
Lawless *(Larry Lehman)*	82ESW024	Osoyoos	82E/03E	Au	Vein	10 rcdh, 670 m; geochem, 440 rock samples
M&R (Teck Explorations Ltd.)	92INE023	Kamloops	92I/10E	Cu, Au	Porphyry	3 ddh, 366 m
MGM/Bend (Teck Explorations Ltd.)		Golden	83D/1W	Zn, Pb, Ag	Massive sulphide	13 ddh, 3159 m; geophys, 19.24 km EM, 31.6 km mag/VLF; geochem, 370 soil
Mega,Boot,Gold (Valerie Gold Resources Ltd.)		Clinton	92O/12E	Cu, Au	Porphyry	geophys, mag 30 km, IP 93 km; geochem, 60 soil
Miracle (G.W.R. Resources Ltd.)	92P 020	Clinton	92P/14W	Cu, Au	Porphyry	6 ddh, 1482 m; 5 trenches, 250 m; geophys, 21 km
Missezula (Cominco Ltd.)	92HNE115	Nicola	92H/15E	Cu, Au	Porphyry	8 pcdh, 640 m; road, 600 m; geochem, 77 soil
Mohawk High (A. Babit)	92O 001	Clinton	92O/3W	Cu, Au	Porphyry, stockwork,breccia	1 ddh, 100 m
Monashee (Cameco Corp.)	82LSE001	Vernon	82L/1W, 2E	Au	Epithermal	geochem, 250 silt
Mt Skinner (Louis Bernoilles)	92N 039	Clinton	92N/9W	Au, Ag	Vein	1 trench; bulk sample, 146 t
Murphy (Murphy Shewchuk)	92HSE124	Similkameen	92H/7E	Cu, Au, Zn	Porphyry	3 ddh, 182 m; 5 trenches, 30 m; geochem
NBS 16, 17 (Cromlech Ltd.)	92HNW052	New West.	92H/13E	Silica, Feldspathic sand	Industrial mineral	6 trenches, 1.5 km; geophys, bulk sample, 500 t; line cutting
Nat 1 (George Wolanski)	92P 102	Kamloops	92P/1E	Aggregate, Feldspar	Industrial mineral	200 pcdh 1000 m; geochem, bulk sample, 50 t
Newton (Rea Gold Corp.)		Clinton	92O/13E	Cu, Au	Porphyry	5 ddh, 970 m; geophys, IP, 50 km
Perkins Peak (Line Drive Mining Construction)	92N 010	Cariboo	92N/14E	Au, Ag	Vein	u/g exploration development, sampling, mapping
Pilot (Cogema Canada Ltd.)	92JNE027	Lillooet	92J/15E	Au	Vein	2.2 km road, geochem, 1 ddh, 115 m
Pilot Gold (Harold Adams)	82LSW058	Kamloops	82L/5W	Cu, Au, Ag	Porphyry	10 ddh, 482 m
Rain (OreQuest Consultants Ltd.)	82M 156	Revelstoke	82M/8E	Cu, Pb, Zn	Massive sulphide	5 pcdh, 903.4 m
Rey Lake (Hera Resources Ltd.)	92ISE160	Nicola	92I/7E	Au, Ag, Cu, Mo	Skarn	geophys, 60 km IP, 60 km mag
Shear *(Placer Dome Inc.)*	92HNE073	Nicola	92H/15E	Cu, Au	Porphyry	6 ddh, 4020 m, 11 trenches, geophys; mag/VLF 94 km, IP 12 km, geochem
Tgp #1 (T.E. Wright)		Vernon	82E/15W	Au, Ag	Vein	15 pcdh, 300 m; 1 trench, 20 m; geochem
Wayside (Chris Sampson)	92JNE030	Lillooet	92J/15W	Au	Vein	u/g rehab
Whipsaw (Phelps Dodge of Canada)	92HSE102	Similkameen	92H/7W	Cu, Au, Mo	Porphyry, vein	4 ddh; geochem, surveying, road 1.2 km

Property (Operator)	MINFILE Number	Mining Division	NTS	Commodity	Deposit Type	Work Done
Wood (Lakewood Mining Co. Ltd.)		Kamloops	92I/10E	Cu, Au	Porphyry	14 ddh, 3810 m

KOOTENAY DISTRICT

Property (Operator)	MINFILE Number	Mining Division	NTS	Commodity	Deposit Type	Work Done
49 Creek Group (McMahon Res. Ltd.)	82FSW269	Nelson	82F/6W	Cu, Au	Porphyry/ shear	5 ddh, approx. 460 m
Big John (Jopec Res. Ltd.)	82FSW025	Nelson	82F/3W	Pb, Zn, Ag	Replacement	5 u/g ddh, 300 m; geochem
Fors (Cons. Ramrod Gold Corp./ Barkhor Res./Chapleau Res.)	82GSW035	Fort Steele	82G/5W	Pb, Zn, Ag	Sedex	7 ddh, 1838 m; geophys
Gold Drop (Trojan Ventures Inc.)	82ESE153 152	Greenwood	82E/2E	Au	Shear/vein	u/g bulk sampling; trenching; geophys; geochem
Greenhills (Westar Mining Ltd.)	82JSE007	Fort Steele	82J/2W	Coal	Sedimentary	4 rdh
Horn (Minnova Inc.)	82FNE062	Fort Steele	82F/9E	Pb, Zn, Ag	Sedex	6 ddh, 2085 m; geophys; geochem
Iron Colt (Vangold Res. Inc.)	82FSW100	Trail Creek	82F/4W	Au	Shear/vein	u/g drifting and raising; u/g drilling; 3 surface ddh
Jolly (Old England) (Lucky 7 Explor. Ltd.)	82ESW021 128, 129	Greenwood	82E/3E	Au, Ag	Vein/ listwanite	5 ddh, 98 m
Jor (Cons. Ramrod Gold Corp./ Barkhor Res./Chapleau Res.)		Fort Steele	82F/9W	Pb, Zn, Ag	Sedex	3 ddh, 636 m; geophys; geochem
Katie (Yellowjack Res. Ltd./ Hemlo Gold/Brenda Mines)	82FSW291	Nelson	82F/3W	Cu, Au	Porphyry	18 ddh, 4477 m
Kenville Mine (Springboard Res. Inc./ Coral Indust.)	82FSW086	Nelson	82F/6W	Au	Vein	u/g drifting, drilling and bulk sampling
Leg (Wilds Creek) (Cons. Ramrod Gold Corp./ Legion Res.)	82FSE005	Nelson	82F/2E	Zn, Pb, barite	Sedex	9 ddh, 2014 m
Lexington (Britannia Gold Corp.)	82ESE041, 042	Greenwood	82E/2E	Au, Cu	Vein/replacement	6 ddh, 227 m; trenching; geophys; geochem
Line Creek (Line Creek Res.)	82GNE020 021	Fort Steele	82G/15E 15W	Coal	Sedimentary	8 ddh, 1266 m; 80 rdh, 17 353 m; geophys
Moyie River Operation (Queenstake Res. Ltd.)	82FSE102	Fort Steele	82F/8E	Au	Placer	10 rdh, 165 m
Mt. Mahon (Minnova Inc.)		Fort Steele	82G/4W	Pb, Zn	Sedex	3 ddh, 564 m
Noah/Arc (Cons. Ramrod Gold Corp./ Barkhor Res./Chapleau Res.)	82FNE129	Slocan	82F/10W	Pb, Zn, Ag, Cu	Replacement	9 ddh, 2209 m; trenching; geophys; geochem
Paulson (Crownex Ltd.)	82ESE040 061, 083, 084	Trail Creek	82E/01E	Au, Pb, Zn, Ag	Vein/skarn	9 rcdh, 1000 m; geophys; geochem
Phoenix (Battle Mountain (Canada) Inc.)	82ESE020	Greenwood	82E/2E	Cu, Au	Skarn	9 ddh, 1374 m

Property (Operator)	MINFILE Number	Mining Division	NTS	Commodity	Deposit Type	Work Done
Rainbow-Tam O'Shanter (Minnova Inc.)	82ESE130	Greenwood	82E/2E, 2W	Au	Vein/disseminated	11 ddh, 1970 m; geophys
Rossland Wollastonite (H. Klassen)	82FSW341	Trail Creek	82F/4W	Wollastonite	Skarn	trenching, 16.3 t bulk sample
Shasta (Kokanee Explor./ Barkhor Res./Chapleau Res.)	82FNE041	Slocan	82F/10W	Pb, Zn, Ag	Replacement	4 ddh, 289 m; geophys; geochem
Stanfield (Bull River) (R.H. Stanfield)	82GNW002 003	Fort Steele	82G/6E 6W, 11W	Au, Cu	Vein	7 ddh, 2800 m; airborne geophys
Star (Cons. Ramrod Gold Corp.)	82FSE002	Nelson	82F/1E	Ag, Pb, Zn	Sedex/vein	1 ddh, 480 m
Sullivan II (Dodge) (White Knight Res. Ltd.)		Nelson	82F/2E	Pb, Zn, Ag	Sedex	2 ddh, 580 m
Surelock (Mountain Minerals Co. Ltd.)		Golden	82K/9W	Barite	Vein	11 ddh, 304 m
Vine (Kokanee Explor. Ltd.)	82GSW050	Fort Steele	82G/5W	Pb, Zn, Ag, Au, Cu	Vein/sedex	2 ddh
Vulcan (Ascot Res. Ltd.)	82FNE093	Fort Steele	82F/16W	Pb, Zn, Ag	Sedex	4 ddh, 1828 m; geophys
Wild Rose (Minnova Inc./ Randsburg Gold Corp.)	82ESE121 154	Greenwood	82E/2E	Au	Vein/disseminated	10 ddh, 1300 m; geophys

SOUTHWEST DISTRICT

Property (Operator)	MINFILE Number	Mining Division	NTS	Commodity	Deposit Type	Work Done
Avalanche (Teck Corp)	092JNE047	Lillooet	92J/10W	Cu, Pb, Zn, Ag, Au	Massive sulphide	8 ddh, 1420 m
Brandywine (La Rock Mining Corp.)	092JSW001	Vancouver	92J/3E	Cu, Pb, Zn Ag, Au	Massive sulphide (?)	58 ddh, 3230 m
Cimadoro (Inco Expln. & Tech. Services)	103F 052	Skeena	103F/1E, W	Cu, Pb, Zn Ag, Au	Massive sulphide	air geophys; geophys; geol; geochem
Dragon (Noranda Expln. Co. Ltd.)		Alberni	92E/16W	Cu, Pb, Zn Ag, Au	Massive sulphide (?)	air geophys; geophys; geol; geochem
Echo (Cons Ramrod Gold Corp.)	092C 108	Victoria	92C/16E	Au, Cu	Shear/vein	4 ddh, 292 m; geochem
Husharnu (Jordex Resources Ltd.)	092L 185	Nanaimo	92L/12W	Cu, Au	Porphyry	4 ddh, 3376 m
Lang Bay (Lang Bay Resources Ltd.)	092F 137	Vancouver	92F/16W	Kaolin		1rdh, 36 m; bulk sample
LeMare (Minnova Inc.)	092L 329	Nanaimo	92L/5W	Cu, Au	Porphyry	6 ddh, 900 m; air geophys; geophys; geochem; geol
Madhat (Orvana Mineral Corp.)	092L 176	Nanaimo	92L/5E	Cu, Au	Shear/vein	5 ddh, 915 m; geochem; geophys
Magnolia (Canquest Resource Corp.)		Nanaimo	92F/9W, 10E	Cu, Au	Skarn/manto	geol; geophys; geochem
Merry Widow (Taywin Resources Ltd.)	092L 044	Nanaimo	92L/6E, W	Cu, Au	Skarn	84 pcdh, 820 m

Property (Operator)	MINFILE Number	Mining Division	NTS	Commodity	Deposit Type	Work Done
Myra Falls (Westmin Resources Ltd.)	092F 330 092F 073	Alberni	92F/12E	Cu, Pb, Zn, Ag, Au	Massive sulphide	40 ddh, 12 100 m; 200 u/g ddh 37 500; u/g development 1000 m; geophys
Quinsam (Hillsborough Resources Ltd.)	092F 319	Nanaimo	92F/14W	Coal		rdh; ddh, 4482 m
Seneca (Minnova Inc.)	092HSW013 092HSW139	New West.	92H/5W	Cu, Zn, Pb, Au, Ag	Massive sulphide	20 ddh, 6361 m; geophys; geochem
Sylvan (A.J. Beaton Mining Ltd.)	092JSE020	Lillooet	92J/7E	Au	Skarn/manto	u/g development
Teeta Creek (Great Western Gold Corp.)	092L 054	Nanaimo	92L/5E	Au, Ag, Cu Pb, Zn	Vein	geochem
Vananda Gold (Vananda Gold Corp.)	092F 269	Nanaimo	92F/10E	Cu, Au, Ag, Pb, Zn	Skarn/manto	23 ddh, 7148 m
Wann (Acheron Resources Ltd.)	092L 087	Nanaimo	92L/12E, W	Cu, Au	Porphyry	14 ddh, 1830 m

NORTHWESTERN DISTRICT

By P.J. Wojdak, M.L. Malott and D.S. Gariépy
District Geology, Smithers

OVERVIEW AND TRENDS

Operating Mines

The disturbing trend of declining mineral production, diminishing employment levels and overall decreasing investment in development and exploration projects continued in 1992. Seven mines were in production in the district at the beginning of the year (Figure A-9). Two of them closed in 1992; Bell Copper mine and the McDame asbestos mine at Cassiar. A third, the Lawyers gold mine, is shut down. Several other mines (Premier Gold, Equity Silver and Golden Bear) have exhausted their open pit reserves and are trying to extend their lives by converting to underground mining. In early 1993 only the Snip mine has a rosy economic future.

Since 1991, 769 direct mining jobs were lost at mine sites in northwest British Columbia. These include 360 at Cassiar, 90 at Bell Copper, 100 at Equity Silver, 64 at Premier Gold and 155 at Lawyers. Approximately 15 jobs were created at Dome Mountain. Employment levels remain unchanged at the Snip and Golden Bear mines.

Excess milling capacity at operations with depleted reserves continues to result in innovation to improve profitability. **Dome Mountain** commenced production in March 1992, without a mill. Ore is trucked 110 kilometres to the Equity Silver mine for custom milling in 2500 to 6000-tonne batchs. Equity and Premier Gold both vied for Dome Mountain processing and continue to solicit other customers. Cheni Gold Mines Inc optioned the **Mets** gold prospect and may mine the deposit next summer, trucking the ore 40 kilometres to the Lawyers mill. This would continue a pattern started in 1991 with the mining of the Al deposit.

Exploration

Exploration project expenditure fell to **$16 million** in 1992 from $45 million in 1991. The prolific Stewart-Iskut camp with its epithermal and subvolcanic shear-hosted gold-silver deposits continues to be the most active area and sought after target, accounting for 27% of the total expenditure (Figures A-10 and A-11). There were twelve projects with programs in excess of $0.5 million with $1.3 million expended both at Golden Bear mine by North American Metals Corp. and also at Sulphurets Gold by Placer Dome Inc. Junior companies accounted for only three of the twelve large projects, continuing a trend away from large junior-financed programs.

The number of **mineral Notices of Work** declined from 377 in 1991 to 194 in 1992 (Figure A-12). Two disturbing patterns emerged: at least twenty programs were cancelled or greatly reduced by companies unable to raise financing; Varitech Resources Ltd.'s cancelled drill program at Big Onion is an example, and four work programs were conducted only to recover reclamation bonds. Recovery of reclamation bonds is a trend that may grow next year as several companies, active in northwest British Columbia in 1992, have drastically reduced their plans in this province for 1993. Details of the work done on 41 major projects in the Northwest are presented in Table 1. Highlights of the largest projects are given in the following sections.

Despite these gloomy conditions some individuals and mining companies remain optimistic about the future. Grassroots exploration was conducted for porphyry copper-gold, clastic-hosted zinc-lead-silver, and volcanogenic massive sulphide (VMS) deposits. Rio Algom Exploration Inc. conducted lake sediment sampling and staked six new properties in the **Babine** region. Other major companies have also recently acquired ground in this area. Cominco Ltd. and Kennecott Canada Inc. explored Paleozoic clastic sedimentary rocks in the **Kechika-Cassiar** belt. Inco Exploration was foremost among several companies interested in VMS prospects and their work on **Pitt Island** on claims optioned from Atna Resources resulted in discovery of the new **Team** showing.

Land-Use Issues

The **Protected Areas Strategy** is a major provincial government initiative to increase the land base set aside for environmental protection. The increase will be from 5 to 6%, to 12%. A large number of study areas have been proposed, amounting to 18% of the land base, with interest groups likely to propose more. Stakeholders, including mining companies and prospectors, will have the opportunity to participate in study teams that will refine boundaries and review options of protection versus development.

An important new trend for the British Columbia Geological Survey is the undertaking of regional mapping and mineral potential surveys to assist with the resolution of land-use issues. A mineral potential study of the Babine Mountains Recreation Area, carried out in 1991, was released in September 1992. At **Windy Craggy**, the Mine

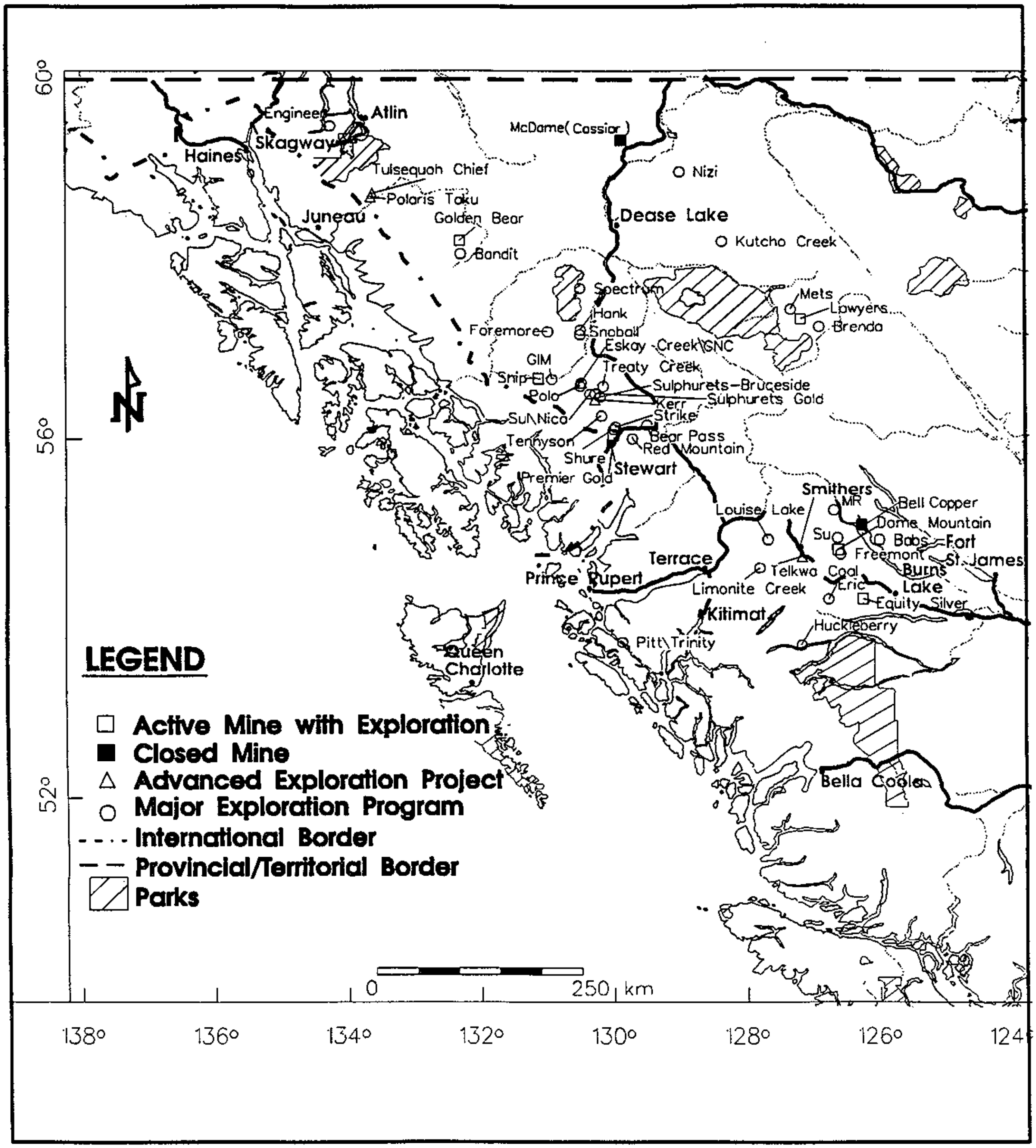


Figure A-9. Major exploration programs, northwestern British Columbia; 1992.

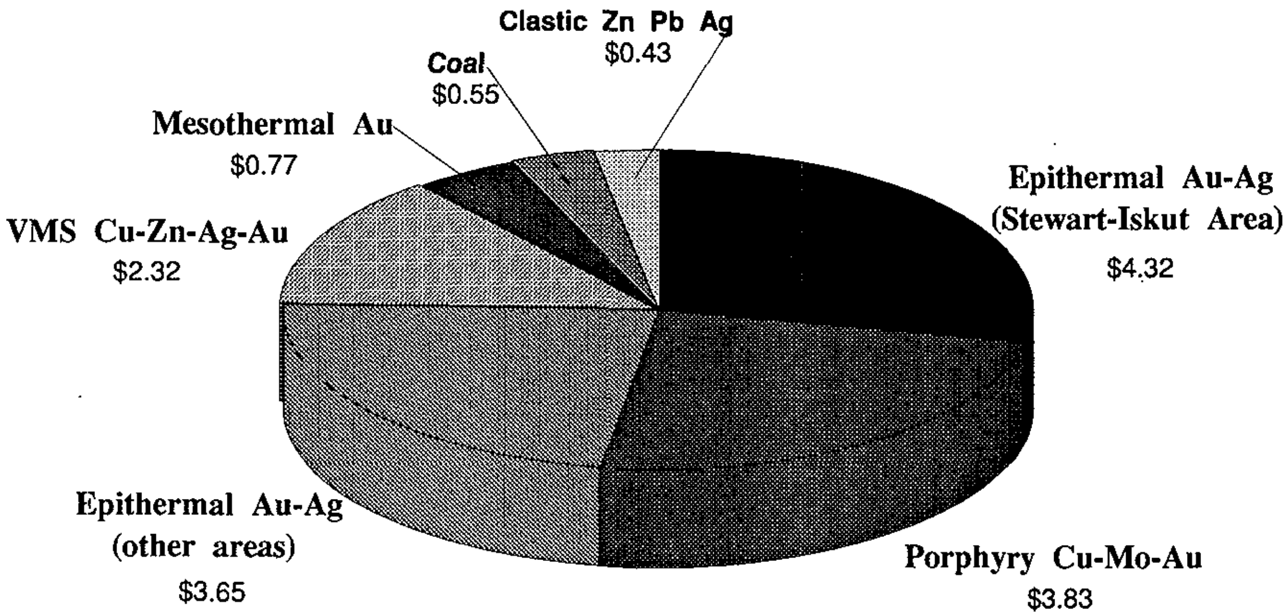
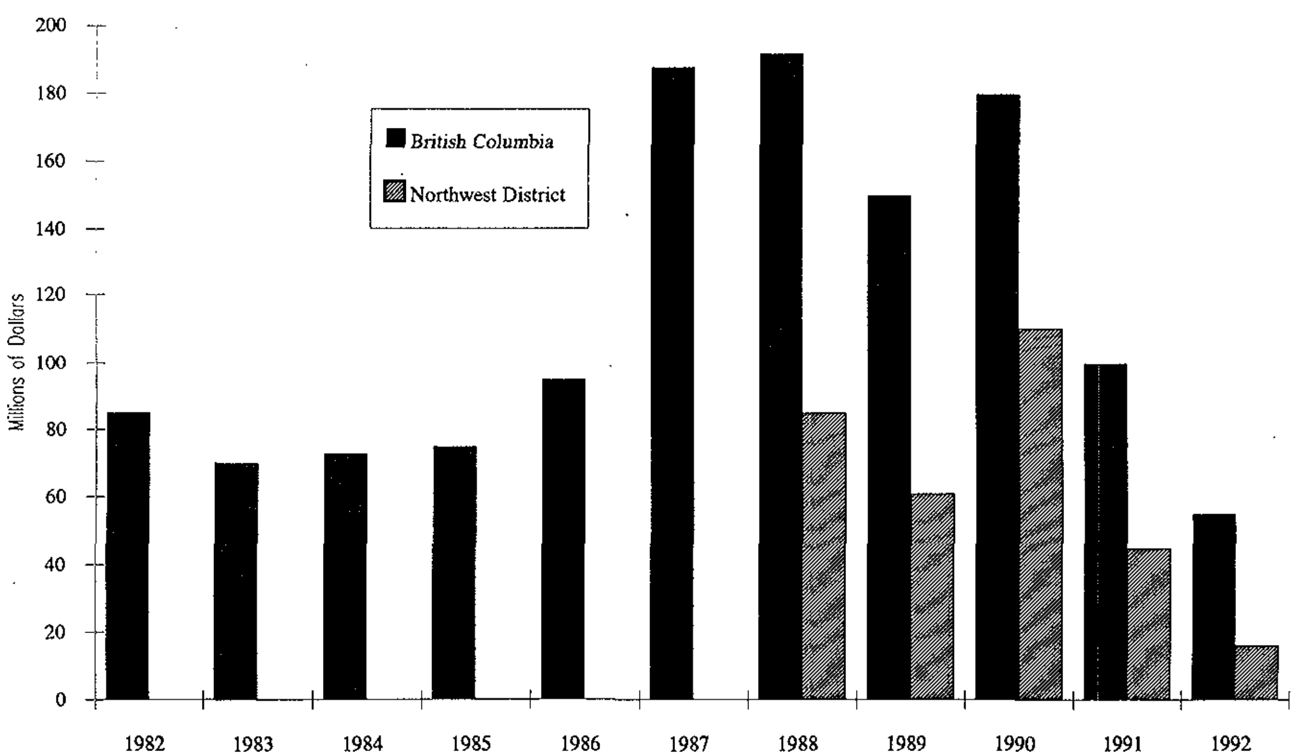


Figure A-10. 1992 expenditures, northwestern British Columbia; total $16 million.



Provincial figures 1981 to 1989 provided by B.C. and Yukon chamber.

Figure A-11. Trends in mineral exploration expenditures, northwestern British Columbia.

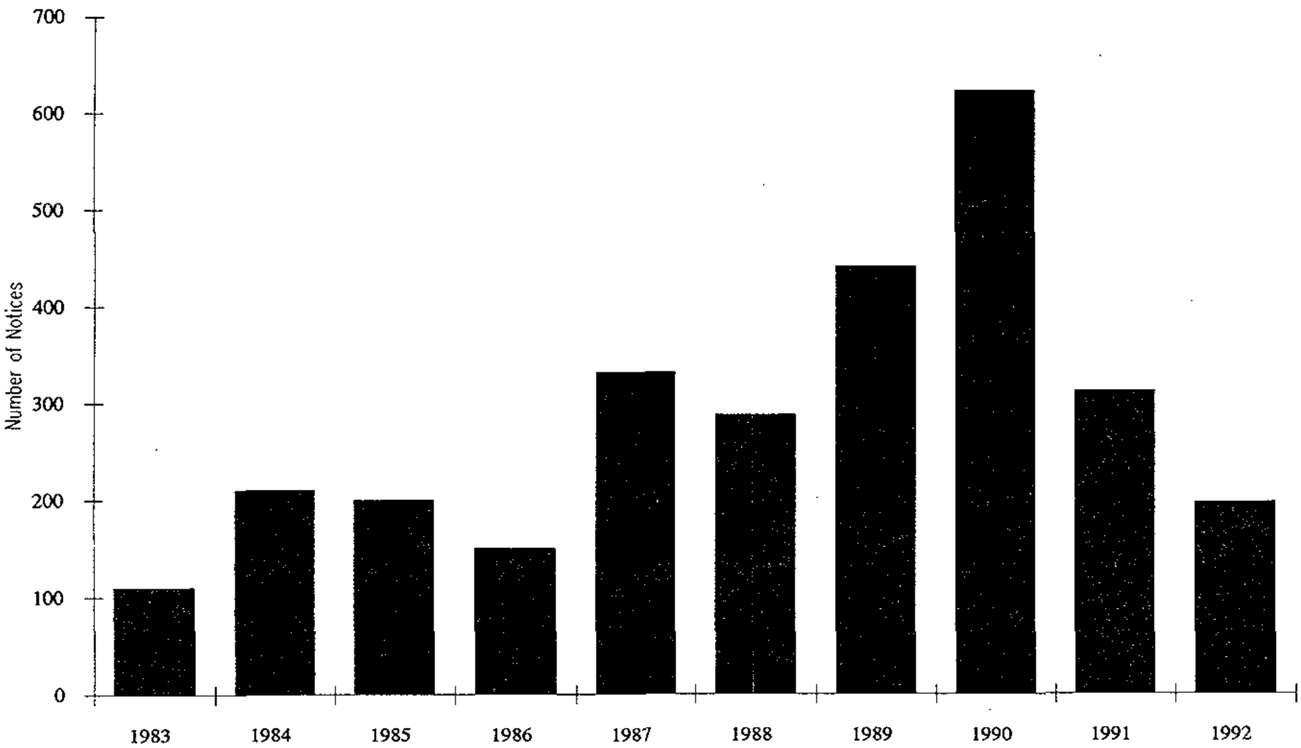


Figure A-12. Trends in mineral notices of work, northwestern British Columbia.

Development Assessment Process was suspended to allow the Provincial Commission on Resources and the Environment (CORE) to conduct a land and water use planning process. A mapping and mineral potential evaluation of the Tatsenshini area by the B.C. Geological Survey resulted in discovery of **Rainy Monday**, a significant new cupriferous massive sulphide occurrence on the Windy Craggy property about 5 kilometres from the main deposit. Another mineral potential survey was conducted in the Recreation Area sector of the Nisga'a Lava Bed Memorial Park in the Nass valley. More field-based and office-based mineral potential surveys can be expected in 1993.

EXPLORATION HIGHLIGHTS AT OPERATING MINES

The **Snip Mine**, owned by Cominco Ltd. (60%) and Prime Resources Ltd. (40%), operates at 450 tonnes per day and produces gold at a cost of $130 to 160 per ounce. Reserves on December 31, 1991 were 872 000 tonnes at 28.2 grams per tonne gold. Gold occurs in the quartz-sulphide Twin vein, and several footwall splays. Exploration in 1992 consisted of 27 underground drill holes (5000 m) to test the Twin vein down-dip and 14 surface holes (3200 m) to test UTEM anomalies down-plunge, northwest of the Twin structure.

The **Golden Bear mine** is operated by North American Metals Corporation (owned 82.8% by Homestake Canada Ltd.). Problems with the roaster in 1991 led to cessation of underground mining of sulphide ore in favour of open-pit oxide ore, but these problems were overcome in 1992. The mill operates at 370 tonnes per day and produces gold at a cost of $330 per ounce. Open-pit reserves were exhausted in 1992 and, with the roaster operating well, Golden Bear returned to underground mining (Plate A-1). There is an urgency to defining additional ore at Golden Bear. A major exploration program, consisting of 29 holes (5656 m), was undertaken along the Bear Fault during 1992. Promising results were encountered in the Bear South Deep zone below the current workings (but at mill level) and to the north in the Fleece zone. A significant new showing was found on the nearby **Bandit** claims.

Open-pit production by **Equity Silver Mines Ltd.** (owned 58.8% by Placer Dome Inc.) was concluded in 1992. Underground development of the North and Waterline zones by J.S. Redpath Limited is underway, with contract mining planned at a rate of 1000 tonnes per day. Definition drilling (37 holes, 2922 m) of a preliminary reserve block containing 750 000 tonnes with an average grade of 0.68% copper, 209 grams per tonne silver and 4.18 grams per tonne gold has encountered better than expected gold grades.

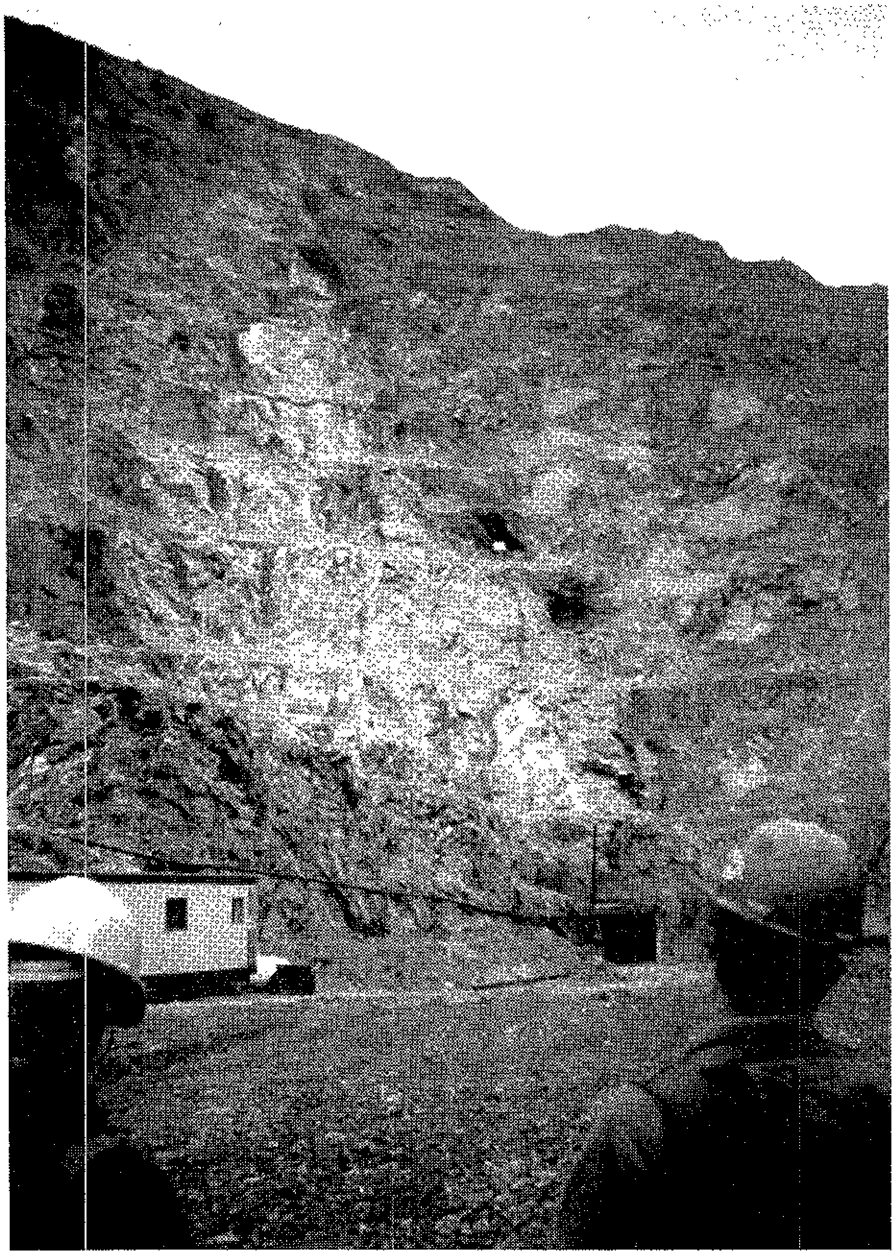


Plate A-1. Doug Reddy (right), senior mine geologist, Golden Bear mine, and GSB geologist, Bob Lane (left), view the fault-bounded limestone lens that controls gold mineralization in the Golden Bear pit. New underground drifting from the 1370 bench follows the Bear fault and opens up underground reserves that now are being developed.

Open pit mining at the **Premier Gold mine** (owned by Westmin Resources Limited) was also completed in 1992. Westmin is working to increase the underground mining rate from the current 140 tonnes to 300 tonnes per day. A drilling program on 5-level (38 holes, 917 m) defined new reserves below 5-level. The company is soliciting custom milling ore from the Iskut camp and from properties from Vancouver Island to Alaska that are accessible to low-cost ocean transport.

Cheni Gold Mines Inc. exhausted reserves in the AGB and Cliff Creek zones early in 1992 and shut down the **Lawyers mine**. Cheni optioned the **Mets** deposit from Golden Rule Resources Ltd. (50%) and Manson Creek Resources Ltd. (50%). A 60-metre decline and 120-metres drift in the ore vein were developed as part of a feasibility study. A reserve of 53 000 tonnes grading 11.6 grams per tonne of gold was estimated. A production decision was deferred until next year. Exploration on the Lawyers property using E-scan, a new geophysical technique, resulted in the discovery and mining of the **Phoenix** deposit. It was small, 4934 tonnes with an average grade of 46.3 grams per tonne gold and 2159 grams per tonne silver, but its significance lies in the success of a new technique and the many additional untested anomalies.

Dome Mountain mine reached full production of 90 to 180 tonnes per day in March, 1993. The operator is Timmins Nickel Ltd. under a joint venture agreement with the property owner, Habsburg Resources Ltd. Pre-production reserves of 295 000 tonnes grading 12.34 grams per tonne gold are contained in a quartz vein that also carries base metal sulphides. Thirteen drill holes (1045 m) delineated additional reserves in the Boulder vein. Financial difficulties have resulted in the Dome Mountain operation being offered for sale, as of December, 1992.

EXPLORATION AND DEVELOPMENT HIGHLIGHTS

Development of the Eskay Creek deposit was delayed by the Homestake-Corona merger and exploration proceeded at a reduced pace for the same reason. Homestake mined a 15-tonne sample in late summer for metallurgical testing and is undertaking a feasibility study. Reserves of 1.19 million tonnes with an average grade of 59.4 grams per tonne gold and 2659 grams per tonne silver were announced in mid-1992. On the adjacent GNC claim, eight exploration holes (3650 m) were drilled on the Eskay horizon, based in part on a seismic survey which probed beneath hanging wall argillite.

Placer Dome Inc. explored the **Sulphurets Gold** and **Kerr** porphyry copper-gold prospects in a joint program in 1992. The two apparently unrelated systems are just 2 kilometres apart and are located in the heart of the Iskut camp, 60 kilometres north of Stewart. At Sulphurets Gold, Placer Dome drilled 23 holes (5577 m) in a program designed to augment a previously established geological reserve of 18 million tonnes grading 0.35% copper and 0.82 gram per tonne gold. The intent of the program at Kerr was to improve the confidence in grade estimates (geological reserve of 126 million tonnes at 0.62% copper and 0.27 gram per tonne gold) by re-drilling previous sites to improve core recovery in the high-grade "Rubble zone". The Rubble zone results from acidic dissolution of a primary gypsum-anhydrite-cemented breccia. Ten holes (1587 m) were completed.

Red Mountain is an important new gold prospect 15 kilometres east of Stewart that is being explored by Lac Minerals Ltd. Gold occurs in heavily disseminated to stockwork pyrite zones in a porphyry-like setting on the margin of the Gold Slide stock. The Marc zone was announced in 1991 to contain 840 000 tonnes grading 12.7 grams per tonne gold. Substantial success was achieved in the adjacent North Zone in 1992 but details are not available at the time of writing. A total of 13 holes (3998 m) was completed.

Tulsequah is a gold-rich base metal volcanogenic massive sulphide deposit 105 kilometres south of Atlin and 75 kilometres northwest of Juneau, Alaska. Ore lenses occur in tightly folded Devonian strata and are steeply dipping. Reserves are 7 800 000 tonnes grading 1.6% copper, 1.2% lead, 6.5% zinc, 2.7 grams per tonne gold and 110 grams per tonne silver. Thirteen holes (5000 m) drilled during the fall of 1992 showed that the thick H-lens extends below current reserves but does not extend above the 5400 level.

Plate A-2. Golden Giant geologist, Robert McIntosh, examines a cleaned outcrop of the Discovery silica-barite vein on the Nizi property. The diamond-sawn sample, location shown in photo, assayed 13.7 grams per tonne gold across 3 metres.

Polaris-Taku is a gold vein deposit 3 kilometres south of Tulsequah that produced 690 000 tonnes of ore grading 10.3 grams gold per tonne during eleven production years between 1938 and 1951. It is currently being explored by Suntac Minerals Corporation and Rembrandt Gold Mines Ltd. Quartz-carbonate-arsenopyrite veins associated with listwanite alteration fill dilatant structures. Best gold grades occur at vein junctions spaced 300 metres apart along the through-going AB structure. Based on an additional 22 holes (6340 m) completed in 1992, geological reserves are 2.59 million tonnes with an average grade of 14.5 grams gold per tonne.

Nizi is a new epithermal gold discovery 80 kilometres northeast of Dease Lake, explored by Gold Fields Canadian Mining Limited under option from Gold Giant Minerals Inc. Quartz-barite veins and carbon alteration occur in a potassium-feldspar rhyolitic tuff within the Devono-Mississippian Sylvester Group (Plate A-2). Trench samples assayed up to 94 grams gold and 841 grams per tonne silver but the best drill intercept is 5.8 grams per tonne gold over 14 metres (approximately true width). Eight drill holes (1300 m) were completed.

Huckleberry is a revived copper-molybdenum porphyry prospect 90 kilometres south of Houston. It was explored 20 years ago and estimated to contain 78 million tonnes grading 0.41% copper and 0.025% MoS_2. New Canamin Resources Ltd. has an option to earn 100% interest from Kennecott Canada Inc. New Canamin's objective in 1992 exploration was to define 40 million tonnes at 0.7% copper or better that could be mined at start-up. To year-end, 36 drill holes (4900 m) had been completed.

The **Telkwa Coal** property was purchased by Manalta Coal Ltd. from Shell Canada Resources Ltd in early 1992. Coal occurs within the Early Cretaceous Skeena Group in two near-surface deposits north and south of the Telkwa River, 8 kilometres southwest of Telkwa. Previously estimated reserves total 36.6 million tonnes of thermal coal. Manalta drilled 5000 metres in a combination of rotary and diamond-drill holes (43 in total) and was successful in upgrading the north deposit, which had been poorly defined. Manalta also located, but did not delineate a new, high quality coal deposit.

There are a number of new projects of interest in northwest British Columbia. At **Bear Pass**, 27 kilometres northeast of Stewart, a breccia zone carrying semimassive sulphides was explored by Trev Corp. and Cameco Corporation. It carries significant gold grades over widths up to 15 metres. New mineralized zones were discovered on the **Bruceside** property by Newhawk Gold Mines Ltd. Surface sampling of the SG zone returned 20.7 grams per tonne gold and 38.4 grams per tonne silver over a 3-metre width and 130-metre length. Surface work at **More Creek** by Adrian Resources and Hemlo Gold Mines Inc. resulted in discovery of a sulphide zone that returned 9.1 grams per tonne gold across a true width of 4.9 metres. At **Limonite Creek**, 40 kilometres southwest of Smithers, Cyprus Canada Inc. discovered an extensive zone of semi-massive pyrite associated with andalusite, sericite and lazulite, an unusual alteration suite that characterizes the Equity Silver deposit. Travel Ventures Inc. has acquired the **Anyox** property and plans a major drilling program in early 1993.

Some important projects had disappointing developments. Most notably, Kennecott Canada Inc. decided not to proceed with exploration at **Galore Creek** and Cominco Ltd. dropped its option on **Kutcho Creek** after completing a UTEM survey.

MINERAL DEPOSIT RESEARCH

The Mineral Deposit Research Unit (MDRU) at The University of British Columbia continues its investigations into the metallogenesis of the Iskut River area. Researchers and projects include:

Peter Lewis: Structural evolution of the Iskut area; Stratigraphic section in the Treaty Creek area.

John Thompson: Alteration at Treaty Creek.

Paul Metcalfe: Lithostratigraphy and structure in the Bronson area.

David Rhys: Geology at Snip mine and Inel property.

Andrew Kaip: Alteration and mineralization on the Hank property.

Roland Bartsch: Detailed geology of the Prout Plateau - Eskay Creek area with emphasis on rhyolite stratigraphy and alteration.

Tina Roth: Geology of the Eskay Creek 21A zone.

James Macdonald: Sulphurets geology, volcanic facies relationships and geochronometry.

David Bridge- Kerr porphyry copper-gold deposit.

The MDRU has initiated studies of porphyry copper-gold and volcanogenic massive sulphide deposits in British Columbia. Cliff Stanley is examining the Galore Creek deposit. Tim Barrett will begin work at Tulsequah in 1993.

The Geological Survey Branch conducted two regional mapping programs in areas of economic interest, in addition to the previously described Tatsenshini mineral potential survey led by Mitch Mihalynuk. Derek Brown carried out field investigations in the Golden Bear area and Jim Logan mapped in the north Iskut River region. Rod Kirkham, Bruce Ballantyne and Don Harris of the Geological Survey of Canada have investigated the Sulphurets area for a number of years and Open File 2416 was released in 1991.

CENTRAL DISTRICT

By E.L. Faulkner
District Geology, Prince George

INTRODUCTION

It was a difficult year for the exploration industry, with major companies having greatly reduced budgets for the district and few junior companies able to secure adequate exploration funds. As in 1991, many projects were scaled down or cancelled due to funding problems. Mineral Notices of Work for the year totalled 146, down 39% from 1991. Figure A-13 shows that the decline in activity occurred in all Mining Divisions, but most notably in the Omineca. As Figure A-14 shows, exploration expenditures in the district also continued to decline. It should be noted, however, that perhaps a quarter of the decline in projects and spending was the result of changes to the district boundaries made early in 1992.

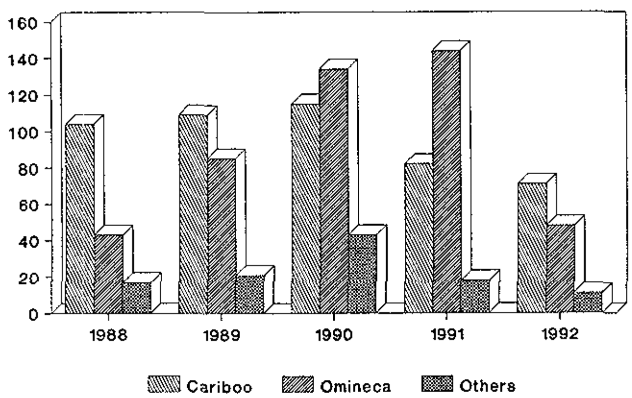


Figure A-13. Notices of work - Central District, 1988-1992.

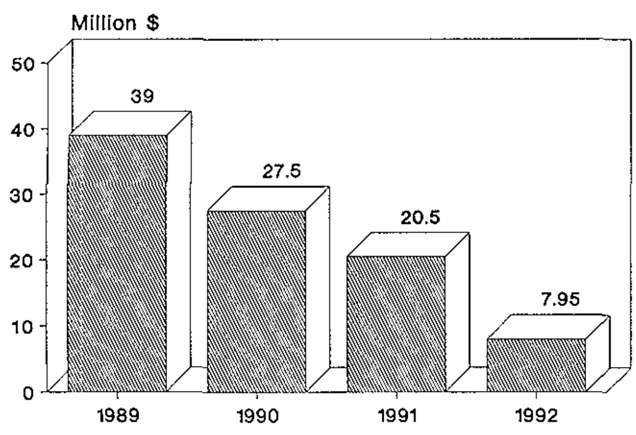


Figure A-14. Exploration expenditures - Central District, 1989-1992.

Precious metals in all types of deposit once again dominated exploration targets, but interest in base metal/silver replacement and sedex targets picked up, as did interest in industrial minerals and stone. The locations of significant exploration projects are shown on Figure A-15. Placer Notices of Work, at 307, were down 23% from 1991.

The four operating mines in the district operated at near capacity and late in the year Mine Development Certificates were issued to Imperial Metals Corporation for the Mount Polley copper-gold deposit and to Curragh Inc for the Stronsay sedex deposit.

QUESNEL TROUGH

There was a sharp decline in interest in porphyry or porphyry-related targets in the Quesnel Trough in 1991. There were few large drilling programs and most companies reported mixed or poor results. In the Kemess camp, the El Condor Resources Ltd. and St. Philips Resources Inc joint venture continued with definition drilling and pre-feasibility studies at the Kemess South deposit, where reserves currently stand at 207 million tonnes grading 0.23% copper and 0.64 gram per tonne gold. On the adjacent Nor property, Rio Algom Limited drilled the western extension of the Kemess South deposit and although the grades of some of the intersections were among the highest recovered to date in the camp, all were at currently uneconomic depths.

El Condor also drilled the Kemess North deposit and other targets on the Kemess property. Mineral reserves for the Kemess North deposit are 116 million tonnes grading 0.19% copper and 0.377 gram per tonne gold and are currently uneconomic, however, the deposit is still open, particularly to the east, and good results from some of the other targets warrant further drilling.

South of the Kemess camp, Swannell Minerals Corporation drilled several porphyry targets and despite the small number of holes per target, reported some encouraging intersections.

There was little activity in the Mount Milligan area in 1992 and no encouraging results were reported. In the southern Quesnel Trough, activity was mostly confined to small programs. Eastfield Resources Ltd optioned the Spanish Mountain basal phyllite hosted gold deposit and removed a large bulk sample for pilot mill testing to get a better idea of the true grade of the mineralization.

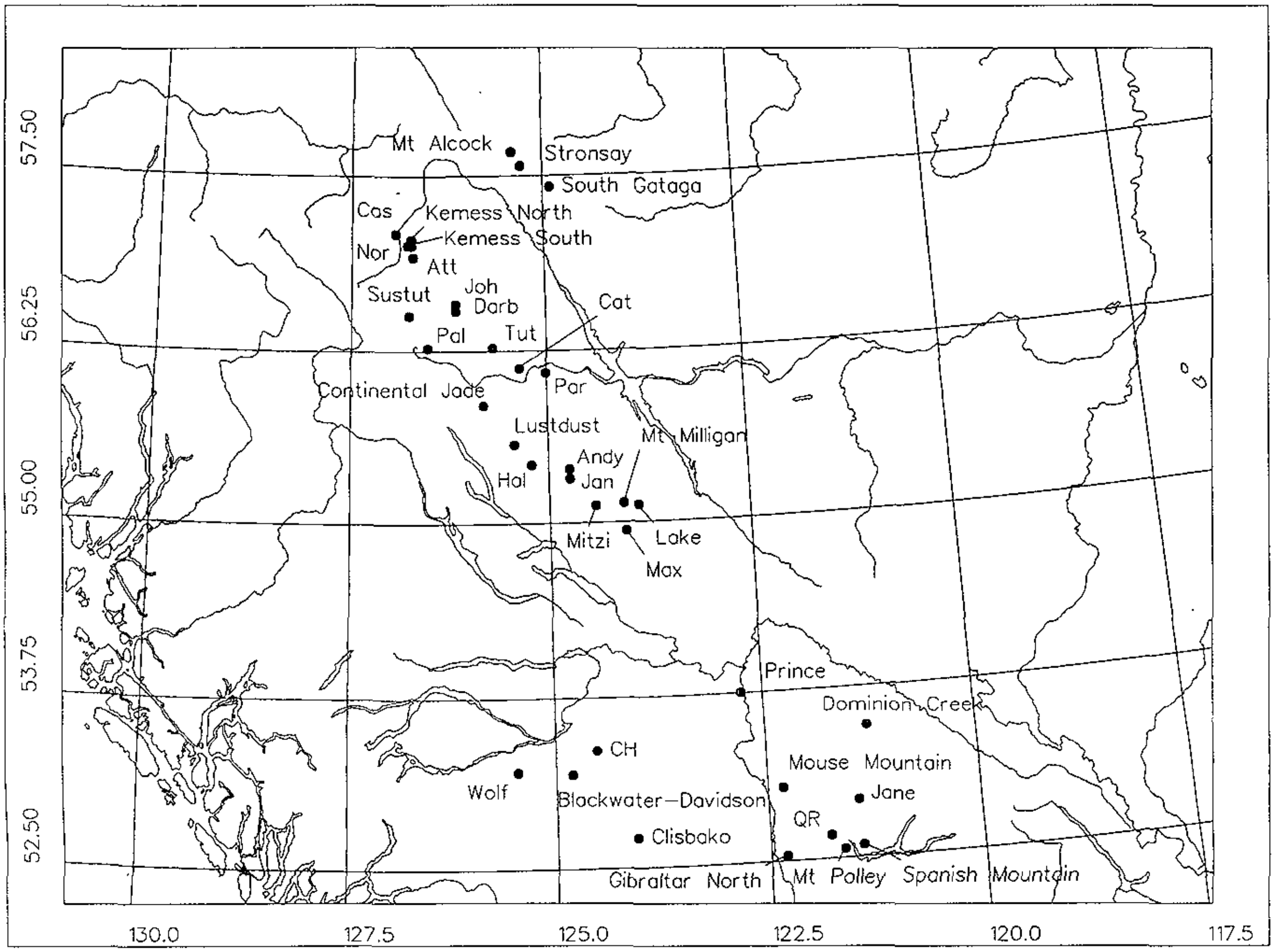


Figure A-15. Locations of significant exploration projects.

FRASER PLATEAU

Interest in both epithermal and porphyry-related precious metal targets on the Fraser Plateau picked up in 1992, with Placer Dome Inc., Minnova Inc., and Granges Inc. being particularly active. The limited vertical extent of epithermal mineralization in Ootsa Lake Group volcanics continues to be a problem at many properties, but Minnova and Granges both reported encouraging results from drilling at the Wolf and Blackwater/Davidson prospects respectively. Late in the year there was significant new staking in the Fawnie Range, Kenney Dam and Euchiniko Lake areas, most notably by Cogema Canada Limited.

OTHER AREAS AND ACTIVITY

Base Metal/Silver Targets

Interest in base metal/silver and sedex deposits picked up in 1992 after several years of modest but steady activity. In the Muskwa Ranges, most of the projects were small-scale reconnaissance programs and only Minnova Inc. reported encouraging results from its South Gataga property. Teck Corporation continued work on the Mount Alcock property with mixed results from a drilling program to test the continuity of the mineralization. In the Swannell Ranges, Cominco Ltd. drilled 17 holes over a strike length of more than 2 kilometres at the Par property and plans further drilling this year.

Cache Creek Terrane

West of the Pinchi fault in the Cache Creek Terrane, Beauchamps Exploration Inc. reported encouraging results from a small drilling program on the Sustut massive sulphide property. Initially thought to be a shear zone replacement in Cache Creek volcanics, the mineralization may be volcanogenic massive sulphide - a new target type for the district. Farther south, Alpha Gold Corp. continued with drilling on the Lustdust replacement prospect, with some more encouraging results.

Placer

Placer operations decreased 23% from 1991 levels, once again as a result of decreased gold prices in real terms coupled with increased costs and sharply increased permitting costs. The smaller mechanized operations were again the most affected group.

PRODUCING MINES

The district's four producing mines operated at near capacity throughout 1992 and the two coal mines, Bullmoose and Quintette, were unaffected by the problems that plagued other coal mines in the province during the year. Gibraltar Mines Limited completed two major drilling programs on the Gibraltar North deposit, discovered in 1990, but despite excellent grades and continuity, the company dropped plans to put the deposit into early production, largely because of the two years of stripping that would be required. Instead the company will drill ground between the Gibraltar North and West deposits.

MINE DEVELOPMENT PROCESS

Late in 1992, Mine Development Certificates were issued to Curragh Inc. and Imperial Metals Corporation for the Stronsay sedex deposit and Mount Polley copper-gold deposit, respectively. Production decisions for the two properties will depend on the difficult tasks of either finding a suitable buyer or securing adequate financing.

CMP Resources Ltd. continued work to convert the Approval in Principal granted for the QR gold deposit to a Mine Development Certificate, and Placer Dome Inc. has completed most of the outstanding requirements for a Mine Development Certificate for the Mount Milligan deposit.

OUTLOOK

Indications to date are that there will be fewer projects and reduced spending again this year. In 1992, Resource Management Branch staff made a record number of inspections for junior companies seeking the return of their reclamation bonds and for major companies wishing to reduce the number of properties covered by their general permits - both clear indications that these properties will either be dropped or that no further work will be done on them this year. Many promising projects, particularly those of junior companies, are likely to suffer from funding difficulties this year.

Like all district offices, the Prince George office is heavily involved in land-use issues, chiefly as a result of the Protected Areas Strategy and other planning initiatives. Despite the obvious need and desirability of settling land-use questions, most prospectors and companies view the uncertainty over land base and tenure as another negative factor in an already difficult exploration climate.

Many companies, however, expect to be active in the district to the extent that their budgets will allow and some aggressive majors recognize that this is an excellent time to acquire quality properties at bargain prices.

SOUTH-CENTRAL DISTRICT

By R.E. Meyers

District Geologist, Kamloops

INTRODUCTION

The general decline in mineral exploration activity, that began throughout the industry in 1990/91, continued during 1992 in South-Central British Columbia. Exploration expenditures (Figure A-16), which totaled $15.14 million, appear to have been sustained at 1991 levels (Table A-5). However, modifications in district boundaries incorporated the Taseko Lakes into the South-Central region. That area alone accounted for approximately half of the total district expenditures for 1992. Consequently, there was, in fact, a major reduction in exploration investment throughout the remainder of the region. The drop in industry investment in the district was more strongly felt by the mine development sector. Mine development expenditures, which reached $30.4 million in 1991, fell by 81% to $5.72 million, for a total 1992 exploration and development investment of $20.86 million for South-Central British Columbia. The variation in the numbers of exploration projects in each Mining Division (Figure A-17) was somewhat disproportionate to associated changes in expenditures (Figure A-18). The most significant increase in the number of projects was in the Clinton Mining Division, where activity was stimulated primarily by work at the Fish Lake copper-gold project. The largest drop in project levels was in the Similkameen Mining Division, where a number of projects slated for continued work, were not funded. Expenditure levels were dramatized by the extraordinary increase in the Clinton Mining Division and illustrate the effect one major project can have on the regional picture.

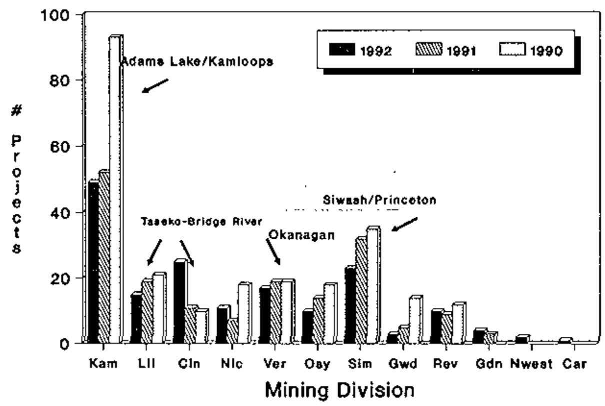


Figure A-17. Exploration projects; South-Central B.C. (based on Mineral Notices of Work).

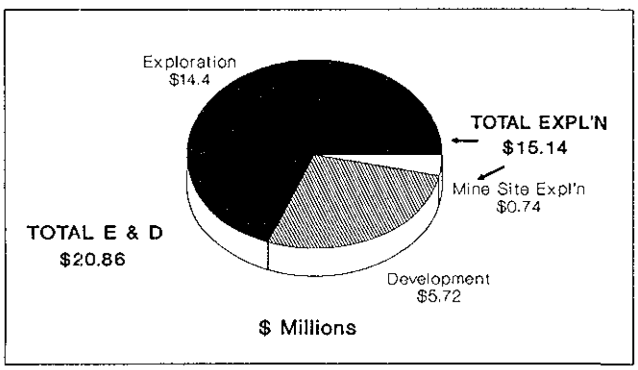


Figure A-16. Exploration and development expenditures; South-Central B.C. 1992 (estimated).

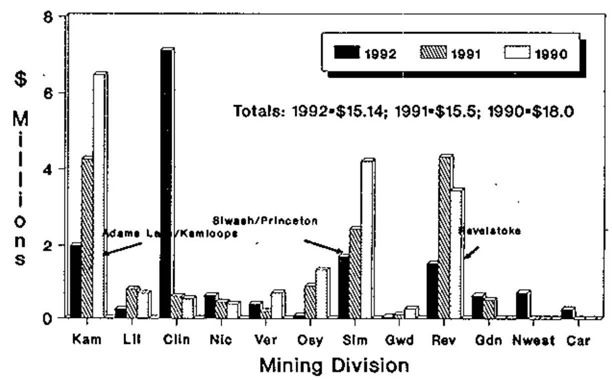


Figure A-18. Mineral exploration expenditures 1992; South-Central B.C.

TABLE A-5
SOUTH-CENTRAL B.C.
SUMMARY OF EXPLORATION AND DEVELOPMENT

EXPENDITURES	1992	1991 ($Millions)	1990
Exploration (all Projects)	15.14	15.5	18.0
Development (operating mines)	5.72	30.4	18.50
Totals	$20.86	$44.9	$36.5

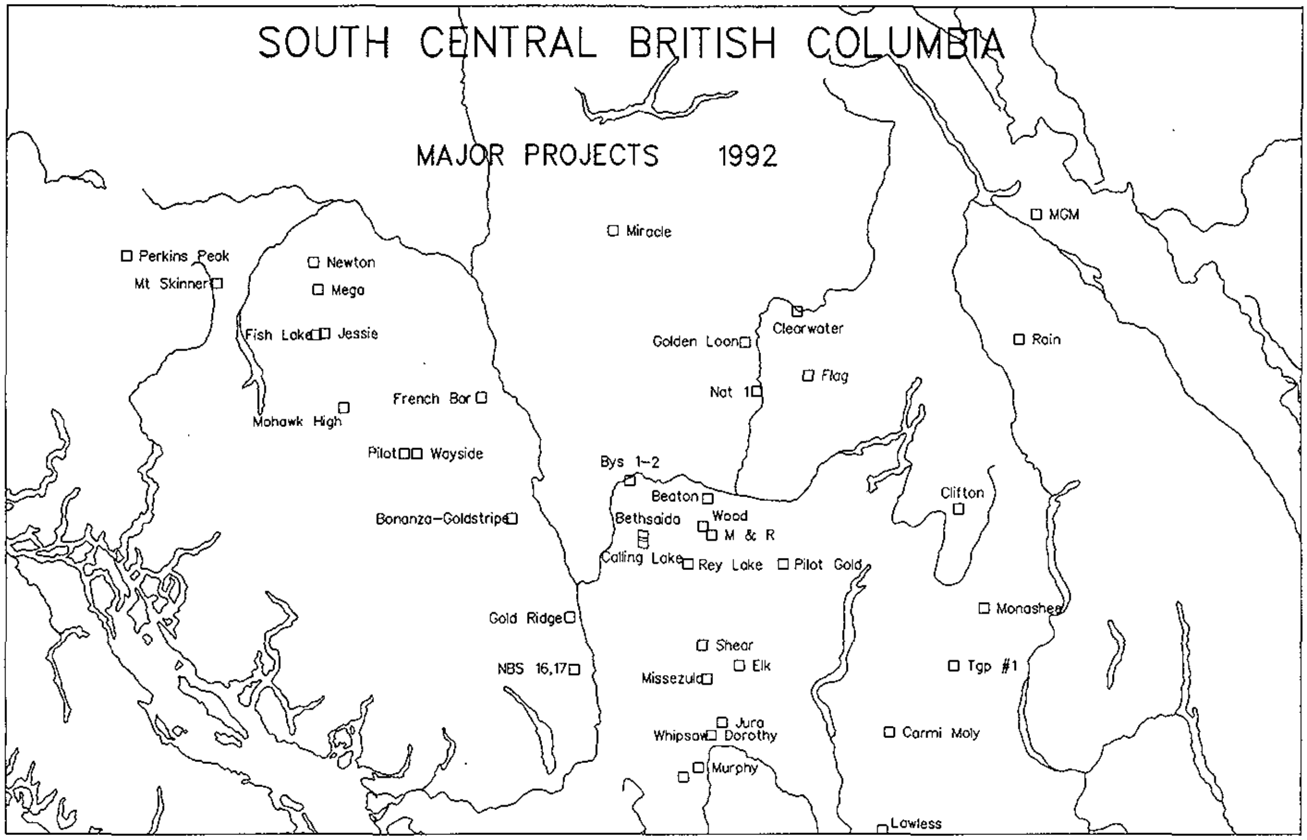


Figure A-19. South-Central B.C.; major projects 1992.

HIGHLIGHTS OF EXPLORATION AND DEVELOPMENT

MAJOR FOCUS AND TARGETS

The major exploration projects in 1992 are shown on Figure A-19 and were focused primarily in the Taseko Lakes area, the Siwash - Princeton area, Kamloops - Quesnel Highlands and the Columbia - Shuswap region. The primary attraction in the Taseko Lakes area was the Fish Lake porphyry copper-gold project, which, in addition to being the premier exploration project in the province, stimulated work on a number of other properties in the area. In the Siwash - Princeton area, the main program was again the Elk project of Fairfield Minerals Ltd., which profitably extracted bulk samples from the Siwash North gold deposit. A number of small to medium-sized projects were operated in the Kamloops area, primarily for porphyry and vein targets, while in the Columbia - Shuswap region, sedimentary exhalative and volcanogenic massive sulphide deposits continue to be the main attraction.

JUNIOR COMPANIES PLAY A MAJOR ROLE

The top three exploration programs in the region in 1992 were operated by junior exploration companies. Taseko Mines Limited Fish Lake project was by far the largest at $7 million in expenditures; the Fairfield Minerals Ltd. Elk project was budgeted at approximately $1.5 million; and the third, the NBS silica project, with expenditures of $0.7 million, was operated by Cromlech CRW Ltd.

INCREASE IN INDUSTRIAL MINERALS EXPLORATION

Increased interest in industrial minerals in the district has developed with the current down-turn in metallic minerals exploration. Traditionally, such commodities have attracted relatively limited investment, however, six of the largest industrial minerals projects in 1992 had combined expenditures of $1.5 million. The main targets have been silica, marble, feldspar, zeolites, fluorite, talc and garnet.

LAND-USE ISSUES AND ACTIVITIES

Increasing concern over the impacts of exploration activities on the regional land base continues to change the focus of activity in the Kamloops district office. The Protected Area Strategy and the Kamloops Resource Management Area Plan are the main areas of direct involvement. Other issues of local, or indirect involvement are Local Resource-Use Plans and Staking Reserves.

Recent reviews of the Crystal Peak Garnet project, which has been subjected to numerous delays and controversy, have determined that it would not have major impacts on other land uses in the Apex area. Consequently, there is high expectation that the project will be approved during 1993.

MAJOR EXPLORATION ACTIVITY

METALS

TASEKO - BRIDGE RIVER AREA

The largest exploration program in British Columbia in 1992 was Taseko Mines Limited Fish Lake project in the Taseko Lakes area, 120 kilometres southwest of Williams Lake. Prior to Taseko's current program, Cominco Ltd. and other companies operated a number of exploration programs on the deposit, the most recent in 1989, included some 2000 metres of diamond drilling in twelve holes to obtain material for metallurgical testing. Most of the holes in this program averaged better than 0.15% copper. In 1991 Taseko initiated work with ten additional holes and, combining these results with previously known data, the company calculated a preliminary geological resource of approximately 600 million tonnes grading 0.32% copper and 0.55 gram per tonne gold. In 1992 the company budgeted approximately $7 million to drill 60 960 metres in 121 drill holes. The deposit was drilled off at 100-metre centres to depths up to 850 metres. The results of this program effectively doubled the previous resource to 1.28 billion tonnes grading 0.22% copper and 0.42 gram per tonne gold (Press Release, May 4, 1993).

The deposit is associated with an Eocene porphyritic stock that occurs within a window in the Miocene Chilcotin Group plateau basalts. Copper and gold mineralization occurs in Cretaceous volcanic rocks cut by at least three phases of quartz and feldspar-bearing porphyries and intrusive breccias. Alteration assemblages are crudely zoned, with a widely distributed sericite-carbonate-clay assemblage, a chlorite-quartz-magnetite dominant zone and a biotite-magnetite-chlorite zone. In 1993 Taseko plans to complete all pre-feasibility work, including a short drilling program.

Motivated by the exploration success at Fish Lake, several other operators pursued porphyry copper-gold targets in the same region. North of the Taseko Mines property, Valerie Gold Resources Ltd. began work on a large tract of land on the Mega-Boot-Gold property that trends north from the Taseko's claims. Valerie carried out 93 kilometres of induced polarization and 30 kilometres of magnetometer surveys, as well as limited soil sampling. A small drilling program included 691 metres in three holes; the results were not encouraging. The program was late starting due to land-use negotiations associated with the permitting referral process and was cut short by the early winter. Kennecott Canada Ltd. held an option and funded the 1992 program, but dropped the option at year-end.

Farther north, Verdstone Gold Corporation and Rea Gold Corporation completed 50 kilometres of induced polarization and 970 metres in five drill holes on the Newton Hill property. The best intersection reported was 0.65% "copper equivalent" over 72 metres. Immediately west of Fish Lake, Panther Mines Ltd. drilled 1500 metres in four holes on the Jesse-Sarah-Rio property.

At the north end of Tatlayoko Lake, Louis Bernoillles undertook a bulk sampling program on the Mount Skinner gold property. A sample of 146 tonnes was extracted from an open cut and shipped to Westmin's Premier mill, near Stewart. The sample was taken from a gold-bearing mesothermal(?) quartz vein that occurs on splays of the Yalakom-Tchaikazan fault system west of Tatlayoko Lake. Results of test milling of the material were 59.14 grams per tonne gold and 34.42 grams per tonne silver with 98% gold recovery. An underground exploration program is planned for 1993.

Farther to the west, Line Drive Mining Construction Ltd. carried out underground mapping and sampling at the Perkins Peak vein gold property. One objective was to test mineralized material for acid generating potential. A more aggressive underground exploration program is planned for 1993.

Southeast of Taseko Lakes and on French Bar Creek limited drilling programs were also carried out on the Mohawk High, by A. Babit and on the French Bar, by R. Clark; both are epigenetic gold prospects.

Exploration during the past three years has been relatively quiet in the Bridge River area, compared with the mid to late 1980s, when several major projects were operated. In 1992 Avino Mines and Resources Limited submitted a prospectus application for a Mine Development Certificate to re-open the Bralorne mine. Avino's program is the third attempt to bring the mine back into production since 1983. The company's incentive to finance an aggressive underground program during 1993 will undoubtedly hinge on an upward trend in the price of gold. West of Gold Bridge, in the Walker Ridge area, Cogema Canada Limited was encouraged by preliminary results from a limited drilling program on the Pilot property. Gold and copper mineralization is associated with quartz-carbonate veins that cut Bridge River Complex rocks occurring with Bralorne diorite. Near Carpenter Lake, Wayside Gold Mines Ltd. and Brigadier Resources Ltd. began an underground exploration program to explore the Wayside gold mine. Work completed in 1992 consisted of dewatering and rehabilitation of a part of the workings. An underground drilling program was underway in early 1993.

KAMLOOPS - QUESNEL HIGHLANDS

In the Lac La Hache area, southeast of Williams Lake , GWR Resources Inc. reported encouraging copper intersections on the Miracle-Murphy property. The company began a drilling program late in the year that carried through to 1993. Copper-magnetite mineralization occurs near the western contact of the Takomkane batholith, where monzodioritic rocks intrude Nicola volcanics and sediments. Significant amounts of magnetite and associated native copper occur in a setting similar to that of the Craigmont copper-iron skarn near Merritt. One of the better intersections returned approximately 70 metres of massive magnetite occurring with 20 centimetres of massive chalcopyrite. The program is ongoing in 1993.

At the Highland Valley Copper joint venture, diamond drilling programs were carried out on the Bethsaida and Calling Lake properties, west of the Lornex fault. Cominco Ltd. drilled two zones west of the Lornex and Valley Copper pits as follow-up work to test induced polarization anomalies outlined earlier in the year. In the Bethsaida zone, southwest of the Valley pit, a significant zone averaging more than 0.2% copper was outlined. This resource is not considered economic at current copper prices and it is unlikely that the company will consider further work on it in the near future.

To the east of the Highland Valley, on the Rey Lake prospect, Hera Resources Ltd. continued geophysical work on a copper-molybdenum-gold prospect that was previously explored in the 1970s by Asarco Ltd. Mineralization occurs in Late Triassic Nicola volcanic rocks as porphyry-style veins within a broad zone of weak magnetite-bearing skarn centred on the Swakum Mountain skarn occurrences to the south. A diamond-drilling program was initiated in the spring of 1993.

West of Kamloops, Lakewood Mining Ltd. and Green Valley Mine Inc. drilled the Wood and Beaton copper-gold prospects. The two properties are underlain by Nicola Group volcanic rocks intruded by augite-hornblende porphyries and occur south of the Iron Mask batholith. Weak hematite and native copper are associated with chlorite, carbonate and clay-sericite alteration. Despite the extensive diamond drilling that was carried out on the two properties, only limited sampling information was reported. On the nearby M&R property, Teck Explorations Ltd. completed a short drilling program for Afton-type copper-gold mineralization. To the east, also within the Nicola belt, Harold Adams drilled the Pilot Gold prospect, where weak gold and silver values are associated with pyrrhotite mineralization.

In the Adams Lake area, a single-hole drilling program was completed on the Flag property, in Eagle Bay rocks, south of Clearwater. From 1984 through 1990 this area was the most heavily explored in the district, but in 1992, with the closure of the Samatosum mine, interest in the area has declined, with relatively little exploration ventures underway, or forecast for the immediate future.

SIWASH - PRINCETON

The second largest exploration program in the district during 1992 was the Elk gold project, operated by Fairfield Minerals Ltd. The company initiated a bulk sampling program on the Siwash North gold zone. A small open cut was excavated and by year end Fairfield had delivered two shipments totaling 1850 tonnes of high-grade vein material to the Horne smelter, in Noranda, Quebec. The shipments contained 8650 ounces (269 kilograms) of gold. Further open-cut sampling is planned for 1993, as well as underground development to gain access to additional material.

To the northwest, on the Shear project, Placer Dome Inc. completed surface work and a six-hole drilling program. The target is porphyry copper-gold mineralization associated with the Big Kid breccia body, an intrusive breccia that cuts Nicola volcanic and sedimentary rocks. One of the better intersections returned 70.4 metres grading 0.20% copper and 0.75 gram per tonne gold. Placer Dome returned the property to International Northair Mines Ltd. at year end.

Elsewhere in the Nicola volcanic belt, Cominco Ltd. drilled copper-gold targets on the Missezula property, near Missezula Lake. Weak mineralization was intersected, but the company has no immediate plans to continue with the project. Small drilling programs were also carried out north of Princeton on the Jura claims, a porphyry copper-gold prospect, by J. Christofferson and on the Dorothy property, a precious metals vein target, by D. Dennis. South of Princeton, near Whipsaw Creek, Phelps Dodge Corporation of Canada Ltd. completed a 4-hole drilling program on the Whipsaw porphyry copper-moly-gold property. This occurrence has a long history of exploration. It lies along a northwest-trending lineament that forms the contact between Late Triassic Nicola volcanic rocks and the Jura-Cretaceous Eagle granodiorite. On adjacent claims to the east, M. Shewchuk drilled three holes on the Murphy prospect, a polymetallic vein target.

In the Midway area, east of Osoyoos, L. Lehman carried out a ten-hole percussion drilling program on the Lawless gold prospect.

COLUMBIA - SHUSWAP

In the Columbia River area, on the northeast side of McNaughton Lake, Teck Explorations Ltd. and Cominco Ltd. completed a second phase drilling program on the MGM and Bend zinc-lead-silver project. The target is a sedex massive sulphide deposit in Cambrian Tsar Creek schists and metapelites, near the contact with overlying Chancellor Group limestones. Mineralization has been traced for 5 kilometres along strike and about 600 metres down dip by diamond drilling and surface surveys . One of the better intersections returned 4% zinc, 0.5% lead and 5 grams per tonne silver over 3.7 metres.

In the northern Selkirk Mountains, near Downie Creek, Bethlehem Resources Corporation initiated drilling on the Rain volcanogenic massive sulphide prospect. Of particular interest was the intersection of a zone of garnet-bearing phyllite that hosts multiple horizons of semi-massive sulphides up to 0.5 metre thick with minor copper and zinc values. The significance of the intersection is its similarity to the garnetiferous assemblage that structurally overlies the Goldstream deposit, 40 kilometres to the north. Bethlehem drilled five percussion holes for 900 metres in 1992 and plans to continue work on the property in 1993. In addition to the company's work, the Geological Survey Branch will begin a two-year mapping project of the Paleozoic stratigraphic succession east of the Columbia River, known to host a number of polymetallic sulphide deposits.

Industrial Minerals

Near Clearwater, American Bullion Minerals Ltd. completed a baseline uranium-thorium survey on the Clearwater Fluorite (Rexspar), with plans to carry out drilling and study the feasibility of producing fluorite (fluorspar) for the hydrofluorocarbon (HFC) market. Late in the fall, however, the company dropped its option on the property.

To the south, in the Barriere area, the Nat 1 (Hagen Mountain) feldspar property was worked by partners George Wolanski and Joe Posteraro. During 1992 the operators completed percussion drilling, rock geochemical work and extracted a 50-tonne bulk sample for test work. Near-surface oxidation created minor quality control problems with the material, that were overcome with deeper excavation. Additional quarry development and market studies are to continue in 1993.

On the Clifton marble property, east of Vernon, Discovery Consultants Ltd., operators for owner Niamat Mughal, extracted a 1000-tonne bulk sample of dolomitic marble. Market targets for the material are the decorative stone industry (facing stone, floor tile) and carved stoneware (vases, lamps and plates).

Cromlech CRW Ltd. submitted a Prospectus in 1992 to the Mine Development Assessment Process to develop the NBS silica property near North Bend in the Fraser Canyon. The deposit is composed of unconsolidated silica-feldspar sand that occurs in the Scuzzy Creek area. Production is planned at 250 000 tonnes annually for domestic and international markets. Indicated reserves are 3.4 million tonnes, with preliminary geological potential of about 20 million tonnes. During the year the company completed six trenches, 1.5 kilometres of geophysical survey and extracted a 500-tonne bulk sample.

In the Ashcroft area, at the northwestern edge of the Guichon Creek batholith, CP Rail completed a drilling program on the Bys 1-2 claims to test the potential for a quarry to supply railroad balast. The company's main criteria for balast material is that it must be free of metallic minerals or associated alteration; a definite departure from contemporary exploration projects.

OPERATING MINES

A summary of highlights at mines operating in South-Central British Columbia is presented in Table A-6 and exploration and development costs are shown in Table A-7. The current trend by mine operators towards economic restructuring and the implementation of tight spending constraints is well-illustrated by the substantial drop in exploration and development investment. Development expenditures were $5.72 million in 1992 down by about 81% from 1991 levels of $30.4 million. Mine site exploration expenditures also dropped to $740 000 from $3.6 million in 1991. Production and reserves information are shown in Table A-8.

HIGHLAND VALLEY COPPER

Production continued at or above capacity at the Highland Valley Copper joint venture during 1992. The operation achieved record mine production of 96.3 million tonnes (ore plus waste), of which 44.1 million tonnes were milled at an average grade of 0.451% copper and 0.009% molybdenum. The mill also made record copper recoveries averaging about 89%. During the year 6600 metres of reserve definition drilling was completed, with year-end reserves announced at 574.3 million tonnes grading 0.414% copper and 0.0068% molybdenum, sufficient for 14 years of production. The company also received awards for mine reclamation and for operating the safest large mining operation in British Columbia for the third consecutive year.

SIMILCO

Similco Mines Ltd. maintained production at 22 000 tonnes of ore per day for a 1992 total of 7.71 million tonnes grading 0.45% copper. Year-end reserves were approximately 137 million tonnes grading 0.4% copper. During 1992, the company was faced with recovering from the 4.5 month strike that took place in mid-1991. In addition, current low copper prices are having a major impact on this and other small to mid-size copper producers. The Virginia orebody, discovered in 1989-90 has been developed for production, which is tentatively planned for mid-1993. A small exploration program was carried out during the year and a more intense effort is expected in 1993.

TABLE A-6
SOUTH-CENTRAL B.C.
OPERATING MINES SUMMARY 1992

HIGHLAND VALLEY COPPER
- 6600 m reserve definition drilling
- 4000 m exploration drilling
- Explored area west of Lornex fault; Bethsaida zone >2% Cu

GOLDSTREAM
- Deep zone development on down-dip extension
- shipped approx 20 Ktonnes Cu since opening May 1991
- Zinc circuit start-up 1992

SIMILCO (Copper Mtn)
- Production maintained at 22,000 tonnes of ore per day
- Small exploration program

CRAIGMONT
- Magnetite tailings recovery
- New Plant complete spring '93
- To produce 60,000 tonnes/year to coal industry

NICKEL PLATE
- North Pit expansion to supply reserves to 1997.
- Canty produced > 1 M tonnes
- Gold price a major factor
- Homestake Canada,new operator

SAMATOSUM
- Mining completed September 92
- Since July/89 produced approx 571.4 K tonnes, from original reserve of 609 K tonnes
- Victim of failed silver price

AFTON/AJAX
- Still (temporarily) closed
- Current low copper price indicates no foreseeable re-opening

PARSON BARITE
- Produce 50 Ktonnes/year
- Maintain on-going expl'n in Parson-Columbia River region

TABLE A-7
SOUTH-CENTRAL B.C.
E & D AT OPERATING MINES

MINE	COMMODITY	EXPLORATION ($)	DEVELOPMT ($)
Highland Valley	Cu,Mo	0.5M	0.75M
Nickel Plate	Au	----	0.9M
Goldstream	Cu,Zn	0.03M	2.25M
Samatosum	Ag,Cu,Zn,Pb,Au	----	0.27M
Similco	Cu,Au	0.01M	----
Parson	Ba	0.02M	0.05
Craigmont	Magnetite	----	1.50M
Candorado	Au (Tailings)	----	----
Totals		$0.74M	$5.72M

SAMATOSUM

Mining operations at the Minnova Inc. and Rea Gold Corporation Samatosum silver-zinc-lead-copper-gold mine were completed by the end of September, 1992. During the nine months of operation in 1992 a total of 129 400 tonnes were mined at an average grade of 566 grams per tonne silver, 0.65% copper, 1.1% lead, 2.05% zinc and 1 gram per tonne gold. The mine operated for three of a projected five years and closed prematurely due to the depressed price of silver, which was the main commodity. Had it not been for forward concentrate sales, the mine would have suffered more severe set-backs in profitability. Since opening in July 1989 the operation produced 571 400 tonnes from an original reserve of 609 000 tonnes.

NICKEL PLATE

The Nickel Plate (Mascot) mine was taken over by Homestake Canada Ltd. during 1992. Production for the year totaled 1 193 000 tonnes grading 2.4 grams per tonne gold. On-going geological re-evaluation of the skarn orebodies at this operation has made significant improvements in grade control and increased ore reserves. Expanded development of the North Pit was approved early in 1993 and will provide for production to 1997.

GOLDSTREAM

The Goldstream copper-zinc mine, north of Revelstoke, is jointly owned by Bethlehem Resources Corporation and Goldnev Resources Ltd. The operation re-opened in June 1991 at a total development and rehabilation cost of $5.6 million. By the end of 1992 the operation had shipped approximately 20 000 tonnes of copper in concentrate. Production in 1992 amounted to 420 000 tonnes grading 4.1% copper and 3% zinc. Revenues from metal sales were higher than anticipated and operating costs were lower than expected, resulting in combined net income for the two companies of approximately $5 million. Year-end reserves were estimated at 1.14 million tonnes grading 4.32% copper and 2.81% zinc. Additional geologically inferred reserves exist in the deeper, down-dip extensions of the deposit and could be developed given more positive trends in copper and zinc prices. The two companies are examining other sources of mill feed, in particular, the high-grade gold reserves at Tillicum Mountain, owned by Columbia Mines Ltd.

TABLE A-8
MINE PRODUCTION AND RESERVES
1991 - 1992
SOUTH-CENTRAL DISTRICT

	PRODUCTION				RESERVES (End 1992)	
MINE	1992 TONNES (000's)	GRADE	1991 TONNES (000's)	GRADE (000's)	TONNES (000's)	GRADE
Highland Valley	44 100	0.451 % Cu	47 500	0.43% Cu	574 300	0.414 % Cu
Copper		0.009% Mo		0.008% Mo		0.0068 % Mo
Similco	7 710	0.45 % Cu	3 960	0.47% Cu	136 972	0.40 % Cu
Samatosum	129.4	566 g/t Ag	174.5	812 g/t Ag	(Closed	—
		0.65 % Cu,		0.95 % Cu	Sept/92)	
		1.1 % Pb		1.21 % Pb		
		2.05 % Zn		2.24 % Zn		
		1.0 g/t Au		1.4 g/t Au		
Afton/Ajax	---	—	2 009	0.49 % Cu	18 735	0.45 % Cu
				0.34 g/t Au	(unchanged)	0.34 g/t Au
Nickel Plate	1 193	2.4 g/tAu	1 261	2.64 g/tAu	5 650	2.5 g/t Au
Goldstream	420	4.10 % Cu	275	4.00 % Cu	1 140	4.32 % Cu
		3.00 % Zn		2.52 % Zn		2.81 % Zn

PARSON

The Parson barite mine, south of Golden, is operated by Mountain Minerals Ltd. The company maintains production at about 50 000 tonnes per year and has been a long-standing supplier of barite for drilling mud products and industrial fillers. Limited exploration is carried out near the mine to maintain reserves, as needed.

AJAX

The Ajax copper-gold mine, owned by Afton Operating Corporation (Teck Corporation) remained closed throughout 1992 after closing in August 1991 due to marginal economic conditions. With the current down-turn in copper prices, the possibility of the mine re-opening is much farther removed.

MAJOR LAND-USE ISSUES

Increased emphasis on land-use issues and initiatives has become a dominant focus of the Kamloops district office during the past two years. Two of the most prominent processes have been the Protected Area Strategy, on a regional scale and the Kamloops Resource Management Plan, on a more local scale.

PROTECTED AREA STRATEGY

The Protected Area Strategy evolved from the Provincial Parks and Wilderness for the 90's program. It is part of the Provincial Land-Use Plan that is to eventually review all land-use planning for the province and was introduced as part of the government's commitment to preserve 12% of British Columbia's land base. When completed, protected areas will incorporate Provincial and National Parks, old-growth areas, wildlife habitats, ecological reserves and cultural heritage sites.

The objective and function of the Ministry of Energy, Mines and Petroleum Resources in evaluating areas under review for protected status, is to assess known and unknown mineral resources and express them in a quan-

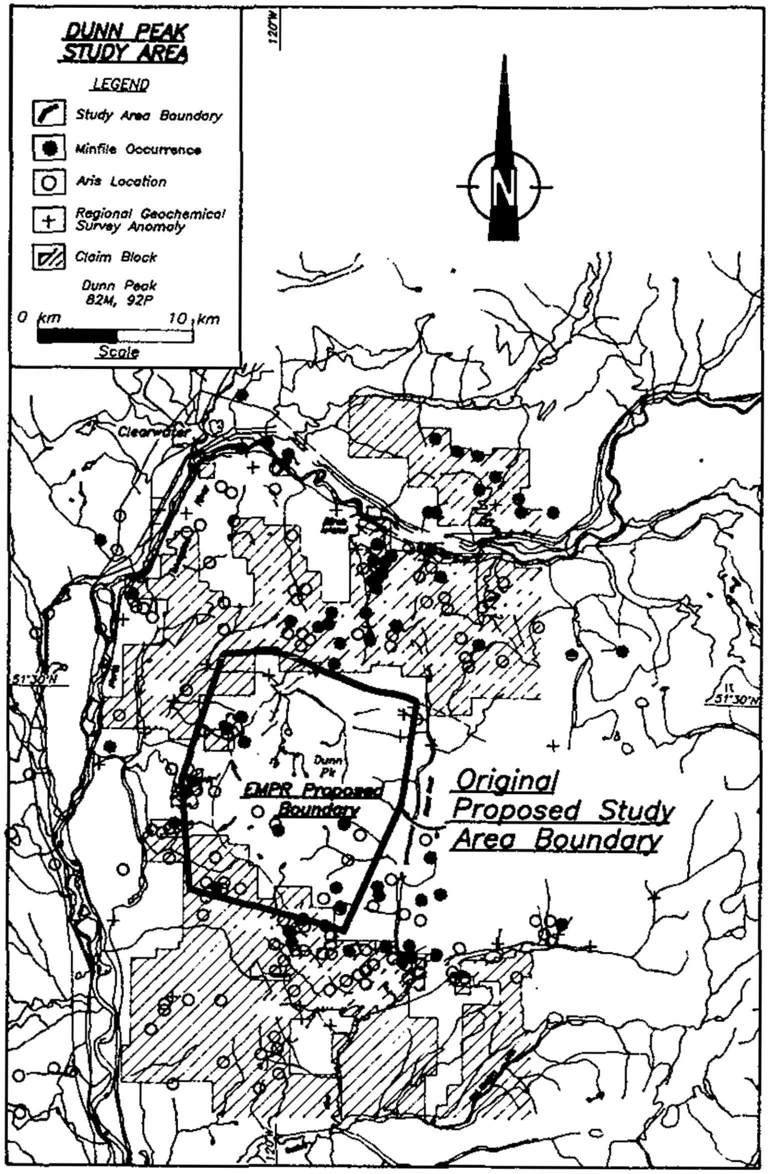


Figure A-20. Original proposed study area boundary.

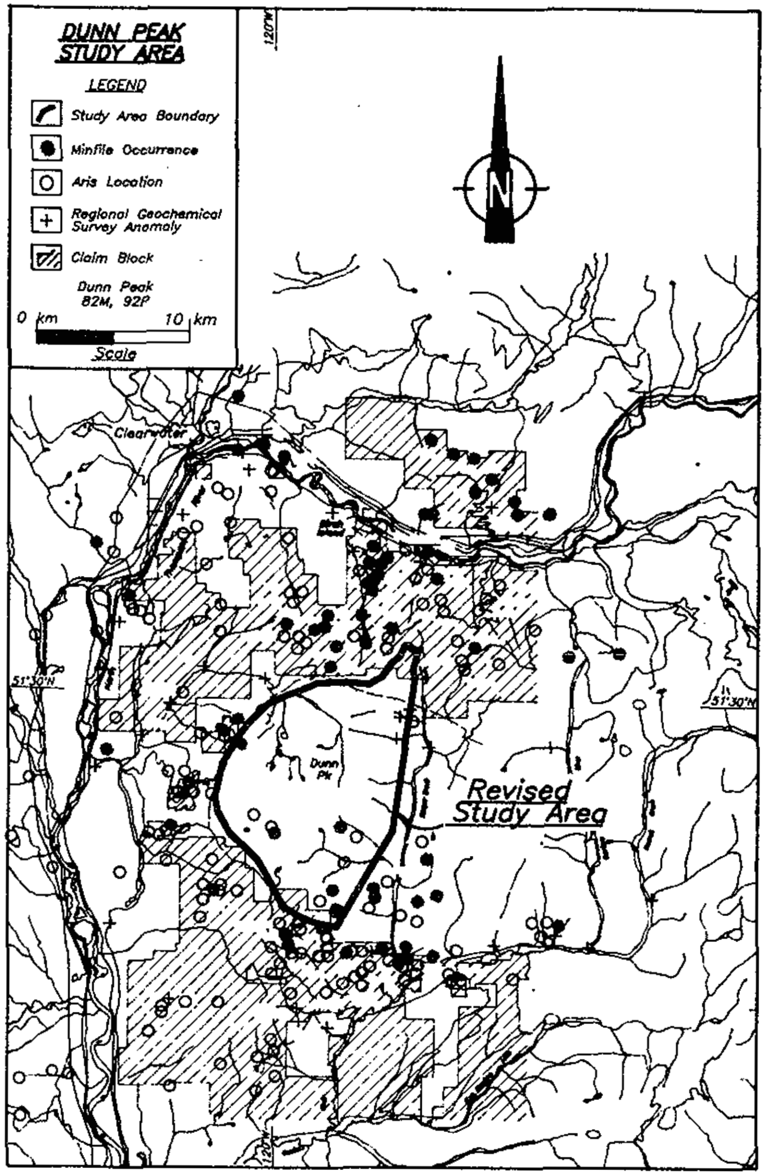


Figure A-21. Revised study area.

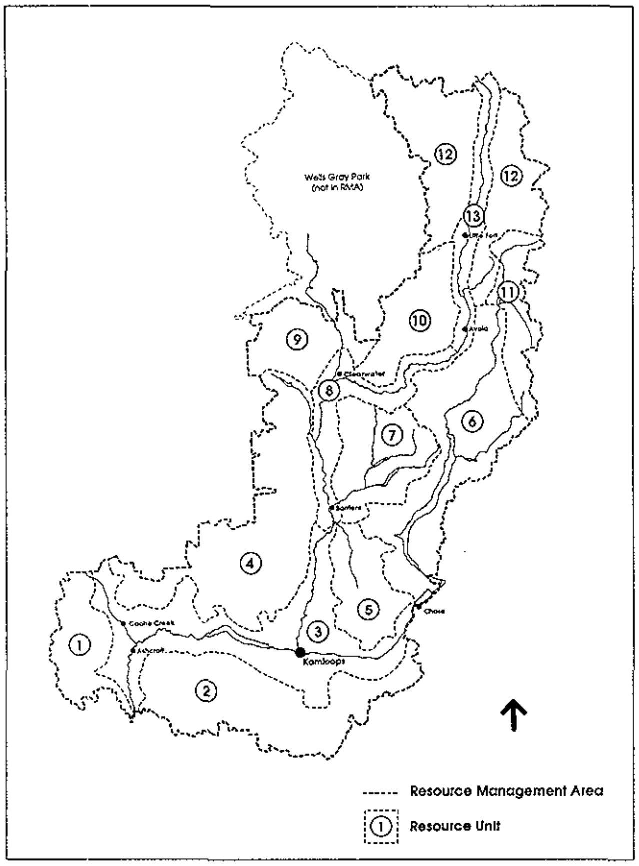


Figure A-22. Kamloops Resource Management Area; Resource Units.

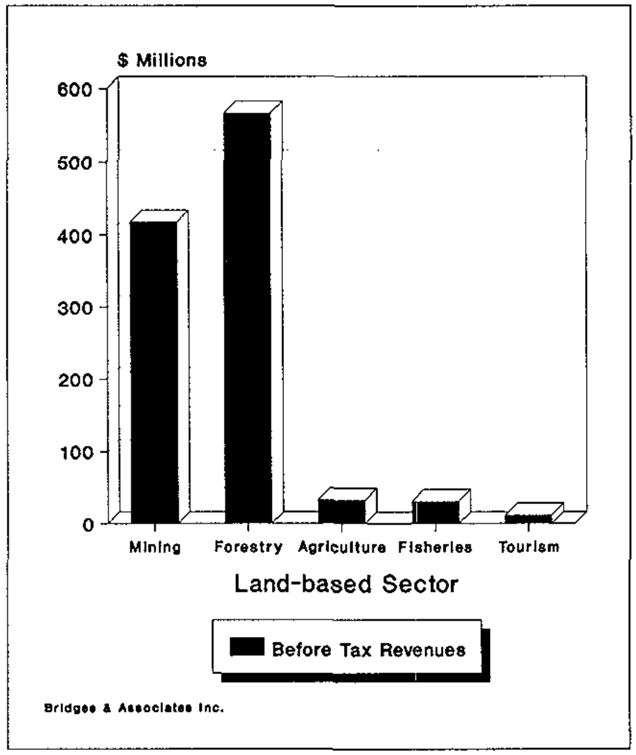


Figure A-24. Production revenues; Kamloops resource management area.

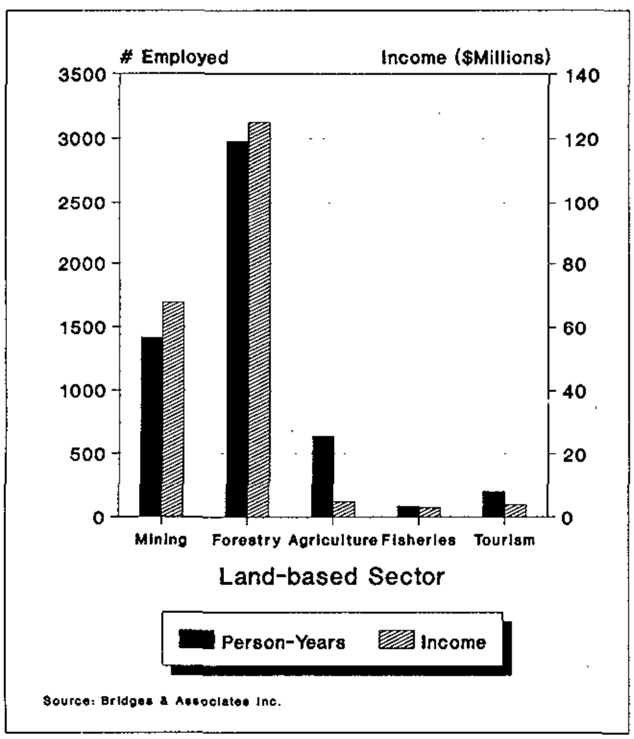


Figure A-23. Employment levels; Kamloops resource management area.

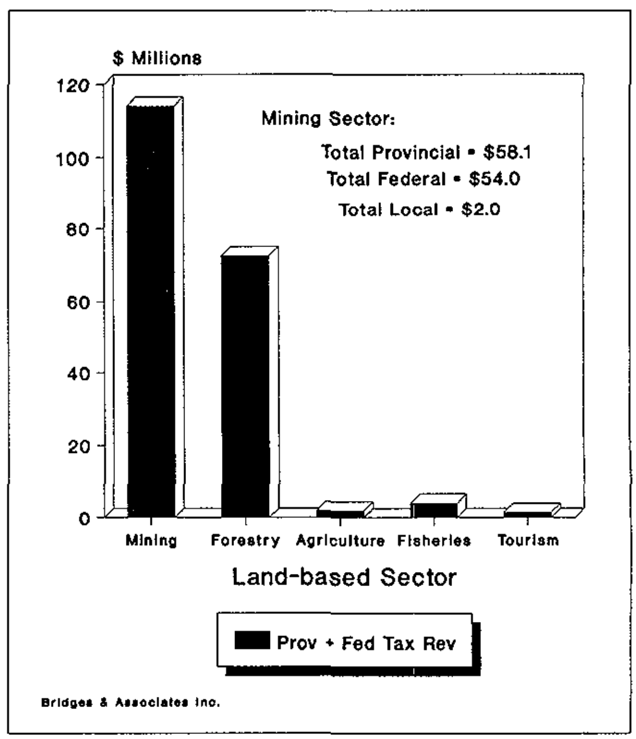


Figure A-25. Government revenues; Kamloops resource management area.

titative format. The Mineral Potential Project of the Geological Survey Branch is currently in the process of meeting this mandate, initially for areas being reviewed by the Commission on Resources and the Environment (*i.e.* Kootenays, Caiboo, Vancouver Island).

In areas not yet under CORE review, protected area studies are proceeding at a rapid pace, particularly in the Kamloops region. In response to study area proposals, preliminary compilation maps of mineral resource information have been prepared and presented as first phase reviews, in advance of more sofisticated evaluation by the Mineral Potential Project team. In some areas the preliminary maps have had significant results in alerting Protected Area study teams of potential impacts on mineral resources. The data shown in Figures A-20 and A-21 on the Dunn Peak study area, south of Clearwater, illustrate how study areas can be modified to accommodate mineral resources. The original proposal (Figure A-20) incorporated areas with established mineral tenures that are underlain by the Paleozoic Eagle Bay and Fennell formations. Both formations are distinguished by a number of known occurrences and high mineral potential; for example, the Chu Chua massive sulphide deposit lies within the southwest corner of the original proposal. The revised boundary (Figure A-21) impacts significantly less on known occurrences and existing mineral tenure. The revised western boundary corresponds more closely with the contact of the Baldy batholith, which has comparatively lower potential than the Paleozoic rocks.

Kamloops Resource Management Area Plan

The Kamloops Resource Management Area Plan is part of the province's Land and Resource Management Planning Process (LRMP), a process that has evolved from the Ministry of Forest's former Timber Supply Area (TSA) planning process. The goal of the process is to identify and develop broadly based land-use and resource management planning consensus at the subregional level. The responsibility for the delivery of the program is the Kamloops Inter-Agency Planning Team, formed in the fall of 1990 and made up of representative resource managers and local government officials. Industry stakeholders and representatives from the public are also involved and take part in quarterly workshops to evaluate resource use with the Resource Management Area (Figure A-22).

Early in 1993, the Economics and Trade Branch of the Ministry of Forests commissioned a consultant, G.E. Bridges and Associates Inc. to prepare a report entitled Kamloops LRMP, Environmental, Economic and Social Profile, for the Kamloops Resource Management Area. The study looked at the five major land-based economic sectors that operate within the resource management area; these are forestry, mining, agriculture, fisheries and tourism.

The results of the economic sector profiles, in terms of employment levels, production revenues and government revenues for the five land-based industries are summarized in Figures A-23, A-24, and A-25. Recognizing that the resource management area has a highly resource-based economy, with major forestry activities and a world-class operating copper-molybdenum mine, the results are as expected for most parameters.

In terms of employment levels and income, the forestry sector leads other industries, providing about twice the number of jobs and gross employment income as the mining sector. The same is true for before-tax production revenues, except that the gap between forestry and mining revenues has lessened, such that forestry revenues are only about one third (36%) higher than mining revenues.

However, in terms of government revenues (Figure A-25) the mining sector leads the forestry sector and all other sectors combined in provincial and federal tax revenues. In addition, the two revenue graphs (Figures A-24 and A-25) illustrate that the mining industry pays tax at about twice the rate of the forestry sector in the Kamloops area.

The results of the study are unique to the Kamloops Resource Management Area. From a mining industry perspective, the fact that the Highland Valley Copper operation lies within the area has a major impact on the economic sector profile. The results do, however, emphasize the importance of mining to the economy of the region. The Ministry of Energy, Mines and Petroleum Resources recognizes its responsibility as a member of the Inter-Agency Planning Team, to ensure that the importance of mineral resources is recognized in all land-use decisions for the region.

ACKNOWLEDGMENTS

The Kamloops district geology office acknowledges the cooperation of mining and exploration industry for its continued and enthusiastic contribution of exploration and development data to the preparation of this article.

SOUTHWESTERN DISTRICT

By R.H. Pinsent

District Geology, Vancouver

INTRODUCTION

The Southwestern District encompasses three geographic regions: the Queen Charlotte Islands, Vancouver and the off-shore islands and the southern part of the Coast Mountains. In 1992, the district office was moved from Victoria to Vancouver and the district boundary was adjusted to better correspond with the Resource Management Branch "Mining Inspection" districts. It now includes the Rivers Inlet (92M) and parts of the Mount Waddington (92N), Bella Coola (93D) and Laredo (103A) map areas (Figure A-26).

The office monitors exploration and other geoscience activity and acts as a source of data and technical analysis for industry, government and the public at large.

HIGHLIGHTS

- Westmin Resources Limited significantly increased its reserves at Myra Falls. The company is currently preparing the Battle zone for production.
- Hillsborough Resources Limited acquired the Quinsam coal mine. The company plans to increase production to 1.0 million tonnes of thermal coal a year.
- Crew Natural Resources Ltd. and Quality Industrial Mineral and Supply Inc. brought the Red Dog and Sumas Mountain sodaspar properties into the Mine Development Assessment Process.
- The Provincial government initiated "land-use" processes aimed at addressing regional (CORE) and local (PAS) land-use issues.

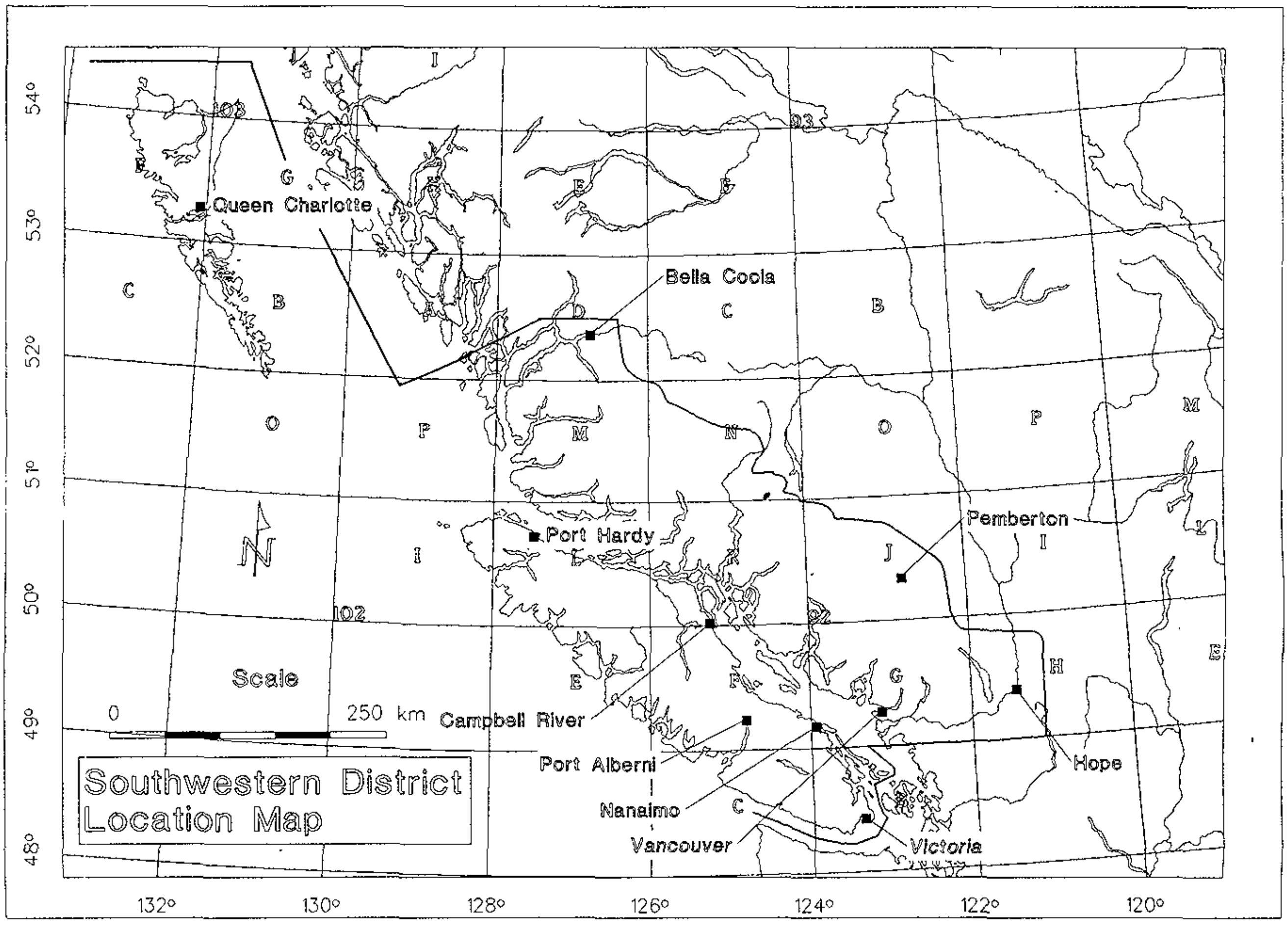


Figure A-26. Southwestern District outline showing NTS designations and major communities.

EXPLORATION TRENDS

The mining and exploration industries in British Columbia had a difficult year in 1992. Activity decreased throughout the province and dropped off significantly in the southwest. As compared to previous years, there were fewer "Notice of Work" submittals filed with Resource Management Branch; there were fewer, and less expensive, "major projects" undertaken; and there were fewer exploration dollars spent.

In Southwestern District, the number of Notice of Work applications for mineral properties declined to 83, down from 88 in 1991, and 137 in 1990. Most were for small programs. Less than 25% incurred costs in excess of $100 000, an arbitrary figure used to define "major projects". Many promising projects that could have qualified failed to do so. Exploration was either deferred or reduced, because of lack of adequate funding.

The total amount invested in exploration in the district in 1992 is estimated at around $8.5 million; down from approximately $9.5 million the previous year.

A total of $4.1 million, or almost one-half, was directed toward on-site exploration at two of the district's operating mines (**Westmin Resource's Myra Falls operation** and **Brinco Coal Mining Corporation's Quinsam coal mine**). Most of the remainder, approximately $3.5 million, was spent on 16 major exploration projects. These comprise five volcanogenic massive sulphide, four skarn/manto, three porphyry, three shear/vein and one kaolin target (Table A-4, Figure A-27).

The greatest single concentration of exploration activity in the Southwestern District was on northern Vancouver Island, close to the Island Copper mine. Active porphyry projects included Red Dog, Hushamu, Wann and LeMare; active skarn/manto projects included Merry Widow; and shear/vein projects included Madhat and Teeta Creek. Several of these projects were clearly predicated on the concept of custom milling ore at the Island Copper mine site.

There was relatively little exploration activity in central and southern Vancouver Island, compared with previous years, although there was some work on shear/vein systems on the Echo and Valentine Mountain properties

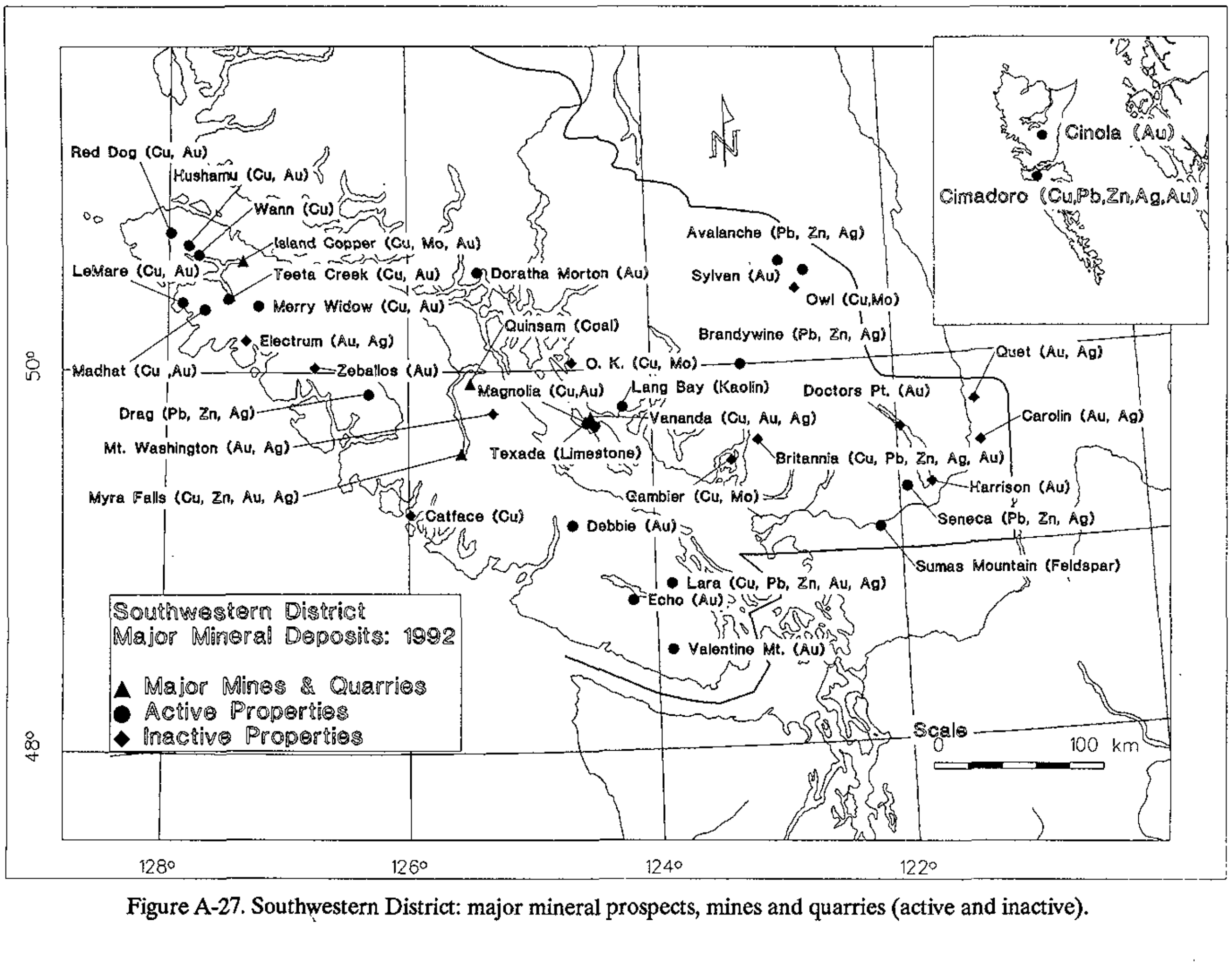


Figure A-27. Southwestern District: major mineral prospects, mines and quarries (active and inactive).

and on volcanogenic massive sulphide targets at Lara/Chemainus.

On Texada Island, two companies explored the Vananda Gold and Magnolia properties for shear/vein and skarn/manto deposits.

Most of the major exploration programs carried out in the south coastal region were directed toward volcanogenic massive sulphide targets, such as Avalanche, Seneca and Brandywine. However, there was also renewed interest in exploring shear/vein deposits such as Doratha Morton and there was some small-scale mining of skarn/manto ore from the Sylvan property.

There was considerable interest in the industrial mineral potential of the south coastal region and the kaolin property at Lang Bay was furthur explored.

Only one major exploration program was carried out on the Queen Charlotte Islands. It was directed at a possibly volcanogenic massive sulphide target on the Cimadoro property.

The level of "grass-roots" activity in the district in 1992 is difficult to assess, but it was probably down relative to levels attained in previous years. At least one major company was active on Vancouver Island and at least one displayed an interest in the Coast Mountains. There was only one announcement of a possibly significant new mineral discovery. Doromin Resources Ltd. reported finding polymetallic massive sulphide float on the Drag property, near Gold River on Vancouver Island.

Claim staking is not invariably indicative of grass-roots exploration, but it is a valid indication of exploration interest. There were 486 four-post and 1888 "other" (one-post, two-post and placer) claims staked in the Southwestern District between June 1st, 1991, and 9th November, 1992. Approximately 36% of the four-post, and a large proportion of the "other" claims, were located in and around five exploration properties, of which three are relatively recent discoveries (LeMare, Drag and Cimadoro) and two are established mining camps (Carolin mine, Doratha Morton).

OPERATING METAL MINES

There are two producing metal mines in the Southwestern District, the Myra Falls operation of Westmin Resources Limited and the Island Copper operation of BHP Minerals (Canada) Ltd. Neither mine operates with particularly high head-grades and both have had to undergo considerable change in an on-going struggle for profitability.

Myra Falls Operation: Westmin Resources Limited owns and operates a nominal 4000 tonne per day underground mine at its volcanogenic massive sulphide deposit at Myra Falls, at the south end of Buttle Lake, on Vancouver Island (Plate A-3). In 1992, the operation milled 1 171 629 tonnes of ore, mainly from the H-W orebody. It produced 71 785 tonnes of copper concentrate and 58 350 tonnes of zinc concentrate containing 17 459 tonnes of copper, 30 726 tonnes of zinc, 20 193 kilograms of silver and 978 270 grams of gold.

The company has changed its principal mining method to long-hole stoping, in an effort to reduce costs, and it has undertaken an ambitious and successful underground exploration program designed to locate higher grade ore reserves.

The company began an aggressive underground drilling program at Myra Falls in 1988 and, in 1991, it located the Gap and Battle zones in a hitherto largely inaccessible, flat lying section of "main zone" stratigraphy west of the H-W shaft. In 1992, it drilled 200 underground diamond-drill holes, for an aggregate length of 37 500 metres. Most of the holes were used to delineate the two zones. By year's end, it had defined proven and probable geological reserves of 634 400 tonnes grading 3.2 grams per tonne gold, 151.5 grams per tonne silver, 1.8% copper, 1.1% lead and 13.3% zinc in the Gap zone and 2 013 700 tonnes grading 1.1 grams per tonne gold, 24.2 grams per tonne silver, 2.6% copper, 0.5% lead and 12.7% zinc in the Battle zone.

Westmin Resources extended the 18-level drift at the H-W mine 1500 metres towards the Battle zone to provide stations for definition drilling. It expects to drill off the lens, ramp down through it, connect with the 24-level haulage drift, and begin production from the Battle zone in 1993. The company has also had other underground exploration successes at Myra Falls. Drilling from the 18-level drift delineated an additional proven and probable geological reserve of 231 000 tonnes grading 1.2 grams per tonne gold, 60.4 grams per tonne silver, 1.7% copper, 0.4% lead and 3.8% zinc at the west end of H-W orebody and drilling elsewhere added to existing reserves in the H-W Ridge, and 42 and 43 reserve blocks.

Westmin Resources carried out spring and autumn surface-drilling programs in the Thelwood valley, at the southeast end of its mining lease. It drilled 40 holes, for an aggregate length of 12 100 metres, in a successful attempt to track "mine series" stratigraphy. The company located the new Trumpeter zone, and delineated proven and probable geological reserves of 61 200 tonnes grading 3.2 grams per tonne gold, 68.9 grams per tonne silver, 6.3% copper, 0.3% lead and 4.6% zinc. It also intersected traces of fragmental ore similar to that found in the 43 block of the H-W mine.

Island Copper Operation: BHP Minerals (Canada) Ltd. owns and operates a nominal 50 000 tonne per day open-pit porphyry copper mine at the east end of Holberg Inlet, on Vancouver Island (Plate A-4). In 1992, the mine processed 18 194 344 tonnes of ore, recovering 47 064 275 kilograms of copper, 417 175 kilograms of molybdenum,

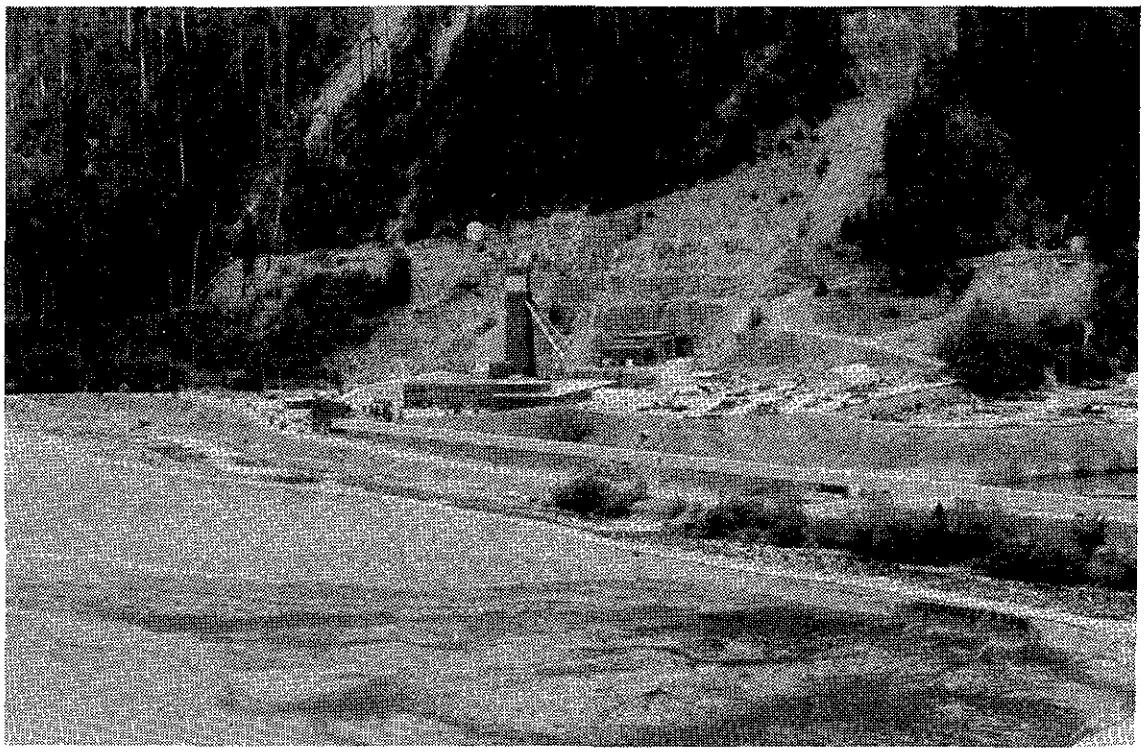


Plate A-3. H-W Shaft, Myra Falls operation: Westmin Resources Limited.

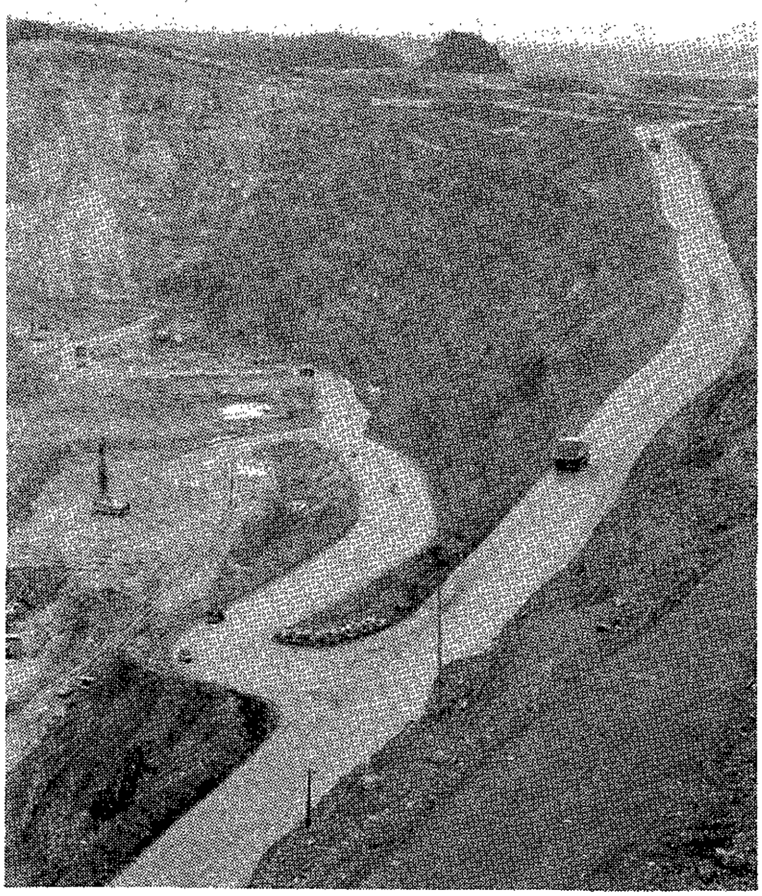


Plate A-4. Island Copper pit, Island Copper mine: BHP Minerals (Canada) Limited.

1 588 619 grams of gold and 14 591 490 grams of silver in concentrate.

The mine has been in operation since 1971 and it is nearing the end of its productive life. BHP Minerals (Canada) Ltd. has struggled to keep the mine profitable. It built an in-pit crusher and completed a major "push-back" of the south wall of the pit in 1991. The push-back required the construction of a sophisticated retaining wall designed to prevent seawater from seeping into the pit. It added sufficient ore reserves for several additional years of operation. As of June, 1992, the company had a proven reserve of 86.5 million tonnes of ore grading 0.36% copper, 0.017% molybdenum and a trace of gold.

In 1992, BHP Minerals focused its efforts on optimising the mining process. It redesigned the configuration of the haulage ramp to provide efficient access to the in-pit crusher. The company deferred its exploration plans until 1993.

OPERATING COAL MINES

There is currently only one producing coal mine in the Southwestern District.

Quinsam Coal: Hillsborough Resources Limited merged with **Consolidated Brinco Limited** in February, 1992, and acquired control of the Quinsam coal mine, at Middle Quinsam Lake, west of Campbell River on Vancouver Island (Plate A-5). The mine is operated by Brinco Coal Mining Corporation. It has a reserve of appoximately 44 million tonnes and a historic rate of production of around 250 000 tonnes of washed thermal coal per year. In 1992, it produced approximately 500 000 tonnes.

The mine currently operates two continuous miners underground in the 2N reserve block. Brinco Coal is currently restructuring the operation. It is phasing out open-pit mining and is planning to increase underground production to around a million tonnes per year. The company plans to operate two more continuous miners in the 2N reserve block and build a duplicate wash plant to handle the increased production.

Brinco Coal currently barges coal to the Holnam West Materials Ltd. quarry on Texada Island for transshipment to ocean-going freighters. It plans to build a deep-water coal-loading facility, capable of handling the increased tonnage, near Campbell River.

In 1992, the company carried out a 42-hole, combined rotary and diamond-drilling program at the mine site (4482 metres of drilling). The program was designed to confirm the quality of the coal in the 2N reserve block and provide engineering data on some minor faults.

MAJOR QUARRIES

Holnam West Materials Ltd. and **Ash Grove Cement Company** are major limestone producers that operate at

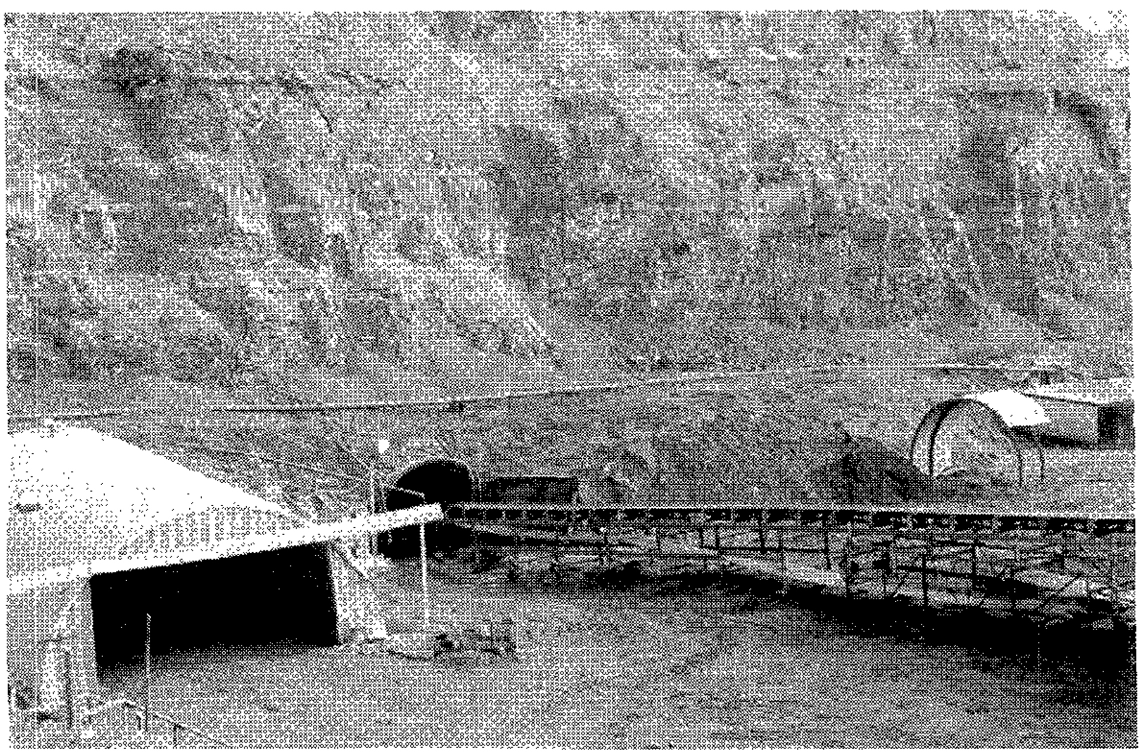


Plate A-5. Quinsam portal, Quinsam coal mine: Brinco Coal Mining Corporation.

Plate A-6. Limestone quarry site: Holnam West Materials Limited.

the north end of Texada Island (Plate A-6). Together, the two companies produce and ship approximately 4.5 million tonnes of "chemical" (97% $CaCO_3$, 0.2 - 0.7% MgO), "cement" (94.0% $CaCO_3$, 0.7 - 1.5% MgO) and "agricultural" grade (90.0% $CaCO_3$, 1.5 - 3.5% MgO) material. Both companies have diversified their product range over recent years. Holnam West now ships "oversized" blocks as "rip rap" and crushed intrusive rock as road aggregate.

MINE DEVELOPMENT SUBMISSIONS

Two properties entered the Mine Development Assessment Process in 1992. Crew Natural Resources Ltd. and Quality Mineral and Supply Inc. each submitted a prospectus. The former for the Red Dog property and the latter for the Sumas Mountain sodaspar property.

Red Dog: Crew Natural Resources Ltd. has identified a reserve of 25 million tonnes grading 0.35% copper and 0.44 gram per tonne gold (at a 0.2% copper cut-off) at the Red Dog porphyry copper property, at the north end of Vancouver Island. The reserve is on the side of hill and is amenable to opencut mining at a low (0.1:1.0) stripping ratio.

The company's development proposal is predicated on negotiation of a custom milling agreement with BHP Minerals (Canada) Limited. It has applied for the permits required to crush and convey 20 000 tonnes of ore per day to a loading facility at Holberg for barging up the inlet to Island Copper.

Sumas Sodaspar: Quality Mineral and Supply Inc. has identified a reserve of 36 million tonnes of relatively pure, fibreglass to ceramic grade (< 0.35% Fe) sodaspar (sodium feldspar) in a suite of felsic dikes that crop out near the top of Sumas Mountain, northeast of Abbotsford. The company has applied for permits to quarry, crush and truck up to 150 000 tonnes of product per year.

EXPLORATION ACTIVITY

VANCOUVER AND TEXADA ISLANDS

Despite the current downturn, there was appreciable exploration activity on Vancouver Island in 1992. Much of it was focused on the north end of the island where companies expended considerable effort on locating porphyry copper deposits in Bonanza Group volcanic rocks close to the Island Copper mine. The level of activity decreased markedly south of Kyuquot Sound.

Hushamu: Jordex Resources Inc. is earning an interest in the Hushamu porphyry copper deposit from **BHP Minerals (Canada) Ltd.** It carried out a winter drilling program, consisting of eight diamond-drill holes, for a total length of 5300 metres, and calculated a preliminary "mineable reserve", in two pits, of 173 million tonnes of ore grading 0.25% copper, 0.31 gram per tonne gold and 0.01% molybdenum (at a combined stripping ratio of 0.6:1.0). The company subsequently conducted a major technical review and economic prefeasibility study.

Wann: Jordex Resources Inc. also conducted a drilling program on **Acheron Resources Ltd.'s** Wann property, to the west of the Island Copper mine. The company drilled 14 diamond-drill holes (aggregate length of 1830 metres) into a large alteration zone that locally displays high-level, transitional to epithermal characteristics. The holes intersected an appreciable amount of subeconomic copper-bearing rock.

LeMare: Minnova Inc. explored a similar "porphyry" to "transitional" deposit in Bonanza Group volcanic rocks south of Quatsino Sound on the west coast of Vancouver Island. It optioned the LeMare property from **Stow Resources Ltd.** and flew an airborne radiometric survey. It then conducted follow-up mapping and lithogeochemical surveys and established the presence of two main areas of alteration and mineralization.

The company implemented a modest diamond-drilling program, comprising six holes for a total of approximately 900 metres, to test the two areas. The holes intersected a large zone of intense potassic alteration and weak copper mineralization and a small zone of intense, near-surface, pyrophyllite alteration and pyrite mineralization.

Madhat: Orvana Minerals Corporation continued its exploration of the Madhat property near the head of the Mahatta River. It drilled five diamond-drill holes, for an aggregate length of 915 metres, to test for the source of gold detected in a linear soil-geochemical anomaly. The holes intersected several zones of intense silicification, locally carrying copper and/or gold, in shattered volcanic rocks.

Merry Widow: Taywin Resources Ltd. was also active at the north end of Vancouver Island. It drilled an area of erratic, "high-grade" copper-gold skarn to obtain sufficient statistical data to calculate a reserve. It drilled 84 short, close-spaced, percussion holes, for a total lengh to 820 metres, into the pit wall immediately adjacent to a mined-out magnetite pipe.

Teeta Creek: Great Western Gold Corporation explored for gold veins on its Teeta Creek property, on the west side of Neroutsos Inlet. The company cut a grid over known showings and collected close-spaced soil samples for geochemical analysis. The program delineated a series of apparently projectable, linear, polymetallic soil anomalies, adjacent to an intrusive contact.

Echo: Consolidated Ramrod Gold Corporation explored for gold in a shear-hosted quartz vein system on the Echo claim near Cowichan Lake, at the south end of Vancouver Island. It drilled four diamond-drill holes, for an aggregate length of 292 metres, below a "high-grade" gold showing. The holes encountered the vein system but core assays failed to confirm surface sampling.

Valentine Mountain: Beau Pre Exploration Ltd. sampled the nuggety, gold-bearing, "C quartz vein" system on its Valentine Mountain property near the Leech River at the south end of Vancouver Island.

There was little exploration on other Vancouver Island gold properties including **Mount Washington, Debbie, Electrum**, or in the **Zeballos camp**. There was no exploration on the **Catface** porphyry copper property.

Lara/Chemainus: Laramide Resources Ltd. optioned the Chemainus claims, adjoining its Lara, volcanogenic massive sulphide property, from **Falconbridge Limited.** It now controls an area of approximately 75 square kilometres of prospective Sicker Group volcanic stratigraphy. The company spent the year combining geological data from the two projects into a single database and defining targets for future exploration.

Drag: Doromin Resources Ltd. optioned the Drag property to **Noranda Exploration Ltd.** which flew an airborne geophysical survey, staked additional ground, and ran a series of ground evaluation programs.

Vananda Gold: Vananda Gold Corporation was active on its Texada Island gold property. The company completed 23 diamond-drill holes, for a total length of 7148 metres, looking for copper-gold skarn mineralization peripheral to the past-producing Texada Mines copper-magnetite skarn deposits. Most of the drill holes were sited on deep induced polarization targets at or below the base of limestone cover within, and adjacent to, the **Holnam West quarry.**

The Company had considerable success in locating altered and pyritic zones at the base of the limestone and in structures in the underlying volcanic rocks. The last three holes of the year intersected a narrow (2.0-3.0 m wide) flat-lying zone of copper-rich massive sulphide "skarn" or "manto" at the base of the limestone, peripheral to a diorite pluton.

Magnolia: Canquest Resource Corporation conducted grid geophysical and geochemical surveys exploring for gold-bearing shear-vein, and copper and gold-rich skarn deposits in calcareous flows south of the **Holnam West quarry.**

Southern Coastal Region

Most of the exploration activity in the southern coastal region was directed at Kuroko-type volcanogenic massive sulphide targets in volcanic pendants within the Coast Plutonic Complex.

Seneca: Minnova Inc. continued to explore the Seneca property, owned by **International Curator Resources Ltd.** Minnova is seeking to expand an existing "probable and possible" geological reserve of 502 000 tonnes of Kuroko-type massive sulphide grading 0.91% copper, 0.22% lead, 7.06% zinc, 68.8 grams per tonne silver and 1.44 grams per tonne gold.

The company completed 20 diamond-drill holes, for an aggregate length of 6361 metres, to test the continuity and extent of a flat-lying zone of alteration and mineralization below the floor of the Chehalis River valley. Most of the holes were targeted on the Fleetwood zone where good intersections were obtained in 1991. The program confirmed the trend of the zone. The best intersection graded 2.23% copper, 2.47% lead, 28.1% zinc, 160 grams per tonne silver and 3.97 grams per tonne gold over 1.95 metres. Other holes cut either shorter or lower grade intercepts or cut dike material at the target depth.

Avalanche: Teck Corporation completed a second year of drilling on the Avalanche property of **Toscana Resouces Ltd.** It completed eight diamond-drill holes, for a total length of 1550 metres, to test for Kuroko-type massive sulphide mineralization in sheared volcanic and sedimentary rocks adjacent to a felsic dome in Cadwallader Group strata, northeast of Pemberton Meadows. The holes cut significant alteration and confirmed the presence of two separate zones of anomalous lead, zinc and silver.

Brandywine: La Rock Mining Corporation also explored for Kuroko-type massive sulphide deposits. It drilled 58 short diamond-drill holes, for a total length of 3230 metres, in the vicinity of the Tedi pit showing on its Brandywine property near Whistler. The program established the presence of a narrow, flat-lying zone of polymetallic, lead, zinc and silver-bearing sulphide-cemented breccia in volcanic rock in a Gambier Group volcanic pendant.

There was no exploration in the **Britannia** massive sulphide camp, and little or no exploration on any of the major porphyry copper properties in the southern coastal region. There was no exploration on the **Gambier Island, O.K.** or **Owl Creek** porphyry prospects. **Cominco Ltd.** conducted a limited soil geochemical survey on a block of claims immediately north of the **Owl Creek** deposit.

Similarly, there was very little exploration for precious metal bearing vein, skarn or intrusion-related gold deposits in the southern coastal part of Southwestern District. The **Quet, Doctor's Point, Harrison Gold** and **Carolin mine** properties were inactive.

Doratha Morton: Ripple Rock Resources Ltd. was active in the Loughborough Inlet area. The company prospected, compiled data and prepared to trench and bulk sample the Doratha Morton gold and silver-bearing quartz vein system.

Sylvan: A.J. Beaton Mining Ltd. took some preliminary steps toward the extraction of a bulk sample of gold-bearing pyrrhotite skarn from an adit on the Sylvan property near Pemberton.

In other activity, there was renewed interest in quarrying for dimension stone and the development of industrial mineral targets.

Lang Bay Kaolin: Lang Bay Resources Ltd. drilled two, large-diameter, rotary-drill holes into its kaolin deposit in weathered granodiorite north of Lang Bay. The holes provided material for preliminary quality appraisal tests. The company subsequently applied for, and received, the permits required to drive an adit into the deposit and extract a 2000-tonne bulk sample.

QUEEN CHARLOTTE ISLANDS

There was only one major exploration project on the Queen Charlotte Islands and it was directed toward the location of massive sulphide mineralization.

Cimadoro: Inco Exploration and Technical Services Ltd. flew an airborne geophysical survey over **Doromin Resource's** Cimadoro property on Moresby Island. The survey identified a series of anomalies and the company completed follow-up ground evaluation programs. It identified lead, zinc and silver minerals in a stratabound zone of barite enrichment in a "sediment-sill" complex that underlies volcanic rocks of the Karmutsen Formation.

City Resouces (Canada) Ltd. did not work on its **Cinola** gold property during 1992. It announced its decision to sell or joint venture the property.

LAND-USE ISSUES

In May, the Government of British Columbia announced its intention to double the amount of "protected land" (Park, Wilderness Area, Wildlife Management Area etc.), to approximately 12% of the province, by the year 2000. It released a 1:2 000 000-scale map, entitled "Towards a Protected Area Strategy for B.C.", that provides a preliminary list of 112 large and 72 small areas to be studied as possible candidates for protection. Most were identified as a result of the "Parks and Wilderness for the 90s" process. As the criteria for studying and recommending areas for protective status evolves in 1993, this list of study areas may be amended. At present, a total of 36 large and 19 small candidate areas either lie within or impinge upon the Southwestern District.

Study areas are subject to interim management guidelines in order to ensure the values being studied for protection are not unnecessarily compromised during the study process. No staking mineral reserves have been established over a limited number of the smaller, higher priority study areas. Work on existing claims is permitted but additional work conditions may be applied. The remainder of the study areas are open to continued claim staking and exploration, but work proposals will be subject to closer review and possibly, additional conditions for approval.

The Protected Areas Strategy aims to protect approximately 12% of the province. This will be done according to specific criteria that address the need to protect conservation, recreation and cultural heritage values. Socio-economic impacts of each area recommended for protection will also be assessed to ensure a balance between the province's economic and protected area objectives is achieved.

The Commission on Resources and Environment (CORE) was also established during 1992. The Commission's mandate is to develop and implement a land-use and related resource and environmental management strategy for British Columbia. This strategy is being implemented through regional, multi-stakeholder, shared-decision making processes that are responsible for developing large scale land use recommendations. CORE planning processes have been established in the Vancouver Island, Cariboo-Chilcotin and Kootenay-Boundary regions first.

The CORE planning process will make recommendations for protected areas on Vancouver Island. The Ministry of Energy, Mines and Petroleum Resources will be updating all available mineral potential and mineral tenure information to ensure this data is fully considered in selecting protected areas. The mining sector will be represented directly in the process.

On the Lower Mainland, land-use studies to develop protected area recommendations in specific study areas, are ongoing. Areas under review or to be reviewed in the near future, include Boundary Bay near Ladner, Tetrahedron near Squamish, Pinecone Lake - Burke Mountain near Coquitlam and Callaghan Lake near Whistler. The study teams expect to make recommendations on these areas by the end of 1993.

GOVERNMENT ACTIVITY AND RESEARCH

The Ministry of Energy, Mines and Petroleum Resources recognizes that the various stakeholder committees negotiating land-use issues will require comprehensive mineral resource data and has responded accordingly. The ministry has representatives on most PAS committees and it supplies the committees with data and analysis for discussion.

A major part of the ministry's response to land-use concerns is a committment to produce a new generation of 1:250 000-scale "Mineral Potential Maps" for the province. It is currently working on maps for Vancouver Island. Other initiatives in 1992, specifically pertinent to the Southwestern District, included the release of data from the Regional Geochemical Survey of Mount Waddington map area [MEMPR BC RGS #34; (92N)]; a till geochemical survey for the Quatsino map area [MEMPR BC Open File 1992-21; (92L/12)] and a mapping program over Bonanza Group volcanic strata east of Neroutsos Inlet (MEMPR BC Open File 1993-10; Geology of the Mahatta Creek Map Area; 1:50 000-scale).

The Geological Survey of Canada was also active in the district. It is finishing off multi-year programs in the Queen Charlotte Islands (Queen Charlotte project) and in the southern Coast Mountains (Georgia Bay project). Both will provide modern maps and an improved understanding of the local stratigraphy and regional structural evolution.

In addition, the Mineral Deposit Research Unit at the University of British Columbia began a research project to study Cordilleran volcanogenic massive sulphide deposits. The project should provide data and analysis of considerable value for future exploration for the deposit type.

ACKNOWLEDGMENTS

The Geological Survey Branch wishes to acknowledge the contribution of numerous public sector and industry geologists and other professionals in the creation of this report.

Editor's Note:

Information for the Kootenay District was not available at the time of publication of this issue of *Exploration in British Columbia*.

PART B

GEOLOGICAL DESCRIPTIONS
OF
PROPERTIES

THE FISH LAKE PORPHYRY COPPER - GOLD DEPOSIT (92O/5)

By Nadia Caira[1] Alastair Findlay[1] and Janet Riddell[2]
[1]Taseko Mines Limited [2]B.C. Geological Survey Branch

LOCATION:	Lat. 51°27'N Long. 123°31'W CLINTON MINING DIVISION. The deposit is located about 5 kilometres east of the Taseko River, 9.5 kilometres north of the north end of the Taseko Lakes. It is about 250 kilometres north of Vancouver and 128 kilometres southwest of Williams Lake.
CLAIMS:	The Fish Lake property consists of 196 mineral claims and fractions (554 units) and 9 placer claims.
ACCESS:	West from Williams Lake via the Bella Coola Highway (Highway 20) to Lees Corner at Hanceville, and then southwest along a government-maintained gravel road to the Davidson Bridge at the Taseko River. A gravel road continues south along the east side of the river for 16 kilometres to the deposit area immediately north of Fish Lake.
OWNER/OPERATOR:	Taseko Mines Limited.
COMMODITIES:	Copper, gold.

INTRODUCTION

The Fish Lake calcalkaline porphyry deposit is situated close to the western boundary of the Interior Plateau, 4 kilometres northeast of the Yalakom fault. Mineralization is spatially and genetically associated with a (?)Tertiary multiphase quartz diorite intrusive complex which cuts andesite flows and volcaniclastic rocks of probable Early Cretaceous age. This report presents an update on the nature of the deposit and its regional setting, and is based on the results of major drilling programs by Taseko Mines Limited in 1991 and 1992, and regional mapping by the B.C. Geological Survey Branch in the Mount Tatlow area in 1992. We acknowledge the permission of Taseko Mines to publish this report.

EXPLORATION HISTORY

Prospectors E. Calep and C. M. Vick made the initial discovery at Fish Lake in the 1930s when they found copper showings in outcrop approximately 1 kilometre east of the main deposit. Phelps Dodge Corporation recognized and drill tested the porphyry copper potential of the showings in 1960. Taseko Mines Limited acquired the property in 1966 and completed 2300 metres of drilling in six diamond-drill and twelve percussion-drill holes. Taseko Mines optioned the property to Nittetsu Mining Company Ltd. in 1970, and then to Quintana Minerals Corporation, which drilled 4800 metres of core in 24 holes in 1973 and 1974. Taseko Mines subsequently optioned the property to Bethlehem Copper Corporation between 1979 and 1981. Bethlehem Copper amalgamated with Cominco Ltd. in 1981; together these companies completed 14 150 and 4800 metres of diamond and percussion drilling, respectively. Extensive ground magnetometer, VLF-EM, and induced polarization surveys and soil sampling were also carried out over the years.

CURRENT ACTIVITY

Taseko Mines drilled 7506 metres of core in ten holes in 1991, and in 1992 completed approximately 60 000 metres of HQ and NQ diamond drilling. The geological resource at Fish Lake is estimated to be 1.146 billion tonnes of ore with an average grade of 0.22% copper and 0.411 gram gold per tonne.

REGIONAL GEOLOGY

The Fish Lake deposit lies on the northwest-striking physiographic boundary between the Coast Mountains and the Interior Plateau, just northeast of the Yalakom fault (Figure 1). This boundary region is a structurally complex zone of Mesozoic volcanic arc and clastic basin sequences that is bounded to the southwest by intrusions of the Coast Plutonic Complex, overlain to the north and east by Neogene plateau lavas of the Chilcotin Group, and intruded by numerous Cretaceous and Tertiary dikes and stocks (Figure 2). The Yalakom fault is the locus of about 115 kilometres of Eocene(?) dextral stike-slip displacement (Riddell *et al.*, 1993). The deposit is hosted by a diorite to quartz diorite intrusive complex within an andesitic volcanic pile.

Previous workers have assigned the andesitic hostrocks at Fish Lake to the Upper Cretaceous Kingsvale Group (Wolfhard, 1976; Tipper, 1963, 1978). The term "Kingsvale Group" has been abandoned by regional mappers following Thorkelson (1985) noted that the term is no longer useful because it has not been used consistently. Much of the ground that was previously

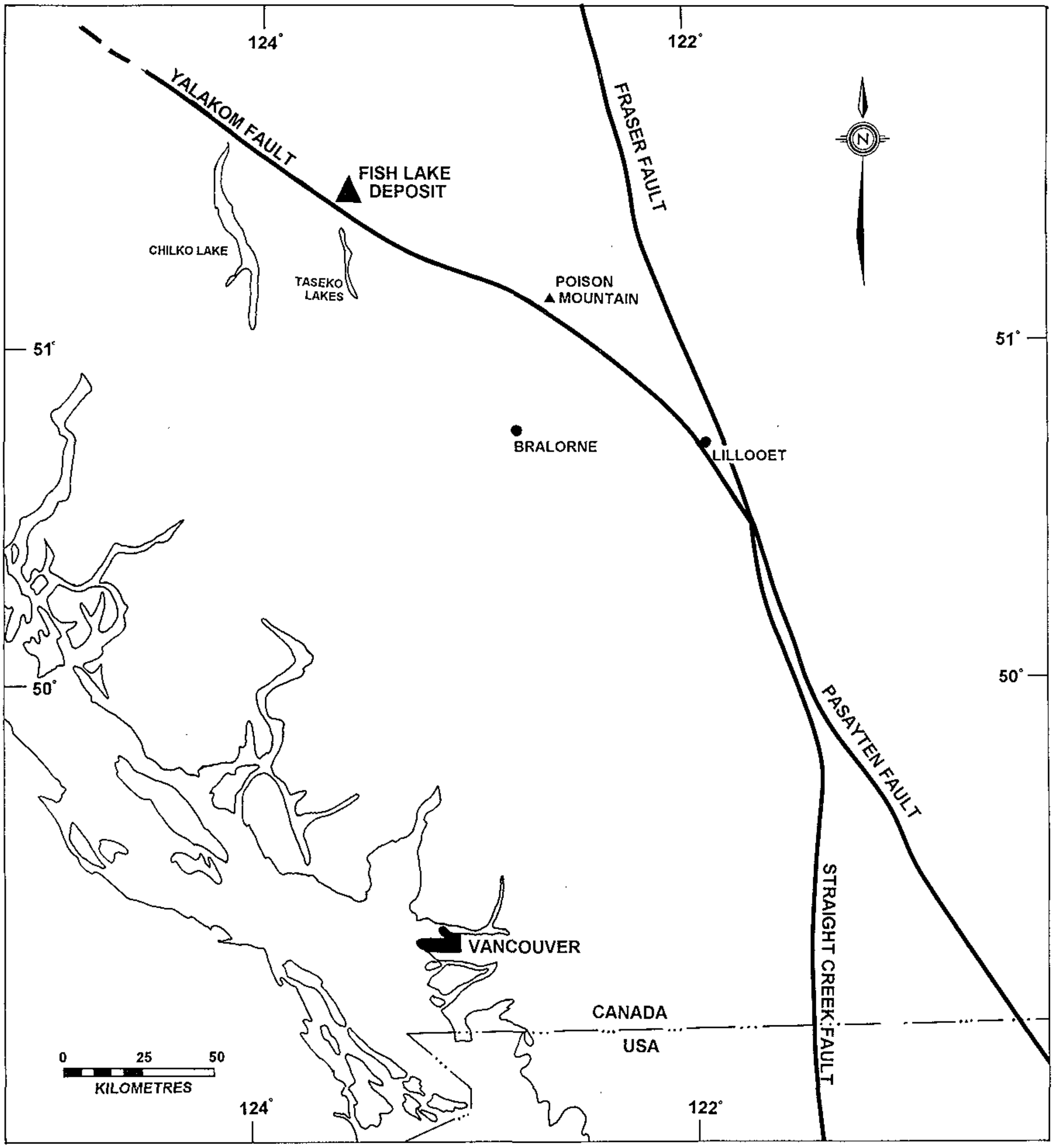


Figure 1. Location map.

mapped as "Kingsvale volcanics" (Tipper) has been correlated with the upper Cretaceous Powell Creek formation (Glover and Schiarizza, 1987; Riddell *et al.*; 1993), but that correlation is not clearly indicated for the andesitic hostrocks at Fish Lake. The host succession is probably related to volcanic and sedimentary rocks (unit lKsv) that are poorly exposed west and north of Fish Lake. The fossil pelecypod *inoceramus* found in interbedded siltstones indicates that the section is, at least in part, Lower Cretaceous (Hauterivian to lower Barremian, J. Haggart, written communication, 1992). These rocks have no obvious correlatives in the area; they are clearly distinct from Lower Cretaceous rocks found across the Yalakom fault to the southwest (Figure 2). They may be related to the Churn facies (Schiarizza *et al.*, in preparation) of the Lower Cretaceous Jackass Mountain Group, as the sequences overlap in age, and sandstones in each contain similar clastic material. At the deposit, sedimentary rocks that may correlate with the Churn facies underlie the andesitic host succession below a gently east-dipping fault. This same fault may constitute the boundary between unit lKsv and exposures of Churn Creek facies west of the deposit (Figure 2), but as the contact is not exposed this is speculative.

Rocks similar to the intrusive suite at the Fish Lake deposit crop out in Fish Creek and in the area around Cone Hill northwest of Fish Lake. These small stocks intrude sedimentary and volcanic rocks of unit lKsv and sedimentary rocks of the Churn Creek facies. Most are hornblende feldspar porphyries with varying abundances of quartz phenocrysts in a grey aphanitic groundmass. Hornblende feldspar porphyries found across the Yalakom fault to the southwest differ from the Fish Lake/Cone Hill suite in that they rarely contain quartz.

The age of the Fish Lake/Cone Hill suite is uncertain. A whole-rock K-Ar age of 77.2±2.8 million years was reported (Wolfhard, 1976) for a sample of hornfels containing 40% secondary biotite. We regard that date with some caution and have collected samples for U-Pb dating of zircons with the objective of providing a reliable age range for the intrusions. Two intrusive episodes are recognized in the deposit (*see* Rock Units below): premineralization (the "older porphyryitic diorite") and synmineralization (the "Fish Lake Intrusive Complex"). We have sampled rocks from both suites. A synmineralization porphyritic quartz diorite sample is currently being dated at the University of British Columbia.

The location of the Fish Lake deposit just a few kilometres northeast of the Yalakom fault suggests a genetic relationship. The Late Paleocene to Early Eocene Poison Mountain porphyry deposit, 75 kilometres to the southeast, is similar in lithology and alteration to Fish Lake (Seraphim and Rainboth, 1976) and has the same spatial relationship with the Yalakom fault (*see* Figure 1).

ROCK UNITS

Andesite flows and volcaniclastic rocks host the greater part of the Fish Lake deposit (Figures 3, 4 and 5). These rocks are cut by a large body of premineralization porphyritic diorite, and underlain at depth, below a major low-angle fault, by sedimentary rocks. The deposit is spatially and genetically related to the Fish Lake Intrusive Complex which consists of a small, steeply dipping lenticular body of quartz diorite (the Fish Creek stock) surrounded by an east-west elongate complex of numerous subparallel quartz feldspar porphyry dikes.

VOLCANIC AND SEDIMENTARY ROCKS

Andesite flows are subordinate to tuffs in the main part of the deposit, but form a thick, relatively distinct unit that hosts a large part of the deposit west of Fish Creek. The flows are almost everywhere porphyritic, containing between 15 and 35% plagioclase phenocrysts and up to 15% hornblende phenocrysts in a very fine grained groundmass. Several relatively coarse, homogeneous, sharp-bordered units may represent synvolcanic dikes or sills. Andesite flows west of Fish Creek are notably homogeneous, and commonly contain small bluish quartz amygdules.

Andesitic volcaniclastic rocks are largely medium to coarse-grained tuff, with less abundant fine-grained laminated tuff and lapilli tuff. Medium to coarse-grained crystal and lesser lapilli tuffs are generally unbedded, although they locally show indistinct bedding marked by subtle grain size variation. Laminated very fine grained tuffs form narrow units that show millimetre-scale planar lamination. Lapilli tuffs contain isolated to packed, subrounded to subangular heterolithic clasts up to several centimetres across, and occur as units up to several tens of metres thick. These probably represent debris-flow deposits.

A distinctive unit of bedded clastic sediments, containing variable but minor amounts of volcanic debris, commonly underlies the Fish Creek fault. This unit includes conglomerate, greywacke, arkose and local volcanic wacke.

OLDER PORPHYRITIC DIORITE

Fine-grained crowded porphyritic diorite forms a shallow easterly dipping body up to 500 metres thick which hosts much of the upper eastern part of the Fish Lake deposit, and underlies a large area to the north and east. This unit typically contains from 45 to 65% uniform sized plagioclase phenocrysts, mostly 1 to 2 millimetres in length, 10 to 15% hornblende phenocrysts, and sparse quartz eyes, in a very fine grained groundmass. This porphyritic diorite closely resembles, and was initially correlated with, the younger QD1 phase of the Fish Lake Intrusive Complex, but is now interpreted to be older.

Fish Lake Intrusive Complex

The Fish Lake Intrusive Complex includes a composite lenticular body of quartz diorite, the Fish Creek stock, surrounded by a complex of subparallel, essentially contemporaneous quartz feldspar porphyry dikes. Sparse "post-ore" porphyritic diorite dikes, which occur throughout the deposit, represent the final event in the emplacement of the complex.

FISH CREEK STOCK

Three quartz diorite variants, which differ mainly in grain size and texture, make up the Fish Creek Stock. **Heterogeneous fine porphyritic quartz diorite (QD1)** is relatively fine grained with a crowded, more or less seriate porphyritic texture. Plagioclase phenocrysts, which vary in abundance from 45 to 60%, average from 1 to 2 millimetres in size. QD1 in places shows conspicuous heterogeneity, particularly in grain size, on a scale of a few centimetres to tens of centimetres. **Coarse seriate porphyritic quartz diorite (QD2)** is coarser grained than QD1 and is characterized by a crowded, more conspicuously seriate porphyritic texture; it contains between 35 and 55% plagioclase phenocrysts, which range in length from 1 to 7 millimetres, and commonly show two distinct size populations. QD2 grades, with increasing abundance of plagioclase phenocrysts and corresponding decrease in abundance of groundmass, into **coarse equigranular to subporphyritic quartz diorite (QD3)**, which typically show an equigranular to subporphyritic texture with an average grain size of approximately 3 millimetres.

These three dioritic phases all contain subhedral quartz grains, most commonly between 3 and 6%, but ranging in abundance from trace to 10%: QD3, however, locally contains up to 15% coarse quartz. Quartz phenocrysts in the relatively coarse variants QD2 and QD3 are

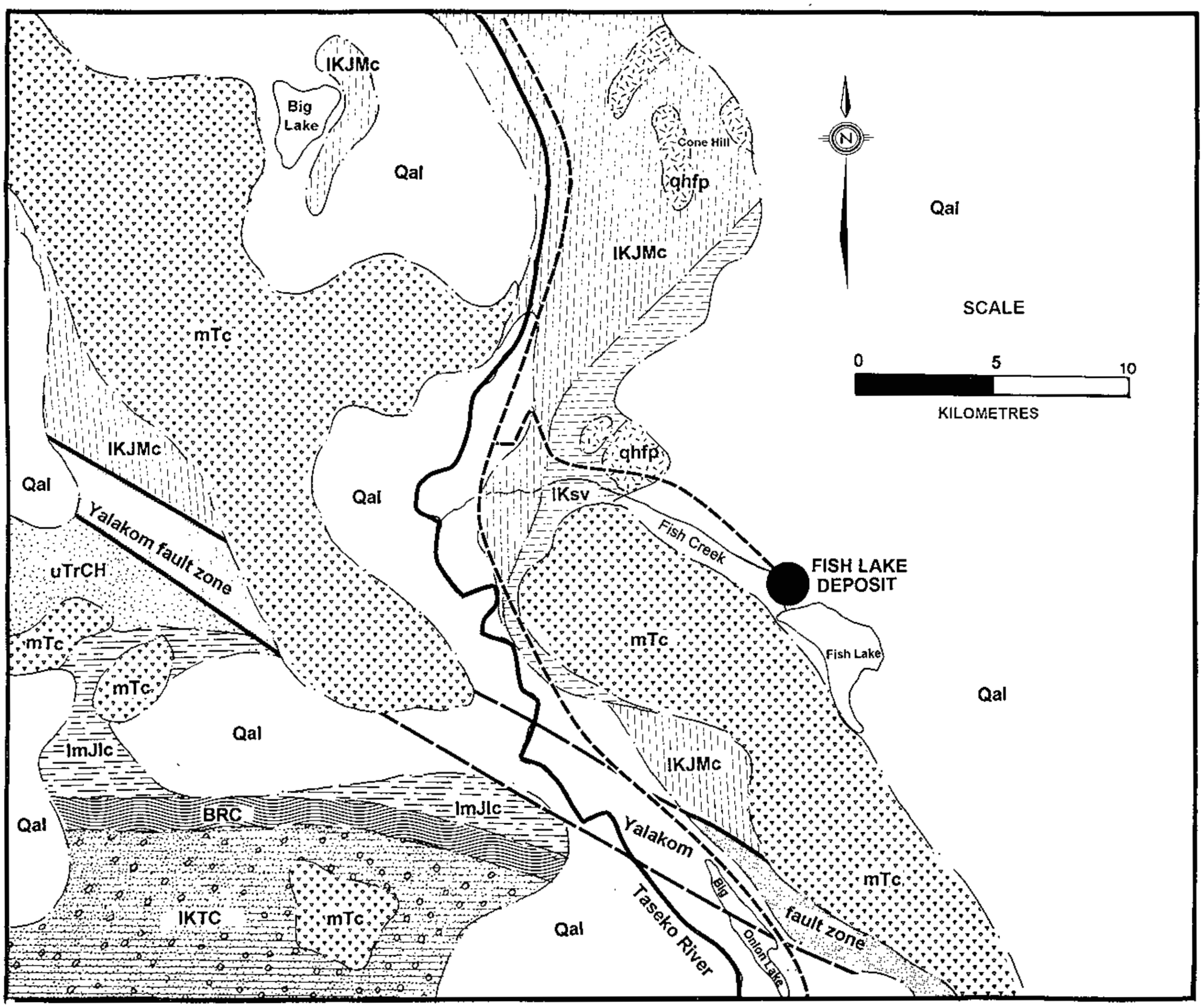


Figure 2. Geology near the Fish Lake deposit.

LEGEND

QUATERNARY

Qal	*unconsolidated glacial, fluvial and alluvial deposits*

MIOCENE TO PLIOCENE

CHILCOTIN GROUP

mTc	*olivine basalt flows, debris flows*

TYAUGHTON BASIN

LOWER CRETACEOUS

ALBIAN

TAYLOR CREEK GROUP

lKTC	*chert-rich pebble conglomerate, black shale, siltstone, sandstone*

BRIDGE RIVER TERRANE

MISSISSIPPIAN TO LATE MIDDLE JURASSIC

BRC	*sheared ribbon chert, chert-rich sandstone, amygdaloidal greenstone, sheared muddy breccia containing boulders of greenstone, chert, and marble*

CADWALLADER TERRANE

LOWER TO MIDDLE JURASSIC

SINEMURIAN TO TOARCIAN

LAST CREEK FORMATION

lmJLC	*well-bedded grey to black cherty argillite, thin fossiliferous micritic limestone beds, minor polymict cobble conglomerate with limy matrix*

UPPER TRIASSIC

HURLEY FORMATION

uTrCH	*thinly bedded calcareous brown-weathering sandstone, black-and-tan siltstone and shale, sandstone with limestone interbeds, limestone-bearing polymict conglomerate;*

METHOW BASIN

CHURN CREEK FACIES

LOWER CRETACEOUS

HAUTERIVIAN TO (?)ALBIAN

JACKASS MOUNTAIN GROUP

lKJMc	*green feldspathic sandstone with abundant carbonized plant remains, overlain by polymict boulder and cobble conglomerate with volcanic and plutonic clasts*

ROCKS NEAR FISH CREEK

LOWER CRETACEOUS

lKsv	*andesite, tuffaceous sandstone, minor rhyolite, phyllite, pebbly sandstone with plant remains and limestone rip-up clasts, black argillite, well-bedded flinty sandstone*

INTRUSIVE ROCKS

qhfp	*Cone Hill/Fish Lake suite - hornblende feldspar porphyry with quartz*

SYMBOLS

Road	▬ ▬ ▬ ▬
Geological Contact	— · — · — ·

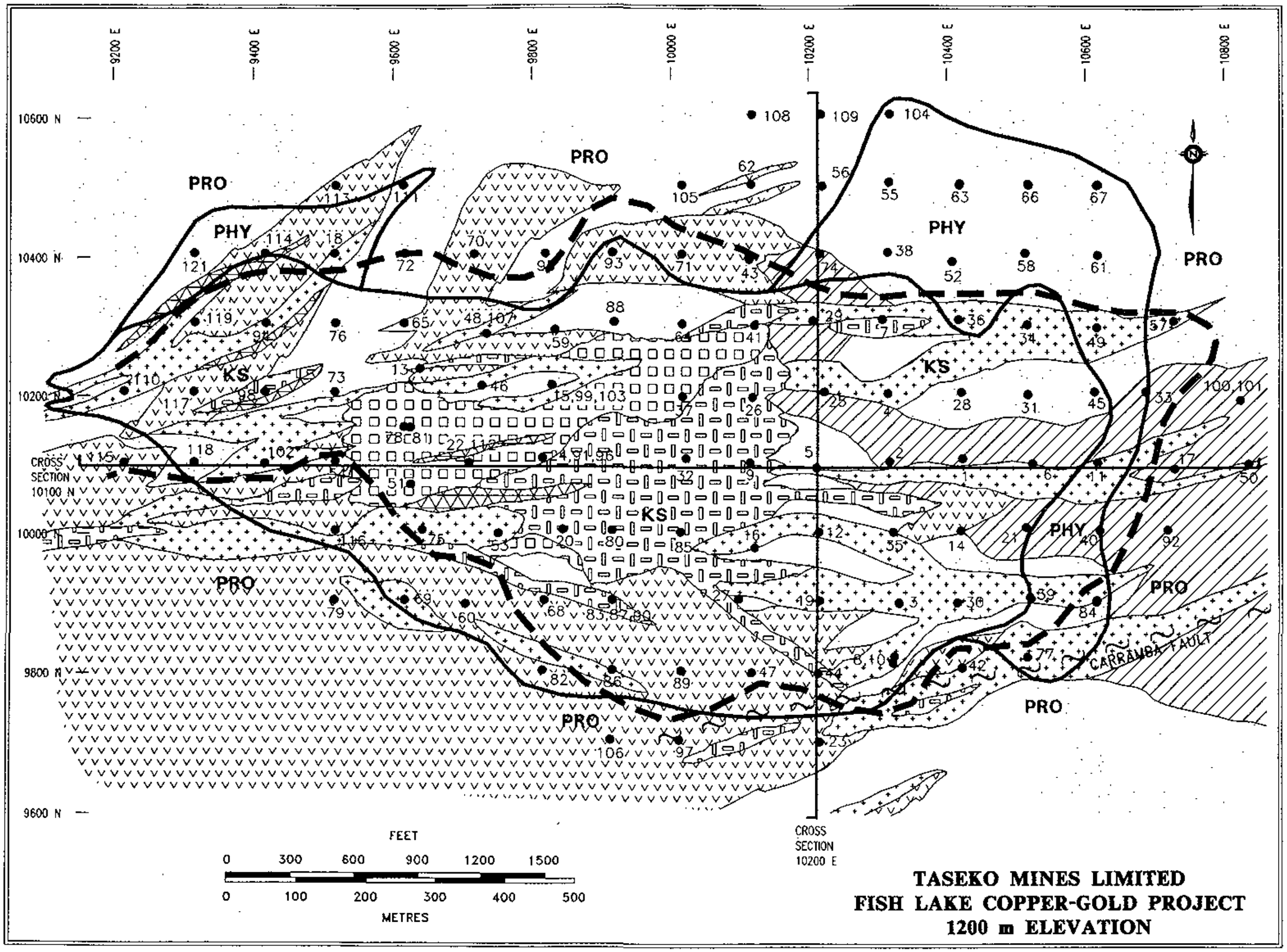


Figure 3. Plan view of the Fish Lake deposit, 1200 m elevation (*see* Figure 4 for legend).

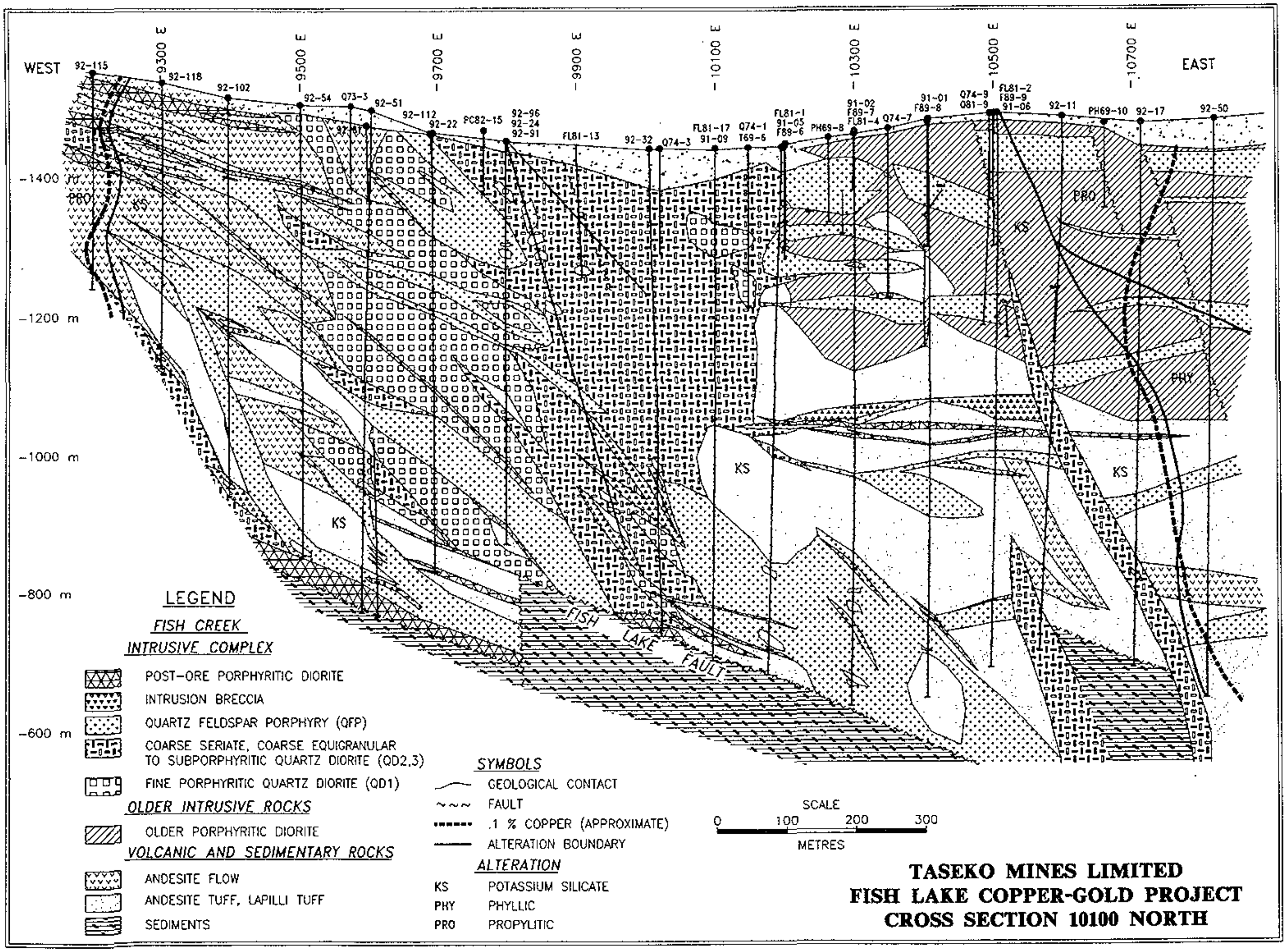


Figure 4. East-west cross section of the Fish Lake deposit 10100 North.

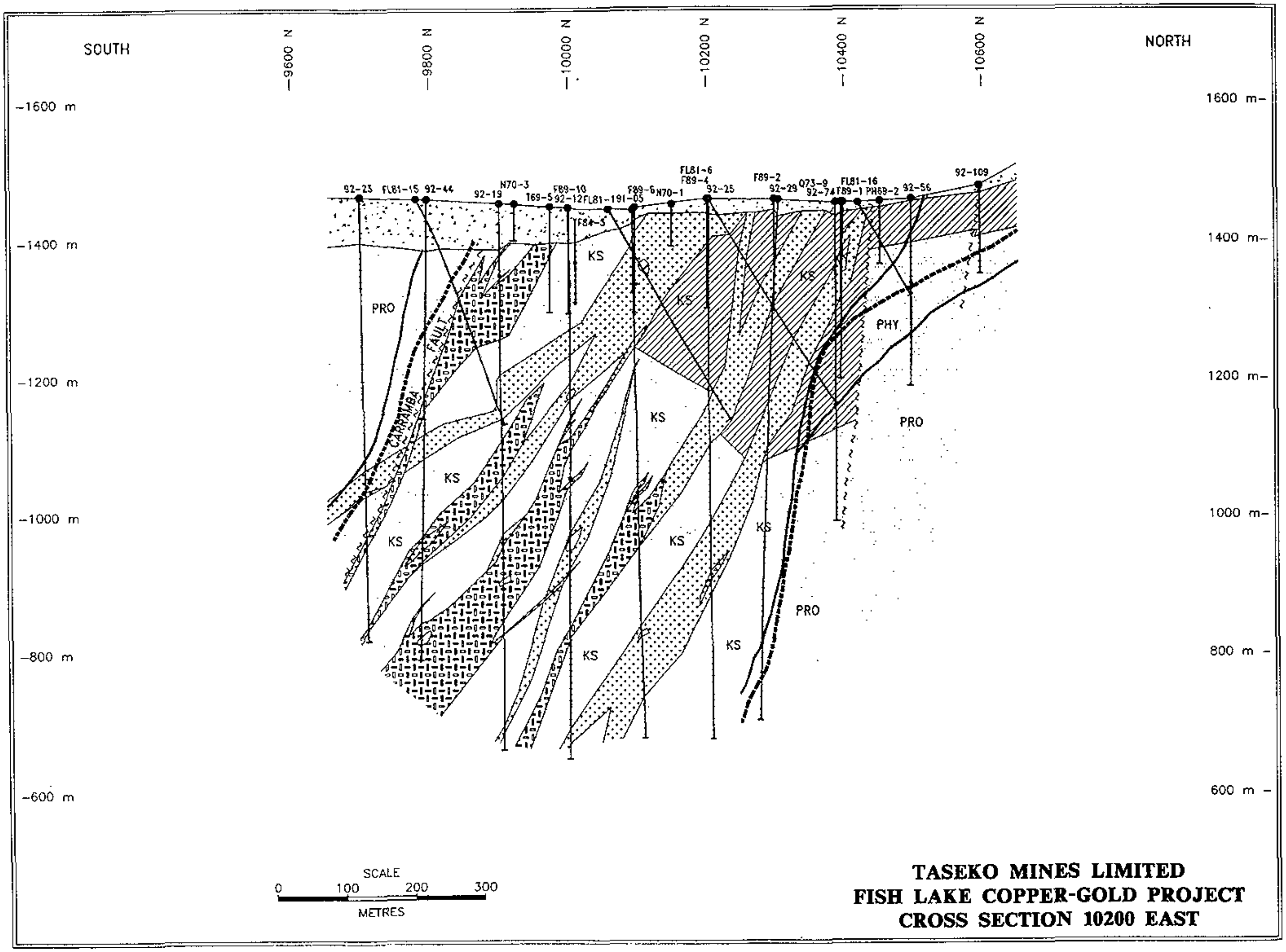


Figure 5. North-south cross section of the Fish Lake deposit 10200 East (*see* Figure 4 for legend).

generally 3 to 5 millimetres in size but range up to 8 millimetres. The matrix of quartz diorite is typically a granular plagioclase-quartz mosaic with an average grain size of a few tenths to a few hundredths of a millimetre, fairly commonly containing minor altered mafic and opaque minerals.

QUARTZ FELSPAR PORPHYRY DIKES

Quartz feldspar porphyry (QFP) typically contains between 25 and 35% subhedral to euhedral plagioclase phenocrysts and 2 to 5% subhedral quartz phenocrysts in a siliceous aphanitic groundmass. Both plagioclase and quartz phenocrysts are relatively uniform in size compared to those seen in QD1, QD2 and QD3. Plagioclase phenocrysts are mostly 3 to 4 millimetres in length, occasionally up to 7 millimetres. The quartz feldspar porphyry contains hornblende phenocrysts 1 to 3 millimetres long, and, where less altered, up to 1% black, euhedral biotite. The groundmass rather closely resembles that of the quartz diorite, although it is typically finer grained, with an average grain size of a few hundredths of a millimetre, and is often composed substantially of quartz.

IGNEOUS BRECCIAS

Both intrusion and subordinate magmatic-hydrothermal breccias occur at Fish Lake. Bodies of intrusion breccia occur along the borders of numerous Fish Lake Complex intrusions. They range in thickness up to a few tens of metres, and typically contain angular to subrounded clasts of andesite flows and tuffs surrounded by an igneous matrix.

Magmatic-hydrothermal breccias are recorded in a few localities, and occur as irregular, discordant, dike-like bodies within quartz feldspar porphyry dikes. The largest such body lies in the eastern part of the deposit, where it is subvertical, and up to 60 metres wide. All the others are much smaller. These breccias contain well-rounded, markedly heterolithic clasts, including many of quartz feldspar porphyry, in a fine-grained "rock flour" matrix which commonly contains abundant magnetite.

POST-ORE PORPHYRITIC DIORITE DIKES

Post-ore porphyritic diorite dikes show a considerable variation in texture. They typically contain between 15 and 45% hornblende phenocrysts, 1 to to 3 millimetres in length, 12 to 15% hornblende phenocrysts, and trace amounts to 2% quartz eyes. The groundmass is fine grained, but typically phaneritic.

NATURE OF THE FISH LAKE INTRUSIVE COMPLEX

The Fish Creek stock is a steep southerly dipping lenticular body up to 300 metres wide and 700 metres long, with highly irregular borders. The northern and western parts of the stock are made up of an irregular lenticular body of QD1, generally between 50 and 150 metres wide, which has been intruded along its southern and eastern sides by the composite QD2-QD3 phase which forms approximately three-quarters of the total volume of the stock. This later phase includes both homogeneous units of QD2 and QD3 several hundred metres thick, and domains where these two units are intermixed on a scale of a few tens of metres. Several units of both QD2 and QD3m, characterized by relatively low copper grades, may well represent late intra-mineral intrusions. The Fish Creek stock appears to "root" to the east or southeast, although geological relationships at depth are obscured by displacement along the Fish Lake fault.

Quartz feldspar porphyry occurs as an east to east-northeast-trending, steep southerly dipping swarm of subparallel dikes, most a few tens of metres, but locally over 100 metres wide. These dikes appear to be very close in age to the Fish Creek stock. The dike complex seems, overall, to be truncated by the stock, although some units of transitional lithology are seen, and the sparse bodies of quartz feldspar porphyry which do occur within the stock may represent younger cross cutting dikes as well as earlier inclusions.

CHILCOTIN GROUP COVER

Chilcotin Group basalt flows and unconsolidated sediments up to 90 metres thick cover the deposit in the southwest corner of the property. Dark grey to black, variably vesicular, microporphyritic basalt flows are commonly separated by narrow rubble zones and, in one instance, by paleotalus. These flows are underlain in most drill holes by unconsolidated, locally well bedded conglomerate, sedimentary breccia and sandstone, which may represent both fanglomerates and fluvial sediments.

STRUCTURE

A major east-dipping low angle fault, the Fish Lake fault, separates volcanic from sedimentary rocks at depths of between 680 to 880 metres below surface, and generally forms the lower boundary of the deposit. This fault is typically composite, consisting of a number of fault-bounded slices of volcanic and intrusive rocks that show penetrative cataclastic deformation. Post-ore dikes are abundant within the Fish Lake fault zone, and are of both syndeformation and postdeformation age. The Carramba fault, a major east-northeast striking, steep southeasterly dipping brittle fault, shows post-ore movement, and forms part of the southern border of the Fish Lake deposit.

ALTERATION

Potassium silicate alteration is the most widespread alteration type associated with the Fish Lake deposit, showing a distribution more or less coextensive with significant copper mineralization. Pervasive phyllic alteration is abundant in a zone several hundred metres wide which surrounds the eastern and northern sides of the deposit and is essentially coincident with the pyrite halo. Propylitic alteration is widespread within the phyllic alteration zone and forms zones, intermixed with weakly altered rocks, along the western and southern borders of the deposit. Late-stage sericite - iron carbonate - clay alteration occurs in abundant, generally narrow zones throughout the deposit. Texture-destructive silicification is locally well developed, particularly in places along the northern border of the potassium silicate alteration zone. Late clay alteration occurs locally within fault zones.

Potassium Silicate Alteration

Potassium silicate alteration is characterized most obviously by the replacement of original mafic minerals by biotite or chlorite, although chlorite is probably largely or entirely a late retrograde alteration product of biotite. Biotite and chlorite have generally replaced original mafic minerals with no significant change in colour index, although strongly biotite-altered rocks (with up to 30% biotite) also occur, mainly along the west side of the Fish Creek stock. Secondary orthoclase, which typically occurs along veinlets and microfractures, is widespread in minor amounts within and immediately adjacent to the stock, but is rare elsewhere.

Potassium silicate altered intrusive rocks and andesite flows typically contain biotite or chlorite-altered hornblende and weakly to moderately sericitized plagioclase. Black biotite generally occurs in fine-grained aggregates pseudomorphing hornblende phenocrysts with good preservation of outline, and in lesser abundance, disseminated in the groundmass. Biotite is commonly altered to chlorite within intervals of a few centimetres to several tens of metres in width which commonly envelop "late" fractures. Significant secondary orthoclase is essentially restricted to the Fish Creek stock, in which it is fairly widespread in minor amounts along microfractures, as quartz±orthoclase veinlets, and disseminated within narrow surrounding envelopes. Such secondary orthoclase rarely exceeds 5% of rock volume.

Altered tuffs within the potassium silicate zone show ubiquitous secondary alteration textures, although it is not clear to what degree these textures are due to synvolcanic rather than synmineral alteration. Mafic minerals are largely represented by chlorite, which is more abundant relative to biotite in altered tuffs than in altered intrusive rocks and andesite flows. Chlorite and biotite are commonly concentrated in abundant subcircular alteration aggregates, 50 to 100 millimetres in diameter, which are commonly aligned along lamination planes and, to a lesser extent, along veinlets and fractures.

Acicular to thin prismatic actinolite pseudomorphs, mostly composed of chlorite, are widely distributed within altered tuff throughout the orebody; they appear to be most abundant close to QFP dike contacts.

Phyllic Alteration

Rocks affected by pervasive phyllic alteration are altered mainly to quartz and fine-grained colourless phyllosilicates ("sericite") with variable destruction of primary textures, and contain relatively abundant pyrite (generally between 3 and 5%). X-ray diffraction studies of three samples of phyllic altered rocks show that muscovite and phlogopite are the most abundant phyllosilicate minerals and that substantial amounts of plagioclase and lesser chlorite are also present. Pervasively phyllic altered rocks typically form intervals several tens to 200 metres wide, which are commonly intermixed with propylitic, and less commonly, potassium silicate altered rocks.

Phyllic alteration also occurs in envelopes bordering quartz-sulphide veins and veinlets, which occur throughout the deposit, but are most abundant toward the northern and eastern borders. Phyllic envelopes are typically 0.5 to 3 centimetres wide, show sharp borders, and are composed of a fine-grained, grey, texture-destructive quartz-sericite-pyrite aggregates.

Propylitic Alteration

Propylitic altered rocks are characterized by moderate to strong sericitization of plagioclase and chloritization of mafic minerals with good preservation of primary textures. They commonly contain abundant disseminated calcite and minor pyrite (generally 1 to 3%). Epidote is common in propylitic rocks along the northern and eastern sides of the deposit. Weakly propylitized rocks, containing chloritized mafic minerals, minor pyrite and relatively unaltered plagioclase, are common along the southern and western sides of the deposit.

Sericite - Iron Carbonate - Clay Alteration

Sericite - iron carbonate - clay altered intrusive rocks and andesite flows occur as relatively uniformly altered, abruptly bordered intervals a few centimetres to several tens of metres in width. In tuffs, this alteration assemblage occurs in less sharply defined intervals with more gradational borders. Sericite - iron carbonate - clay altered rocks are typically relatively hard and competent, pale in colour, and show good preservation of primary textures. Plagioclase phenocrysts are typically altered to a soft, white sericite-clay mixture containing minor carbonate; mafic phenocrysts are imperfectly pseudomorphed by aggregates of iron carbonate (ankerite or ferroan dolomite) mixed with kaolinite and colourless (?)chlorite. Mafic pseudomorphs are typically cream coloured when newly cored, but weather over a period of months to a buff to medium brown colour.

Intervals of sericite - iron carbonate - clay alteration are most abundant in the upper eastern part of the deposit, but occur with remarkable consistency throughout, and, overall, host at least one-fifth of the mineralization. These intervals are commonly associated with channels of fluid access spatially related to faults and post-ore dikes. Sericite - iron carbonate - clay alteration is commonly demonstrably associated with late, sulphide-free carbonate (?dolomite) veins; crosscutting relationships indicate that this alteration, at least locally, postdated pervasive phyllic alteration.

MINERALIZATION

The Fish Lake deposit is oval in plan and is 1.5 kilometres long, up to 800 metres wide, and locally extends to a depth of 880 metres; its long axis parallels the east-west trend of the Fish Lake Intrusive Complex. The deposit is essentially coextensive with the potassium silicate alteration zone. An irregular pyrite halo several hundred metres wide surrounds the northern and eastern sides of the deposit, and is essentially coextensive with the phyllic alteration zone. The major low-angle Fish Lake fault limits the deposit at depths of between 680 and 880 metres.

Pyrite and chalcopyrite are the principal sulphide minerals and occur in subequal proportions throughout much of the deposit. They are accompanied by widespread subordinate bornite, sparse tetrahedrite-tennantite and molybdenite, and rare sphalerite, pyrrhotite, digenite, covellite, chalcocite, galena, marcasite and enargite. Bornite, although almost everywhere subordinate to chalcopyrite, occurs in minor amounts throughout a large part of the deposit, particularly in the east. Sparse molybdenite occurs in quartz±anhydrite veins and veinlets, most abundantly along the borders of the Fish Creek stock. Magnetite and anhydrite occur throughout the deposit, commonly in abundances of several per cent. Gold occurs as grains several microns to tens of microns in size along sulphide grain boundaries and disseminated within chalcopyrite, pyrite and tetrahedrite grains.

Sulphide minerals everywhere show the thoroughly dispersed mode of occurrence characteristic of porphyry copper deposits. Disseminated, and veinlet and fracture-fill sulphides occur in subequal proportions in the eastern half of the deposit. In the western part, sulphides occur predominantly along veinlets and veins hosted largely by competent quartz diorite and andesite flows; in this area mineralized quartz stockwork is locally abundant, particularly within and immediately adjacent to the Fish Creek stock.

Sulphide veins (greater than 3 millimetres wide) are everywhere subordinate to disseminated, veinlet and fracture-fill sulphide. They are typically several centimetres wide, and contain one or more of the minerals galena, sphalerite, tetrahedrite and tennantite. Sulphide veins are relatively abundant in the east, within the uppermost few hundred metres of the deposit, and also along its eastern border. Pyrite-arsenopyrite veins in the Albert zone, 1 kilometre east of the main deposit, carry gold, and are locally accompanied by chalcopyrite and pyrrhotite. Late-stage veins include: sulphide-free magnesium and iron carbonate veins, probably genetically related to sericite - iron carbonate - clay alteration, and gypsum veins, which are everywhere abundant but have been destroyed by groundwater circulation in the uppermost 100 to 150 metres of the deposit. Sulphide veins and veinlets show consistent moderate to steep dips almost everywhere, whereas the later gypsum and carbonate veins have more varied attitudes.

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ASSESSMENT OF THE APPLICABILITY OF LAKE SEDIMENT GEOCHEMICAL SURVEYS FOR MINERAL EXPLORATION IN THE NECHAKO PLATEAU AREA OF BRITISH COLUMBIA

By Steven Earle

INTRODUCTION

The Geological Survey Branch of the British Columbia *Ministry of Energy, Mines and Petroleum Resources* is planning geochemical sampling programs in the Nechako region of the northern Interior Plateau (Nechako Plateau) as part of a continuing program of regional geochemical surveys in British Columbia. In most previous Regional Geochemical Surveys (RGS) in British Columbia, stream sediments have been used as the sampling medium. Exploration experience in the Nechako Plateau area has shown that stream sediment sampling is not particularly successful in this terrain, largely because of the subdued topographic relief, the poorly defined drainage systems and the limited development of clastic sediment within streams. On the other hand, lakes are relatively abundant on the plateau, and lake sediment surveys have been applied successfully to mineral exploration programs in several parts of the region.

The objective of this study is to evaluate the applicability of regional lake sediment sampling on the Nechako Plateau. The following topics are considered:

- The feasibility of lake sediment sampling as constrained by the distribution of lakes.
- Variations in the limnological characteristics of lakes in the area.
- Geochemical implications of differences in limnological characteristics.
- Differences in geochemical response between lake sediments and other regional sampling media.
- Consideration of viable techniques to apply in follow-up to anomalies detected in a lake sediment sampling program.

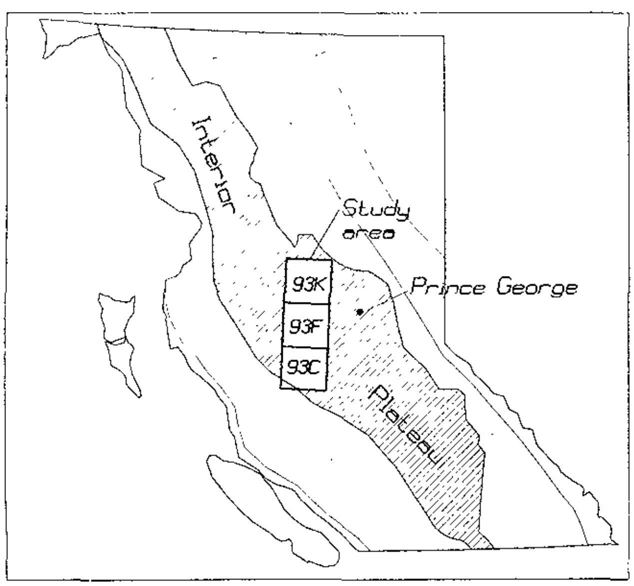


Figure 1. Location of the study area.

The project is based on a review of pertinent published information on limnology and lake geochemistry. The report includes recommendations on additional research and the design of orientation surveys which would provide answers to some of the important remaining questions concerning the application of lake sediment geochemistry within the Nechako Plateau.

STUDY AREA

The study area comprises three 1:250 000-scale map sheets, 93K, 93F and 93C, covering a large part of the Nechako Plateau, a major division of the Interior Plateau. The area is situated to the west of Prince George (Figure 1).

GEOLOGY

The major lithological features of the study area, based on geological information included on MINFILE maps, are shown on Figure 2. Triassic to Tertiary volcanic rocks of the Takla, Hazelton, Skeena, Ootsa Lake, Endako and Chilcotin groups are the predominant lithological units throughout most of the area. These assemblages are dominated by volcanic flows and tuffs ranging from rhyolitic to basaltic composition, together with subordinate clastic sediments. Clastic sediments of the Mississipian to Triassic Cache Creek Group are exposed along a northwesterly trending belt extending across sheet 93K, and carbonate sediments, also of the Cache Creek Group, crop out to the northeast of this belt.

A granitoid gneiss and pegmatitic schist complex of unknown age (Wolverine Metamorphic Complex) has been mapped in the southeastern corner of sheet 93C. Granitic to dioritic intrusions ranging in age from Jurassic to Tertiary are exposed in various parts of the study area. Large areas in the southeastern part of 93C, and also along a northwesterly trending belt extending from the

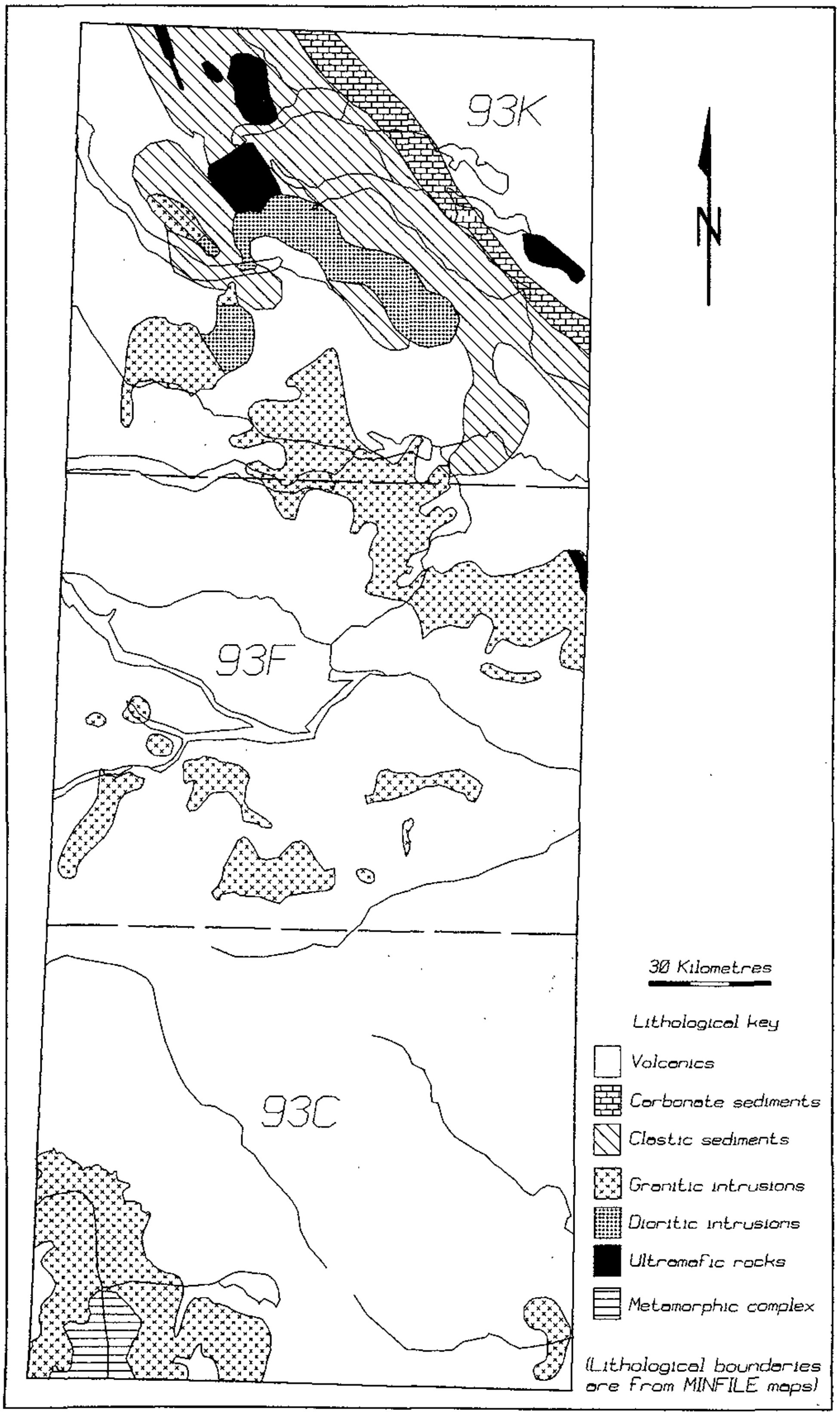


Figure 2. Lithological map of the Nechako Plateau.

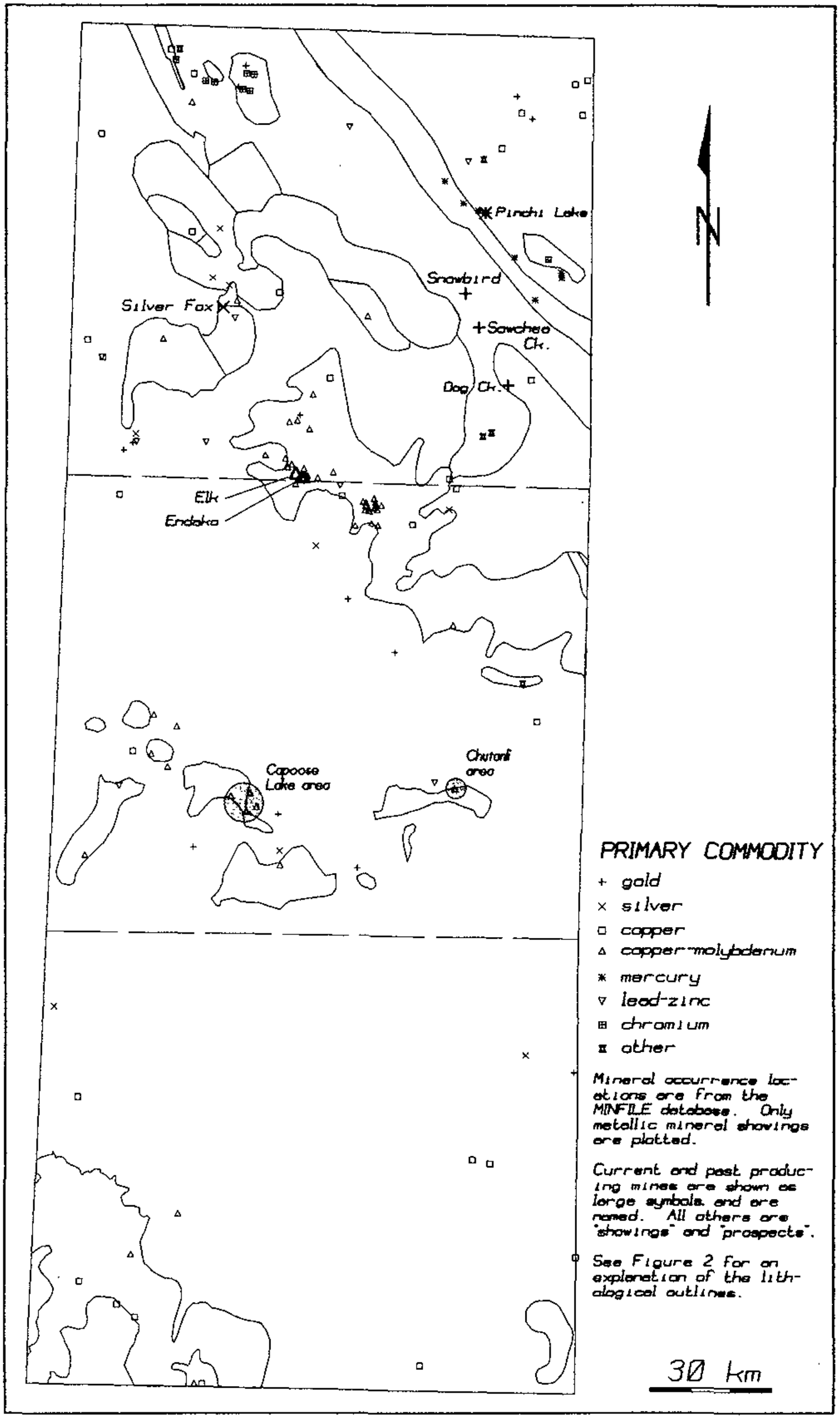


Figure 3. Mineral occurrences of the Nechako Plateau.

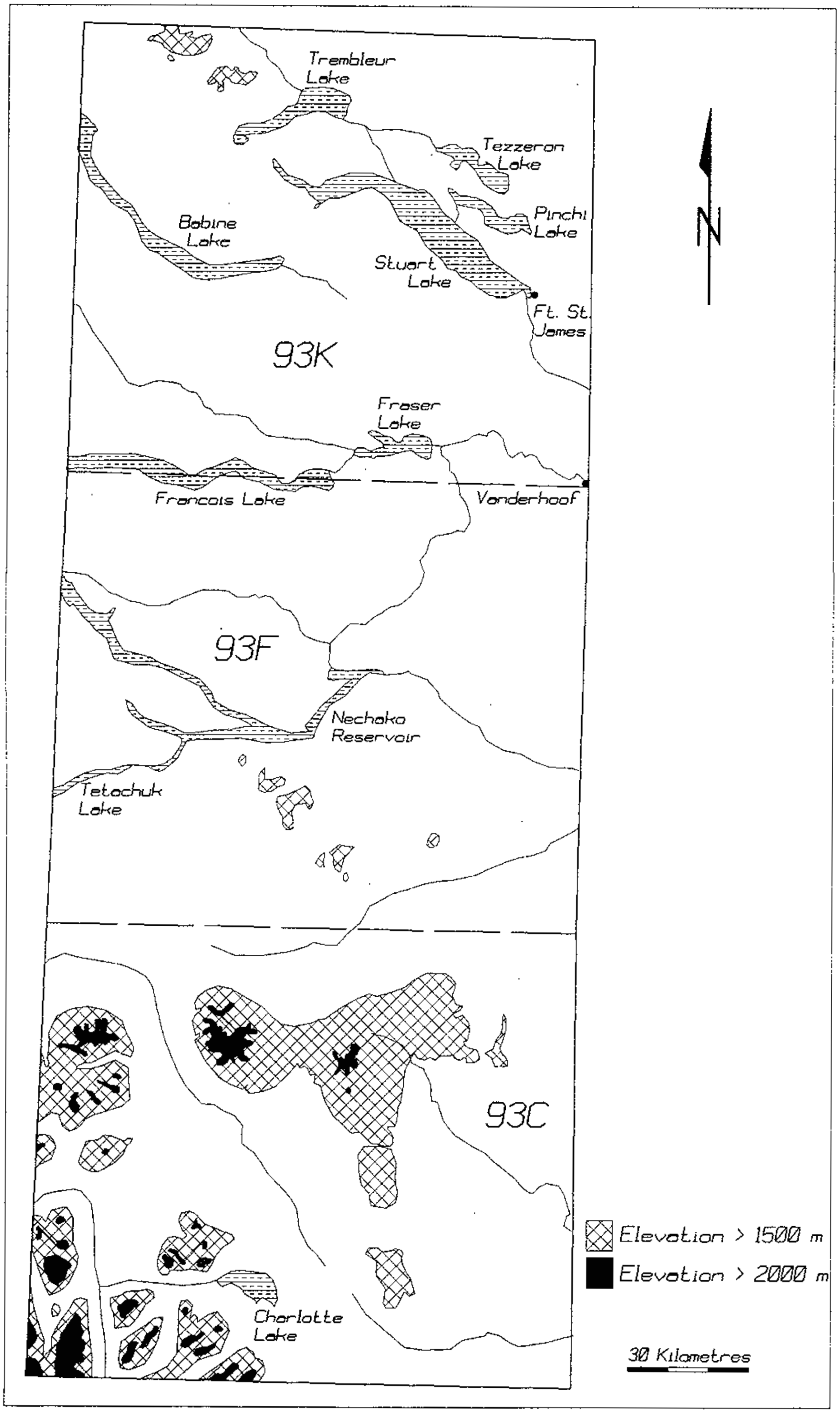


Figure 4. Topographic features of the Nechako Plateau.

northern part of 93F into 93K, are underlain by intrusive rocks. There are several smaller granitic bodies in the southern part of 93F. Permian to Triassic Trembleur ultramafic rocks, now recognized as an obducted ophiolite suite, are exposed in various parts of sheet 93K, and within the northwestern part of 93F.

Pleistocene ice movement on the Nechako Plateau was from southwest to northeast (Tipper, 1971). Ice-advance features, such as drumlins, are common in some parts of the area, while ice-retreat features, such as ablational moraine, are also present.

The locations of metallic mineral occurrences in the study area are shown on Figure 3. The MINFILE publications indicate that there are one current and several past producing mines within map sheet 93K, whereas the known occurrences within 93C and 93F are only showings and prospects. Most of the occurrences in the area are porphyry copper and/or molybdenum deposits, such as that currently being mined at Endako. Minor showings of gold and silver, hosted by several different rock types, are scattered throughout the study area. There are several mercury showings along the Pinchi fault, including the former Pinchi Lake mine. Several chromium occurrences are known within the ultramafic bodies in the northern part of 93K.

Geochemical data from the vicinity of copper-molybdenum mineral prospects at Capoose Lake and Chutanli Lake are described below, and these locations are indicated on Figure 3.

Physiographic Features

The major topographic features of the study area are shown on Figure 4. The elevation of the plateau ranges from an average of approximately 1300 metres within 93C, to 1050 metres within 93F and 93K. Surface elevations of large lakes range from 1200 metres in 93C, to 850 metres in 93F and 700 metres in 93K. Within 93C there are extensive areas with elevations in excess of 1500 metres, including the area underlain by granitic rocks in the southwestern corner (the eastern edge of the Coast Range), an area along the western edge of the map sheet, and a large area in the central part of the sheet. Parts of the elevated regions in the central and western areas of 93C are underlain by Tertiary Endako Group volcanic rocks, and these are high-relief areas. Other parts of this elevated region have moderate or low relief. There are small areas within 93F and 93K with elevations in excess of 1500 metres, but these do not correspond with any specific geological features. The topographic relief on these northern two sheets is otherwise consistently low.

PREVIOUS WORK

Limnology

Although there is a broad base of limnological information available for British Columbia, very little attention has been focused understanding regional limnological trends within the province. According to T. G. Northcote (personal communication, 1992) the most recent studies of this kind were those of Northcote and Larkin (1956, 1963), which involved compilation of limnological information from 100 lakes in south and central British Columbia. On the basis of this compilation, the province was divided into a number of different limnological regions. Some of the data compiled by Northcote and Larkin are summarized in Table 1.

Although Northcote and Larkin did not report dissolved oxygen data and did not include classifications of trophic status, they did report plankton volumes, and this information provides some indication of the trophic status of the lakes. Lakes with high plankton contents are more likely to be eutrophic than those with low plankton contents (Welch, 1952). An indication of lake basin morphometry is given in Table 1, expressed as the depth to area ratio value, while the total dissolved solids (TDS) value reflects the lake basin lithology and the climate (average temperature and rainfall) of the drainage basin.

There are some dramatic differences in the average sizes of the lakes in the different regions. For example, the average size of lakes studied in the Columbia Mountains is over 5000 hectares, while that of lakes in the Rocky Mountains and Rocky Mountain Trench is only 92 hectares. It is unlikely that there is a 50-fold difference in the average size of lakes in these two regions, and some of this difference is probably attributable to a bias in the choice of lakes sampled. Such bias would probably affect the other statistics shown in Table 1.

In spite of this shortcoming there are some obvious and undoubtedly significant limnological differences between the areas. In general, the lakes in mountainous areas have higher depth ratios (*i.e.* steeper basin profiles)

TABLE 1
SUMMARY OF LIMNOLOGICAL DATA FOR BRITISH COLUMBIA

Lake name	n	Mean depth m	Max. depth m	Surface area ha	Depth ratio	Plankton cm^3	TDS ppm
Coast & Insular Mts.	18	39	89	1069	2.8	1.9	48
Columbia Mountains	9	48	109	5462	2.6	1.5	139
Vancouver I. lowland	4	6	11	116	1.2	7.1	91
L. Fraser Valley	6	4	11	59	1.8	2.0	44
N. interior plateau	8	11	28	1100	0.9	4.9	105
S. interior highland	6	5	11	69	1.4	1.8	70
S. interior plateau	40	14	33	326	2.6	4.3	242
Rocky Mts. & Trench	8	9	20	92	2.1	2.4	250

Values shown are averages of the data in Northcote and Larkin (1956). All averages are arithmetic, except for the area averages, which are logarithmic. Depth ratio is the maximum depth (m) over the square root of the lake area (ha). "Plankton" is the volume of plankton in a number 10 net within a standard volume of water. TDS is "total dissolved solids".

than those in the lower relief areas. An exception is the southern Interior Plateau, which has relatively deep lakes. Plankton contents are highest in the Vancouver Island lowland (Saanich Peninsula and Gulf Islands) and the northern and southern parts of the Interior Plateau, and lowest in the Columbia mountains, southern Interior highlands and Coast and Insular Mountains. The Lower Fraser Valley lakes also have relatively low plankton contents. Total dissolved solid levels are lowest in the Coast and Insular mountains, the Lower Fraser Valley and the southern Interior highlands, and highest in the southern Interior Plateau and Rocky Mountain area.

The present study area falls within the "northern Interior Plateau" region of Northcote and Larkin, although only eight lakes were sampled within the region, and most of these are outside the study area. Compared with the other regions, this area has relatively shallow lakes with high plankton contents and moderate dissolved solids levels.

Anderson (1974) studied plankton communities in 340 lakes in the Rocky Mountains - largely within the National Parks. His results were reported in number of plankters per litre, and hence cannot be directly compared with the plankton data of Northcote and Larkin. Anderson also recorded TDS levels and found these to range from 2 to 29 800 ppm, although most lie within the range of 50 to 200 ppm.

Stockner and Northcote (1974) have studied the limnology of some of the lakes in the Okanagan Valley, and noted that the large mainstem valley lakes (*e.g.* Okanagan, Kalamalka and Skaha lakes) are generally oligotrophic in character, while the smaller headwater lakes are more commonly eutrophic. They also observed that the TDS levels were lower in the headwater lakes than the mainstem lakes. The mainstem lakes have TDS levels in the order of 150 to 250 ppm.

Gintautas (1984) studied the geochemistry of 2797 lakes within part of the present study area, and the area to the west. Although he did not carry out thorough limnological investigations on all of these lakes, he did measure a number of parameters which provide useful limnological information, including lake depth, lake water pH and conductivity, and trace and major element contents of the lake sediments. Gintautas summarized his data set by using cluster analysis to divide the lakes into a number of groups. To some extent, these groups reflect differences in limnological character.

For example, 36 of the lakes are classified as "carbonate" lakes because the sediments have an average of 18% calcium, and an average nonorganic volatile level of 19% (based on ignition at 1000°C). Gintautas suggests that the carbonate material in these sediments is of biological origin. He also identified 23 "clastic" lakes on the basis of low organic matter contents and high levels of aluminum, potassium and magnesium. Some of these "clastic" lakes are oligotrophic, while others are situated adjacent to glaciers. A total of 948 lakes with relatively low levels of organic matter in the sediments, and elevated iron and manganese contents, are classified as oligotrophic, while 458 lakes with high average sediment organic matter contents are classified as eutrophic. Some 721 lakes with average depths of 3 metres, and relatively low metal levels, are classified as "bog" or "dystrophic" lakes.

Since 1915 the Fisheries Branch of the British Columbia Ministry of Environment, Lands and Parks has gathered limnological information on lakes within the province. As of 1990, data were available for 2905 lakes. The available information has been catalogued by Balkwill (1991), but has not analyzed in any way. Data pertaining to the study area have been obtained from the Fisheries Branch files and are presented below.

Lake Geochemistry

During the past two decades several regional lake sediment geochemistry studies have been carried out within and around the present study area. These include lake sediment sampling programs covering parts of map sheet 93J to the east of sheet 93K, (Spilsbury and Fletcher, 1974), parts of sheet 93F and adjacent sheet 93G to the east, (Hoffman, 1976; Hoffman and Fletcher, 1976), and parts of sheets 93F and 93K and adjacent sheets 93E and 93L to the west (Gintautas, 1984; Gintautas and Levinson, 1984). Lake sediment sampling has also been carried out within parts of map sheets 93E and 93L as part of the Regional Geochemical Survey program (Johnson *et al.*, 1987a,b).

The sampling program reported by Spilsbury and Fletcher (1974) involved collection of 1100 near-shore lake sediment samples from the area around the Salmon and Muskeg rivers. Multiple regression analysis was used to study the relationships amongst several variables, including sand, iron, organic matter, copper and zinc content of the sediments, and water pH. Spilsbury and Fletcher concluded that copper and zinc contents are closely related to iron and sand contents, and that the presence of an almost continuous cover of glacial drift has subdued regional differences in bedrock geochemistry.

Hoffman (1976) collected lake sediment samples from approximately 500 lakes in the Nechako River drainage basin. Unlike the Spilsbury and Fletcher study, these samples were collected from lake centres. Hoffman found that lake sediment geochemistry reflected geochemical variations in bedrock, and also that lake sediment anomalies are associated with all known mineral occurrences. On the other hand, he noted that within- lake geochemical variation can also be very high.

Based on the cluster analysis described above, Gintautas (1984) concluded that, for most of the 2797 lakes in his survey, the sediment geochemistry reflects the geochemistry of the drainage basin. One exception is the "bog" class. In this type of environment he suggests that the sorption capacity of the terrain surrounding the lake is too high to allow metals into the lake basin.

A comprehensive review of the application of lake sediment geochemistry to mineral exploration has been published by Coker *et al.* (1979). A small set of lake sediment data from the Gibraltar mine area, to the east of the present study area, is described in this paper, and as pointed out by the authors, the correlation between copper and molybdenum anomalies and the mineralized zone is very clear.

During 1986, lake sediment samples were collected as part of joint Federal-Provincial Regional Geochemical Survey (RGS) programs within map sheets 93E and 93L. A total of 214 sites were sampled within 93E and 243 sites within 93L. The results are published in GSC open file reports (Johnson *et al.*, 1987a, b), together with a very brief interpretation.

A summary of an analysis of differences between duplicate and replicate samples for the RGS data is given in Table 2. Average differences between pairs of field duplicates have been determined, and these are expressed as percentages. For most elements the average percent-difference values are less than 10%, and in many cases they are around 5%. The molybdenum value is 1.4%, but this is probably because most of the molybdenum results reported are at the detection limit, hence there is very little variability in the data. The silver and arsenic values are just under 14%, while the gold and lead values are both over 20%. Percent-difference statistics are also reported for 52 replicate gold analyses (repeat analyses on subsamples), and in this case the percent-difference level is actually worse (24%) than for the field duplicates. The inference from this observation is that most of the error in the gold data is related to subsampling and laboratory imprecision, rather than sampling variability.

TABLE 2
SUMMARY OF RESULTS OF DUPLICATE AND REPLICATE SAMPLES COLLECTED IN THE RGS LAKE-SEDIMENT SURVEYS OF 93E AND 93L

	Zn ppm	Cu ppm	Pb ppm	Ni ppm	Co ppm	Ag ppm	As ppm
Avg. of 1st dups.	120	38	13.3	21	8.3	0.2	5.0
Avg. of 2nd dups.	123	36	11.2	21	8.5	0.2	4.8
Per cent difference	5.1	7.7	20.8	5.6	7.2	13.9	13.8

	Mn ppm	Fe %	Mo ppm	LOI %	pH	Au ppb	Au-rep ppb
Avg. of 1st dups.	496	2.9	1.4	30.9	6.4	2.4	4.2
Avg. of 2nd dups.	531	2.8	1.8	33.7	6.3	4.0	2.6
Per cent difference	5.4	6.2	1.4	5.0	0.9	21.0	24.3

Rows 1 and 2 represent the average levels in the pairs of duplicate samples collected at each of 26 sites. Row 3 is the average of the percentage by which each member of each pair differs from the mean for that pair. For example, for two values of 11 and 9, the average is 10 and each value differs from that average by 1 unit, or 10%. Under the column labelled "Au-rep" the same statistics are given for 52 samples for which replicate gold analyses were carried out.

A summary of the variations in the levels of selected constituents as a function of bedrock lithology is given in Table 3. The variations between rock types are generally relatively small, however, some of the notable differences are as follows:

- Zinc is low over granite and high over rhyolitic and tuff areas.
- Copper is low over granite.
- Lead is low over the mafic volcanic rocks and in the till-covered areas.
- Nickel is high over the mafic volcanic and siltstone areas.
- Cobalt is high in areas underlain by sedimentary rocks and low in till-covered areas.
- Gold is low over shale and high over granite, granodiorite, tuff and volcanic breccia.
- Arsenic is very high over shale and low over granite and in till-covered areas.
- Manganese is high over shale and low in till-covered areas.
- Iron is high over shale and siltstone and low in till-covered areas.
- Molybdenum is very high over granite.
- Loss on ignition is low over granite.

Most lake sediment geochemical surveys in Canada have been carried out in shield areas, where the physiographic and geological conditions are quite different

TABLE 3
LAKE-SEDIMENT GEOCHEMICAL VARIATIONS AS A FUNCTION OF BEDROCK LITHOLOGY FOR RGS SAMPLES FROM 93E AND 93L

Rock type	n	Zn ppm	Cu ppm	Pb ppm	Ni ppm	Co ppm	Ag ppm	Au ppb
Granite	20	97	21.9	7.6	13.4	7.5	0.14	2.3
Granodiorite	15	130	38.1	9.5	17.4	6.4	0.22	2.0
Qz.-monzonite	12	116	38.9	7.3	16.5	7.5	0.18	1.4
Rhyolite	92	134	37.4	10.8	19.1	8.0	0.21	1.8
Tuff	114	136	41.3	9.7	15.7	7.6	0.21	2.2
Volc. Breccia	8	117	49.9	6.6	16.6	5.9	0.12	2.6
Andesite	51	105	30.4	7.0	20.8	6.9	0.14	1.6
Basalt	7	117	35.3	7.5	22.4	7.6	0.14	1.6
Shale	8	127	34.2	11.9	16.9	9.3	0.13	1.3
Siltstone	27	120	35.8	9.3	24.2	8.8	0.17	1.6
Till	117	102	28.1	7.0	17.3	5.8	0.16	1.7

Rock type	n	As ppm	Mn ppm	Fe %	Mo ppm	LOI %	pH
Granite	20	2.2	631	2.6	3.3	20.0	5.7
Granodiorite	15	4.6	437	2.1	1.6	38.6	6.7
Qz.-monzonite	12	3.0	456	2.8	2.3	23.6	6.7
Rhyolite	92	4.0	442	2.6	1.6	29.2	6.4
Tuff	114	5.0	425	2.6	1.9	33.0	6.6
Volc. Breccia	8	5.1	422	2.8	1.1	46.8	7.1
Andesite	51	3.4	347	2.3	1.3	34.5	6.6
Basalt	7	2.1	322	1.9	1.6	26.8	5.6
Shale	8	8.3	938	3.8	1.8	29.1	6.9
Siltstone	27	4.6	629	3.1	1.3	36.1	6.7
Till	117	2.8	326	1.8	1.5	29.5	6.0

All averages are based on log-transformed data, except LOI and pH. Data are from Johnson *et al.* (1987a, b).

from those of the Nechako area. The technique has been applied quite extensively in Atlantic Canada, however, and the results from these areas may be more relevant to the present study.

A compilation of Newfoundland lake sediment data is reported by Davenport (1982), who states that lake sediment geochemical data effectively reflect the major lithological variations of the region. In a more recent study, Davenport and McConnell (1988) report on the effectiveness of lake sediment geochemistry for gold exploration. They analyzed samples for gold and a number of elements commonly enriched in gold deposits, and concluded that lake sediment gold geochemistry does reflect the location of many, but not all, gold showings. The gold levels reported in this study of 1217 samples range up to 106 ppb, but the 99th percentile is only 8 ppb. Davenport and McConnell also concluded that pathfinder elements (*e.g.* As, Sb, Pb, Se and W) are also useful in defining gold mineralization, but only in conjunction with data for gold itself.

A regional study of the application of lake sediment geochemistry to identification of metallogenic domains in Nova Scotia has been carried out by Rogers *et al.* (1990). They concluded that single-element contour maps are useful for outlining known occurrences of tin, tungsten, gold and silver, and also in defining regional structural trends. They point out that multi-element score maps (based on percentiles) are effective in defining bedrock metallogenic domains and areas with high mineral potential.

Rogers *et al.* (1990) point to the presence of discrete grains of various resistant minerals, such as cassiterite, scheelite, wolframite, monazite and zircon, as evidence of mechanical dispersion of metals into lake sediments. Rogers (1988) also found free gold in the sediment from one lake in central Nova Scotia, and suggests that some gold anomalies may also be partly related to mechanical dispersion processes.

RESULTS

The characteristics of the lakes within and around the study area are summarized in the following section. Topographic maps have been used to assess lake densities and the relationships between lakes and their surrounding terrain, and Ministry of Environment, Lands and Parks limnological data have been used to assess variations in the characteristics of lakes within the region. The geochemical behaviour of trace and major elements within and around lakes is reviewed. Relationships between lake sediment geochemistry and mineral occurrences, and between lake sediments and other geochemical media, are examined by looking at lake sediment and other geochemical data from areas of known mineral showings.

Assessment of Lake Distributions and Characteristics

DENSITY OF POTENTIAL LAKE SEDIMENT SAMPLE SITES

An assessment of the distribution of potential lake sediment sample sites has been derived by dividing the study area into 510 ten by ten kilometre squares based on the UTM grid. Within each of 100 square kilometre block, the number of potential lake sediment sample sites has been counted. In determining potential sample site densities, the following criteria have been used:

- Very small lakes (1 ha in area) have not been counted because, in the experience of the author, it is commonly found that such lakes do not have the fine-grained lake sediment typical of other lakes.
- Large lakes (with areas greater than 5 km^2), which have no well-defined bays or sub-basins, have not been counted because it is difficult to determine the source area of samples from such lakes.
- Recently created reservoirs and oxbow lakes have not been counted where other lakes are available.
- In Order to maintain a regular sample distribution, the maximum sampling density within any specific area has been limited to one sample per 4 square kilometres.

Around the edges of the study area many of the UTM squares fall partly outside of the map sheets. In such cases the potential sample site density has been recorded on the basis of sites per 100 square kilometres. Data have not been gathered in cases where less than 20 square kilometres of the grid square lies within the study area.

Within the entire study area the average density of potential lake sediment sample sites is 7.1 per 100 square kilometres. The average densities within the three map sheets, (in sites per 100 km^2), range from 6.0 in the north (93K), to 7.2 in the south (93C) and 8.0 in the centre (93F).

The potential lake sediment sample site densities for each of the grid squares is shown on Figure 5. Within both 93C and 93K there are large regions where the density is less than 5 sites per 100 square kilometres. In 93C such regions account for one-third of the total area, while the proportion is only slightly less within 93K. Some 10% of the area of both 93C and 93K has potential sample densities of less than 3 sites per 100 square kilometres.

LIMNOLOGICAL DATA

Limnological data for 225 lakes, including all surveyed lakes covered by NTS map sheets 93C, 93F and 93K and selected lakes from the eastern parts of 93E and 93L, have been acquired from the Ministry of Environment, Lands and Parks.

The data include the lake name, the survey date, the NTS sheet, the lake area and maximum known depth, the Secchi-disk turbidity reading, the total dissolved solids

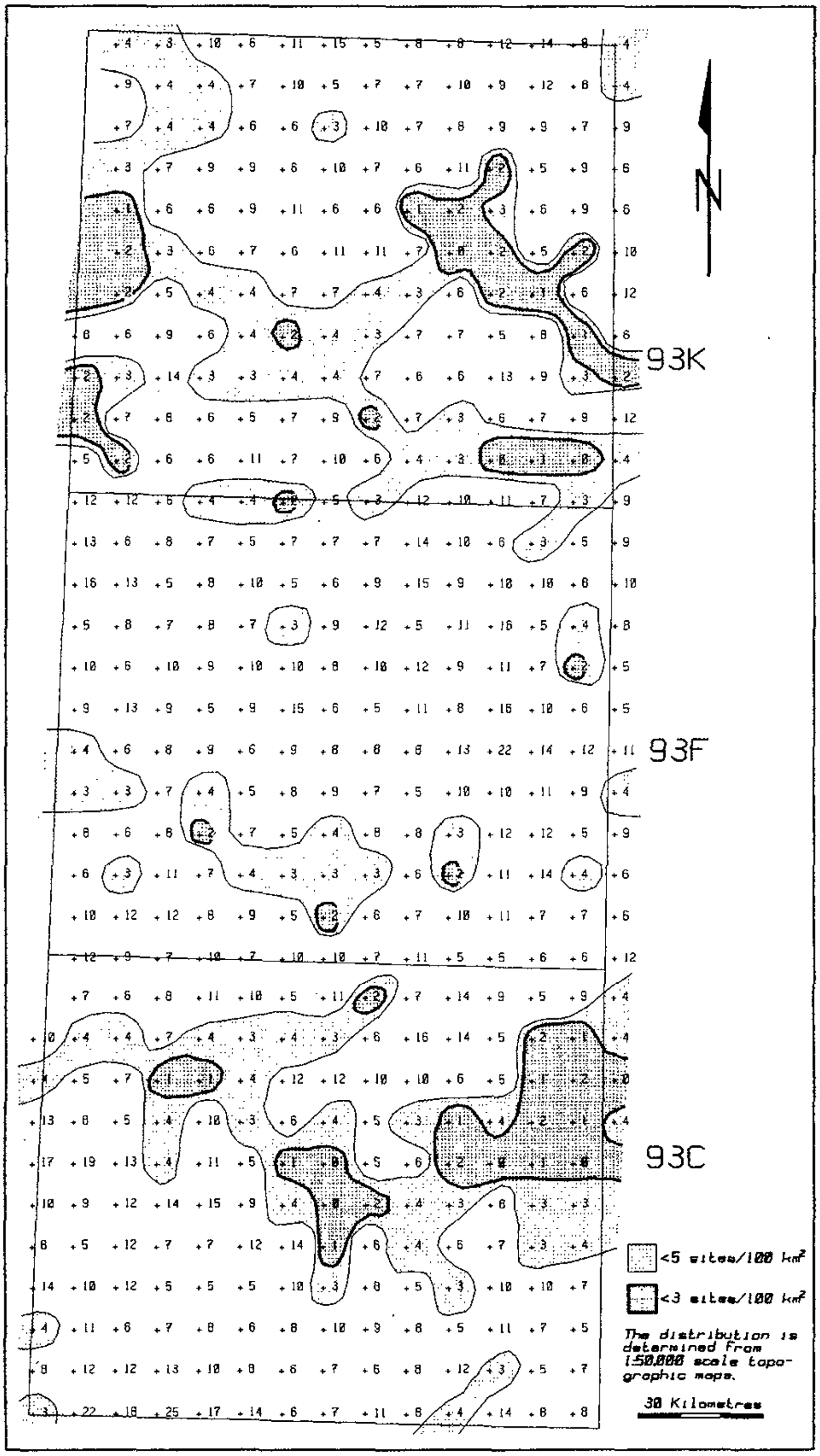


Figure 5. Potential lake-sediment sample densities on the Nechako Plateau.

(TDS) level in the surface water, the vertical temperature profile characteristics, and the pH and dissolved oxygen levels of surface and bottom waters. Not all of these data are available for each lake.

The information acquired has been used to classify the lakes into limnological types based on trophic status and mixing frequency. A complete listing of the data, together with UTM locations of the lake centres, some derived variables and the classifications, is given in Appendix 1. The information is summarized in Table 4.

Lakes have been classified as "polymictic" (*i.e.* unstratified) if there is no significant difference between the top and bottom temperature readings. This criterion has only been applied to lakes surveyed in the summer months. Lakes surveyed in May, October or in late September seldom show thermal stratification and, unless they are stratified, these lakes have been classified "unknown". All other lakes are assumed to be dimictic, and they are arbitrarily classified here on the basis of the ratio of bottom water to surface water oxygen levels. The lake is termed oligotrophic where the ratio is greater than 75%, and eutrophic where the ratio is less than 25%. Lakes with ratios between 25 and 75% are termed mesotrophic. According to Hutchinson (1957), trophic classification should be based on the rate of oxygen depletion, rather than the depletion observed in one measurement. Depletion rates are not available for these lakes, but the available data do provide a reasonable indication of trophic status. Goldman and Horne (1983) have emphasized the subjectivity of these classification terms, and have pointed out that a "eutrophic" lake in one area may be more aptly termed "mesotrophic" in another.

As shown in Table 4, there are some significant and consistent differences in the characteristics of the different types of lakes. For example, the eutrophic lakes are generally smaller than the mesotrophic lakes and much smaller than the oligotrophic lakes. The eutrophic lakes are also shallower than the mesotrophic and oligotrophic lakes, but when the depth is expressed as a function of the lake area it is evident that the basins of the eutrophic lake basins are just as steep as those of the other lakes. On the other hand, the lakes which are classified as polymictic, are characterized by consistently shallow basins, with an average "depth ratio" of 0.7 and an average maximum depth of only 9 metres. Based on Secchi disk measurements the waters of the oligotrophic lakes are generally more transparent than those of the other lakes, especially the polymictic lakes, which are the least transparent of all of the lake types considered.

There is a consistent trend of increasing dissolved solid content with trophic activity. The average TDS level is 60 ppm in the oligotrophic lakes, as compared with 84 ppm in the mesotrophic lakes and 105 ppm in the eutrophic lakes. The polymictic lakes have an average TDS of 87. Differences in pH are quite small, but the oligotrophic lakes do have generally lower pH levels than the other lakes. On the other hand, there are significant variations in the differences between surface and bottom-water pH levels. In the oligotrophic and polymictic lakes these differences are small (0.3 and 0.2 pH units respectively), while in both mesotrophic and eutrophic lakes the pH differences average 1.1 unit. The polymictic lakes are characterized by higher bottom-water pH levels than the dimictic lakes.

Bottom-water oxygen levels are lower in the eutrophic lakes than in the oligotrophic lakes, but this is hardly surprising as the classification is based on the oxygen data. The surface water oxygen levels are generally consistent. The polymictic lakes are characterized by relatively high bottom-water oxygen levels and by slightly lower surface-water oxygen levels than the dimictic lakes.

There are some consistent limnological differences amongst the three maps sheets 93C, 93F and 93K. For example, on average, the lakes within 93K are larger than those in 93C and 93F. The 93F lakes are generally shallower than those of the other map sheets. Secchidisk

TABLE 4
SUMMARY OF LIMNOLOGICAL DATA FOR NECHAKO PLATEAU LAKES

Lake type	n	Max Depth m	Area ha	Depth ratio	Secchi depth m	TDS ppm	pH top	pH bot	pH t-b	Oxygen (ppm) top	Oxygen (ppm) bot.	Oxygen % b/t
All	225	18	553	1.3	3.2	84	7.3	6.7	0.7	8.7	4.6	50.1
Oligotrophic	35	31	943	1.7	4.1	60	7.2	6.8	0.3	9.0	8.3	90.7
Mesotrophic	49	23	416	1.3	3.2	84	7.9	6.9	1.1	9.4	4.7	50.7
Eutrophic	64	16	199	1.6	3.5	105	7.9	6.8	1.1	8.9	0.6	6.8
Polymictic	47	9	313	0.7	2.4	87	7.5	7.3	0.2	8.6	7.6	91.6
NTS 93 K	66	23	1184	1.4	2.8	88	7.6	6.9	0.7	9.4	5.3	51.9
NTS 93 F	73	15	270	1.2	3.2	93	7.8	6.9	1.0	8.9	3.2	37.5
NTS 93 C	33	21	423	1.5	4.3	102	7.7	7.3	0.4	9.2	7.1	73.3

Data are from the B.C. Ministry of Environment Lands and Parks.
All values shown are arithmetic means of all available data.
"Max depth" is maximum known depth.
"Depth ratio" is the depth (m) over the square root of the area (ha).
"pH t-b" is the difference between top and bottom pH readings.
"Oxygen % b/t" is the bottom O divided by the top O expressed as a per cent.

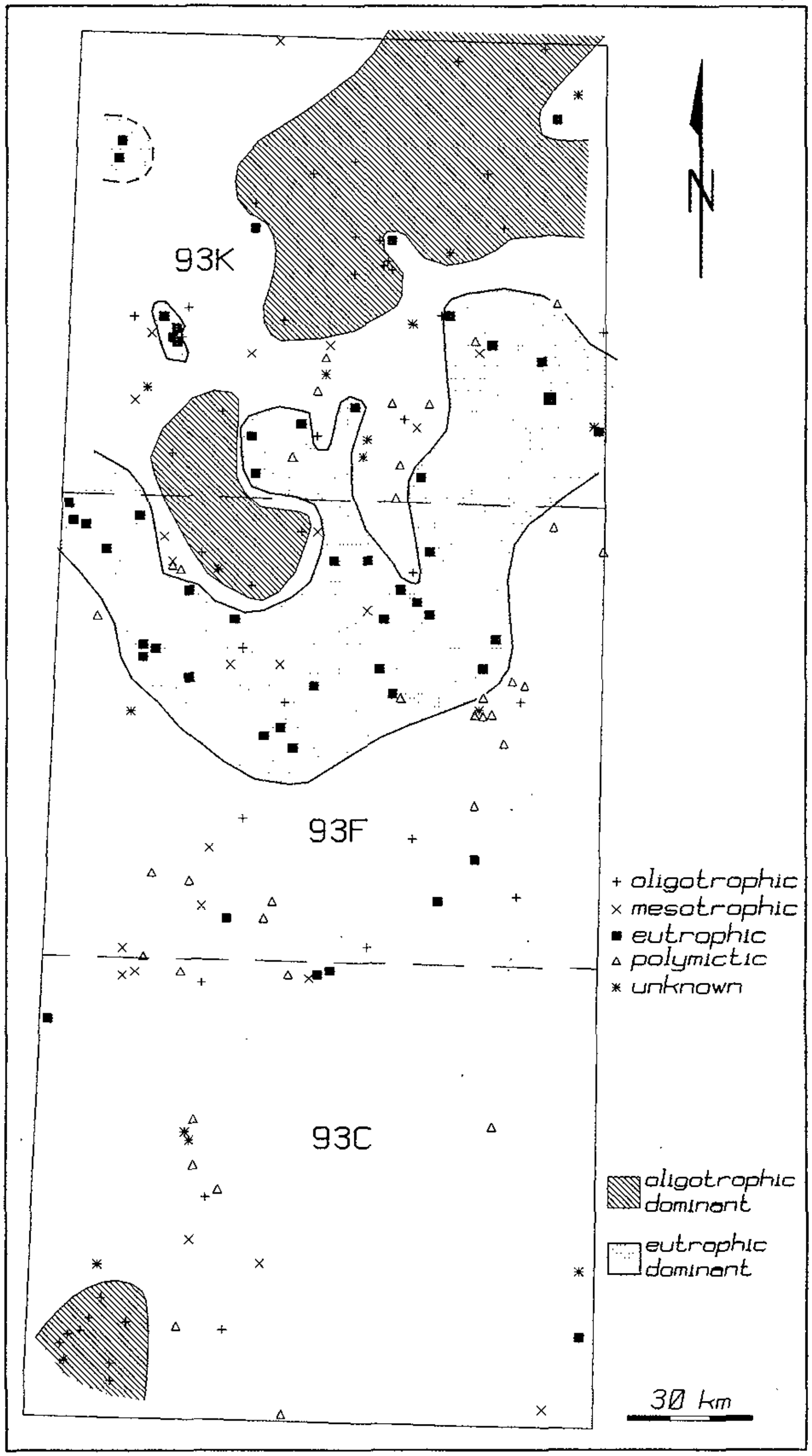


Figure 6. Limnological features of lakes on the Nechako Plateau.

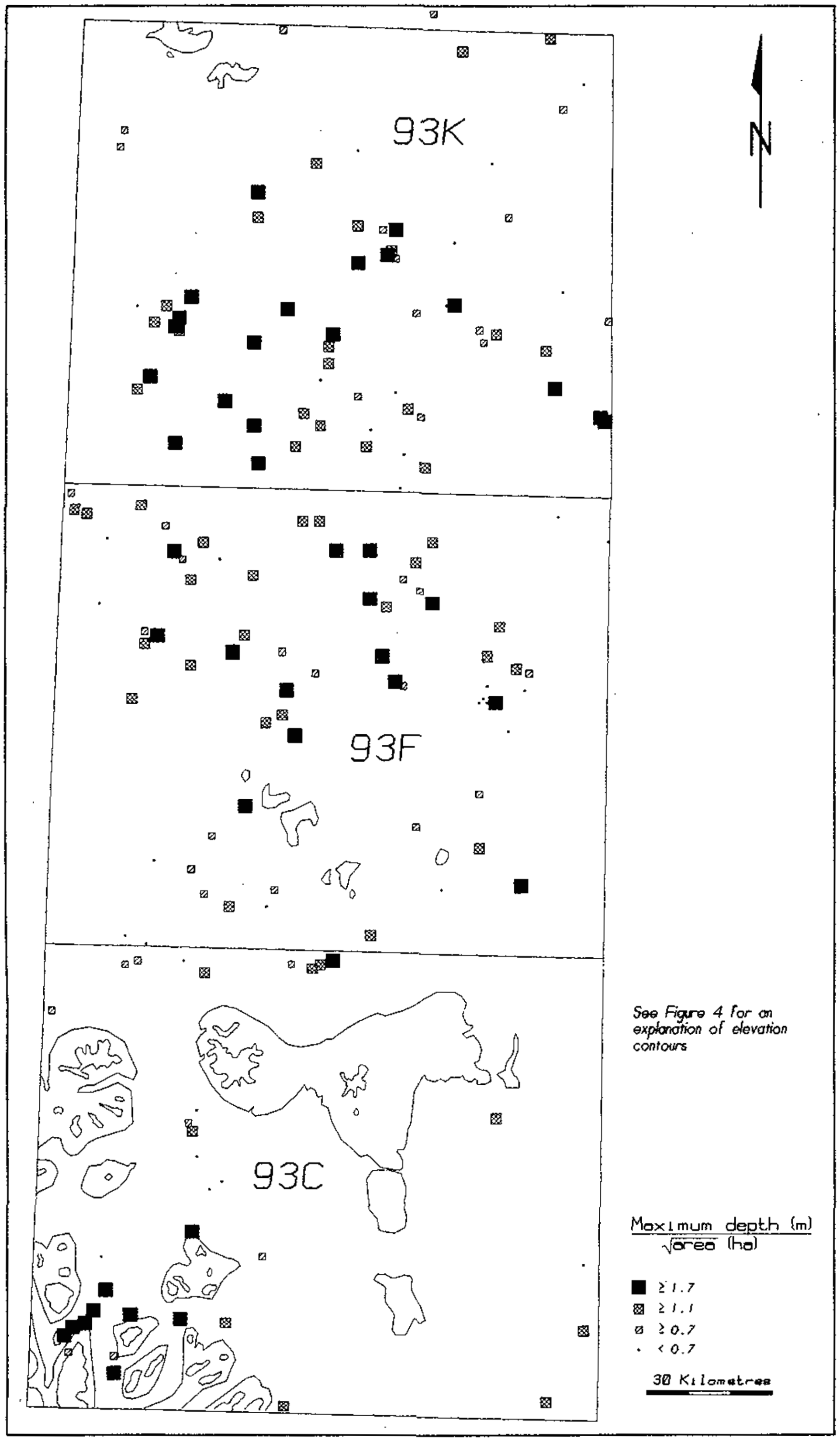


Figure 7. Depth to area ratios for lakes on the Nechako Plateau.

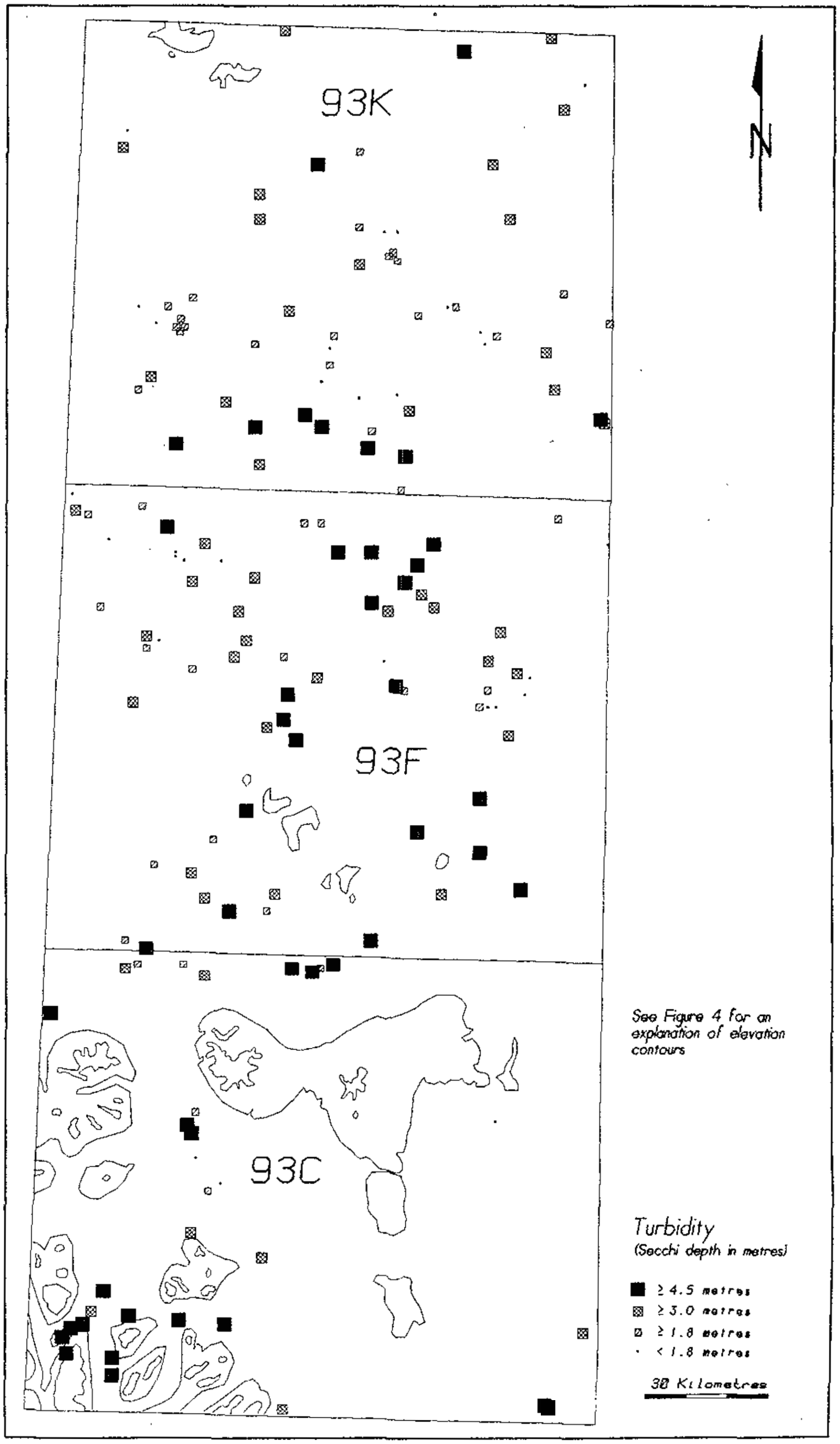


Figure 8. Turbidity levels in lakes on the Nechako Plateau.

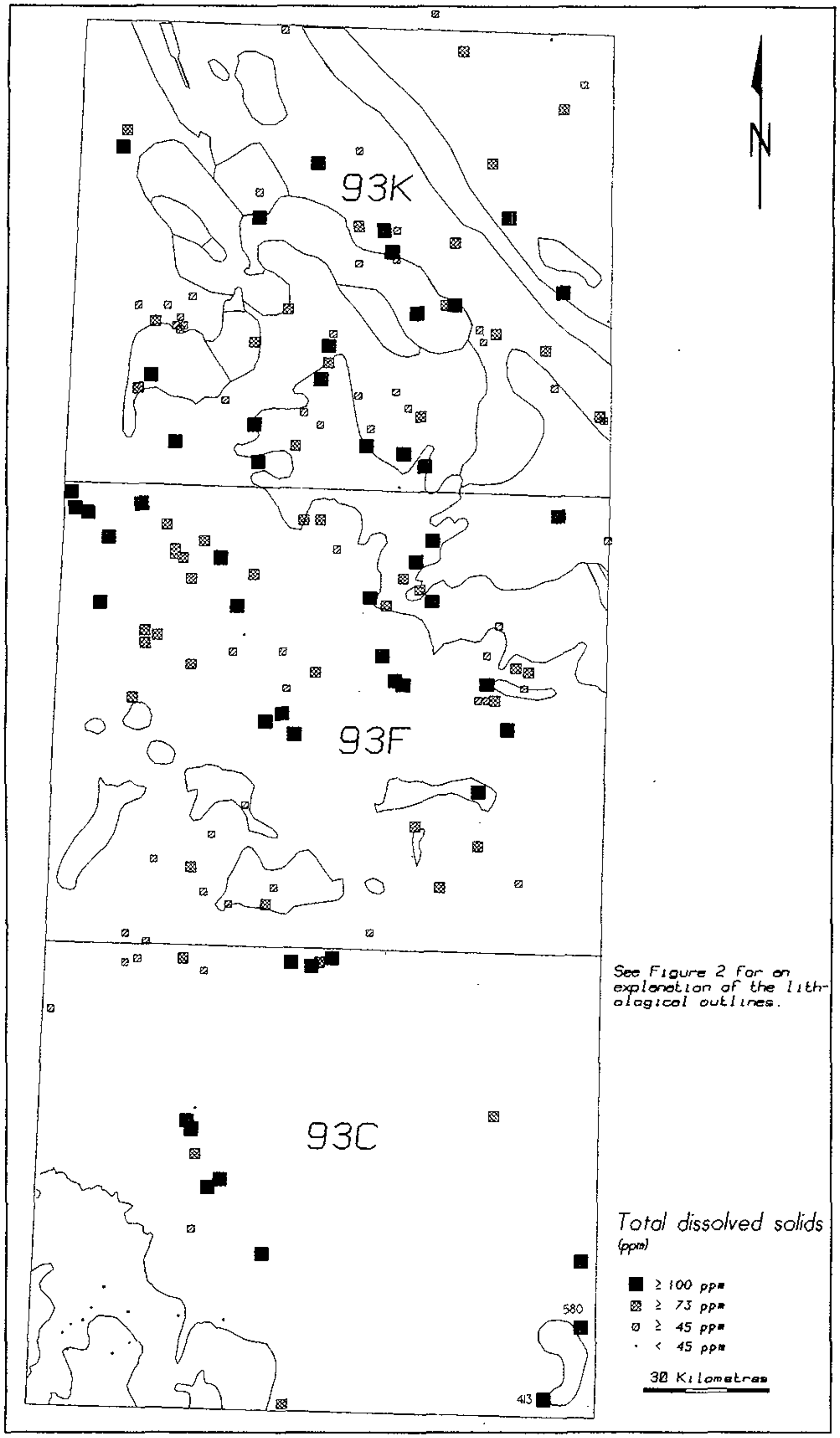


Figure 9. Total dissolved solid levels of lakes on the Nechako Plateau.

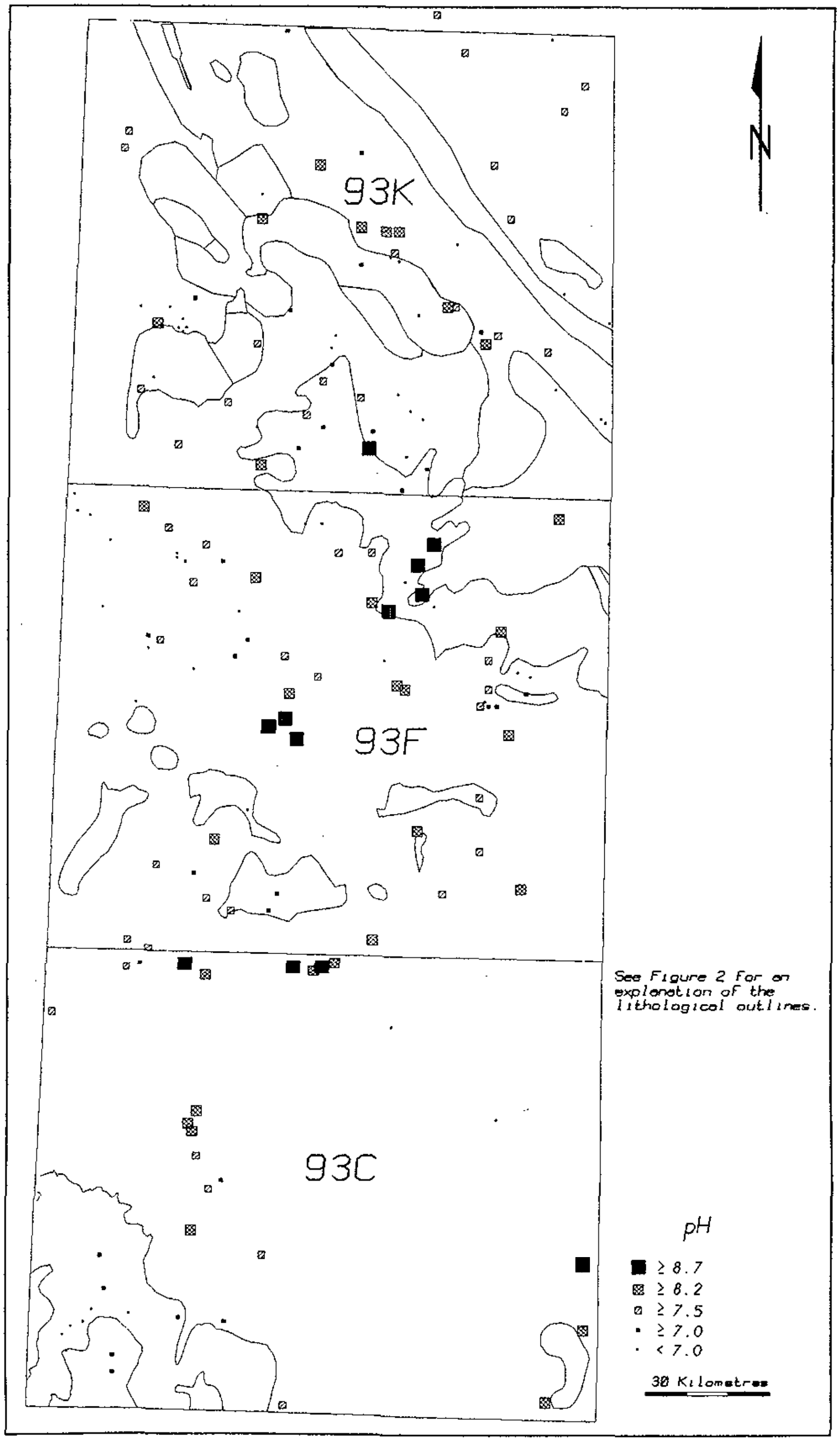


Figure 10. Surface-water pH of lakes on the Nechako Plateau.

transparencies are greatest in 93C and lowest in 93K. Total dissolved solid levels are also greatest in 93C and lowest in 93K. Surface-water pH levels do not differ significantly, but top-bottom pH differences are substantially greater in 93F than the other two areas. Bottom-top oxygen ratios are also lower in 93F than in the other areas.

The spatial distributions of some of the limnological parameters described above are shown on Figures 6 to 10. Unfortunately the distribution of data points is quite irregular. For example, there is no limnological information available for much of sheet 93C.

Lake types are plotted on Figure 6. The relatively high-relief southwestern part of sheet 93C is dominated by oligotrophic lakes, and, in general, this map area has very few eutrophic lakes. The northeastern part of 93K is also dominated by oligotrophic lakes. The northern half of 93F and the southern part of 93K are dominated by eutrophic lakes. Polymictic and mesotrophic lakes are scattered throughout the study area.

Lake depth to area ratios [depth/square root (area)] are shown on Figure 7. There is a concentration of relatively steep-profile lakes in the southwestern part of 93C, while most of the lakes in the northern part of 93K, the southern part of 93F and the northern part of 93C have shallow or moderate profiles. The lakes in the central and northern parts of 93F and the central and southern parts of 93K show a wide range of profile characteristics. Apart from the southwestern corner of 93C, there is no obvious correlation between lake profiles and topographic relief.

The distribution of turbidity levels, expressed as Secchi-disk transparency readings, is shown on Figure 8. Within much of the central part of 93K transparency depths are consistently less than 3.0 metres, while most of the lakes in the southwestern part of 93C have transparency depths of greater than 4.5 metres. Within the remaining areas there is little consistency in the patterns of lake water turbidity variations.

Total dissolved solid levels are shown on Figure 9. Again the high-relief granitic terrain of the southwestern part of 93C is distinctive from the rest of the study area, in this case with TDS levels consistently below 45 ppm. TDS levels are generally low in the southern part of 93F, and the northeastern part of 93K, and consistently high in the southeastern corner of 93C, where two lakes have over 400 ppm TDS. There is a wide range of TDS levels in other parts of the study area, but no other lakes have more than 260 ppm TDS.

The distribution of surface-water pH is shown on Figure 10. The pH is consistently less than 7.5 in the southwestern part of 93C, and generally above 7.5 in the rest of 93C and in the southern part of 93F. Several lakes within 93F, and in the northern part of 93C, have pH levels over 8.7. Some of these high-pH lakes are underlain by granitic rocks, while others are underlain by volcanic rocks. pH levels are quite variable in 93K, although there is only one lake with pH above 8.7.

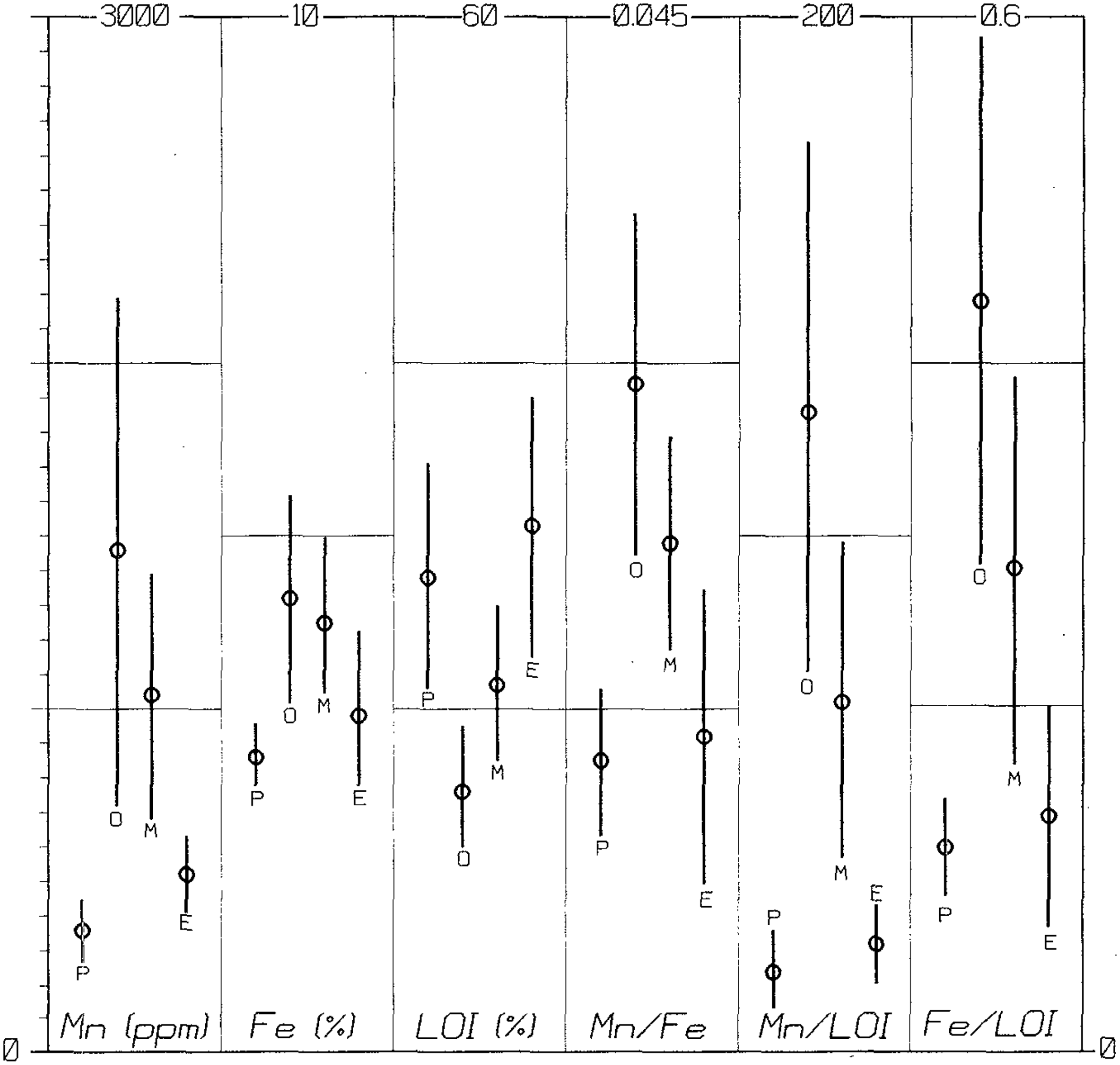
The limnological data obtained for lakes in 93E and 93L have been compared with the available RGS lake sediment geochemical data to provide some indication of limnological controls over lake sediment geochemistry. Only the eastern parts of 93E and 93L, adjacent to the present study area, have been considered. Both limnological and geochemical data are available for 36 lakes. In many cases these lakes have been sampled in more than one location. Geochemical data for 61 samples from the 36 lakes are listed in Appendix 2.

The lakes have been grouped limnologically, and average levels of the various constituents are shown in Table 5. For many of the elements analyzed there are no consistent differences between the different lake types, however there are consistent and significant differences for manganese, iron and loss on ignition (LOI), and some trace elements. The statistics for iron, manganese and LOI are presented graphically on Figure 11, where the

TABLE 5
SUMMARY OF 93E AND 93L LAKE SEDIMENT DATA BY LAKE TYPE

Lake type		Mn ppm	Fe %	LOI %	Mn/Fe	Mn/LOI	Fe/LOI	Mo ppm	Co ppm	As ppm	Au ppb
All data (n=61)	mean	925	3.67	21.0	0.0198	63.5	0.251	2.0	10.4	9.0	3.8
Polymictic	mean	361	2.87	27.6	0.0127	16.5	0.120	1.8	7.3	6.1	2.2
(n=9)	s.e.*	44	0.14	3.3	0.0016	3.7	0.014	0.4	0.7	0.7	0.5
Oligotrophic	mean	1455	4.44	14.8	0.0291	125.2	0.436	2.5	12.7	11.3	4.0
(n=22)	s.e.	365	0.50	2.0	0.0037	25.3	0.076	0.4	1.3	3.2	1.6
Mesotrophic	mean	1039	4.24	21.3	0.0222	68.6	0.280	1.9	12.7	10.8	6.5
(n=16)	s.e.	177	0.37	2.3	0.0023	15.4	0.056	0.3	1.1	3.4	3.2
Eutrophic	mean	519	3.06	30.5	0.0182	21.3	0.138	1.9	8.4	7.1	1.9
(n=14)	s.e.	56	0.25	3.7	0.0023	3.7	0.032	0.4	0.8	2.0	0.2

*"s.e." is the standard error of the mean



Lake types: P=polymictic (n=9). O=oligotrophic (n=21). M=mesotrophic (n=16). E=eutrophic (n=14). Centre point is the mean. Bars represent the mean plus and minus 2 standard errors. (Data are from RGS surveys in map sheets 93E and 93L)

Figure 11. Comparison of sediment geochemistry for various lake types within map sheets 93E and 93L.

standard error values have been used to show the 95% confidence limits of the mean.

For the variables shown on Figure 11 there is a clear distinction between eutrophic and oligotrophic lakes. For example, manganese levels are highest in the oligotrophic lakes and lowest in the eutrophic lakes, with the mesotrophic lakes falling in between. The trend in iron levels is similar, although the differences are less pronounced. Loss on ignition shows the opposite pattern, with lowest levels in the oligotrophic lakes and highest levels in the eutrophic lakes. The most prominent difference between the groups is shown by the Mn/LOI ratio, for which there is no overlap between the eutrophic and mesotrophic limits, and only a small overlap between the mesotrophic and oligotrophic limits. In most cases the polymictic lakes show similar characteristics to the eutrophic lakes. In fact the polymictic lakes have even lower levels of manganese than the eutrophic lakes.

Of the trace elements, arsenic shows the greatest differences in behaviour within different lake types. Arsenic levels are highest in the oligotrophic lakes and lowest in the eutrophic and polymictic lakes. Cobalt, molybdenum and gold behave similarly, but the trends are not as pronounced.

Variations in Geochemical Behaviour Within and Around Lakes

Recognizing the obvious diversity of terrain and lake types within the study area, it is important to have some understanding of the processes which can affect geochemical behaviour within lake drainage basins and within lakes. Two of the important factors to consider include variations in the mode of transport of metals into lakes and variations in the rate of exchange between water and sediment.

VARIATIONS IN INPUT FACTORS

Geochemical input into lakes takes place in several different ways (Allan and Timperley, 1974), but in the present context the three most important media are stream water, seepage water and groundwater. In stream water and seepage water, metals are transported in solution or in suspension, or adsorbed onto organic or clastic particles. In groundwater, metals are only likely to be transported in solution. The relative importance of the transport medium will vary from area to area and from lake to lake, depending on a variety of factors, and it is impossible to generalize about their importance without the benefit of detailed hydrological studies. This question is important, however, since the input mechanism can affect the way in which metals are distributed within the lake.

Metals transported within streams are likely to be introduced into the surficial water, within the zone where significant circulation takes place, and thus will probably be distributed around the lake basin before becoming incorporated into the lake sediment. Metals transported in seepage water will also be introduced to the surficial layer, although a large proportion of the metal may never actually reach the lake basin, particularly if there are abundant scavenging materials along the shoreline. Metals transported in groundwater can also be trapped by scavenging substrates within the lake sediment, and thus may not be evenly distributed around the lake. In cases where groundwater enters the lake at depth, any metal which is not immediately scavenged by the lake sediment may still be restricted to a small area around the discharge point because, except in polymictic lakes, the extent of circulation at depth is limited during most of the year.

Hoffman (1976) has discussed the problem of variations in the mode of geochemical input into lakes, and presents data which show significant enrichment of metals within specific parts of two different lakes. In reference to Capoose Lake, in the central part of map sheet 93F, Hoffman and Fletcher (1981) state that: "a significant proportion of the trace elements, together with iron and manganese, enter the lake dissolved in groundwater", and that both iron and manganese oxides, which precipitate at subaqueous groundwater discharge zones, "compete to scavenge other inflowing metals".

In reference to a group of several hundred shallow lakes described as "bog" lakes, Gintautas (1984) suggests these lakes may have abnormally low metal levels because of high rates of metal sorption in the sphagnum bogs which surround them. The inference here, although not stated by Gintautas, is that, in these cases, much of the water coming into the lakes is seeping through the bog areas rather than flowing in through specific inlet streams.

VARIATIONS IN GEOCHEMICAL BEHAVIOUR WITHIN LAKES

Relationships between metals and various potential metal-scavenging media in lakes have been studied in many different environments both by limnologists and by exploration geochemists. On the basis of this research it is clear that metals are strongly scavenged by both fine-grained organic matter, and by oxides of iron and manganese. The rate of absorption onto these substrates is different for each metal under consideration, and can also be affected by a number of other factors, such as pH, oxidation potential and the physical and chemical nature of the substrates.

ORGANIC MATTER

Lakes with organic-rich sediments are a distinctive feature of areas with cool climates and slow rates of decomposition (Koljonen and Carlson, 1975). According to Hutchinson (1957) organic lake sediments can be divided into two classes depending on whether the material was formed within or outside of the lake basin. Autochthonous organic matter is commonly referred to as "gyttja", while allochthonous organic matter is known as "dy". Hutchinson also states that gyttja predominates in productive but relatively uncoloured lakes, while dy is more abundant in brown humic lakes, and originates in the peat bogs in the terrain surrounding the lake.

Stumm and Morgan (1981) suggest that the humic substances found in natural waters are polymers containing phenolic OH and carboxolic groups, with molecular weights between 300 and 30 000. In terms of molecular composition, these materials are similar to the humic substances found in soils, and it is suggested that they are ultimately derived from soils (Reuter and Perdue, 1977). Humic substances are present in both dissolved and particulate forms. Reuter and Perdue report that the ratio of dissolved organic compounds to particulate organic compounds (based on an arbitrary distinction at a particle size of 0.45 %), ranges from 10:1 to 6:1, with the lower ratios typical of highly productive (eutrophic) lake waters. Koljonen and Carlson (1975) suggest particulate compounds are derived from dissolved compounds through a process of polymerization and aggregation, and that these particles eventually precipitate to the lake bottom.

Humic substances in general are strong adsorbers of metal cations (Stumm and Morgan, 1981), and it is likely that such metal fixation takes place in the water flowing into a lake, within the lake water itself and within the sediment. A strong relationship between metals and organic matter has been demonstrated in a great many lake sediment geochemical studies, and in most cases it has been suggested that the variability in this process can be accounted for through the use of regression or ratio techniques. In other words, it is assumed that there is a simple relationship between a metal and organic matter, and that this relationship will be consistent from lake to lake.

The existence of such a consistent relationship is unlikely. Although the relationships between lacustrine organic matter and various metals are not very well understood, it is known that the ability of a humic polymer to adsorb metal cations is partly dependant on pH (Stumm and Morgan, 1981), and on the concentration of other more abundant cations, such as calcium and magnesium (Reuter and Purdue, 1977). Variability amongst these parameters in the lakes of the Nechako Plateau is likely to lead to variability in the rate of metal adsorption by organic matter.

IRON AND MANGANESE OXIDES

Iron and manganese oxides can accumulate to high levels in lake sediments because of the close relationship between oxidation potential and the solubility of iron and manganese. Iron and manganese are soluble in environments with low oxidation potential, such as groundwater; but are readily precipitated, as amorphous and crystalline oxides, hydrated oxides and hydroxides, under oxidizing conditions. They accumulate preferentially in oligotrophic lakes where oxygenated conditions extend to the lake bottom for at least part of the year, or in the shallower parts of any lake.

The relationships between various metals and the hydrous manganese and iron oxides have been reviewed by Jenne (1968), who has shown that they are strong but variable adsorbers of most trace metals. There are many factors which can affect these relationships, and some of these have been summarized by Tessier *et al.*, (1985). They include pH, temperature, physical characteristics of the absorbent surfaces - such as porosity and surface area, the presence of other cations at high concentrations, and the presence of inorganic and organic ligands (including humic substances).

As is the case for organic matter, there are many studies describing the empirical relationships between iron and manganese and trace metals in both streams and lakes. In many cases a simple regression equation or element ratio is used to account for variable levels of iron and/or manganese. It is reasonable to expect, however, that differences in the adsorbing effects of iron and manganese substrates in different lake types could interfere with any consistent relationship between iron or manganese and the trace metals.

Comparison Between Lake Sediment Sampling and Other Geochemical Methods

Within the context of this study, which has not involved collection of new data, the only available means of comparing lake sediment geochemistry with other methods is through existing data sets, either published or unpublished. Few such comparative data sets are available for this region, and it is not necessarily useful to apply the results of comparative studies from other areas because of significant terrain, climate and geological differences. Comparative data are available for three areas within and adjacent to the study area, and these are described below.

RGS DATA FROM THE DOME MOUNTAIN AREA

Lake sediment and stream sediment geochemical data are available from RGS surveys carried out within NTS sheets 93E and 93L, west of the present study area. Although both types of samples have been collected, the sampling density for lake sediments is significantly lower than that for stream sediments. A useful comparison between lake and stream sediments is possible east of Smithers, in the northeastern part of map sheet 93L. This area includes mineral occurrences at Mount Cronin, Dome Mountain and Grouse Mountain.

Mineralized zones in these areas are described by MacIntyre (1985), MacIntyre *et al.*, (1987) and MacIntyre and Desjardins (1988). Near Mount Cronin vein-type silver-copper and lead-silver-copper-zinc deposits occur within Mesozoic volcanic rocks. The Cronin deposit, which has been mined during several different periods since 1910, also contains 1.7 grams per tonne gold. At Dome Mountain gold and silver-bearing quartz-pyrite veins cut Hazelton Group volcanic rocks. The Free Gold property was mined sporadically in the 1930s and 1940s. At Grouse Mountain silver, zinc, copper and gold--bearing veins are also hosted by Hazelton Group volcanic rocks.

Within the 40 by 50 kilometre area surrounding these mining camps, 57 lake sediment samples and 113 stream sediment samples were collected during a 1987 National Geochemical Reconnaissance survey (Johnson *et al.*, 1987b). This represents a sample density of 2.9 samples per 100 square kilometres for lakes, and 5.7 samples per 100 square kilometres for streams.

The Dome Mountain and Grouse Mountain areas are characterized by moderate relief (maximum eleva-

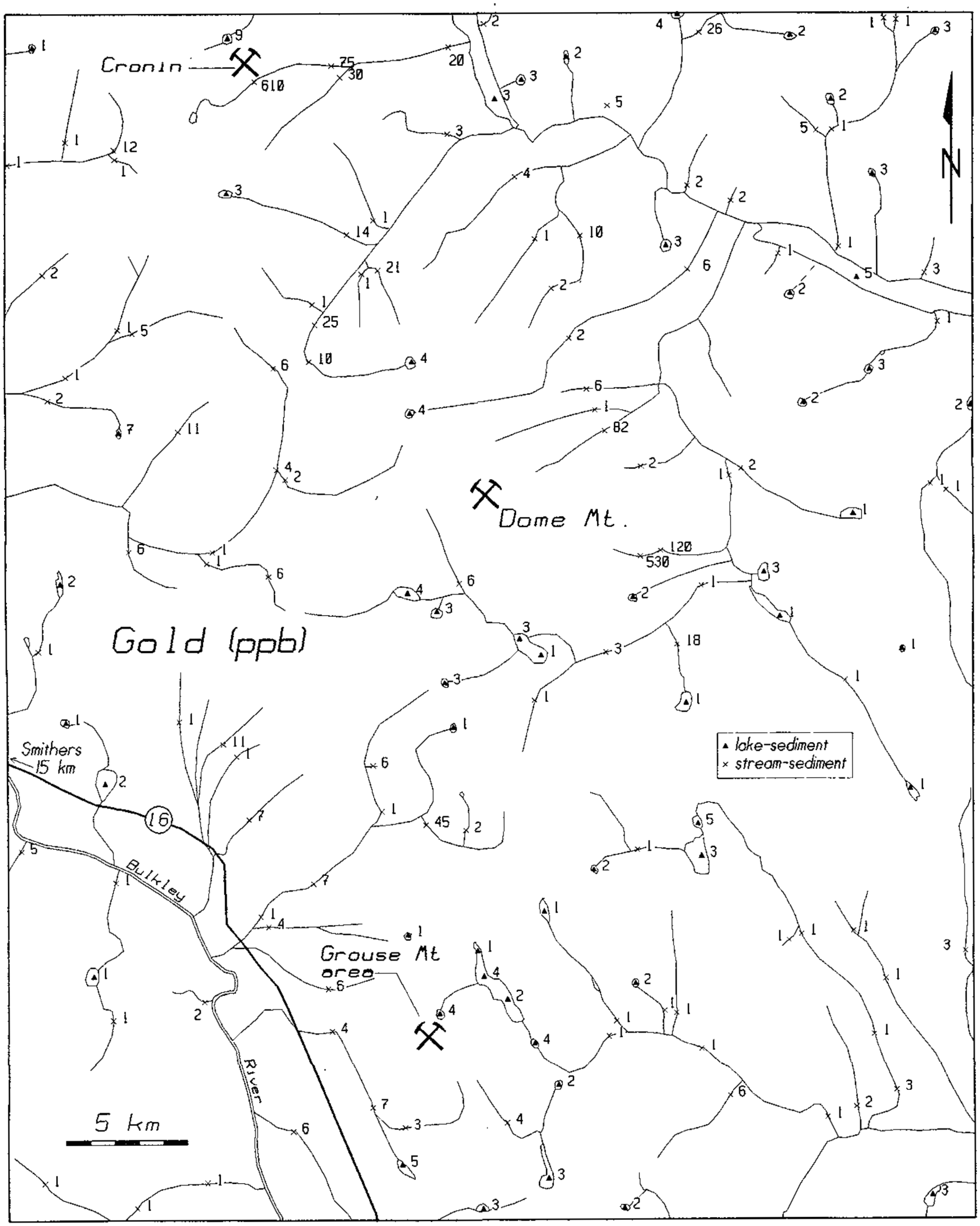


Figure 12. Gold in stream and lake sediments in the Dome Mountain area.

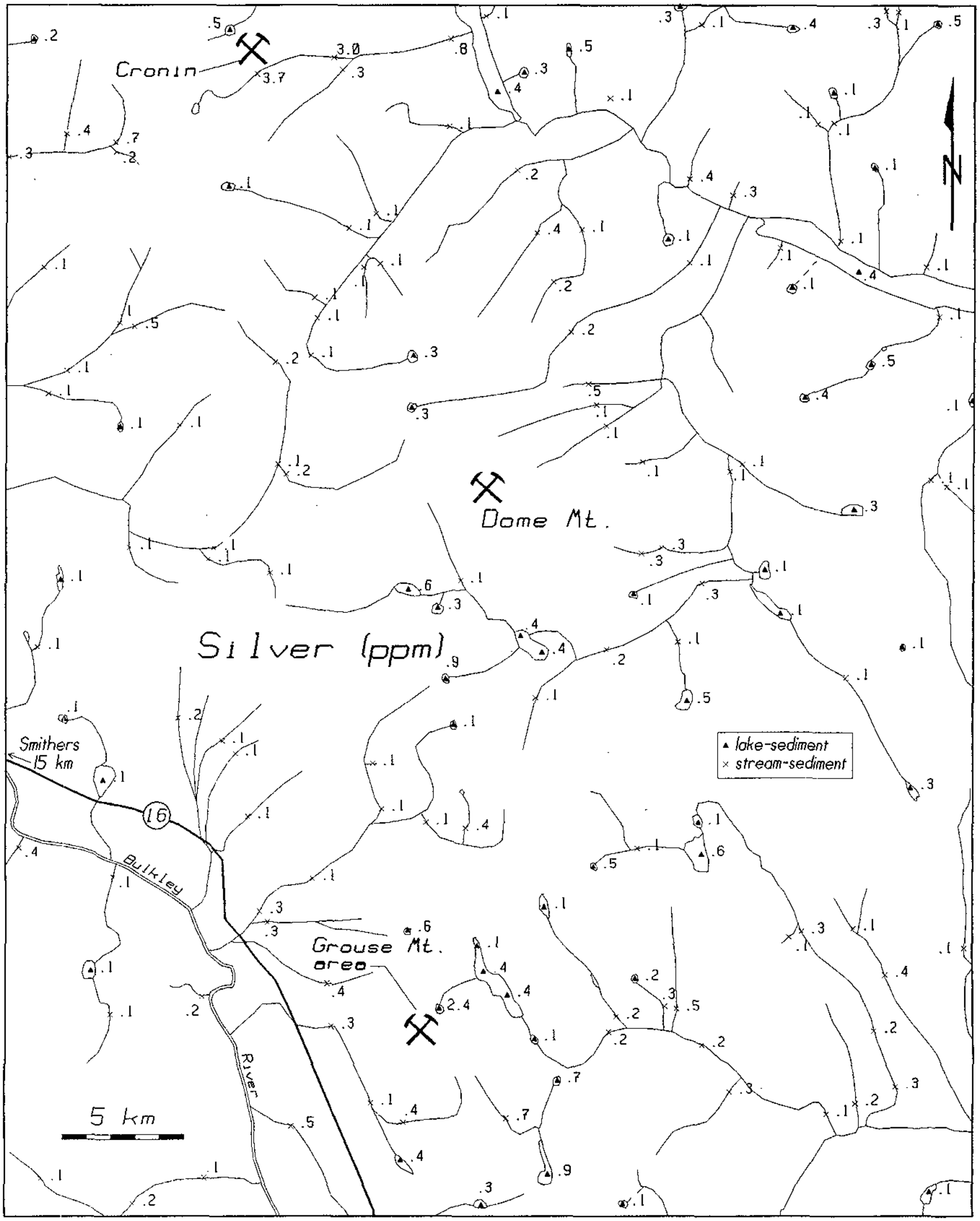


Figure 13. Silver in stream and lake sediments in the Dome Mountain area.

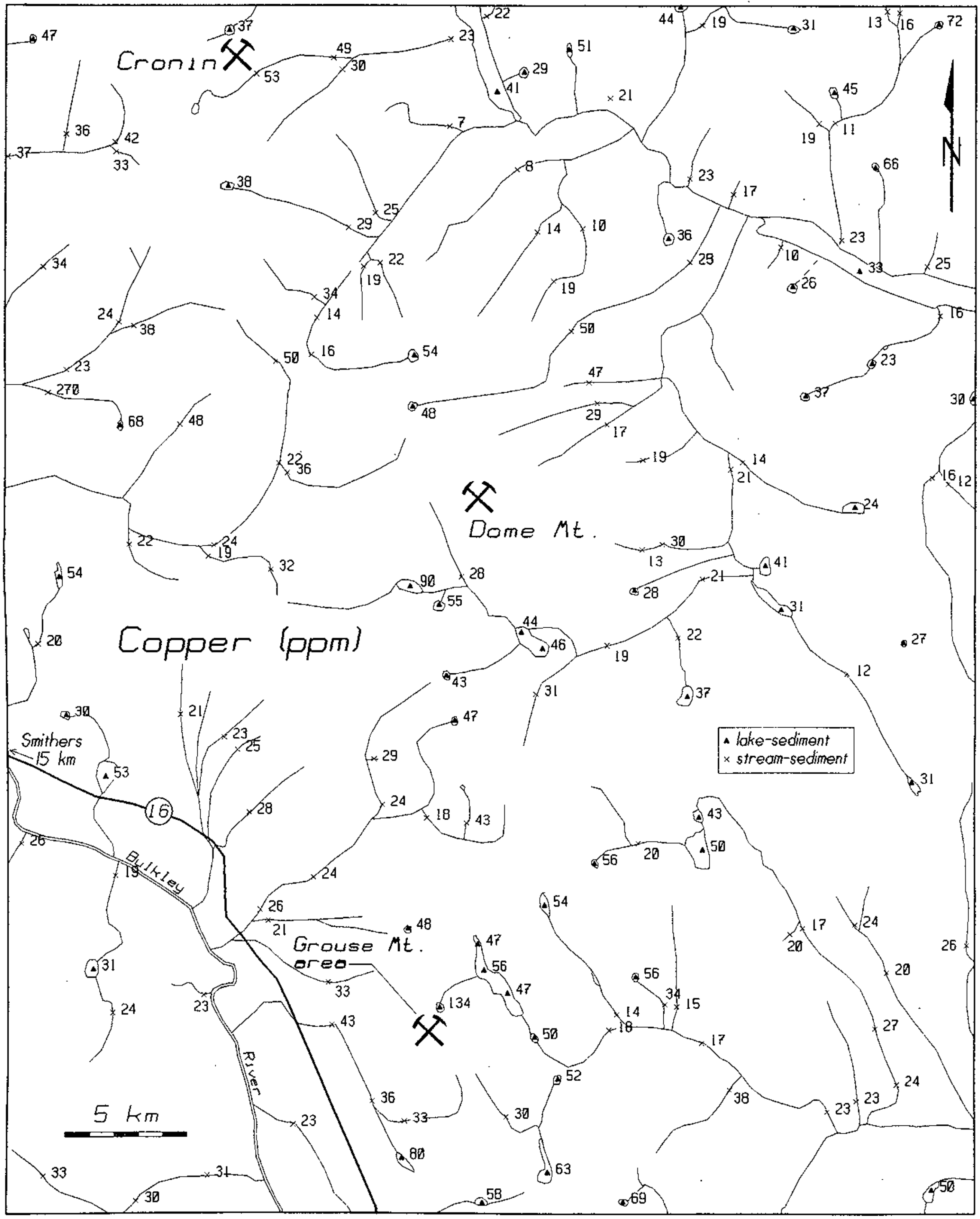


Figure 14. Copper in stream and lake sediments in the Dome Mountain area.

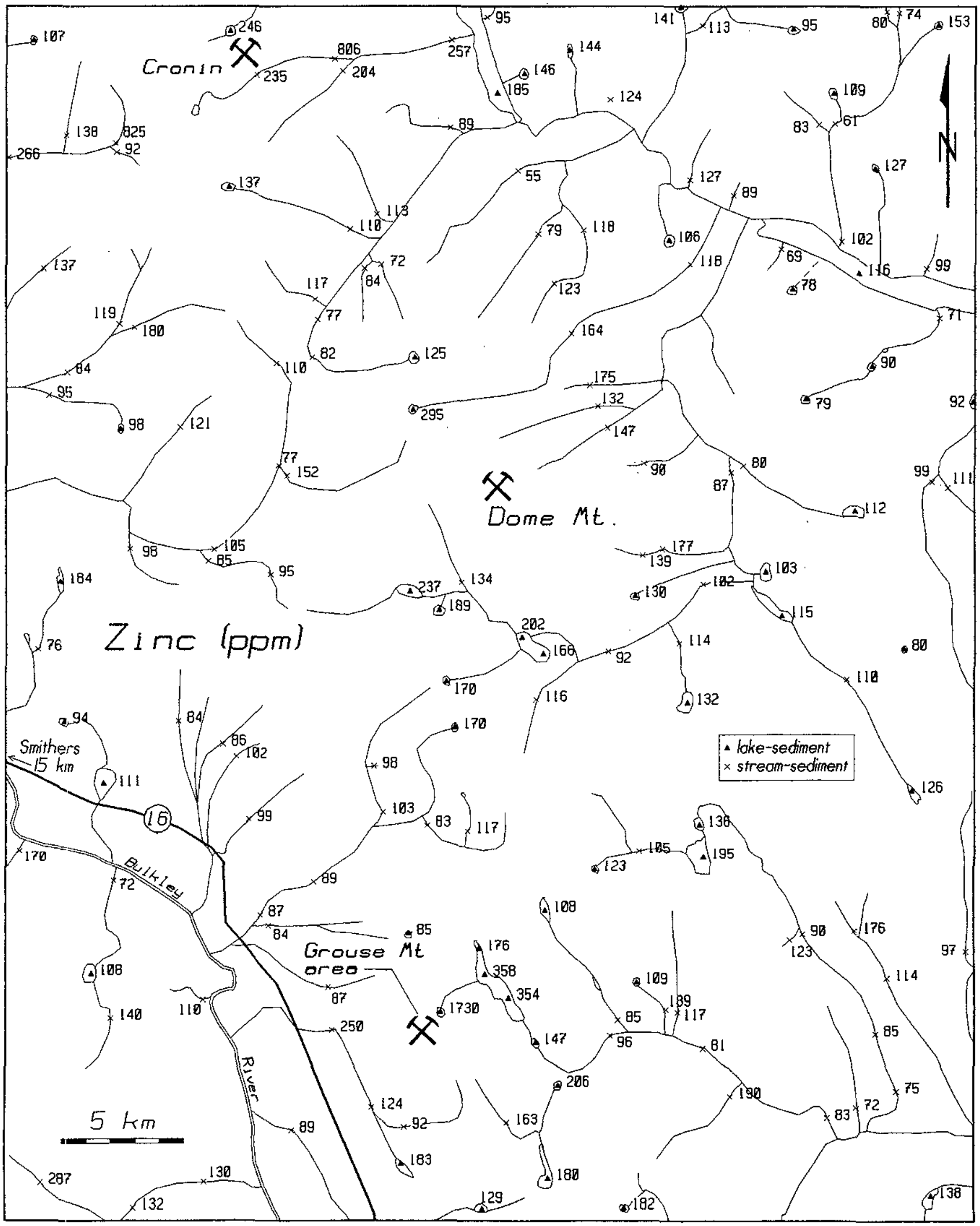


Figure 15. Zinc in stream and lake sediments in the Dome Mountain area.

tions are in excess of 1500 m), while the Cronin mine is in a high-relief area, with several peaks over 2000 metres. In all three areas the topographic relief is more extreme than that of most of sheets 93C, 93F and 93K. Of the fourteen lakes for which limnological data are available, five are oligotrophic, two are mesotrophic, five are eutrophic and two are polymictic.

The analytical results for gold, silver, copper and zinc are presented on Figures 12 through 15, with lake sediment and stream sediment results shown together on each map. It is important to point out that these data are unprocessed. No corrections have been made for variations in the organic matter, iron or manganese levels. Percentiles for all samples collected from the eastern half of map sheet 93L are given in Table 6.

Gold levels in stream sediments and lake sediments are shown on Figure 12. The stream sediment gold background range within map area 93L, arbitrarily based on the 30th and 70th percentiles, is 1 to 2 ppb. Both of the areas with known gold occurrences - Cronin and Dome Mountain - are associated with several samples which have strong gold enrichment (25 ppb). At Cronin there are strong anomalies in the stream draining the mine area. At Dome Mountain there are strong anomalies in two of the streams draining the eastern side of the area, and a weak anomaly in the stream draining towards the south. There are weak gold anomalies in stream sediments collected in the Grouse Mountain area, and there are also stream sediment gold anomalies in several areas remote from known gold occurrences, particularly in the area between Dome Mountain and Cronin, and to the north and northwest of Grouse Mountain.

The lake sediment gold background range is 1 to 3 ppb. There are gold anomalies in lake sediments in the general vicinity of all three mineralized areas, but the contrast with background is low. The maximum gold level in lake sediments is 9 ppb, in a sample from immediately north of the Cronin mine. Lake sediment samples have

TABLE 6
PERCENTILES FOR LAKE AND STREAM SEDIMENT DATA FROM THE EASTERN PART OF MAP SHEET 93L

	PERCENTILES						
Stream sediments (n=379)	30	50	70	80	90	95	97.5
Au ppb	1	1	2	4	9	22	41
Ag ppm	0.1	0.1	0.2	0.3	0.4	0.5	0.6
Cu ppm	17	21	25	28	34	48	52
Zn ppm	74	83	100	113	138	175	220
Lake sediments (n=205)	30	50	70	80	90	95	97.5
Au ppb	1	2	3	3	4	5	7
Ag ppm	0.1	0.1	0.3	0.4	0.5	0.7	0.8
Cu ppm	32	38	47	53	60	71	86
Zn ppm	104	125	145	161	185	258	347

not been collected from the anomalous drainage systems identified by the stream sediment samples at either Cronin or Dome Mountain

The regional stream sediment silver background is 0.1 to 0.2 ppm (based on 30 and 70th percentiles for all samples from the eastern part of 93L). There are strong silver anomalies in stream sediments at Cronin, with two samples over 3 ppm and one of 0.7 ppm (Figure 13). There are moderate anomalies south of Grouse Mountain and east of Dome Mountain. Based on this low background, however, many of the streams in the study area are anomalous in silver. A more realistic background range, for this specific area, may be 0.1 to 0.5 ppm, in which case only the Cronin anomalies would be significant.

The lake sediment silver background ranges from 0.1 to 0.3 ppm. There is a strong silver anomaly in one sample immediately adjacent to the Grouse Mountain zone, and there are several moderate anomalies to the south of Grouse Mountain. There is a weak silver anomaly to the north of Cronin and several weak anomalies to the south and southwest of Dome Mountain.

The stream sediment copper background is 17 to 25 ppm. There is moderate copper enrichment in the streams around the Cronin area, weak enrichment to the south of Grouse Mountain, and no significant enrichment at Dome Mountain (Figure 14). On the other hand, there is a strong copper anomaly (270 ppm) in one stream 10 kilometres to the southwest of Cronin.

The lake sediment copper background is 32 to 47 ppm. There is no lake sediment copper anomaly at Cronin, but there is a moderate anomaly to the south of Dome Mountain. At Grouse Mountain there is a strong anomaly in the lake adjacent to the mineralized zone, and weak anomalies in several of the surrounding lakes.

The background range for zinc in stream sediments is 74 to 100 ppm. There are strong zinc anomalies in stream sediments both to the east and west of Cronin, and moderate anomalies around Dome Mountain and to the south of Grouse Mountain (Figure 15). On the other hand, there are numerous other samples with elevated zinc levels scattered around the study area.

The lake sediment zinc background ranges from 104 to 145 ppm. There are particularly strong zinc anomalies in lake sediments at Grouse Mountain. The lake adjacent to the mineral zone has more than 1700 ppm zinc, and two others exceed 300 ppm. The lake to the north of Cronin is moderately anomalous in zinc, as are those to the north and south of Dome Mountain.

In summary, both stream and lake sediment samples appear to respond to the mineralization at Cronin, Dome Mountain and Grouse Mountain, but the level of response is not consistent. It is difficult to provide an objective evaluation of these results, especially considering the relatively low sampling density and the difference in sampling density between streams and lakes. It is clear, however, that gold enrichment is more pronounced in the streams than in the lakes. Copper does not respond strongly in either medium. For silver and zinc the stream sediment anomalies are more prominent at Cronin, while the lake sediment anomalies are more prominent at Grouse Mountain. These differences can be attributed, in part, to the spatial relationships between the mineral occurrences and the stream and lake sample sites in the two areas.

GEOCHEMICAL DATA FROM THE CHUTANLI PROSPECT

Lake and stream sediment and soil data from the Chutanli prospect south of Burns Lake (93F-7) have been reported by Mehrtens *et al.* (1973) and Mehrtens (1975). Detailed lake sediment studies carried out in the same area have been described by Hoffman (1976). The location of the Chutanli prospect is given on Figure 3.

Mineral showings at Chutanli comprise a stockwork of pyrite and molybdenite in altered siliceous sediments adjacent to a granitic intrusion. The mineralized zone is exposed near to the top of a hill which rises approximately 150 metres above the surrounding terrain. As currently defined, the zone of mineralization covers an area of 200 by 800 metres. The most recent ice-advance direction in this area is towards the east-northeast.

There is a molybdenum soil anomaly which extends approximately 2000 metres down-ice from the subcrop of the mineralization (Figure 16). Within this area molybdenum levels exceed 5 ppm and many are greater than 15 ppm. The molybdenum background in soils appears to be less than 5 ppm. Both stream and lake sediment samples have been collected around the mineralized zone, and the molybdenum levels in these samples are also shown on Figure 16. The apparent background level in both types of sediments is 1 to 2 ppm molybdenum. There are strong lake sediment molybdenum anomalies (9 and 25 ppm) in

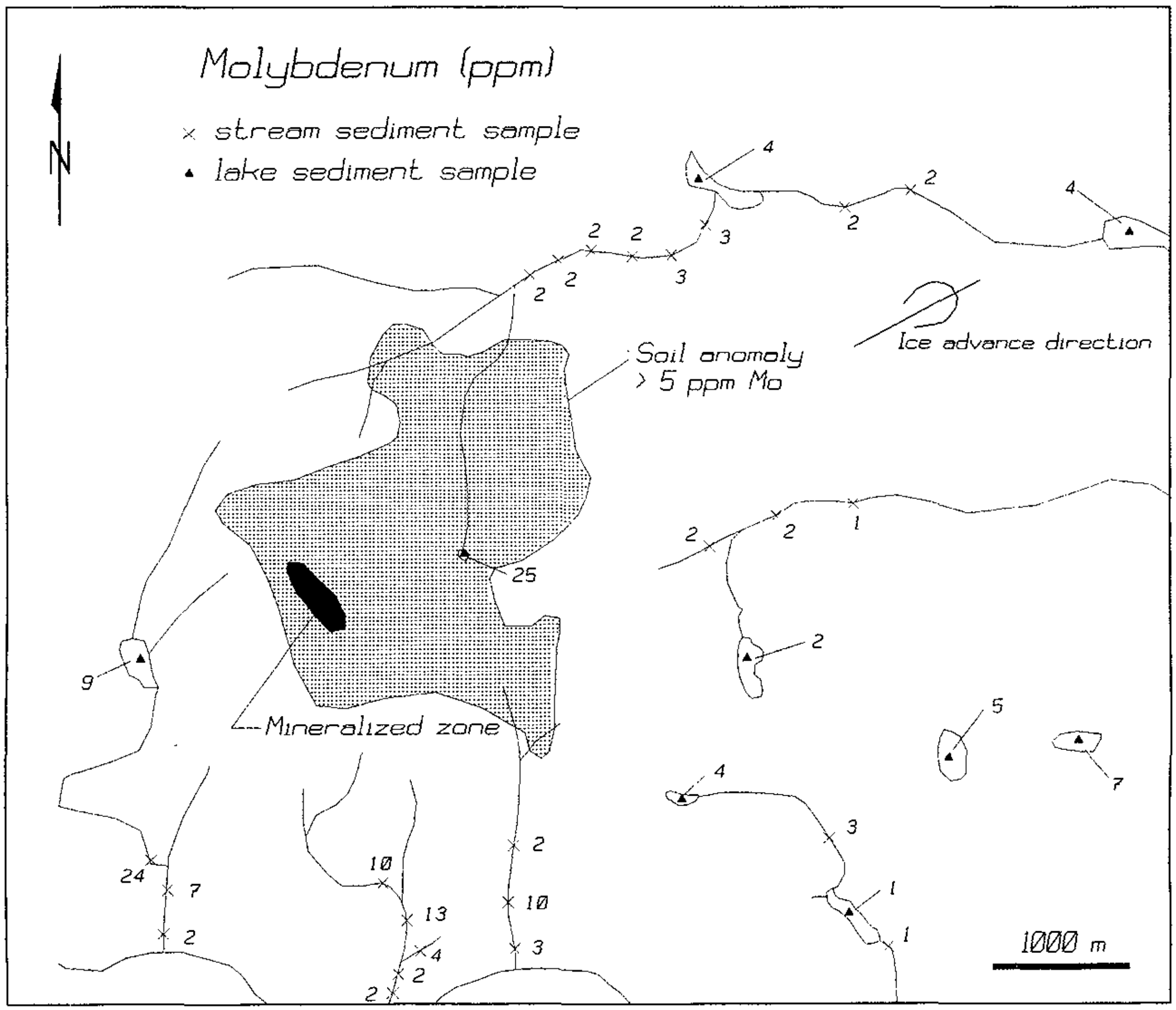


Figure 16. Molybdenum geochemical data from the Chutanli prospect.

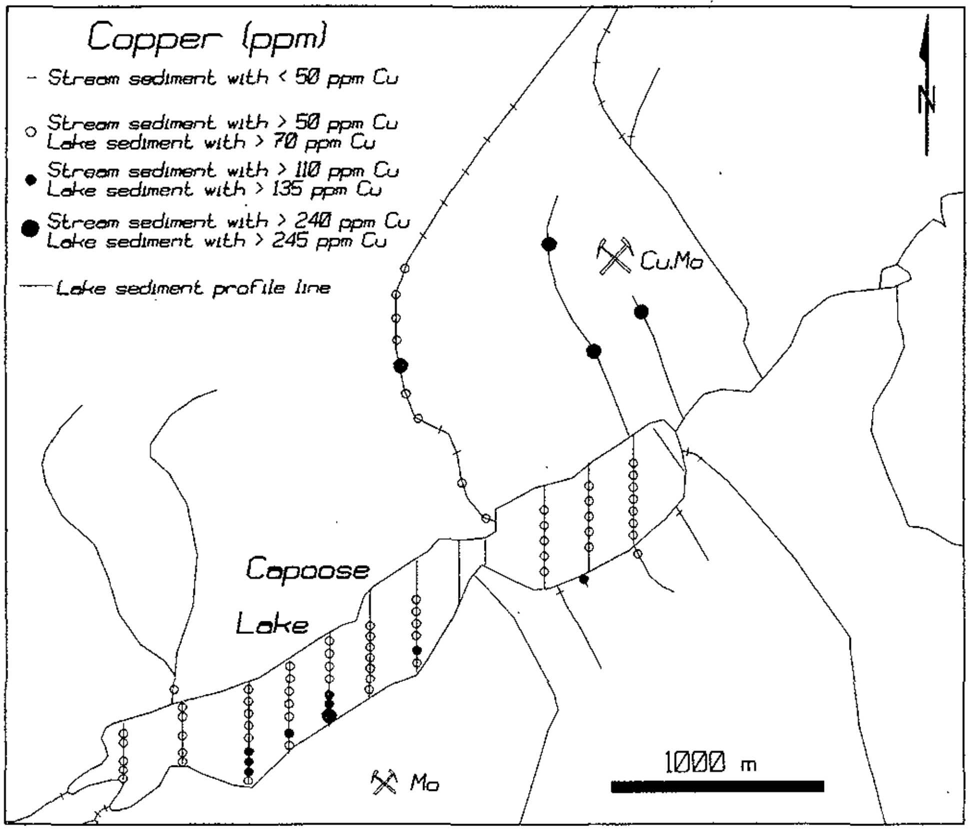


Figure 17. Copper in lake and stream sediments at Capoose Lake.

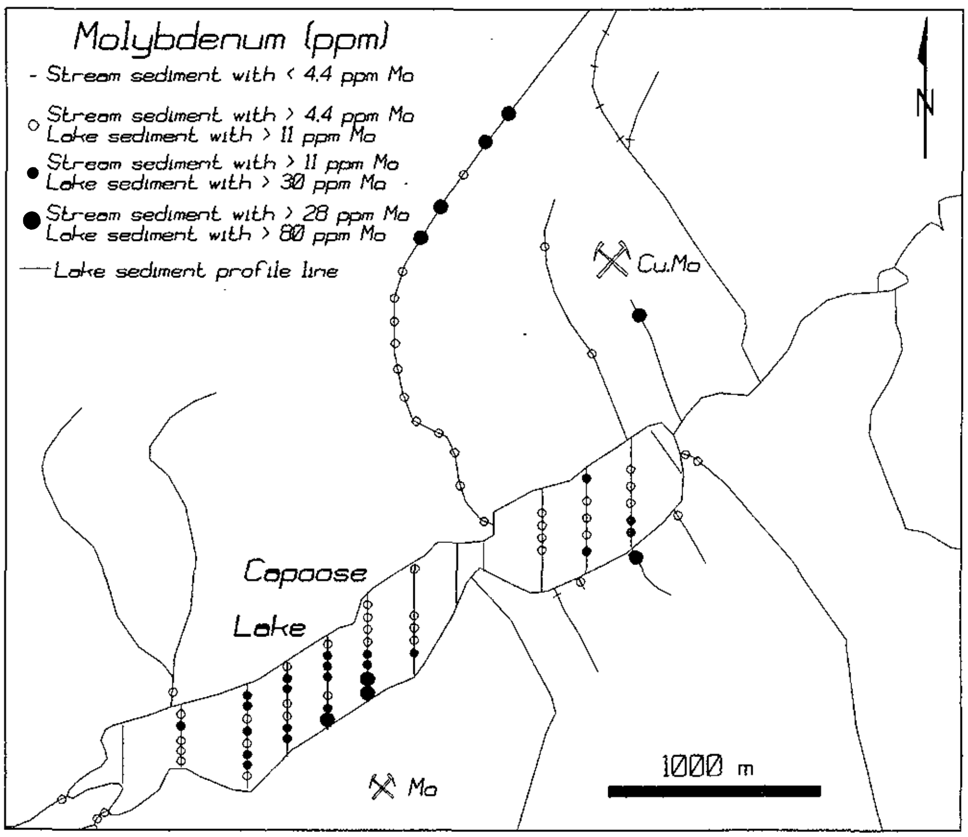


Figure 18. Molybdenum in lake and stream sediments at Capoose Lake.

two lakes 1000 metres to the east and west of the mineralized zone, and weak to moderate anomalies (4 to 8 ppm) in several other lakes within 5 kilometres in the general down-ice direction.

There are strong molybdenum anomalies in sediments collected from streams to the south of the mineralized zone, but no significant anomalies in other streams in the immediate area. The upper parts of the drainage systems were not sampled in these surveys.

Hoffman (1976) has carried out detailed stream and lake sediment sampling in the area around the two anomalous lakes closest to the Chutanli mineralized zone. In general, Hoffman reports higher molybdenum levels that those found by Mehrtens. He sampled the upper parts of the drainages, close to the mineralized zone, and found elevated molybdenum levels in stream sediments.

In summary, there are significant molybdenum anomalies in both lakes and streams in the Chutanli area, although the lake sediment anomaly pattern appears to be more extensive than the stream sediment pattern.

GEOCHEMICAL DATA FROM THE CAPOOSE LAKE AREA

A variety of exploration data from the Capoose Lake area have been presented by Boyle and Troup (1975), Hoffman (1976) and Hoffman and Fletcher (1976, 1981). Capoose Lake is on map sheet 93F/6, some 40 kilometres west of the Chutanli prospect (*see* Figure 3). The area is characterized by disseminated copper-molybdenum and copper-zinc-silver mineral occurrences in several zones within a large granodioritic body. The geochemical studies cited above were concentrated largely on the copper-molybdenum zones.

Copper and molybdenum results from stream and lake sediments collected by Hoffman (1976) from within and around Capoose Lake are shown on Figures 17 and 18. There is a zone of copper-molybdenum mineralization north of the eastern end of Capoose Lake and a smaller zone of molybdenum mineralization south of the lake.

The sediments from Capoose Lake were sampled in detail along a number of profile lines. Most of the streams flowing into the lake were sampled, some at only one location and others at regular intervals of approximately 150 metres. As actual element concentrations are not given by Hoffman, variations in the data are portrayed here through the use of symbols. The symbol cutoff levels are the same as those used by Hoffman.

Several of the stream sediment samples taken in the immediate area of the mineralized zone north of the lake have strongly anomalous copper levels, and most of the other streams flowing into the lake have moderately anomalous levels (Figure 17). All of the samples with more than 50 ppm copper would be anomalous compared with the regional stream sediment average of 18 ppm, as determined by Boyle and Troup (1975). Most of the lake sediment samples are also anomalous compared with Hoffman's regional background of 20 ppm. The highest copper levels in Capoose Lake are in samples collected along the southern shore of the lake, downslope from the molybdenum prospect.

The molybdenum patterns are generally similar to those for copper (Figure 18). Most of the stream sediment samples are at least moderately anomalous in molybdenum compared with the regional background of 1 ppm, as defined by Boyle and Troup (1975). There is a very strong lake sediment anomaly in the western basin of Capoose Lake, and a weak anomaly in the eastern basin. Again, all of these anomalies are well above Hoffman's regional background of 1 ppm.

It is clear that virtually any regional stream sediment or lake sediment sample taken in this area would be anomalous in both copper and molybdenum with respect to the regional background, although the contrast between the anomalies and background appears to be higher for lake sediments than for stream sediments.

Several other types of surveys were carried out in this area by Boyle and Troup (1975), including soil sampling, bog sampling, surface-water sampling and vegetation sampling. Soil and bog samples showed a strong anomalous response close to mineral concentrations, but in both cases several apparently spurious anomalies were detected, and dispersion patterns around known prospects were quite restricted. In the stream water samples, only molybdenum showed an anomalous response. Similarly, the phloem layer of lodgepole pine and black spruce were anomalous only in molybdenum, and the anomaly pattern was quite restricted.

DISCUSSION

The information presented here provides a basis for evaluating the potential application of lake sediment sampling to regional geochemical reconnaissance of the Nechako Plateau. The following discussion is focused on addressing the points of inquiry raised in the introduction.

FEASIBILITY OF LAKE SEDIMENT SAMPLING IN THE NECHAKO AREA

Although there is no fixed sampling density at which regional lake sediment samples "must" be collected, the objective within map areas 93C, 93F and 93K should be to use a density which is compatible with those used on RGS surveys in adjacent map areas. The sampling density in the RGS stream sediment survey of 93J is just over seven samples per 100 square kilometres, while those for combined stream- and lake sediment samples in sheets 93E and 93L are close to eight samples per 100 square kilometres.

The density of potential lake sediment sample sites within the entire study area is 7.1 samples per 100 square kilometres. Within sheet 93F the density is 8.0 samples per 100 square kilometres, and there are few areas where the density would be lower than five samples per 100 square kilometres. Sheets 93C and 93K have average densities of 6.2 and 7.0 samples per 100 square kilometres. On both sheets there are significant areas where the sampling density would be lower than 3 sample sites per 100 square kilometres.

These sample-site densities are based on the premise that every site identified will yield a sample. The author's experience in lake sediment sampling in an adjacent region has shown that samples may not be obtainable from some potential sample sites, because of inadequate development of fine-grained sediment.

VARIATIONS IN LIMNOLOGICAL CHARACTERISTICS

Based on both limnological and geochemical studies cited above, it is evident that there is a wide diversity in the limnological character of lakes on the Nechako Plateau. The different limnological classes believed to be important in terms of their implications for lake sediment geochemistry, are listed in Table 7, together with the evidence for their existence, and criteria for their identification.

There is little doubt about the existence of both oligotrophic and eutrophic lakes on the Nechako Plateau. These classifications represent the end-members of a continuum of varying biological productivity within the lakes, and as there is such a significant difference in the sediment geochemistry of oligotrophic and eutrophic lakes, the inclusion of an intermediate mesotrophic class is justified.

The polymictic lakes are, by definition, only distinct from the other lakes in this region in that they are not thermally stratified during the summer. They are also relatively shallow (average depth 8 m), which contributes to their repeated mixing. On the other hand, most of the polymictic lakes for which sediment geochemical data are available have high organic matter contents and very low manganese to organic matter ratios, and thus could be interpreted to be strongly eutrophic, in spite of the observed high oxygen levels in their bottom waters. This class of lakes may be equivalent to the "bog" or "dystrophic" class of Gintautas (1984), which are also consistently shallow, and have low manganese to organic ratios.

There is some controversy concerning the use of the term "dystrophic". Goldman and Horne (1983) equate "dystrophic" with "bog-stage", and apply these terms to lakes which have a strong brownish colour due to humic matter. Schwoerbel (1987) defines dystrophic lakes in terms of biological productivity, but his range of productivity overlaps with those of both oligotrophic and mesotrophic lakes. Welch (1952) describes dystrophic lakes as being shallow, with abundant organic matter, low calcium, phosphorous and nitrogen content, high humic content and low bottom-water dissolved oxygen. In these respects his dystrophic class differs from his eutrophic class only in the levels of dissolved calcium, phosphorous, nitrogen and humic matter. Hutchinson (1957), on the other hand, argues against the use of the term dystrophic

TABLE 7
LIMNOLOGICAL CLASSIFICATION OF LAKES ON THE NECHAKO PLATEAU

Classification	Evidence	Criteria
1 Oligotrophic	F.B. Oxygen data*	Bottom O > 75% sat. or > 75% of surface water O
	RGS geochemical data	Mn/LOI ratio > 75
2 Mesotrophic	F.B. Oxygen data	Bottom O 25-75% sat or 25-75% of surface water O
	RGS geochemical data	Mn/LOI ratio 33-75
3 Eutrophic	F.B. Oxygen data	Bottom O < 25% sat. or < 25% of surface water O
	RGS geochemical data	Mn/LOI ratio < 33
4 Polymictic	F.B. temperature data	no thermocline
	RGS geochemical data	no established criteria although Mn/LOI ratios are < 33
5 Dystrophic (or "bog")	Gintautas geochemical data	no established criteria Gintautas used shallow depth and low metal concentrations
6 Dilute alpine	F.B. TDS data	TDS < 25 ppm
7 Saline	F.B. TDS data	TDS > 400 ppm
8 Carbonate	Gintautas geochemical data	no established criteria Gintautas used high Ca levels
9 Clastic	Lake sediment data	no established criteria Gintautas used low LOI and high Al, K and Mg

*F.B. denotes Fisheries Branch of the B.C. Ministry of Enviornment, Lands and Parks altogether, suggesting that eutrophic and oligotrophic be maintained to define rates of oxygen consumption, while organic colour levels should be described separately. Whatever terminology is used, it is important to recognize the features of these shallow, iron and manganese-poor and organic-rich lakes. Whether or not there is a significant difference between the "polymictic" lakes defined here, and the "bog" lakes of Gintautas, is a question which should be addressed.

The "dilute alpine" class is included here to represent a number of low dissolved solids, low pH and low turbidity lakes situated in the southwestern part of sheet 93C. They are underlain by granitic rocks, however there are other extensive granitic terrains in the study area within which dissolved solid levels are not low. There are also other alpine areas within 93C, underlain by Endako Group volcanic rocks, rather than granitic rocks. As there are no limnological data for these volcanic areas, it is difficult to assess the importance of lithology in determining whether a lake might belong to this class. Based on the Northcote and Larkin (1956) data, summarized in Table 1, lakes in the Coast and Insular mountains are generally dilute relative to other areas (average TDS is 48 ppm). It is likely that these dilute alpine lakes are characterized by distinctive geochemical behaviour of trace metals.

Two of the lakes examined from the Fisheries Branch files have TDS levels in excess of 400 ppm, and although these cannot strictly be called saline [a TDS level of 3000 ppm has been suggested as the lower limit for "salt lakes", (Goldman and Horne, 1983)], they are sufficiently different from the other lakes studied to suggest that they too may be characterized by distinctive geochemical behaviour of trace metals. It is likely that there are other salt-rich lakes in this southern part of the study area, since there are numerous *bona fide* saline lakes in the central and southern parts of the Interior Plateau.

The carbonate-rich lakes identified by Gintautas are clearly distinctive in terms of the geochemistry of their sediments. Although Gintautas does not record the locations of all 36 lakes classified as "carbonate", the two which he does identify are on sheet 93F, and it is possible that there are other lakes of this type within the study area.

Some of the "clastic" lakes identified by Gintautas are situated adjacent to glaciers and simply have high clastic inputs. Others may be oligotrophic lakes with extremely low organic matter productivity. There are several glaciers in the southwestern part of sheet 93C, and some of the "dilute alpine" lakes in that area may fall within Gintautas' "clastic" category, although the limnological data for those lakes indicate low turbidities.

Geochemical Implications of Limnological Variability

A number of different lake types have been identified within the study area, and it is necessary to determine whether these different types of lakes are characterized by different geochemical behaviour, and whether such differences could affect the interpretation of a regional survey of lake sediment geochemistry. Some aspects of this question can be answered on the basis of the existing data, however, a thorough evaluation of the problem is dependant on detailed sampling of lakes which represent of each group.

Based on the data for different types of lakes within map areas 93E and 93L, it is clear that there are significant differences in the geochemistry of oligotrophic versus mesotrophic versus eutrophic lakes, and that the polymictic lakes are different again. The relatively high levels of oxygen found in the bottom waters of oligotrophic lakes contribute to substantial accumulation of iron and manganese oxides, and inhibit the accumulation of organic matter. On the other hand, the low levels of oxygen found in eutrophic and polymictic lakes restrict the accumulation of iron and manganese and contribute to the preservation of organic matter. These types of geochemical differences have been observed in many lake sediment surveys, and their effects on the behaviour of trace metals have generally been accounted for through the use of regression analysis or ratios. The important question is whether there are more fundamental differences in trace metal behaviour in the different types of lakes, that is, for example, whether a copper-manganese relationship which is typical of oligotrophic lakes would be significantly different from that observed in eutrophic lakes.

Differences in Geochemical Response Between Lake Sediments and Other Regional Sampling Media

Several examples have been given comparing the geochemical response of lake sediments versus other regional geochemical media, particularly stream sediments. For most of the elements considered, the lake sediment responses are equivalent to or stronger than those of the other methods. This is the case for molybdenum, copper, zinc and silver, but not necessarily for gold. In the Cronin and Dome Mountain areas several stream sediment samples have more than 50 ppb gold, and two have more than 500 ppb gold. On the other hand, the highest level of gold in lake sediments is 9 ppb for a sample adjacent to the Cronin mine. It is evident that, in this setting, gold is not enriched to the same degree in lake sediments as in stream sediments.

Relatively low levels of gold have also been observed in lake sediments adjacent to gold mineralization elsewhere. Sopuck and Earle (1987) reported maximum gold levels of less than 10 ppb adjacent to mineralization in the northern and central parts of the La Ronge belt, Saskatchewan, while Chapman *et al.* (1989) report up to 30 ppb gold adjacent to mineralization in the southern part of the La Ronge belt. In the same area, however, Coker *et al.* (1982) report up 190 ppb gold in detailed lake sampling of lakes adjacent to mineralization. The median gold level in 3000 southern Nova Scotia lake sediment samples analyzed by Rogers (1988) is 4 ppb, while the 95th percentile is 11 ppm, and the 99th percentile is 35 ppb. Davenport and McConnell (1988) reported up to 106 ppb gold in lake sediments from two areas in Newfoundland, although only 21% of the samples had more than 2 ppb gold, and only 1% had more than 8 ppb gold. In spite of these relatively subdued responses, lake sediment geochemistry has proven to be a successful exploration tool for gold in various different regions. The key to success is adequate precision in the gold analysis, down to the 1 ppb level.

An important factor which should not be overlooked in this respect is that the topographic relief in the Cronin and Dome Mountain areas is high relative to most of map areas 93C, 93F and 93K. Based on the conclusions of Fletcher (1990), it seems probable that gold is more likely to be concentrated in the high-energy streams of high-relief areas than the low-energy streams of low-relief areas. One might expect a more equitable response between lake sediments and stream sediments in the low-energy drainage systems which are typical of most of map sheets 93C, 93F and 93K.

FOLLOW-UP EXPLORATION PROCEDURES

The most appropriate initial follow-up strategy for any lake sediment survey is to continue with more detailed lake sediment sampling in the anomalous region. This approach is recommended for several reasons. It allows verification of the original anomalies, and it provides more precise definition of the anomaly pattern using a medium already known to give a response in the area of interest. In follow-up lake sediment sampling each lake should be sampled in several locations. As pointed out by Hoffman (1976) and Hoffman and Fletcher (1981), and as clearly shown here in Figures 17 and 18, secondary dispersion processes operating in this environment can lead to considerable variability in sediment geochemistry within a lake. Multiple sampling within lakes can provide valuable information concerning the source area of the metals. Stream sediment sampling would also be useful at an early stage in the follow-up program, firstly in an attempt to trace the source of the anomaly, but also to assess the nature of geochemical input into the anomalous lakes. For example, if the stream sediment geochemical levels are consistently low, one might begin to look for evidence of metal introduction through seepages or groundwater.

In this, as in any glaciated environment, the second phase of a follow-up program should be to acquire a thorough knowledge of the surficial geology. Surficial deposits should be mapped, paying specific attention to ice-direction indicators, glacial deposit types and overburden thickness. Where significant thicknesses of glacial deposits are present, and where it is apparent that the metals in the anomaly may be derived from these materials rather than from bedrock, some effort should be focused on estimating glacial transport distances. If glacial materials are relatively thick (several metres) and widely distributed, and if they are dominated by basal till rather than ablational or water-lain deposits, the geochemical program should continue with till sampling. In gold exploration, both particulate and fine-fraction gold levels should be measured, using techniques similar to those outlined by Sopuck *et al.* (1985). If glacial materials are generally thin or absent, the geochemical program should continue with soil sampling.

CONCLUSIONS

A review of limnological and lake sediment geochemical information from the Nechako Plateau area of central British Columbia has shown that lake sediment geochemistry has potential as a valuable exploration tool in an area where other geochemical methods have not been particularly successful. It is important to note, however, that the limnology of the area is quite variable, and this should be taken into account in planning lake sediment surveys and interpreting lake sediment data.

The specific conclusions can be summarized as follows:

- The distribution of lakes within map sheets 93C, 93F and 93K is such that regional lake sediment surveys are feasible, although there would be some areas, especially within 93C and 93K, where the average density would be less that 3 samples per 100 square kilometres.
- Comparison of the results of lake sediment surveys with other regional geochemical exploration techniques (particularly stream sediment surveys) has shown that for most metals of interest, the response to mineralization in lake sediments is essentially equivalent to, or more pronounced than that in stream sediments. One important exception to this trend is that of gold. Around areas of gold mineralization in a mountainous region east of Smithers, gold levels in lake sediments are at least an order of magnitude lower than those stream sediments. The disparity between lake and stream sediments is likely to be substantially less, however, in the low-energy

drainage systems characteristic of much of the Nechako Plateau.

- Owing to widely varying terrain and geological characteristics, limnological diversity in the Nechako area is substantial, and probably much greater than that in shield areas where lake sediment geochemistry has been used most extensively in the past. In addition to the expected oligotrophic and eutrophic end-members, there is evidence of the existence of saline lakes, carbonate-rich lakes, clastic-dominated lakes and dilute alpine lakes. It is possible that trace metal behaviour is different for each of these lake types, and that a thorough evaluation of the results of a regional program would have to be carried out in the context of these limnological differences.

RECOMMENDATIONS FOR REGIONAL GEOCHEMICAL EXPLORATION

A number of important questions should be resolved before regional lake sediment surveys are carried out within the Nechako Plateau area of British Columbia. The following work is recommended:

- At least two lakes representing each important limnological type should be sampled in detail in order to assess geochemical characteristics of the different lake types, and at least 20 samples should be collected from each lake. The samples should be concentrated within the profundal zones, but should be spaced around the lakes so that material with varying organic and iron-manganese levels is sampled. Where possible, lakes adjacent to known mineralization should be chosen for these studies. The sediment samples should be analyzed for a range of trace and major elements, including iron, manganese, calcium and gold. Selective extraction procedures should be applied where necessary to add to the understanding of specific geochemical problems. Stream sediments, and representative glacial materials and rocks from around the lakes should also be collected and analyzed for the same suite of elements. The limnology of the lakes should be assessed by measuring temperature and dissolved oxygen profiles, pH and TDS of the water, and turbidity; and by mapping the bathymetry.
- At least two lakes in the vicinity of known gold occurrences should be sampled in detail in order to assess the nature of dispersion of gold into lakes in this environment. These lakes should be studied using the techniques described above, but particular attention should be given to assessing the dispersion of gold in and around the lakes. Bedrock, glacial materials, soil, and stream sediments should be sampled in the areas between the gold occurrences and the lakes being studied.

Orientation studies have recently been carried out in the Nechako Plateau area, in follow-up to similar recommendations in an earlier version of this report. Detailed limnological data have been gathered and over 600 lake sediment samples have been collected from 16 lakes of varying limnological characteristics and geological settings Cook (1993). An interpretation of the data from this project has not yet been completed.

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APPENDIX 1
LISTING OF LIMNOLOGICAL INFORMATION FOR NECHAKO PLATEAU LAKES

Lake name	NTS	Survey date	Lake centre UTM coord. East	North	Max. Depth m	Area ha	Depth ratio m/√ha[1]	Secchi depth m	TDS ppm	pH top	pH bot.	pH diff	Thermocline from (m)	Thermocline to (m)	Oxygen ppm top	Oxygen ppm bot.	Oxygen Bot/top %	status[2]
Pyper	C 1	Aug 19	419000	5766000	17	169	1.3	6.4	413	8.5	8.0	0.5	7.0	13.0	7.0	3.0	43	m
Puntzi	C 1	Aug 23	428000	5783000	44	1707	1.1	4.0	590	8.5	7.5	1.0	24.0	29.0	7.0	1.0	14	e
Charlotte	C 3	Jun 26	342000	5785000	101	6599	1.2	7.4	32	7.1	6.9	0.2	8.0	30.0	10.0	10.0	100	o
Little Charlotte	C 3	Jun 25	331000	5786000	32	159	2.5	6.7	31	7.0	7.0	0.0			10.0	10.0	100	p
Big stick	C 3	Jun 22	356000	5765000	15	141	1.3	3.0	78	7.6	7.4	0.2			8.0	7.0	88	p
Rainbow	C 4	Jun 1	315000	5777000	9	170	0.7	5.8	36	7.1	7.1	0.0	3.0	9.0	11.0	11.0	100	o
Junker	C 4	Jun 29	308000	5785000	57	175	4.3	6.7	15	6.7	6.7	0.0	12.0	31.0	10.0	9.0	90	o
Vista	C 4	Jun 30	319000	5787000	16	60	2.1	6.2	18	6.7	6.3	0.4			9.5	8.5	89	p
Widgeon	C 4	Jun 27	305000	5784000	45	90	4.7	7.3	28	6.6	6.3	0.3			10.0	10.0	100	p
Lonesome	C 4	Jun 4	313000	5793000	41	408	2.0	5.2	28	7.3	6.8	0.5	18.0	26.0	10.0	12.0	120	o
Cutthroat	C 4	Jun 30	310000	5788000	11	13	3.1	4.4	19	6.7	6.5	0.2	1.0	10.0	9.0	9.0	100	o
Kidney	C 4	Jun 25	303000	5782000	50	95	5.1	4.5	23	6.8	6.2	0.6	9.0	30.0	10.0	8.5	85	o
Elbow	C 4	May 28	315000	5773000	31	100	3.1	5.5		7.3	7.1	0.2	6.0	27.0	12.0	11.0	92	o
Ant	C 4	Jun 22	304000	5778000	6	50	0.8	5.1	16	6.7	6.7	0.0			10.0	10.0	100	x
Stillwater	C 5	Jun 14	312000	5801000	5	90	0.5			7.1	7.2	-0.1			10.0	10.0	100	x
Kappan	C 6	Aug 3	334000	5807000	31	346	1.7	3.0	60	8.3	6.6	1.7	4.6	12.0	10.0	3.0	30	m
Anahim	C 6	Jun 23	341000	5819000	4	147	0.4	1.2	130	7.1	7.7	-0.6			10.0	9.0	90	p
Nimpo	C 6	Jun 25	351000	5801000	24	988	0.8	3.0	155	8.1	7.1	1.0	21.0	27.0	9.0	4.0	44	m
Pelican	C 6	Jun 22	338000	5817000	4	85	0.4	2.4	200	8.0	9.0	-1.0	1.0	4.0	8.0	8.0	100	o
Chilcotin	C 8	Aug 8	428000	5799000	1	340	0.1		133	9.5					8.0			x
N. Poison	C 11	Sep 26	333000	5833000	8	75	0.9	7.6	182	8.3					11.0	9.5	86	x
S. Poison	C 11	Sep 26	334000	5831000	10	55	1.4	8.0	170	8.5	8.4	0.1			8.7	8.6	99	x
Lessard	C 11	Aug 2	335000	5836000	3	180	0.2	2.4	44	8.2	8.2	0.0			7.0	8.0	114	p
Abuntlet	C 11	Jun 23	335000	5825000	3	230	0.2	1.2	74	7.6	7.6	0.0			10.0	10.0	100	p
Gatcho	C 13	Aug 9	318000	5871000	11	229	0.7	3.0	58	8.0	6.9	1.1	1.0	8.0	9.0	4.0	44	m
Squiness	C 13	Jul 18	300000	5860000	10	175	0.8	4.7	50	7.5	7.0	0.5	3.0	10.0	9.0	1.0	11	e
Malaput	C 13	Aug 8	321000	5872000	9	118	0.8	2.5	64	7.4	6.6	0.8	4.0	7.0	10.0	5.0	50	m
Basalt	C 13	Jul 17	332000	5872000	4	63	0.4	1.8	78	8.8	8.8	0.0			7.0	7.5	107	p
Tsetzi	C 14	Jul 20	365000	5871000	11	80	1.2	2.5	92	8.8	6.9	1.9	2.0	9.0	9.0	0.0	0	e
Tsilbekuz	C 14	Jul 17	358000	5871000	11	260	0.7	7.0	162	9.0	9.0	0.0			8.0	9.0	113	p
Eliguk	C 14	Jul 17	337000	5869000	21	364	1.1	4.0	62	8.3	7.8	0.5	2.0	12.0	9.0	5.0	56	m
Cluchuta	C 14	Jul 18	363000	5870000	18	139	1.5	5.4	140	8.3	7.2	1.1	2.0	14.0	9.0	3.0	33	m
Blue	C 15	Jul 19	368000	5872000	19	65	2.3	6.5	190	8.3	8.0	0.3	2.0	15.0	9.0	2.0	22	e
Nahlouza	E 1	Jun 12	689789	5886437	15	613	0.6	3.7	36	6.9	6.3	0.6	1.0	12.0	9.5	7.5	79	o
Mink	E 1	Sep 1	676386	5897831	16	112	1.5	6.8	41				3.0	15.0	7.4	1.5	20	e
Blanchet	E 8	Aug 14	677692	5917774	32	785	1.1	6.7	8	6.7	5.5	1.2	6.0	30.0	8.5	7.5	88	o
Glatheli	E 9	Aug 8	667212	5942931	23	1090	0.7	5.0	22	7.3	7.1	0.2			9.0	9.0	100	p
Ghitezli	E 9	Aug 13	682342	5942761	5	462	0.2	4.6	24	7.5	7.5	0.0	1.0	3.0	9.0	9.5	106	o
Chief Louis	E 9	Aug 11	696448	5935314	19	678	0.7	5.5	28	7	6.6	0.4	0.0	19.0	9.0	6.0	67	m
Suscha	F 1	Aug 13	403000	5899000	16	155	1.3	7.5	98	8.0	6.7	1.3	4.0	12.0	9.0	0.0	0	e
Euchinko	F 1	Jul 21	413000	5890000	33	303	1.9	4.5	68	8.3	7.5	0.8	0.0	5.0	8.0	7.0	88	o
Tsacha	F 2	Jul 19	377000	5878000	70	1930	1.6	7.0	46	8.3	7.3	1.0	25.0	40.0	8.0	5.5	69	m
Kuyakuz	F 2	Aug 15	394000	5889000	14	822	0.5	4.0	90	8.0	7.0	1.0	4.0	13.0	9.0	0.6	7	e
Johnny	F 3	Aug 15	337000	5888000	17	581	0.7	4.0	56	7.6	6.7	0.9	3.0	17.0	9.0	4.0	44	m
Williamson	F 3	Jul 26	352000	5885000	4	140	0.3	2.3	94	7.4	7.5	-0.1			7.3	6.1	84	p
Cow	F 3	Jul 26	334000	5894000	13	297	0.8	3.6	94	7.3	7.2	0.1			8.4	6.5	77	p
Laidman	F 3	Jul 27	354000	5889000	11	219	0.7	3.1	60	7.2	6.9	0.3			8.1	5.4	67	p
Moose	F 3	Jul 29	343000	5885000	19	199	1.3	4.5	72	7.7	6.9	0.8	3.0	17.0	8.4	0.2	2	e
Entiako	F 4	Aug 17	339000	5902000	18	653	0.7	2.5	68	8.5	6.7	1.8	4.0	12.0	10.0	3.0	30	m
Tsayakwacha	F 4	Aug 9	323000	5876000	6	199	0.4	5.0	54	8.0	6.6	1.4			9.0	5.0	56	p
Tschick	F 4	Aug 11	325000	5896000	5	96	0.5	2.0	48	7.8	7.3	0.5			10.0	7.0	70	p
Majuba	F 4	Aug 9	318000	5878000	5	94	0.5	1.8	72	8.0	6.8	1.2	3.0	5.0	9.0	4.0	44	m
Yellow Moose	F 6	Aug 19	359000	5926000	23	60	3.0	4.5	172	9.0	7.8	1.2	9.0	15.0	8.0	0.4	5	e
Emmet	F 6	Aug 29	356000	5931000	18	143	1.5	5.0	134	9.0	6.8	2.2	2.0	14.0	9.0	0.0	0	e
Capoose	F 6	Aug 11	347000	5909000	31	134	2.7	4.5	48	6.8	6.5	0.3	1.0	28.0	8.0	7.0	88	o
Tatelkuz	F 7	Jul 16	388000	5904000	29	927	1.0	5.5	86	8.5	6.9	1.6	7.5	17.0	9.0	5.0	56	m

1) Depth ratio is maximum depth over square root of lake area, 2) o=oligotrophic, m=mesotrophic, e=eutrophic, p=polymictic, x=unknown

Lake name	NTS	Survey date	Lake centre UTM coord. East	North	Max. Depth m	Area ha	Depth ratio m/sq(h	Secchi depth m	TDS ppm	pH top	pH bot.	pH diff	Thermocline from (m)	to	Oxygen ppm top	Oxygen ppm bot.	Oxygen Bot/top %	status
Chutanli	F 8	Aug 12	403000	5912000	9	175	0.7	5.0	108	8.0					9.0	9.0	100	p
Lavoie	F 8	Sep 6	410000	5927000	7	232	0.5	3.6	150	8.2					10.0			p
Johnson	F 9	Aug 7	405000	5945000	13	119	1.2	4.0	48	7.5	6.0	1.5	2.0	13.0	8.0	0.6	8	e
Andros	F 9	Aug 30	403000	5934000	4	66	0.5	2.7	56	8.0					9.0			p
Ray	F 9	Aug 31	407000	5934000	5	8	1.8	0.9	78	7.4					10.0			p
Jardine	F 9	Aug 31	407000	5834000	4	13	1.1	1.0	76						8.0			p
Bostrum	F 9	Aug 30	405000	5934000	2	12	0.4	1.5	65	7.3					10.0			p
Duten	F 9	Sep 2	415000	5941000	6	47	0.9	1.2	73						9.0			p
Finger	F 9	Aug 28	414000	5937000	12	877	0.4	1.5	68	7.2	7.1	0.1			8.0	7.0	88	p
Provis	F 9	Sep 5	405000	5938000	2	30	0.4	1.8	103	7.5					10.0			p
Finnie	F 9	Aug 9	404000	5935000	1	40	0.1											x
Hawley	F 9	Aug 31	407000	5934000	2	17	0.5	1.0	73	7.3					9.0			p
Home	F 9	Aug 9	408000	5952000	12	97	1.2	3.0	58	8.5	6.8	1.7	5.0	12.0	8.0	0.0	0	e
Secord	F 9	Sep 3	412000	5942000	7	40	1.1	3.0	81	6.0	6.0	0.0			9.0			p
Hobson	F 10	Sep 15	385000	5938000	7	72	0.8	2.2	176	8.2	7.4	0.8			9.8	9.2	94	p
Copley	F 10	Aug 2	381000	5957000	12	130	1.1	3.5	88	9.0	6.8	2.2	4.0	10.0	9.0	0.0	0	e
Berts	F 10	Jul 21	380000	5945000	6	3	3.3	1.5	160				1.0	5.0	8.0	0.2	3	e
Chief Gray	F 10	Sep 16	383000	5939000	15	27	3.0	7.0	162	8.3	7.6	0.7	4.0	9.0	8.5	0.5	6	e
Cicuta	F 11	Aug 6	364000	5941000	12	174	0.9	3.0	92	8.0	6.8	1.2	2.0	12.0	9.0	1.8	20	e
Chaoborus	F 11	Aug 5	347000	5950000	16	111	1.5	4.0	44	7.3	6.6	0.7	0.0	14.0	9.0	5.0	56	m
Bird	F 11	Aug 3	356000	5946000	13	319	0.7	2.5	68	8.0	6.6	1.4	2.0	12.0	10.0	3.0	30	m
Cheslatta	F 11	Oct 4	345000	5957000	13			3.0	154				6.0	8.0	10.5	0.8	7	e
Smith	F 11	Aug 5	344000	5946000	20	60	2.6	3.0	68	7.3	6.5	0.8	2.0	12.0	10.0	5.0	50	m
Hoult	F 11	Aug 29	352000	5929000	9	60	1.2	4.0	134	9.0			1.0	9.0	9.0	0.0	0	e
Lucas	F 11	Aug 20	357000	5937000	69	864	2.3	6.0	60	8.5	7.3	1.2	6.0	50.0	9.0	6.0	67	m
Robison	F 12	Aug 25	323000	5948000	9	40	1.4	2.0	96	6.9	6.4	0.5	3.5	8.0	7.0	0.0	0	e
McDonell	F 12	Aug 20	326000	5950000	8	20	1.8	0.8	88	8.0	6.5	1.5	0.0	6.0	17.0	0.0	0	e
Island	F 12	Jul 10	312000	5958000	4	52	0.6	1.8	203						6.0	6.0	100	p
White Eye	F 12	Oct 3	320000	5935000	13	69	1.6	3.0	74	6.8	6.8	0.0			7.0	7.0	100	x
Enz	F 12	Aug 26	323000	5951000	6	33	1.0	3.0	96	7.1	6.8	0.3	3.0	5.0	7.0	0.0	0	e
Sam Hardy	F 12	Aug 17	334000	5943000	7	32	1.2	2.0	85	6.7	6.5	0.2	3.0	6.0	7.0	0.0	0	e
Hewson	F 13	Aug 17	330000	5970000	5	50	0.7	1.5	90	6.9	6.9	0.0			7.0	6.0	86	p
Tatalrose	F 13	Jul 9	305000	5985000	8	136	0.7	0.6	113				4.0	6.0	11.0	0.5	5	e
Takysie	F 13	Jul 11	314000	5974000	13	500	0.6	1.2	159				5.0	10.0	9.0	1.0	11	e
Edlund	F 13	Aug 21	330000	5971000	8	19	1.8	1.5	96	6.7	6.2	0.5	1.0	4.0	8.0	4.0	50	m
Binta	F 13	Aug 9	337000	5973000	40	789	1.4	4.0	74	8.0	6.7	1.3	7.0	20.0	10.0	6.0	60	m
Getzuni	F 13	Aug 18	332000	5969000	8	103	0.8	1.5	84	6.8	6.8	0.0			7.0	7.0	100	p
Mollice	F 13	Aug 6	322000	5982000	19	187	1.4	2.5	113	8.5	6.6	1.9	2.0	14.0	10.0	0.0	0	e
Ootsane	F 13	Aug 3	334000	5964000	29	429	1.4	3.0	78	8.0	6.7	1.3	3.0	18.0	9.0	1.6	18	e
Uncha	F 13	Aug 9	328000	5977000	37	1270	1.0	4.5	98	8.0	6.8	1.2	9.0	20.0	10.0	5.0	50	m
Tatalaska	F 13	Jul 11	309000	5980000	14	166	1.1	2.7	121				5.0	7.0	9.0	2.0	22	e
Bickle	F 13	Jul 9	306000	5981000	14	122	1.3	3.4	104				3.0	7.6	9.0	0.5	6	e
Knapp	F 14	Aug 14	349000	5965000	36	586	1.5	3.5	84	8.5	7.1	1.4	4.0	18.0	9.0	6.0	67	m
Anzus	F 14	Jul 4	361000	5978000	20	305	1.1	2.4	79				5.0	7.6	9.0	5.0	56	m
Borel	F 14	Jul 4	365000	5978000	19	198	1.3	2.7	86				5.0	9.0	8.0	3.0	38	m
Cabin	F 14	Aug 17	369000	5971000	39	209	2.7	5.0	48	8.0	6.5	1.5	8.0	25.0	9.0	0.8	9	e
Wapoose	F 14	Oct 1	341000	5969000	5	83	0.5	1.5	104	7.0	7.0	0.0			7.0	7.0	100	x
Laurie	F 15	Aug 15	377000	5971000	23	90	2.4	4.5		8.0	6.8	1.2	7.0	18.0	8.5	0.0	0	e
Kathy	F 15	Jul 21	392000	5958000	8	15	2.0	3.0	125				1.0	6.0	8.0	0.6	8	e
Triangle	F 15	Jul 8	385000	5964000	7	75	0.8	5.3	90	6.5	6.5	0.0	3.0	7.0	9.0	2.0	22	e
Bentzi	F 15	Aug 22	377000	5959000	32	182	2.3	6.0	116	8.5	6.7	1.8	4.0	13.0	9.0	3.0	33	m
Dorman	F 15	Jul 17	392000	5973000	12	128	1.1	4.8	160	9.0	7.5	1.5	6.0	10.0	9.0	0.8	9	e
Bungalow	F 15	Aug 4	389000	5961000	9	98	0.9	3.5	82	9.0	7.0	2.0	5.0	9.0	9.0	0.2	2	e
Tahultsu	F 15	Jul 15	388000	5968000	32	606	1.3	8.0	148	9.0	7.7	1.3	8.5	15.0	9.0	6.0	67	m
Tachick	F 16	Aug 6	422000	5979000	8	2203	0.2	1.8	120	8.5								p
Sinkut	F 16	Jul 14	434000	5973000	5	353	0.3	1.0	63									p
Fountain	K 1	Oct 12	432000	6003000	11	41	1.7	5.5	90	6.3			11.4	0.6				x
Echo	K 1	Oct 16	421000	6010000	14	36	2.3	3.0	50				0.0	13.0	11.8	1.0	8	e

1) Depth ratio is maximum depth over square root of lake area, 2) o=oligotrophic, m=mesotrophic, e=eutrophic, p=polymictic, x=unknown

Lake name	NTS	Survey date	Lake centre UTM coord. East	North	Max. Depth m	Area ha	Depth ratio m/sq(h	Secchi depth m	TDS ppm	pH top	pH bot.	pH diff	Thermocline from (m)	to (m)	Oxygen ppm top	Oxygen ppm bot.	Oxygen Bot/top %	status
Wonder	K 1	Oct 14	433000	6002000	17	31	3.1	4.0	67				12.0	14.0	12.0	0.5	4	e
Stern	K 2	Jul 16	377000	6000000	3	137	0.3	1.8	68	7.0			17.1	6.0	6.0			x
Justine	K 2	Aug 18	374000	6008000	10	231	0.7	1.5	56	8.0	6.8	1.2	1.0	8.0	10.0	0.0	0	e
Drywilliam	K 2	Aug 19	390000	5991000	13	96	1.4		146	7.4	7	0.4	3.0	12.0	8.0	0.5	6	e
Angly	K 2	Aug 31	392000	6100000	7	55	0.9	1.4	63	7.9	7.4	0.5			8.0	7.0	88	p
Peta	K 2	Jul 2	383000	6009000	4	70	0.5	1.5	70						7.0	8.0	114	p
Foster	K 2	Aug 18	384000	5986000	4	77	0.5	2.4	19	7.1	6.9	0.2			7.0	7.0	100	p
Oona	K 2	Jul 1	386000	6005000	23	337	1.3	3.0	69				1.0	22.0	9.0	5.0	56	m
Fraser	K 2	Aug 15	385000	5994000	31	5466	0.4	6.0	100				3.0	20.0				p
Ormond	K 2	Jun 30	389000	6003000	15	316	0.8		75				4.0	12.0	11.0	3.0	27	m
Deserter	K 2	Sep 30	376000	5996000	11	69	1.3	7.0	146	9.2	6.9	2.3			7.8	7.4	95	x
Owl	K 3	Jul 14	361000	6004000	11	79	1.2	4.5	58	7.8	6.6	1.2	2.0	11.0	9.0	0.4	4	e
Priestly	K 3	Aug 11	349000	6001000	37	31	6.6	11.9	190				2.0	23.0	9.0	2.0	22	e
Tatin	K 3	Jul 10	365000	6001000	19	230	1.3	5.5	60	7.2	6.8	0.4	2.0	12.0	9.0	8.0	89	o
Hanson	K 3	Jul 17	365000	6012000	7	173	0.5	1.5	112	8.0	8	0.0			8.0	8.0	100	p
Savory	K 3	Aug 18	359000	5996000	8	25	1.6		89	7.4	7	0.4			8.0	7.0	88	p
Haney	K 3	Jul 12	350000	5992000	21	99	2.1	4.0	132	8.5	6.9	1.6	2.0	14.0	10.0	0.4	4	e
Co-op	K 3	Aug 12	342000	6007000	10	31	1.9	3.2	60	8.0			3.7	7.0	7.0	7.0	100	o
Tchesinkut	K 4	Jun 28	330000	5997000	149	3382	2.6	8.6	149	7.5	7.5	0.0	8.0	30.0	11.4	11.2	98	o
Kager	K 4	Jul 16	324000	6013000	12	15	3.1	3.7	138				1.5	7.9				x
Burns	K 4	Jul 2	321000	6010000	40	1180	1.2	2.4	90	7.9	6.9	1.0	2.0	14.0	10.7	4.1	38	m
Division	K 5	Aug 15	325000	6026000	6	24	1.3	1.2	90	8.5	6.9	1.6	1.0	5.0	11.0	5.0	45	m
Ling	K 5	Aug 16	332000	6025000	4	69	0.5	1.8	54	6.9	6.7	0.2	1.0	4.0	8.0	7.0	88	o
Wort	K 5	Aug 18	434000	6026000	3	8	1.0	2.1	30	6.8	6.8	0.0	0.0	2.7	9.0	8.0	89	o
Nuphar	K 5	Aug 18	331000	6027000	16	12	4.6	2.1	50	6.9	6	0.9	1.0	9.0	8.0	0.2	3	e
Sponge	K 5	Aug 20	330000	6025000	8	18	1.9	1.8	66	6.9	6	0.9	1.0	8.0	8.0	0.0	0	e
Pinkut	K 5	Oct 3	328000	6030000	32	575	1.3	2.6	64	6.7	6.5	0.2	1.0	30.0	8.0	2.0	25	e
Packrat	K 5	Aug 18	331000	6024000	13	96	1.4	2.1	60	6.9	6.3	0.6	1.0	13.0	8.0	2.0	25	e
Nellian	K 5	Jul 26	321000	6030000	5	65	0.6	1.3	56				1.0	5.0	10.0	6.7	67	m
Augier	K 5	Aug 20	334000	6032000	60	852	2.1	2.4	60	7.4	6.5	0.9	3.0	16.0	9.0	8.0	89	o
Hannay	K 6	May 26	367000	6020000	11	72	1.3	1.5	119	6.6	6.6	0.0			12.0	11.0	92	p
Henrietta	K 6	Oct 10	357000	6029000	13	51	1.8	3.0	89	7.4	7.6	-0.2			10.0	9.0	90	p
Taltapin	K 6	Aug 22	349000	6021000	96	2110	2.1	2.7	74	7.5	6.9	0.6	10.0	21.0	16.7	6.1	37	m
Leech	K 6	Oct 11	368000	6023000	15	36	2.5	1.8	56	6.8	6.7	0.1			9.0	3.0	33	m
Helene	K 6	Oct 7	367000	6016000	20	170	1.5	2.7	93	7.3	7.3	0.0			7.0	7.0	100	x
Grassham	K 7	Jul 9	383000	6041000	24	666	0.9	2.4	60	6.9	6.7	0.2	2.0	20.0	9.0	7.0	78	o
Camsell	K 7	Jul 17	374000	6040000	62	844	2.1	3.7	66	7.2	7	0.2	18.0	27.0	10.0	10.0	100	o
Nilan	K 7	Jul 7	397000	6030000	12	22	2.5	2.9	102	8.0	6.8	1.2	1.0	7.0	11.0	0.2	2	e
McKnab	K 7	Oct 7	388000	6028000	9	144	0.8	2.1	257	6.9	6.9	0.0			9.0	9.0	100	x
Karena	K 7	Jul 8	395000	6030000	6	114	0.5	1.0	78	8.5	7	1.5	0.5	5.0	12.0	7.0	58	m
Nanna	K 8	Aug 16	407000	6023000	13	160	1.1	1.8	74	8.0	6.5	1.5	1.0	8.0	9.0	0.8	9	e
Looncall	K 8	Jul 13	419000	6019000	11	56	1.4	3.1	90	7.6	6.5	1.1	1.0	7.0	8.0	0.0	0	e
Marie	K 8	Aug 13	404000	6021000	12	192	0.8	1.0	60	8.5	6.6	1.9	1.0	10.0	10.0	4.0	40	m
Spad	K 8	Jul 17	423000	6033000	3	46	0.4	1.8	214						11.0	11.0	100	p
Tulle	K 8	Jul 11	403000	6024000	4	20	1.0	1.4	72	7.0	7.0	0.0			9.0	9.0	100	p
Pinchi	K 9	Jun 22	410000	6051000	68	5554	0.9	3.1	116	8.0	7.3	0.7	1.0	30.0	11.0	10.0	91	o
Tezzeron	K 9	Jun 29	406000	6064000	43	7810	0.5	3.4	88	7.8			1.0	40.0	11.0	10.0	91	o
Tandat	K 10	Aug 1	380000	6048000	4	19	1.0	1.1	118	8.2	7	1.2	0.0	4.0	9.0	6.0	67	m
Shass	K 10	Jul 9	381000	6042000	8	20	1.7	2.4	58	6.9	6.9	0.0	0.0	7.0	9.0	10.0	111	o
Whitefish	K 10	Jul 12	374000	6049000	30	688	1.1	2.1	86	8.5	6.9	1.6	10.0	23.0	11.0	8.0	73	m
Tseket	K 10	Aug 10	383000	6048000	10	29	1.9	0.6	70	8.5	6.5	2.0	1.0	10.0	11.0	0.0	0	e
Ogston	K 10	Jul 6	382000	6043000	15	148	1.2	2.0	186	8.0	8	0.0	1.0	15.0	10.0	7.0	70	m
Tarnezell	K 10	Jul 10	374000	6067000	7	388	0.4	1.9	64	7.2	6.9	0.3	3.0	7.0	9.0	7.0	78	o
Stuart	K 10	Jul 15	397000	6045000	97	36437	0.5		87				3.0	30.0				x
McKelvey	K 11	Jul 7	364000	6064000	39	835	1.3	5.2	104	8.2	7.1	1.1	2.0	20.0	10.0	7.0	70	m
Rubyrock	K 11	Jul 6	350000	6057000	50	110	4.8	3.7	70	6.8	6.8	0.0	1.0	10.0	9.0	9.0	100	o
Cunningham	K 11	Aug 4	350000	6051000	65	2998	1.2	3.0	118	8.5	7.4	1.1	2.0	60.0	10.0	1.0	10	e
Sargent	K 12	Aug 23	317000	6068000	6	41	0.9	3.0	100	8.0	6.3	1.7	2.0	5.0	6.0	0.0	0	e

1) Depth ratio is maximum depth over square root of lake area, 2) o=oligotrophic, m=mesotrophic, e=eutrophic, p=polymictic, x=unknown

Lake name	NTS	Survey date	Lake centre UTM coord. East	North	Max. Depth m	Area ha	Depth ratio m/sq(h	Secchi depth m	TDS ppm	pH top	pH bot.	pH diff	Thermocline from (m)	to (m)	Oxygen ppm top	Oxygen ppm bot.	Oxygen Bot/top %	status
Big Loon	K 13	Aug 21	318000	6072000	9	165	0.7	1.5	80	8.0	7.5	0.5	3.5	7.0	8.0	0.0	0	e
Natazutlo	K 14	Aug 12	356000	6096000	18	311	1.0	3.5	64	7.4	6.5	0.9	1.0	11.0	10.0	5.0	50	m
Inzana	K 15	Sep 16	399000	6091000	95	3661	1.6	8.0	78	7.7	7	0.7	1.0	50.0	10.0	9.0	90	o
Otterson	K 16	Jul 123	423000	6077000	6	73	0.7	3.7	94	8.0	6.7	1.3	1.0	6.0	9.0	0.0	0	e
Cripple	K 16	Jul 14	428000	6083000	5	157	0.4	1.2	58	8.0	7.6	0.4	14.4	11.0	10.0			x
Kalder	K 16	Jul 13	420000	6094000	13	103	1.3	3.7	36	6.9	6.5	0.4	1.0	13.0	10.0	7.0	70	m
Lu	L 1	Oct 23			9	16	2.3	2.1	36	6.9	6.9	0.0			10.0	11.0	110	x
Parrott-4	L 1	Aug 27			3	20	0.8	1.3	82	6.7	6.7	0.0			8.0	7.0	88	o
Parrott-1	L 1	Aug 25	664023	5997372	27	249	1.7	3.0	72	7.6	6.5	1.1	5.0	27.0	9.0	5.0	56	m
Goosly	L 1	Aug 16	673487	6005331	20	242	1.3	1.8	63	7.6			5.0	10.0	8.0	3.0	38	m
Tsichgass	L 1	Aug 25	667421	5990566	18	267	1.1	2.1	57	6.8	6.1	0.7	1.5	17.0	8.0	0.0	0	e
Owen	L 2	Aug 31	647117	5997575	38	297	2.2	2.1	56	7.1			5.0	15.0	7.0	5.0	71	m
Parrott-2	L 2	Aug 25	658691	5998795	17	73	2.0	3.0	72	7.4	6.7	0.7	1.5	17.0	9.0	4.0	44	m
Parrott-3	L 2	Sep 5	657472	6000020	36	368	1.9	2.6	68	7.2	6.7	0.5	6.0	21.0	8.0	6.0	75	o
Lamprey	L 3	Aug 28	614277	5985418	21	91	2.2	4.6	36	6.9	6.3	0.6	1.0	21.0	9.0	6.0	67	m
McBride	L 3	Aug 30	606546	5991972	27	779	1.0	4.6	42	6.9	6.5	0.4	2.0	15.0	8.0	7.0	88	o
Summit	L 7	Aug 14	651879	6038508	14	31	2.5	3.7	81	8.5	7.0	1.5	5.0	12.0	8.0	3.0	38	m
Helen	L 7	Aug 26	649653	6040485	4	18	0.9	1.2	104	6.5	6.5	0.0			8.4	6.5	77	p
Johnson	L 7	Aug 28			5	9	1.8	1.8	90	7.1			3.0	5.0	6.0	1.0	17	e
Dunalter	L 7	Aug 11	645591	6037873	19	21	4.2	3.3	58				3.0	10.0	8.8	1.0	11	e
Day	L 8	Aug 14	678656	6029177	25	313	1.4	5.5	70	8.5			3.0	11.0	9.0	0.0	0	e
Sunset	L 8	Aug 13	670736	6041320	26	125	2.3	3.4	70	8.5			3.0	11.0	8.0	1.0	13	e
Elwin	L 8	Sep 20	676729	6033400	18	269	1.1	6.5		6.5	6.5	0.0	4.0	9.0	9.0	0.4	4	e
Broman	L 8	Aug 17	685835	6034328	3			0.6	44	6.7					6.0	6.0	100	p
Maxan	L 8	Sep 10	690009	6018334	25	638	1.0	2.0	77	7.5	6.7	0.8	3.0	12.0	9.0	7.0	78	o
Bulkley	L 8	Aug 24	687430	6029283	15	238	0.9	1.5	64	8.0			5.0	8.0	9.0	4.0	44	m
Guess	L 10	Aug 30	646636	6065975	28	64	3.4	4.6	70	8.2			6.0	14.0	8.0	6.0	75	o
McQuarrie	L 10	Sep 20			11	216	0.7	5.0	62						9.4	9.6	102	x
Hidden	L 10	Aug 14	652383	6041729	9	49	1.3	3.0	68				4.0	8.0	8.0	0.0	0	e
Seymour	L 11	Sep 8	618779	6067219	8	80	0.9	1.8					2.0	7.0	9.1	0.6	7	e
Tyhee	L 11	Aug 24	626267	6064960	22	318	1.3	7.5	172				6.0	12.0	10.0	0.0	0	e
McDonnell	L 13	Aug 21	591522	6071535	15	223	1.0	7.3	45	7.4			5.0	15.0	8.0	7.0	88	o
Taltzen	L 13	Aug 13	595386	6087756	4	10	1.2	1.0	74	6.5	6.5	0.0			7.0	6.0	86	p
Bigelow	L 14	Aug 24	618078	6068797	7	11	2.1	2.4	106				0.0	7.0	7.1	0.5	7	e
Aldrich	L 14	Aug 20	604995	6068454	8	48	1.2	4.0	23	6.6			0.0	8.0	8.0	5.0	63	m
Dennis	L 14	Aug 22	601190	6069594	6	131	0.5	3.7	45	7.3			2.0	5.0	8.0	7.0	88	o
Chapman	L 15	Aug 24	648516	6091218	27	1019	0.8	3.0	63	7.2			6.0	11.0	8.0	6.0	75	o
Doris	L 15	Aug 24	656767	6091639	13	113	1.3	1.8	56	7.3			3.0	8.0	7.0	2.0	29	m
Boomerang	L 15	Aug 28	654000	6095000	6	50	0.9	1.3	68	6.0	6.0	0.0	3.0	5.0	8.2	1.6	20	e
Pinetree	L 15	Aug 25	652534	6095526	8	47	1.2	2.5	67	6.0	6.0	0.0	2.0	5.0	9.0	7.0	78	o
Tanglechain	L 15	Aug 11	657796	6089978	7	101	0.7								8.0	5.0	63	p
Averages:																		
All data (n=225)					18	565	1.3	3.2	86	7.5	6.8	0.7			8.8	4.7	50.6	
Oligotrophic lakes (n=35)					32	943	1.7	4.1	60	7.2	6.8	0.3			9.0	8.3	90.7	
Mesotrophic lakes (n=49)					23	416	1.3	3.2	84	7.9	6.9	1.1			9.4	4.7	50.7	
Eutrophic lakes (n=64)					16	199	1.6	3.5	105	7.9	6.8	1.1			8.9	0.6	6.8	
Polymictic lakes (n=47)					8	313	0.7	2.4	87	7.5	7.3	0.2			8.6	7.6	91.6	
NTS 93 C (n=33)					20.6	423	1.5	4.3	102	7.7	7.3	0.4			9.2	7.1	73.3	
NTS 93 F (n=73)					15.1	270	1.2	3.2	93	7.8	6.9	1.0			8.9	3.2	37.5	
NTS 93 K (n=66)					23.1	1184	1.4	2.8	88	7.6	6.9	0.7			9.4	5.3	51.9	

1) Depth ratio is maximum depth over square root of lake area, 2) o=oligotrophic, m=mesotrophic, e=eutrophic, p=polymictic, x=unknown

APPENDIX 2
GEOCHEMICAL AND LIMOLOGICAL DATA FOR RGS LAKES FROM MAP SHEETS 93E AND 93L

Lake name	Sample number	UTM coordinates East	North	Zn ppm	Cu ppm	Pb ppm	Ni ppm	Co ppm	Ag ppm	Mn ppm	Fe %	Mo ppm	LOI %	As ppm	Au ppb	pH	Max. Depth m	TDS ppm	Oxygen Bot/top %	status
Mink	93E 7047	676386	5897831	72	10	7	19	2	0.1	500	1.5	1	18.6	1	1	6.3	16	41	20	e
Nahlouza	93E 7054	689789	5886437	70	11	10	9	6	0.1	510	2.7	2	6.8	3	1	6.1	15	36	79	o
Nahlouza	93E 7055	690411	5885401	68	11	6	8	8	0.1	870	3.2	1	7.6	4	1	6.4	15	36	79	o
Nahlouza	93E 7056	688652	5885155	97	29	8	16	13	0.1	2000	6.3	2	9.2	4	1	6.3	15	36	79	o
Nahlouza	93E 7058	689579	5884525	114	22	10	18	12	0.1	2800	8.2	1	11.0	8		6.8	15	36	79	o
Blanchet	93E 7100	681224	5921214	134	16	7	20	7	0.2	480	1.9	4	21.4	1	1	5.0	32	8	88	o
Blanchet	93E 7102	677692	5917774	185	17	7	35	17	0.1	1400	4.4	6	19.0	1	28	5.2	32	8	88	o
Blanchet	93E 7104	674335	5916301	147	16	3	19	14	0.2	960	3.2	5	27.8	1	24	5.1	32	8	88	o
Ghitezli	93E 7172	682342	5942761	66	17	5	16	9	0.1	1000	3.7	2	2.4	3	1	5.4	5	24	106	e
Ghitezli	93E 7174	680845	5945938	95	38	11	21	8	0.2	360	2.4	1	22.2	3	1	5.4	5	24	106	e
Chief Louis	93E 7180	696448	5935314	70	14	5	17	9	0.1	570	2.3	1	7.8	1	1	5.3	19	28	67	o
Glatheli	93E 7202	667212	5942931	118	28	20	11	8	0.2	415	3.3	1	27.4	9	1	5.5	23	22	100	p
Glatheli	93E 7203	669606	5944778	95	14	15	10	7	0.3	480	3.1	2	19.4	6	1	5.9	23	22	100	p
Glatheli	93E 7204	673310	5944843	94	13	8	10	7	0.1	620	2.6	1	15.4	7	4	5.6	23	22	100	p
Glatheli	93E 7206	666150	5953830	81	11	15	5	3	0.1	350	2.8	4	16.2	3	1	4.5	23	22	100	p
Owen	93L 7002	647117	5997575	302	35	30	24	14	0.6	1800	4.7	4	18.2	17	4	6.8	38	56	71	o
Owen	93L 7003	646984	5994739	390	46	33	27	15	0.7	2600	6.8	4	24.6	10	7	6.8	38	56	71	o
Owen	93L 7004	649289	5993408	391	43	38	28	18	0.5	1600	5.7	3	21.2	10	4	6.9	38	56	71	o
McBride	93L 7014	606546	5991972	70	19	6	18	7	0.1	320	2.2	1	11.4	4	2	6.8	27	42	88	o
McBride	93L 7015	613298	5990922	118	35	12	29	11	0.3	680	5.3	2	18.2	8	1	6.6	27	42	88	o
Lamprey	93L 7016	614277	5985418	95	32	10	20	7	0.3	280	1.9	1	35.2	2	3	6.6	21	36	67	o
Parrott-1	93L 7033	664023	5997372	145	42	11	21	11	0.3	1700	6.0	2	29.6	9	4	6.8	27	72	56	o
Parrott-1	93L 7034	661810	5998484	126	41	10	22	9	0.1	460	3.4	1	26.4	3	1	6.8	27	72	56	o
Parrott-2	93L 7035	658691	5998795	132	40	12	19	9	0.3	360	3.6	1	27.2	3	1	7.0	17	72	44	m
Parrott-3	93L 7036	657472	6000020	13	13	5	3	2	0.1	180	0.4	5	5.2	1	1	6.8	36	68	75	o
Parrott-3	93L 7055	654817	6001915	176	32	12	18	15	0.1	2400	4.2	3	24.2	54	1	7.1	36	68	75	o
Tsichgass	93L 7066	667421	5990566	103	9	6	9	7	0.1	230	2.2	1	4.6	2	1	6.5	18	57	0	e
Tsichgass	93L 7067	668078	5991377	151	32	11	16	10	0.1	540	3.2	1	25.8	3	2	6.5	18	57	0	e
Goosly	93L 7076	673487	6005331	139	75	19	31	19	0.3	1300	5.5	1	13.0	12	6	7.2	20	63	38	m
Goosly	93L 7077	671543	6006277	137	64	19	39	23	0.1	1200	4.6	2	4.8	9	3	7.0	20	63	38	m
Goosly	93L 7078	670047	6006149	88	122	8	31	11	0.5	270	2.2	2	27.6	19	5	7.0	20	63	38	m
Maxan	93L 7089	690009	6018334	102	27	11	28	11	0.1	430	3.6	1	10.2	3	1	6.9	25	77	78	o
Maxan	93L 7090	688940	6022161	131	40	10	40	14	0.1	740	4.7	1	17.2	4	2	7.0	25	77	78	o
Bulkley	93L 7097	687430	6029283	95	31	12	30	15	0.1	560	4.0	1	6.6	4	1	6.8	15	64	44	m
Bulkley	93L 7098	688772	6033686	139	44	10	35	8	0.1	320	3.5	1	28.6	3	1	6.5	15	64	44	m
Broman	93L 7099	685835	6034328	145	45	7	42	8	0.1	220	3.1	1	28.8	2	1	6.3	3	44	100	p
Day	93L 7108	678656	6029177	92	27	7	25	7	0.1	280	2.6	2	27.6	5	1	7.1	25	70	0	e
Day	93L 7109	677785	6030145	101	34	8	28	10	0.2	360	3.1	3	29.6	9	1	7.1	25	70	0	e
Elwin	93L 7110	676729	6033400	103	27	6	23	11	0.1	340	2.8	1	29.2	5	3	6.9	18		4	e
Elwin	93L 7113	675245	6034990	78	28	6	14	7	0.1	360	1.6	7	25.0	31	1	7.0	18		4	e
Sunset	93L 7122	670736	6041320	95	22	6	23	11	0.1	650	4.2	1	11.8	4	1	7.2	26	70	13	e
Summit	93L 7126	651879	6038508	154	54	13	25	12	0.1	1100	4.9	1	34.2	5	4	7.6	14	81	38	m
Helen	93L 7127	649653	6040485	129	58	11	28	10	0.3	250	3.0	1	37.8	6	5	7.1	4	104	77	p
Helen	93L 7128	649653	6040485	123	60	9	29	9	0.4	250	3.0	1	37.0	7	1	7.1	4	104	77	p
Dunalter	93L 7129	645591	6037873	131	56	7	39	9	0.2	370	3.3	1	34.0	2	3	6.6	19	58	11	e
Hidden	93L 7144	652383	6041729	180	63	11	21	11	0.9	640	3.9	3	43.0	7	3	7.0	9	68	0	e
Seymour	93L 7156	618779	6067219	160	53	12	26	13	0.1	530	3.9	1	27.2	5	2	6.7	8		7	e
Aldrich	93L 7157	604995	6068454	988	103	497	6	15	9.2	2000	6.0	4	14.6	60	55	6.4	8	23	63	o

Additional limnolgocial data are listed in Apendix 1 (status: o=oligotrophic, m=mesotrophic, e=eutrophic, p=polymictic)

Lake name	Sample number	UTM coordinates East	North	Zn ppm	Cu ppm	Pb ppm	Ni ppm	Co ppm	Ag ppm	Mn ppm	Fe %	Mo ppm	LOI %	As ppm	Au ppb	pH	Max. Depth m	TDS ppm	Oxygen Bot/top %	status
Dennis	93L 7158	601190	6069594	304	48	45	17	20	0.5	820	6.0	2	11.2	39	7	7.0	6	45	88	o
McDonnell	93L 7159	591522	6071535	175	36	16	18	17	0.1	3100	6.2	1	10.2	19	1	7.3	15	45	88	o
McDonnell	93L 7160	588704	6070694	196	38	16	22	21	0.1	1900	6.3	3	9.6	12	1	7.0	15	45	88	o
Taltzen	93L 7169	595386	6087756	136	40	4	19	5	0.1	210	1.8	4	44.4	8	2	6.2	4	74	86	p
Bigelow	93L 7173	618078	6068797	178	50	7	28	5	0.1	620	5.0	1	58.4	14	3	7.3	7	106	7	e
Guess	93L 7215	646636	6065975	237	90	15	28	17	0.6	8000	9.9	7	26.8	33	4	7.2	28	70	75	o
Tyhee	93L 7216	626267	6064960	125	39	5	24	6	0.1	940	2.6	1	47.6	5	2	7.4	22	172	0	e
Tyhee	93L 7218	627317	6063263	120	38	8	24	9	0.1	910	2.8	2	44.0	6	2	7.4	22	172	0	e
Tanglechain	93L 7256	657796	6089978	141	44	7	27	9	0.3	450	3.1	1	21.6	7	4	7.0	7		63	p
Doris	93L 7257	656767	6091639	161	38	9	23	8	0.2	500	2.9	1	21.4	5	4	6.7	13	56	29	m
Pinetree	93L 7259	652534	6095526	118	43	5	10	6	0.1	215	1.2	1	40.8	3	2	6.8	8	67	78	o
Chapman	93L 7274	648516	6091218	137	23	18	26	25	0.2	450	4.5	1	5.2	7	1	7.1	27	63	75	o
Chapman	93L 7275	650256	6086478	185	41	25	39	20	0.4	2400	7.2	3	8.6	34	3	6.8	27	63	75	o

Additional limnolgocial data are listed in Apendix 1 (status: o=oligotrophic, m=mesotrophic, e=eutrophic, p=polymictic)

SOME NEW DIMENSION STONE PROPERTIES IN BRITISH COLUMBIA

By Z.D. Hora and K.D. Hancock

INTRODUCTION

During 1992, several sites in the southwestern part of British Columbia produced small quantities of granite blocks. Some of the stone was split and used in the form of ashlar for facing and retaining walls (Plate 1). Blocks from three properties, Chilliwack Lake, Skagit Valley and East Anderson River were processed into cut and polished tile (Plates 2 and 3). While the rock petrography varies from granite to granodiorite or monzonite and syenite, the industry uses the name "granite" for all types of intrusive rock.

REGIONAL GEOLOGY

All quarry sites are situated in southeastern British Columbia in the Coast Plutonic Complex and granitoid intrusions within the Cascade fold belt. Squamish and Stawamus Chief sites are within the Cretaceous granite phase of the plutonic complex while the Chilliwack and Skagit sites are part of the Late Tertiary granodiorite phase of the Chilliwack batholith; the Hope quarry is in a smaller Early Tertiary granodiorite intrusion, and the East Anderson River and Cascade sites are in Early Tertiary quartz monzonite Needle Peak Pluton (Wheeler and McFeely, 1991). The latter three intrusive bodies are within the Cascade fold belt.

EAST ANDERSON RIVER

LOCATION: Lat. 49°40′13″ Long. 121°08′12″ (92H/11E)
New Westminster Mining Division. Approximately 35 kilometres east of Boston Bar at the headwaters of the East Anderson River.

ACCESS: From Highway 1 on a logging road north of Alexandra Bridge.

OWNERS: Pacific Quarry Industries Ltd.

OPERATOR: Pacific Quarry Industries Ltd.

COMMODITIES: Dimension stone - granite.

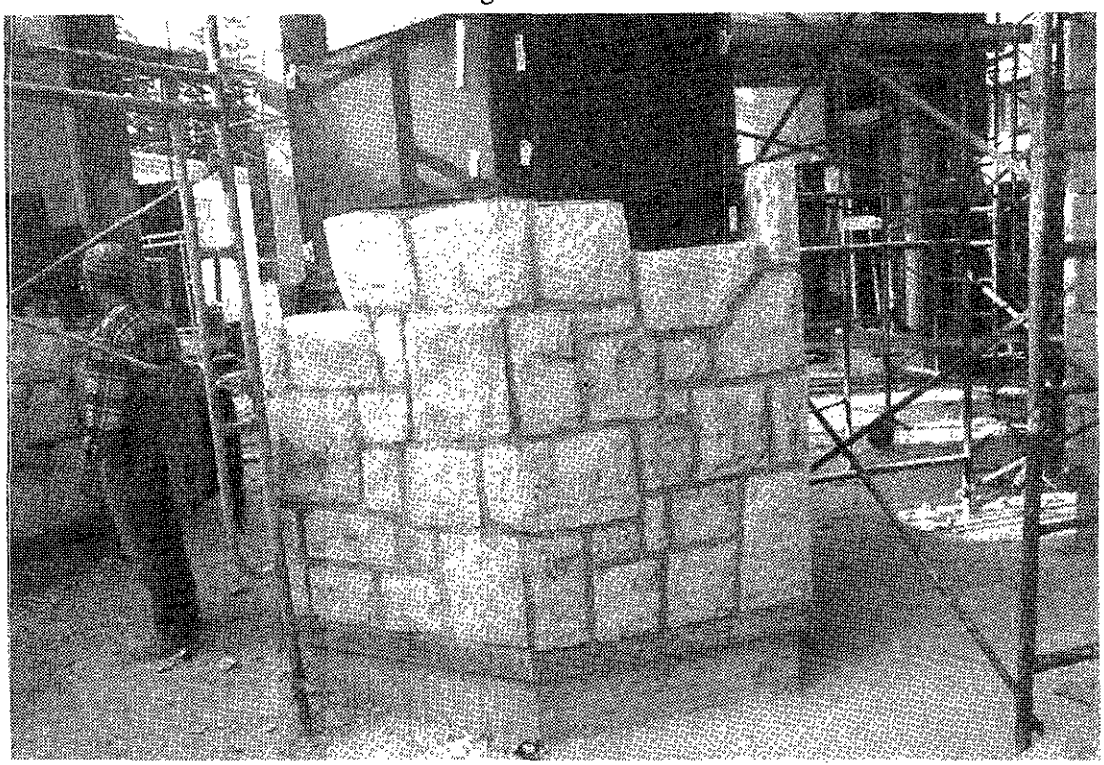

Plate 1. Split granite blocks used for facing at Whistler.

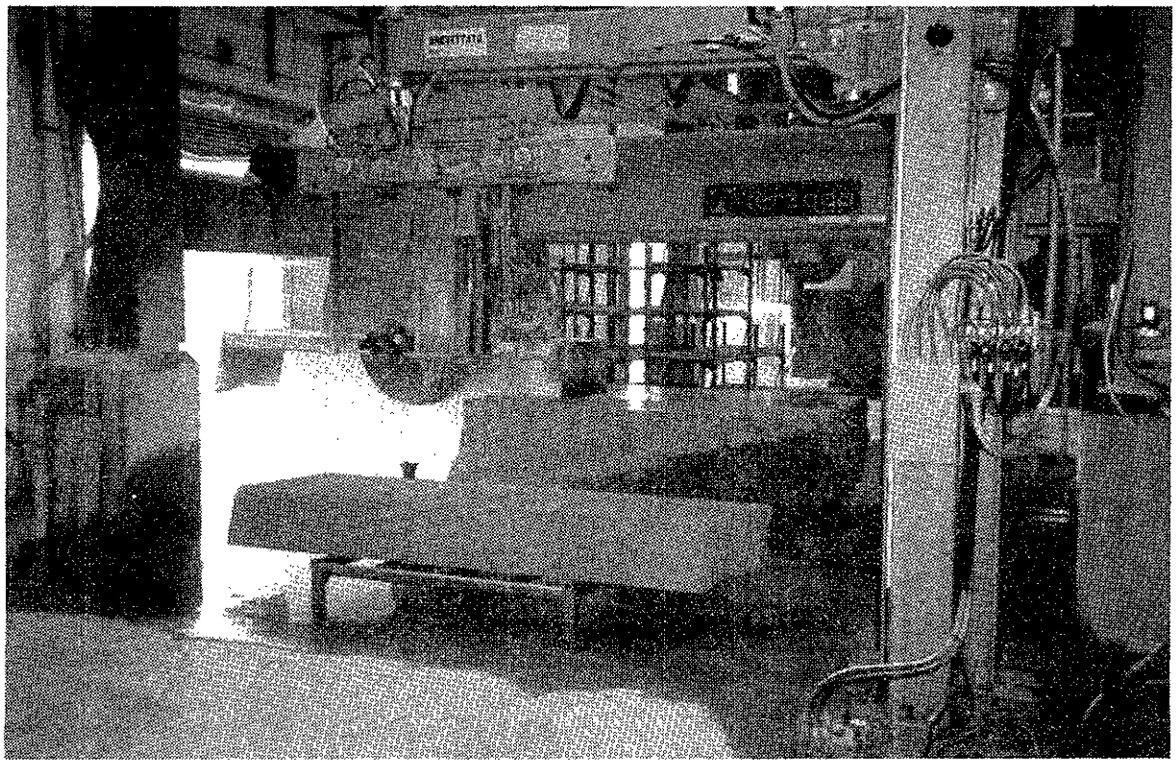

Plate 2. Diamond saw for cutting the slabs from granite blocks, Surrey, B.C.

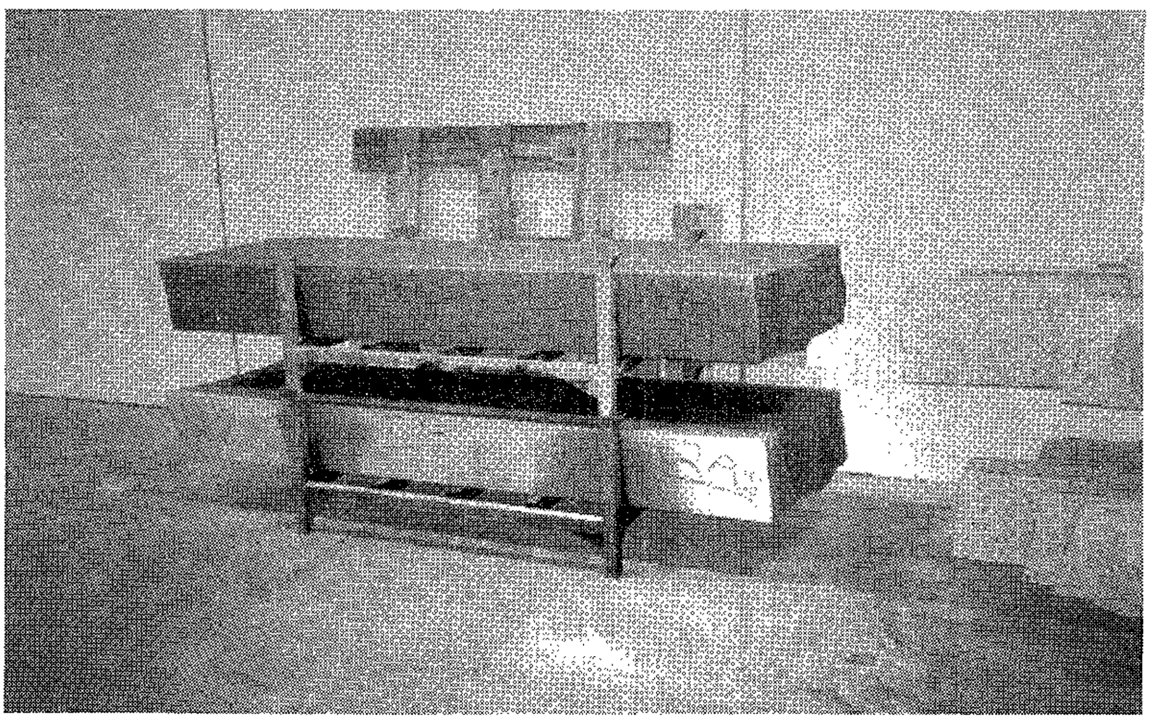

Plate 3. Granite slabs to be polished and cut to tile size.

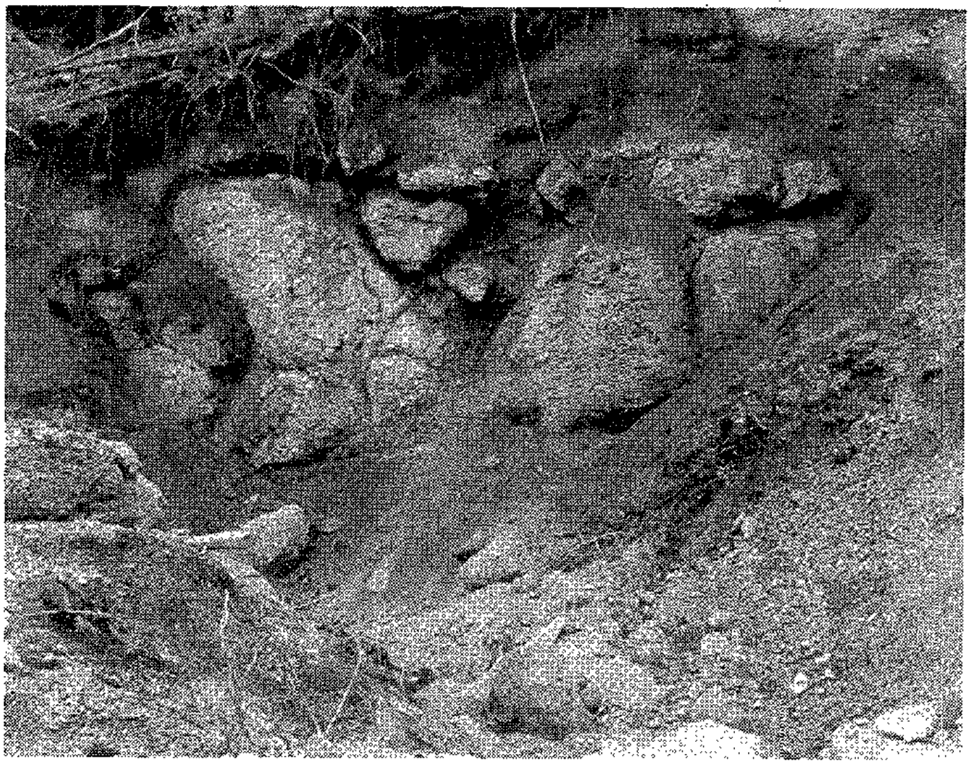

Plate 4. Weathering of the Needle Peak granite, Siwash Creek valley.

Plate 5. East Anderson River quarry.

LOCAL GEOLOGY

The East Anderson River quarry is located in coarse-grained, green-white granite of the Tertiary Needle Peak pluton which intrudes the Cascade fold belt. The quarry area at the river's headwaters is characterized by bare valley walls of granite faces and granite-boulder felsenmeer The great size of the boulders as well as large exposed rock faces indicates low fracture density. The rock is homogeneous without visible dark mineral accumulations or inclusions. Only scattered aplitic veins have been observed.

Some rock exposures indicate irregular fracture networks which result in crumbling under pressure or upon impact (Plate 4). Some road-cuts show a tendency to exfoliation. The site of the test quarry, however, is free of microfractures and presents a sound, fresh looking rock.

After initial processing of blocks from the boulder field where the stone contained numerous microfractures, a new site has been developed on a bare, north-facing rock slope (Plate 5).

The blocks are removed from the face on benches 2 metres thick between two parallel fracture planes. The stone is processed into granite tile product in Surrey, British Columbia

PETROGRAPHY

Stone from East Anderson River is greenish pink quartz monzonite to granite. It is similar to stone at the Cascade site described below. The light green-pink colour is dominant, with quartz giving a smoky grey overtone. There is an even, finely disseminated iron staining from tiny pyrite grains (<1 mm) within quartz and feldspar grains. The result is a flecked staining. Even with the wide range of grain sizes, the texture is uniform. Constituent minerals include orthoclase, plagioclase, quartz, biotite and pyrite. The grains are well interlocked. Plagioclase is often strongly albitized and there is weak secondary sericite seen as small flakes within plagioclase. Pyrite is disseminated evenly throughout the rock and is commonly oxidized. Grain sizes are less than 1 millimetre and the individual stains are typically around 1 cubic millimetre. Quartz shows some crackling and some feldspars are cracked along cleavage. Few through-going cracks are seen. The rock takes a very good polish (8-9/10) with few cracks or pits on an otherwise tight surface. The pitting is restricted to the edges of some biotite grains.

SKAGIT VALLEY

LOCATION:	Lat. 49°07′16″	Long. 121°12′46″	(92H/3E)
	New Westminster Mining Division. Approximately 32.5 kilometres south of Highway 1 at Hope.		
ACCESS:	From Highway 1 on the road through Skagit Valley.		
OWNERS:	Pacific Quarry Industries Ltd.		
OPERATOR:	Pacific Quarry Industries Ltd.		
COMMODITIES:	Dimension stone - granite.		

LOCAL GEOLOGY

At present, Pacific Quarry Industries Ltd. shapes square blocks from the boulder train of an ancient rock slide. Boulders, some of them the size of a small house, are spread throughout the flat valley bottom. The source is probably massive outcrops on the west side of the valley which are part of the late Tertiary Chilliwack batholith. The rock is homogeneous, without visible dark mineral accumulations or inclusions; no dikes were observed in exposed blocks. Two granite phases are present on the site. Although most of the boulders are pink, fine-grained granite, an older phase of grey-greenish coloured, fine-grained granodiorite is also present and is more susceptible to weathering. Squared blocks are shipped to Surrey where they are processed into granite tile.

PETROGRAPHY

Stone from the Skagit locality is a pink, fine-grained granite. The colour is quite uniform with a slight peppering by mafic grains. There is essentially no iron staining. The grain size ranges from 1 to 4 millimetres. Minerals present are plagioclase, quartz, orthoclase, microcline, biotite and opaques. There is less than 1% of fine-grained, disseminated pyrite. There is some albitization and sericitization of plagioclase. Perthite is present in about half the orthoclase and all the microcline. There is some cracking in quartz and feldspar. There are a few short (<5 cm), tight cracks in the rock but no notable fractures. The rock takes a very good (8-9/10) polish with virtually no pitting, resulting in a good, tight surface.

CHILLIWACK LAKE

LOCATION:	Lat. 119°05′49″	Long. 121°25′55″	(92H/3W)
	New Westminster Mining Division. At the north end of Chilliwack Lake, 38 kilometres east-southeast of Chilliwack.		
ACCESS:	From Highway 1 upstream along the Chilliwack River to Chilliwack Lake.		
OWNERS:	Pacific Quarry Industries Ltd.		
OPERATOR:	Pacific Quarry Industries Ltd.		
COMMODITIES:	Dimension stone - granite.		

LOCAL GEOLOGY

The Chilliwack Lake quarry is located in a fine to medium-grained granodiorite of the late Tertiary Chilliwack batholith. Quarrying has taken place at the northeast end of Chilliwack Lake, at the base of irregular bluffs of bare rock which form the side of the valley (Plate 6). The size of the bluffs indicates that both horizontal and vertical joints are several metres apart.

The quarry face exhibits the inhomogeneity of the rock in the form of occasional dark inclusions and cross-cutting dikes (Plate 7). The stone is processed into granite tile product in Surrey, British Columbia. Some of the stone has also been used in the form of split slabs for masonry and facing.

PETROGRAPHY

The stone at Chilliwack Lake is fine to medium-grained, pink to light grey biotite granodiorite. The colour is somewhat uneven as the pink rock has patches of medium grey granodiorite interspersed throughout. The rock appears to be free of any iron staining. It is fine to medium grained with grain sizes ranging from 1 to 4 millimetres and the majority between 1 and 2 millimetres. Minerals present are plagioclase, quartz, orthoclase, biotite, pyrite, prehnite, chlorite, (?clino-)zoisite and sphene. Some plagioclase is partially to totally albitized and sericite alteration is weakly developed. The small amount of chlorite ($<1\%$) is after biotite. Prehnite and (?clino-)zoisite are present in small amounts ($<1\%$ each) and interstitial to the major minerals. All grains are well interlocked and there is some minor crackle in quartz grains. Only one through-going crack was seen and no fabric is visible. The rock takes an excellent polish (9/10) with a very tight surface. There are some small (<0.5 mm^3) pits at mafic grains.

ISLAND WHITE QUARRY - SQUAMISH

LOCATION:	Lat. 49°42′48″	Long. 123°08′19″	(92G/11E)
	Vancouver Mining Division. One kilometre northeast of Squamish, 150 metres east of the old Whistler Highway, next to the BC Rail tracks.		
ACCESS:	From Whistler Highway and old Whistler Highway by 150 metres of dirt haul road.		
OWNER:	Northern Ore Hunter Inc.		
OPERATOR:	Northern Ore Hunter Inc.		
COMMODITIES:	Dimension stone - granite.		

LOCAL GEOLOGY

The Squamish quarry is opened in a Cretaceous granite-granodiorite phase of the Coast Plutonic Complex (Plate 8). This intrusion, exposed at the head of Howe Sound, has an irregular shape. It crops out on both sides of Howe Sound south of the community of Squamish and is approximately 20 kilometres in diameter. The quarry is located near the northeast contact of the intrusive body. The white, medium to coarse-grained granodiorite, with small specks of mafic minerals, is quarried from the base of the hill on the east side of the valley. Massive rock outcrops indicate widely spaced jointing and the capability to remove large blocks. Numerous dark inclusions and aggregates of mafic minerals prevent use of this rock for decorative applications in spite of an otherwise very attractive colour. The quarry was developed during 1989 and 1990 and the stone can be seen on the newly renovated Canada Customs building on Government Street in Victoria. Part of the production has

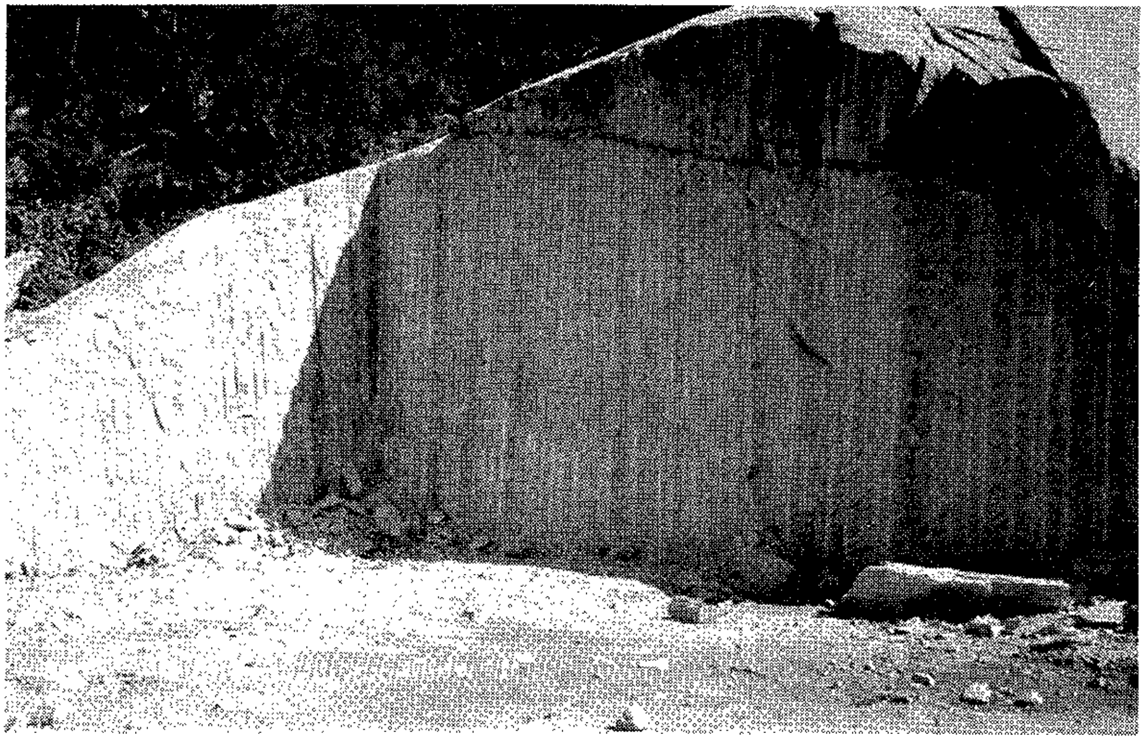

Plate 6. Chilliwack Lake quarry.

Plate 7. Typical inhomogeneities at Chilliwack Lake quarry.

Plate 8. "Island White Granite" quarry site.

been used in split slabs for outside facing and retaining walls. The trade name used for this particular stone is "Island White Granite".

PETROGRAPHY

The stone from the Squamish quarry is a white, medium to coarse-grained biotite granodiorite. It is white with an attractive peppering of mafic minerals. There are scattered, small (<2 mm) greenish spots of chloritized biotite. Pyrite is fresh and shows no staining. The texture appears coarse with grain sizes between 1 and 15 millimetres and an average size range of 5 to 10 millimetres. Minerals present are plagioclase, quartz, microcline, biotite, orthoclase and opaques. All minerals are fresh looking and there is a small amount of sericite alteration in plagioclase. Pyrite content is much less than 1% and appears to be always within biotite grains. The grains are well interlocked. There is much weblike, hairline cracking of quartz and feldspar grains. There are, however, few through-going fractures or cracks. The rock takes a good polish (8-9/10) with a tight surface. There are some grain boundary cracks and a few, small (<<1 mm^3) pits at the corners mafic grains.

STAWAMUS CHIEF

LOCATION:	Lat. 40°40′50″	Long. 123°06′05″	(92G/11E)
	Vancouver Mining Division. Three kilometres east of Squamish.		
ACCESS:	From Whistler Highway to Stawamus River valley on the Shannon Creek road, some 7 kilometres from the highway.		
OWNER:	B.C. Rockworks International		
OPERATOR:	B.C. Rockworks International		
COMMODITIES:	Dimension stone - granite.		

LOCAL GEOLOGY

This site is located in the same intrusive phase of the Coast Plutonic Complex as the "Island White" quarry (described above) to the north. The area has numerous large outcrops of granitic rocks. One was used to open a

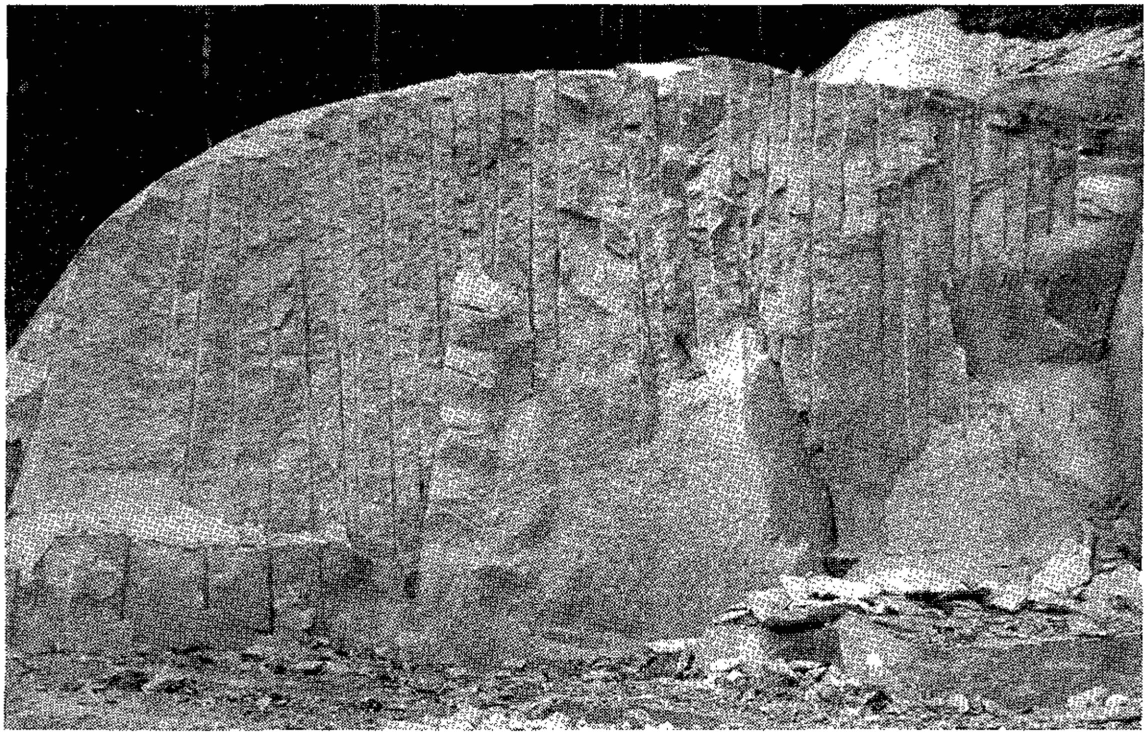

Plate 9. Hope quarry site.

Plate 10. Dark inclusions in the Hope granite.

test quarry in 1992. As judged from a few exposures, the stone seems to be more homogeneous, with fewer dark inclusions than the "Island White" quarry site.

PETROGRAPHY

The stone from Stawamus Chief is a buff-grey, medium to coarse-grained granite. The colour is fairly uniform with small specks of iron staining. Grain size varies from 2 to 12 millimetres with most grains near the larger size. Minerals present are plagioclase, orthoclase, quartz, biotite, sericite, chlorite and opaques. Sericite is present as discrete grains within plagioclase unlike the usual fine-grained, "scaly" habit for such alteration. Perthite is moderately well developed within orthoclase. Iron staining is noticeable as narrow halos around half of the mafic grains. A few (< 1%) mafic xenoliths, up to 10 millimetres on longest axis, are scattered through the rock. The crystals are all well interlocked. Quartz grains are crackled and feldspar grains are cracked along cleavage. The result is a 5-millimetre spaced, web-like cracking of the rock. The cracks do not appear to be open as fractures. The rock takes a good polish (7-8/10) and has a tight surface with a few tiny (< < 1 mm^3) pits at the edges of the biotite grains.

HOPE

LOCATION:	Lat. 49°22′19″	Long. 121°21′09″	(92H/6W)
	New Westminster Mining Division. Approximately 6 kilometres east of the community of Hope, near Nicolum Provincial Park.		
ACCESS:	From the ramp between Highway 3 and Highway 5.		
OWNER:	B.C. Granite Limited.		
OPERATOR:	B.C. Granite Limited.		
COMMODITIES:	Dimension stone - granite.		

LOCAL GEOLOGY

The Hope quarry is located in fine to medium-grained, grey granite. It is part of an early Tertiary granodiorite and quartz diorite body which intruded the Cascade fold belt. The exposures in highway cuts and valley slopes indicate a low fracture density and is suitable for block quarrying (Plate 9). The rock is homogeneous, but contains scattered rounded, dark inclusions (Plate 10). It has been quarried for masonry and paving stone; some is split into slabs and used for outside facing.

PETROGRAPHY

Stone from the Hope location is a fine to medium-grained granite. Colour varies from light to medium grey. Two samples were examined and the difference in colour is noticeable and indicates some variability across the deposit. The darker sample shows weakly developed iron staining around some of the mafic grains. The texture is fairly uniform with grain sizes between 1 to 3 millimetres. Minerals present are orthoclase, quartz, plagioclase, microcline, biotite, hornblende and opaques. There is some sericitization of plagioclase and little albitization. Hornblende and biotite look fresh. Pyrite content is much less than 1 per cent. Grains are well interlocked and no structural fabric is seen macroscopically. In thin section some crystals are cracked but these are within individual grains. The rock takes a moderately good polish (6-7/10). There is a significant amount of pitting at the edges of mafic grains and there are thin grain boundary cracks.

CASCADE

LOCATION:	Lat. 49°36′10″	Long. 121°16′40″	(92H/11W)
	New Westminster Mining Division. Approximately 22 kilometres east of Boston Bar in the Siwash Creek watershed.		
ACCESS:	From Highway 1 on Siwash Creek main line road.		
OWNER:	B.C. Granite Limited.		
OPERATOR:	B.C. Granite Limited.		
COMMODITIES:	Dimension stone - granite.		

LOCAL GEOLOGY

The Cascade property is located at the headwaters of the northern tributary of Siwash Creek. Bare, smooth granite slopes form the sides of the valley; occasional boulder fields from rock slides are found on the valley floor. The rock is very similar to the East Anderson River quarry with less of a green shade of colour. Stone is split from large boulders for use as masonry and similar rough-surface products. The stone is homogeneous without dark knots or inclusions. Some outcrops indicate a tendency for weathering similar to the East Anderson River stone.

PETROGRAPHY

Stone from the Cascade site is coarse-grained quartz syenite. The colour is smoky, light-grey with a light green cast. There is no iron staining. The texture is very coarse with the grain size range from 3 to 15 millimetres and the majority between 8 and 15 millimetres. Minerals present are orthoclase and microcline, quartz, plagioclase, biotite, pyrite ($<<1\%$) and sphene. Perthite texture is very strongly developed to the point of being anti-perthite. The result is that microcline is probably present but is difficult to distinguish. All the minerals look fresh. In the sample examined, quartz is extensively crackle fractured, feldspars are cracked along cleavage and there are abundant through-going cracks with a definite parallel fabric spaced about 5 millimetres apart. This, however, is most probably an artifact of the sample more than a true representation of the whole body. The rock takes a good polish (7-8/10) but has a fairly open surface due to the cracks. This again is probably a feature of the specific sample.

SUMMARY AND CONCLUSIONS

After decades of neglect, the last several years have seen a renewed interest in producing dimension stone from British Columbia sources. The seven properties described provide a sufficient variety of colours and textures to establish local stone in the marketplace. This should reduce the import of standard types of dimension stone to the Pacific Northwest from overseas sources and permit gradual penetration of export markets.

No results of test of physical properties are yet available, but the study of thin sections indicates that the fine to medium-grained granite varieties compare favourably with similar types already in the marketplace. The coarse-grained granites usually require more careful site selection because of generally higher susceptibility to breaking under applied pressure. The development of the East Anderson River property demonstrates that the industry is successfully solving this potential problem.

While the homogeneity of the stone is paramount in ornamental tile and facing applications, uses in masonry, curbstones and paving blocks can absorb larger quantities of stone with imperfect texture as aesthetics are less important. Here, durability plays a most important role and our concrete and asphalt culture should absorb more stone products, as has happened in other parts of the world.

ACKNOWLEDGMENTS

The authors thank Claudio Corra and Sante Iacutoni for providing a tour of the Margranite Industries Ltd. tile processing plant, and together with Ray Morris for helping to arrange the visits to all the quarry sites. The report benefited from the editorial comments of J.M. Newell and B. Grant.

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THE HOWELL CREEK STRUCTURE, SOUTHEASTERN BRITISH COLUMBIA

By Andrew Legun

INTRODUCTION

This report provides improved definition of geologic features of the Howell Creek structure. This feature is located in the Front Ranges of the Rocky Mountains in the Flathead area of southeastern British Columbia. Access to the area is by logging roads leaving Highway 3 near Morrissey, 13 kilometres south of Fernie, for a distance of about of 60 kilometres following Morrissey, Lodgepole and Harvey creeks. Mapping was first conducted in 1988 to clarify relationships between intrusive rocks, faults, late Cretaceous sediments and hydrothermal alteration. The results of that work were reported by Skupinski and Legun (1989). At that time Placer Dome Inc. was evaluating alkaline intrusives in the area for their gold potential.

Additional mapping by the second author has since suggested a new interpretation of the structural framework. This report describes and discusses the new interpretation and identifies constraints on the origin of the structure.

STRUCTURAL SETTING

The Howell Creek structure is a geologic enigma. It comprises a block of Upper Cretaceous rocks of the Alberta Group surrounded by Paleozoic and Precambrian rocks of the MacDonald dome.

The structure is rectangular in plan with the long axis oriented northwest-southeast. It is bounded on the northeast by the Harvey normal fault. On the southwest a major low-angle thrust was recognised by Price (1965). The Howell fault defines the southeast margin. This fault has been interpreted both as a normal fault (Labreque and Shaw, 1973) and a young thrust that developed discordantly across a pre-existing structure (Price 1965).

The structure lies along a northwest-trending zone of normal faults extending from Commerce Creek and the Flathead Valley fault. Although Cretaceous strata are downdropped against the Harvey normal fault the overall structure has the features of a tectonic window, where erosion through the upper plate has exposed the younger (Cretaceous) rocks below. Part of the enigma lies in the fact that the Cretaceous rocks of the lower plate are roughly at the same elevation as the surrounding Paleozoic section. In an attempt to explain the position of Cretaceous rocks, Jones (1977) interpreted the structure as superficial, the Cretaceous rocks representing a Paleogene slide block.

RESULTS OF MAPPING

Mapping results are presented in Figure 1 with a comparison to previous mapping by Price (1965). Most significantly, the southwest margin of the structure is defined by a steep and straight fault and not a low-angle fault with a sinuous trace. Two structural outliers of Proterozoic rocks are found within the structure.

The bounding faults of the Howell structure are described in more detail below, in a counterclockwise direction starting in the northwest.

BOUNDING STRUCTURES

NORTHWEST BOUNDING FAULT

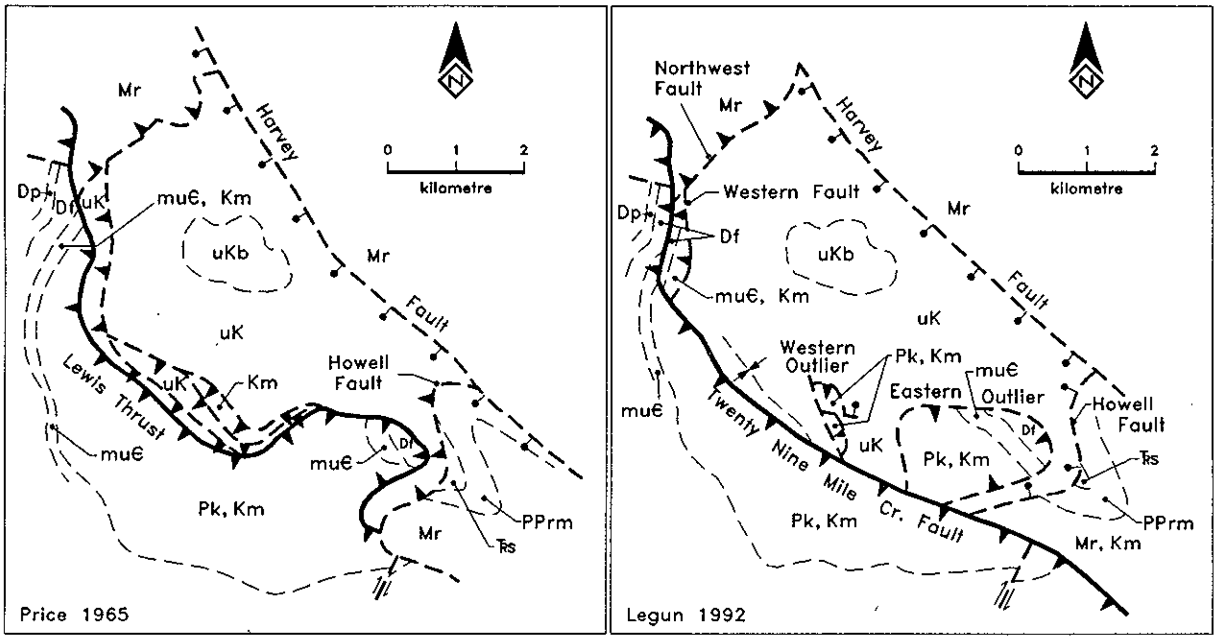
The northwest bounding fault is exposed along the Lodgepole Creek road juxtaposing Paleozoic limestone over Cretaceous shale. A shallow dip of less than 10° to the northwest was measured. To the northeast this thrust fault terminates against the Harvey fault. To the southwest its trace is straight over steep topography, indicating a steepening of dip. Against the fault, Upper Cretaceous sandstones strike parallel and dip steeply southeast.

WESTERN FAULT

The western bounding fault follows a curved trace from the northwest bounding fault to the Twentynine Mile Creek fault. This reverse fault places intrusive rocks and folded strata of the Cambrian Elko Formation against Alberta Group shales and sandstones. Its mapped trace across a ridge indicates a strike of about 010° and a dip of about 50° to the west.

TWENTYNINE MILE CREEK FAULT

This steep reverse fault is subparallel to the crest of a northwest-trending ridge. Along the ridge a large igneous body is faulted against steeply dipping and folded Cretaceous sandstones and shales. The fault is exposed along a road cut at the south end of the ridge, 300 metres below the ridge top. The fault contact is steep, the dip estimated to be 70° or more to the southwest. The fault can be traced up the slope to the ridge top. It is marked by a zone of sheared and granulated rock several metres wide which includes Cretaceous sediments and intrusive material. Outcrop mapping indicates the fault must continue southeast along the valley of Twentynine Mile



LEGEND

UPPER CRETACEOUS
ALBERTA GROUP
uK — Dark grey shale, siltstone, sandstone

LOWER CRETACEOUS
FLATHEAD INTRUSIONS
Km — Trachyte, syenite, breccia

TRIASSIC
SPRAY RIVER FORMATION
Ts — Grey and brown dolomitic siltstone, siltstone and shale

PENNSYLVANIAN AND PERMIAN
ROCKY MOUNTAIN FORMATION
PPrm — Sandstone, quartzite, dolomite, dolomitic sandstone

MISSISSIPPIAN
RUNDLE GROUP
Mr — Mostly limestone and dolomite with chert

DEVONIAN
PALLISER FORMATION
Dp — Dark limestone and dolomitic limestone
FAIRHOLME GROUP AND ALEXO FORMATION
Df — Limestone, dolomite, silty to argillaceous; quartzitic sandstone

CAMBRIAN
FLATHEAD AND ELKO FORMATIONS
mu€ — Quartz sandstone; grey dolomite and black mottled dolomitic limestone

PROTEROZOIC
KINTLA FORMATION
Pk — Reddish sandstone, siltstone, quartzite

Figure 1. Geology of the Howell Creek structure.

Creek, outside of the Howell Creek structure. Its throw appears to decrease in that direction. To the northwest the fault continues in Paleozoic rocks and its throw also decreases, as mapped by Price (1965). A segment of this fault follows the trace of a fault mapped by Price as a major thrust but it is too steep to have the configuration depicted by Price (1965).

HOWELL FAULT

The Howell fault forms the southeast boundary of the structure. It strikes northeast (about 035°) and dips northwest at 025° to 030° with Cretaceous sediments in the hangingwall and Triassic and older sediments in the footwall.

HARVEY FAULT

The Harvey fault is a southwest-dipping normal fault bounding the Cretaceous strata of the Howell Creek structure on the northeast side. The fault was intersected at a depth of 1054 metres in an oil well (CIGOL - IOE *et al.* HOWELL a-16-B) drilled to test the structure (Labrecque and Shaw, 1973). Calculations show it dips at approximately 75° at this location. The well intersected intrusive rocks in the footwall.

GEOLOGY WITHIN THE HOWELL STRUCTURE

Upper Cretaceous Alberta Group shales and sandstones are folded into a broad open syncline within the structure. The lowest stratigraphic unit is apparently sandstone of the Cardium Formation which Jones (1977) found at a few locations at the periphery of the structure. Above the Cardium sandstone is a thick sequence of Wapiabi shale. The youngest unit, the Belly River Formation, consisting of gently dipping sandstones, caps a mesa in the core of the structure.

The basal sediments are tightly folded against the Twentynine Mile Creek fault. At one location a few metres of volcanic conglomerate are exposed at the base of the Cretaceous succession.

The southern half of the structure contains two structural outliers of Proterozoic to Paleozoic strata cut by a subvolcanic swarm of alkaline dikes. The eastern outlier forms most of the exposure on a ridge immediately north of Twentynine Mile Creek. The western outlier is smaller and adjacent to the west across a topographic saddle underlain by Cretaceous shale.

EASTERN OUTLIER

The eastern outlier consists of an east to northeast-dipping section ranging from the Proterozoic Kintla Formation to the Devonian Fairholme Formation. Jones (1977) identified an exposure of Tertiary Kishenin Formation conglomerate on the ridge crest of the outlier. The outlier is cut by fine-grained and porphyritic intrusions, mostly sills, but including dikes, irregular plugs and intrusive breccias. A thick but discontinuous sill appears to lie at the base of the Paleozoic carbonates.

In 1988 reverse circulation drilling was conducted on the northern and eastern sides of the outlier to test gold geochemical anomalies. This drilling for Placer Dome Inc. (Cameron and Fox, 1989) helped clarify the geometry of the bounding faults. The north boundary of the outlier dips steeply to the south as calculated from the surface trace and drill-hole data (138 HRC 24). The east boundary dips about 30° to the west based on its trace across the topography and drilling results. The southern boundary near Twentynine Mile Creek appears to dip to the north-northwest. The west boundary fault is steep near Twentynine Mile Creek based on its surface trace. The base of the structural outlier thus appears to dip inward on all sides, although the dip varies considerably and more than one fault surface may be involved. The geometry of the structural outlier is crudely cone-like (a horst?) with the eastern lip noticeably shallow.

The west boundary fault of the structural outlier is perpendicular to the Twentynine Mile Creek fault and apparently truncated by it. There is a small problematic area of white limestone near the intersection of the faults.

WESTERN OUTLIER

This outlier is truncated by a subvertical fault on its west side. Nearby, beds of the Alberta Group dip 35° westward. A west-dipping thrust truncates the east border of the outlier. The trace of this thrust is offset by an east-striking fault that appears to be a normal fault, uplifting the southern half of the outlier. Farther south the thrust is exposed more or less in section along the valley wall of Twentynine Mile Creek. The trace of the thrust swings in the down-dip direction (west), and is presumed to be cut off by the subvertical fault.

DISCUSSION

The Twentynine Mile Creek fault on the southwest side of the Howell Creek structure cannot be reconciled with a low-angle thrust with a sinuous trace as interpreted by Price (1965). It is a steep reverse fault that over-rides the hangingwall of the Western fault.

The geometry and extent of the Howell fault are uncertain. Labreque and Shaw (1973) interpret the Howell fault to swing parallel to the Harvey fault, striking northwest. This interpretation is questionable as it requires a considerable change in strike in the the Howell fault. Where exposed, the Howell fault dips westward and thus probably underlies most of the structure, as envisaged by Price (1965). The Lower Cretaceous was not intersected in the Cigol well, nor is it exposed anywhere at the base of the Cretaceous sequence. The base of the Upper Cretaceous sequence appears to be fault bounded (or an unconformity?) along the margins and floor of the structure.

The distribution of alkaline intrusive bodies about the structure suggests vertical tectonics have been dominant in the immediate area.

Jones (1977) noted the presence of Cardium sediments at the boundary of the structure in several localities, and in the Cigol well, and concluded that the entire structure was underlain by Cardium sandstone. He basically interpreted the trace of the shallow Howell fault as the base of a gravity plane and showed the Cretaceous Cardium overlapping the Twentynine Mile Creek fault and other structures. This is not the case. Peripheral structures such as the western fault and a portion of the northwest fault clearly over-ride the Cretaceous.

The following facts need to be considered with regard to the structural outliers:

- The western structural outlier of Proterozoic sediments is surrounded by Cretaceous shale. It is not part of the hangingwall of the Twentynine Mile Creek fault. It has been affected by normal faulting.

- The eastern structural outlier is adjacent to the Twentynine Mile Creek fault. The geometry of the outlier indicates a structural section is missing between it and the hangingwall of the Twentynine Mile Creek fault.

The eastern outlier was apparently exposed in the early Tertiary, as evidenced by the deposition of the Kishenin Formation. Deposition of the Kishenin Formation in the Flathead area is related to Tertiary normal faulting (Jones, 1969). This suggests the outlier was affected by movement on the Harvey fault.

The age of the intrusive rocks has been reported to be 98.5±5 Ma (mid-Albian), about the same age as the Crowsnest volcanics to which they are chemically similar. This U-Pb age is reported by Skupinski and Legun (1989) from samples collected by David Grieve and analyzed by Donald Murphy of the Geological Survey of Canada.

Osadetz *et al.* (1990), reported zircons and apatites derived from the Belly River Formation and the nearby intrusions have concordant fission track ages. These data were interpreted to indicate that a local thermal event occurred prior to Laramide deformation. This event reset both zircons and apatite. One may infer the sediments were in proximity to the intrusions at this time, otherwise a common local signature would not be recorded in both intrusives and Cretaceous sediments. There is field evidence for the sediments being near their present position early in the deformation. The Northwest fault overrides the sediments and is itself cut by the Harvey fault. The writer suggests the sediments were emplaced by movement on the Howell fault, and that the Howell fault is an early feature of the structure.

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LABORATORY SIMULATION OF IN SITU NEUTRALIZATION OF ACID ROCK DRAINAGE

By M.A. Chaudhry and R.E. Lett

INTRODUCTION

Acid drainage from mine waste rock containing sulphide minerals has long been recognized by mine operators, regulatory bodies, environmental agencies and the public as an environmental concern. Much of the existing technology for treating mine drainage has focused on removing metals from the leachate stream or limiting the metal content in tailings. (Kuit, 1980; Lecuyer, 1983). Each year an estimated 25 million tonnes of mainly pyrite and pyrrhotite-bearing waste rock are produced by Canadian mines (Filion *et al.*, 1990). In spite of strict guidelines and precautions for the safe disposal of waste rock, acid generation cannot be completely ruled out. Abandoned, orphan mines in remote areas are a particular problem because of high treatment costs. Methods for neutralizing the acid drainage from waste rock and minimizing dispersion of metals can be active or passive.

Active methods involve the chemical treatment of the waste-rock leachate, generally with calcium hydroxide under controlled conditions in a mixing plant where the acid is neutralized, metals are precipitated as hydroxides and sulphate is precipitated as calcium sulphate. Such plants are either separated from other operations or are integrated into existing metallurgical plants. Clearly this approach, while very effective, suffers from the disadvantage of high construction and maintenance costs and the problem of safe disposal of metal-enriched sludge from the neutralization process. Annually, the volume of the sludge produced by the Canadian mining industry exceeds 150 000 dry tonnes (Kondos *et al.*, 1991).

Passive methods for treating acid rock drainage include: covering the waste rock and tailings with a synthetic or natural low permeability material (*e.g.* glacial till); immersing the waste rock under water; mixing the rock with limestone or adsorbing the heavy metals by channeling the leachate through wetlands. Another approach to passive neutralization is to apply a neutralizer on the surface of the waste rock or to inject a neutralizer slurry into the rock pile. *In situ* treatment methods are more economical than neutralizing acid drainage from the waste and the problem of sludge disposal is solved by containing it within the rock pile cavities. Injection of a neutralizer into waste rock is not as efficient as plant controlled neutralization, but may, over a period of time offer, the benefit of slowing the rate of sulphide oxidation due to the formation and accumulation of oxide and hydroxide coatings on the sulphide surfaces (Nicholson *et al.*, 1990; Goldhaber, 1983).

A research project was carried out in the Analytical Sciences Laboratory, Geological Survey Branch to study the efficiency of *in situ* neutralization applied to sulphide-bearing waste from the abandoned Mount Washington mine site, British Columbia. This site was chosen because it is a source of heavy metal contamination (Erickson and Deniseger, 1987) and is currently undergoing reclamation by the Ministry of Energy, Mines and Petroleum Resources, Resources Management Branch.

PRINCIPLE FOR IN SITU NEUTRALIZATION

The objective of calcium hydroxide injection into an acid-generating waste-rock pile is to provide a neutralizing medium. Ideally, this medium is dispersed through the pile by the movement of groundwater and, in the process, neutralizes the products of mineral sulphide oxidation such as hydrogen ions, sulphate and dissolved metals. The metals are precipitated from alkaline solution and the quality of the water draining the waste is thereby improved. Chemical reactions typical of mineral sulphide (*e.g.* pyrite) oxidation are:

$$2FeS_2(s) + 7O_2 + 2H_2O = 2Fe^{2+} + 4SO_4 + 4H^+$$

Ferrous iron will oxidize to ferric iron

$$4Fe^{2+} O_2 + 4H^+ = 4Fe^{3+} + 2H_2O$$

The oxidation process may be mediated under acid conditions by bacteria (*e.g. Ferrobacillus ferrooxidans*) producing ferric hydroxide:

$$Fe^{3+} + 3H_2O = Fe(OH)_3(s) + 3H^+$$

The ferric hydroxide may, in turn, react with more pyrite and other mineral sulphides to produce ferrous iron and sulphuric acid.

$$FeS_2 + 14Fe^{3+} + 8\ H_2O = 15\ Fe^{2+} + 2SO_4 + 16H^+$$

Similar reactions involving other mineral sulphides produce Cu^{2+}, Zn^{2+} and Pb^{2+} ions.

When calcium hydroxide is added to sulphuric acid the first reactions increase pH and produce calcium sulphate.

$$Ca(OH)_2 + H_2SO_4 = CaSO_4 + 2H_2O$$

$$Ca(OH)_2 + CO_2 + H_2O = CaCO_3 + 2H_2O$$

Metals ions such as Cu^{2+}, Zn^{2+} and Pb^{2+} can then react with the hydroxide ions to produce metal hydroxides.

$$MSO_4 \ (M = Cu^{2+}, Zn^{2+}, Pb^{2+}) + Ca(OH)_2 = M(OH)_2 + CaSO_4$$

$$M_2(SO_4)_3 \ (M = Fe^{3+}, Al^{3+}) + 3Ca(OH)_2 = 2M(OH)_3 + 3CaSO_4$$

The formation of acid and its neutralization is controlled by the rate and direction of water movement through the waste. Placement of the neutralizing agent in the waste-rock pile could be achieved by the following methods:

- Spraying an alkaline slurry over the surface of the waste. The efficiency of surface application is governed by the size, shape and surface permeability of the waste-rock pile.
- Placing calcium hydroxide in trenches excavated up slope from the waste pile to intersect the path of the maximum groundwater flow so that the neutralizing plume covers a large area. The efficiency of using this type of application will be determined by topography and ground water hydrology.
- Injecting a calcium hydroxide slurry under pressure through bore holes placed at different depths on a grid pattern into the oxidizing part of the rock pile.

Conversion of some calcium hydroxide to calcium carbonate, especially in the drier part of the pile, is inevitable due to the flow of air and the absorption of carbon dioxide by the calcium hydroxide. Calcium carbonate will serve as an additional buffering material. Air flow may be increased by changes in the barometric pressure or by convection caused by the exothermic pyrite oxidation reactions.

LABORATORY EXPERIMENTS

The laboratory neutralization studies consisted of mixing sulphide-bearing waste rock from the Mount Washington mine site with a calcium hydroxide slurry. Calcium hydroxide was chosen because this compound is readily available for the cost of transport to the mine site and is formed as a by product of acetylene gas production by calcium carbide in a plant close to Mount Washington. The calcium hydroxide, presently stored as a sludge in ponds, is potentially a very low cost neutralizing agent as it is a waste product of the process.

The experiments involved loading two (19 cm diameter by 130 cm tall) plexiglass cylinders with waste rock collected from the floor of the abandoned Mount Washington north pit. This material, similar to that forming the 2 million tonnes of waste dumped at the mine site, consist largely of felsic volcanic rock containing varying amounts of pyrite, pyrrhotite, chalcopyrite, arsenopyrite and molybdenite. Based on an average of seven samples from the open pit and east waste dump the waste contains 0.248% copper, 5.16% iron and 0.92% sulphur. The waste was sorted by size into + 10 centimetre fragments, - 10 + 2 centimetre fragments and - 2 centimetre fragments before loading and the amount of waste in each column was estimated to be 55 kilograms. Each column was loaded with equal amounts of the three size fractions to simulate typical waste pile permeability. One column was used to study the neutralization by calcium hydroxide and the other as a control (reference) column. The design of the column with the sample collection ports is shown in Figure 1.

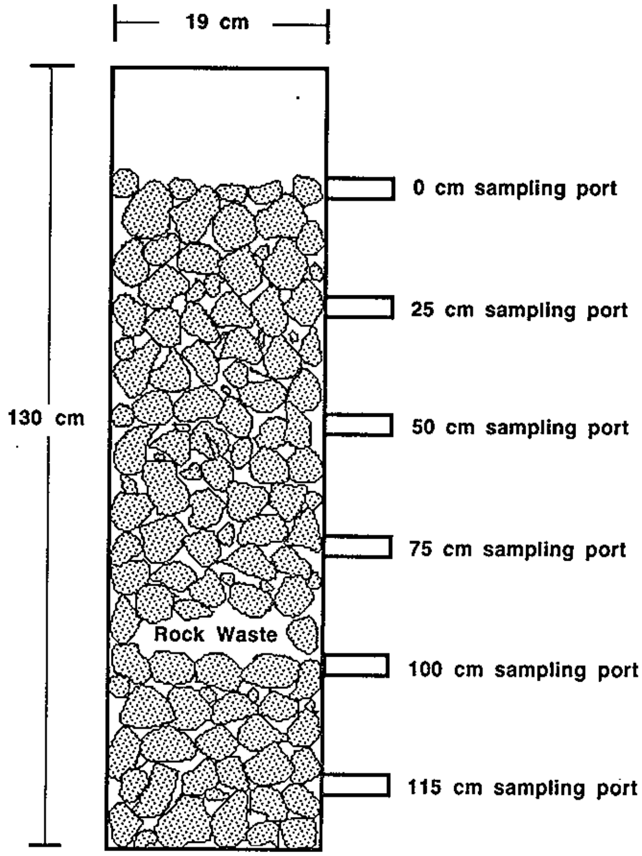

Figure 1. Plexiglass column design.

Before addition of calcium hydroxide the columns were filled with water until all the rock fragments were immersed; the water level was then lowered to the 50-centimetre depth and the leachates discarded. This treatment was designed to pack the fine rock material in each column and established a vertical drainage pattern through the waste. The first column contained 10.2 litres and the second column 9.8 litres of water. On September 5 1991 100 grams of calcium hydroxide slurry (27.4 gram equivalent of calcium oxide) was poured onto the surface of the rock in column 1. Both columns were refilled with distilled water and left undisturbed for 4 hours so that their contents could approach chemical equilibrium.

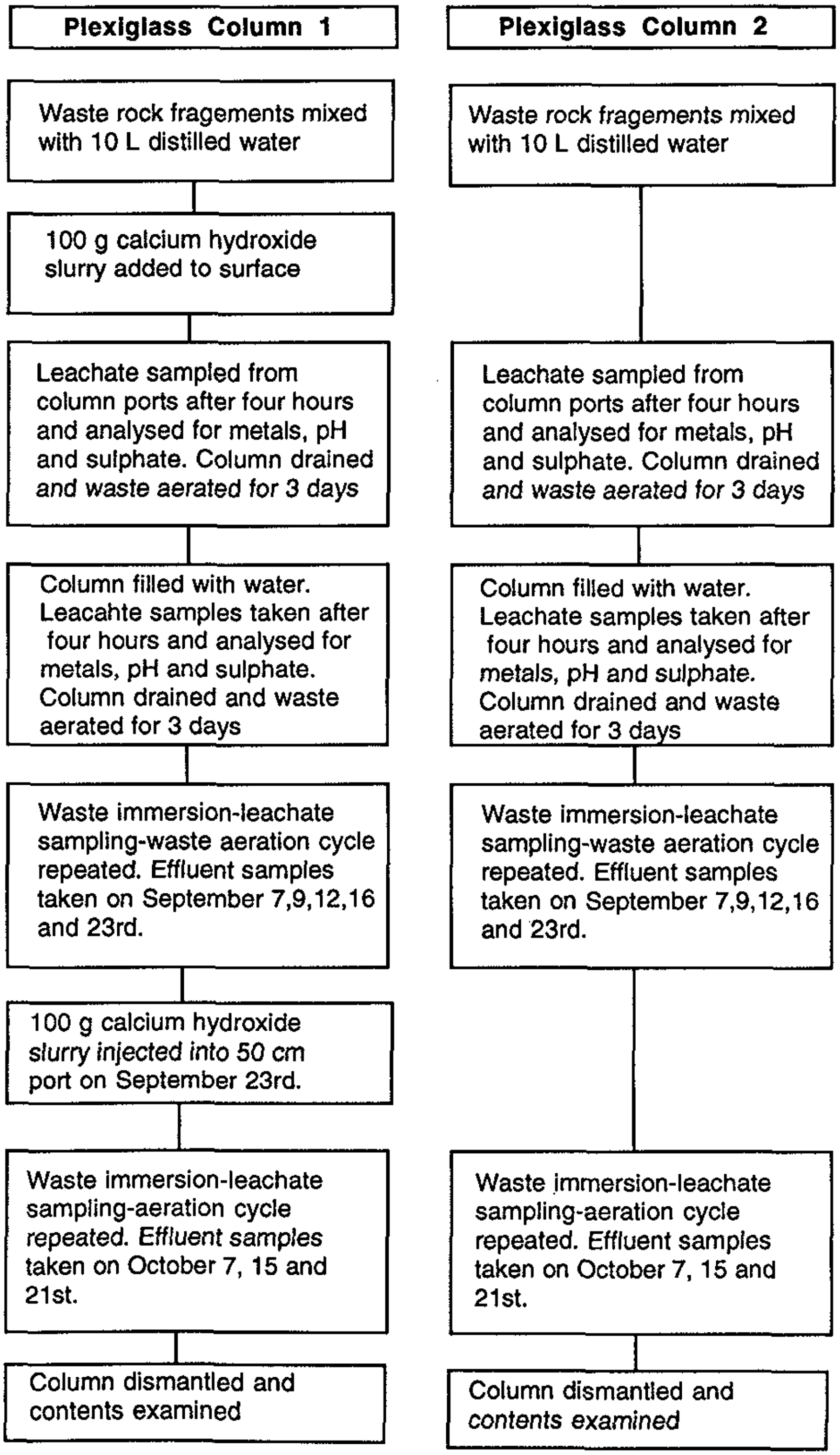

Figure 2. Experimental scheme.

After 4 hours a 100-200 millilitre sample of the leachate was collected from the 0-centimetre, 25-centimetre, 50-centimetre, 75-centimetre, 100-centimetre and 115-centimetre ports. The pH was measured and a sub-sample filtered through a 0.45-micron membrane filter and preserved with nitric acid for metal analysis. An second, unacidified sample was taken for sulphate analysis. The sampling procedure is summarized in Figure 2.

After the first sampling (September 5) the columns were drained and the contents left undisturbed for 3 days except for steady aeration with compressed air (0.5 litres/minute). The columns were refilled with distilled water and leachate collected from the sampling ports. No further addition of neutralizer was made to the surface of the material in column 1. This aeration-immersion sequence was designed to simulate the rise and fall of the groundwater table through a waste-rock pile. The cycle was repeated four more times with samples collected on September 9, 12, 16 and 23. On September 23 an additional 100 grams of calcium hydroxide slurry was injected into the 50-centimetre port of column 1. The immersion-aeration cycle was repeated three more times and samples were taken on October 7, 15 and 21.

Mean annual precipitation in the Mount Washington area (based on analysis of records for 6 years) is 2000 millimetres and values up to 4200 millimetres have been reported. Total amounts of water passed through the column represent wet precipitation of 3200 millimetres typical of that at the Mount Washington mine site. The amount of calcium hydroxide applied to the column is equivalent to a field application of 7 kilograms per cubic metre (1.9 kilograms per cubic metre equivalent calcium oxide) provided that the permeability of the column is similar to that occurring in the field.

The filtered, acidified water samples were analysed for arsenic, aluminum, calcium, copper, iron, lead and zinc by inductively coupled plasm emission spectrometry and the unacidified samples for sulphate. The samples were also analysed for copper by flame atomic absorption spectrometry. Standards and blind replicate samples were inserted to monitor the quality of the data. Samples of the three waste-rock size fractions were assayed by aqua regia digestion and atomic absorption spectrometry for copper, non-sulphide copper, arsenic, lead, manganese, iron and zinc; for sulphur and for dilute acid soluble sulphate.

RESULTS AND DISCUSSION

Analysis of the waste rock (Table 1) revealed that samples of the three size fractions contain up to 1.56% copper, 566 ppm lead and 5610 ppm arsenic. The metals are most abundant in the smaller (-2 centimetre) fragments and more than 80% of the copper is in sulphide form.

TABLE 1
ANALYSIS OF MOUNT WASHINGTON WASTE ROCK

Element	+ 10 cm size	-10 + 2 cm size	- 2 cm size
Arsenic (ppm)	1465	2890	5610
Sulphate (%)	0.38	0.41	2.72
Sulphur (%)	3.21	2.35	3.45
Copper (%)	1.42	1.56	1.28
Iron (%)	6.01	5.39	11.70
Lead (ppm)	36	106	566
Manganese (ppm)	185	250	145
Zinc (ppm)	160	88	128

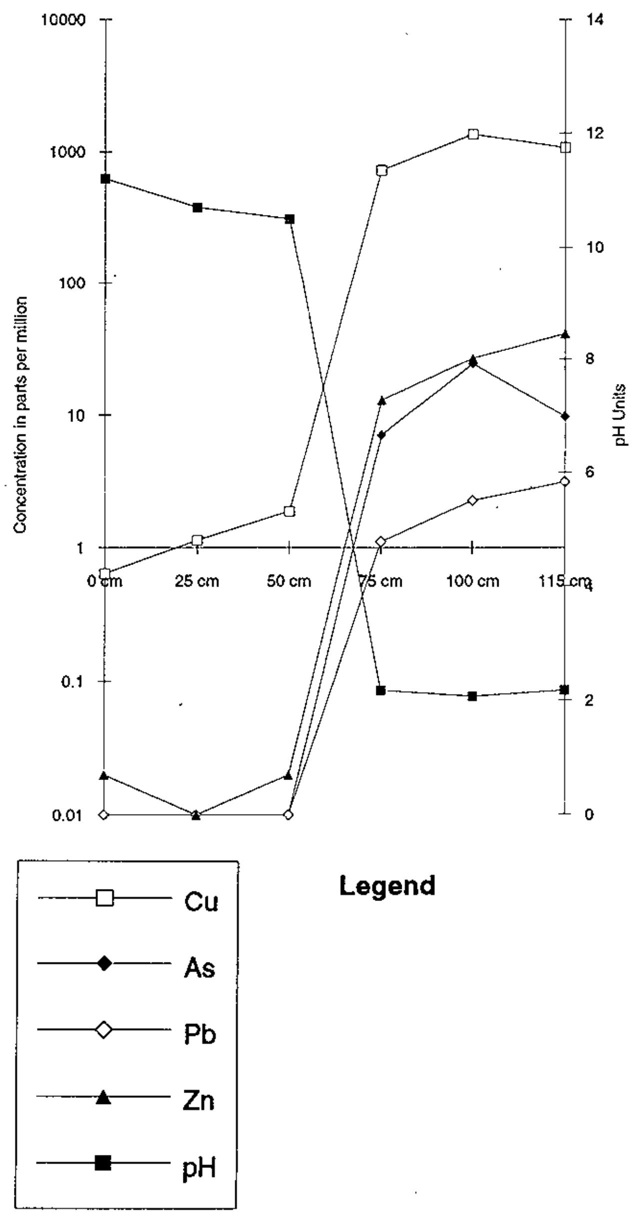

Figure 3. September 5, 1991: Column 1 leachate chemistry - calcium hydroxide slurry added to surface of sample.

Copper, arsenic, lead, zinc and pH of leachate sampled from the six column 1 ports on September 5 are displayed in Figure 3. These data show that after surface addition of the calcium hydroxide pH fell sharply from 10.5 at 50 centimetres to 2.0 at 75-centimetre depth and metal concentrations increased over the same depth interval. The impact of the neutralizer is demonstrated by the distribution of copper which changed from 0.64 ppm in the 0-centimetre leachate to 1807 ppm at 115 centimetres. Clearly, the first flushing cycle transports the calcium hydroxide to the 50-centimetre depth and effectively immobilizes the metals. The distribution of copper, iron, aluminum, calcium, sulphate and pH in both neutralizer column 1 and the control column 2 on September 9, 12, 16, 23 and October 7, 15 and 21 is shown in Figures 4 to 9. Only data for the 25-centimetre, 50-centimetre, 75-centimetre and 100-centimetre leachate samples are shown because they illustrate most significant changes occurring within the columns.

By September 9 (Figure 4) the strongly alkaline pH of the leachate (pH 10.15) at 75 centimetres showed that the calcium hydroxide penetrated to this depth in column 1. Copper content of the 75-centimetre leachate from column 1 was 1.05 ppm compared to 425 ppm in the 100-centimetre sample. The distribution of aluminum was similar to copper. Arsenic and lead were below detection level at 0, 25, 50, 75 centimetres, but increased to 1 ppm in the deeper column 1 leachate samples. Zinc was less than 0.03 ppm in the 75-centimetre sample, but increased to 5.8 ppm in the 100-centimetre sample. In the control column the metals and sulphate also increased with depth, although the concentration gradient was more gentle. Column 2 leachate pH remained below 3 at all depths. Similar distributions were revealed by the September 12 sampling (Figure 5) showing that even after two flushings of the waste the calcium hydroxide was still very effective in immobilizing metals and neutralizing acid produced from the oxidizing sulphides.

Element and pH distributions for both column leachates sampled on September 16 (Figure 6) are more similar showing the effect of neutralizer consumption. By September 23, (Figure 7) the pH of leachate samples from all depths is less than 7.0 reflecting almost complete consumption of the calcium hydroxide. Copper content of the 100-centimetre column 1 leachate was 112 ppm compared to 1301 ppm at the same depth on September 5. By contrast the copper content of the control column 100-centimetre depth leachate changed from 1539 ppm on September 5 to 167 ppm on September 23 because the soluble salts are leached from the waste. Although the calcium hydroxide applied to the surface of the waste ceased to effectively neutralize the acid produced by September 23, it was still capable of reducing copper levels in the leachate.

The pH change in column 1 compared to column 2 from September 23 through October 7 (Figure 8) to October 15 (Figure 9) reflects injection of calcium hydroxide into the 50-centimetre port. By October 15, pH increased from 8 at 25 centimetres to above 12 at 115 centimetres. Copper was less than 0.4 ppm in all leachates and lead, arsenic and zinc were below detection limit. By October 21 (Figure 10), leachate pH increased steadily from 8 at 50 centimetres to 13 at 115 centimetres showing that an unreacted calcium hydroxide front had moved downward through the column. Compared to October 15, however, the pH of all October 21 leachate samples was lower due to consumption of the calcium hydroxide. Although the calcium hydroxide was still effective there was evidence of remobilization of metals in the deeper part of column 1. For example, copper increased from 0.064 ppm at 75 centimetres to 1.8 ppm at 115 centimetres depth. Lead, arsenic and zinc remained below detection level. Aluminum increased from below detection level at 25 centimetres to 0.55 ppm at 115 centimetre depth.

Long term remobilization of metal-rich precipitates was examined further by analysing column 1 and 2 leachates collected on January 20 for copper and pH. These data show that although the leachate pH for both columns was below 2.0, copper content in the 115-centimetre leachate for column 1 (427 ppm) is still lower than for column 2 (1165 ppm). Metal hydroxides, formed by reaction with calcium hydroxide neutralizer, would be expected to dissolve as the pH falls below 4.0, releasing metals into the waste pore water. Moreover, dissolved metal concentrations in column 1 could possibly surpass those detected in the pore water of the control column because of the lower stability of freshly precipitated hydroxides compared to the more mature oxides and sulphides typical of the waste.

One explanation for the observed element and pH changes after long term neutralization may be the form of the precipitates developed. Mineralogical examination of the sludge from the bottom of the dismantled column 1 revealed that, in addition to copper hydroxide, there were 1 to 2 millimetre sized nodules of unreacted calcium hydroxide coated with a green to brown coloured film. Complete release of metals from dissolving hydroxides would not be possible until all of the calcium hydroxide is exhausted. The slower metal release from the calcium hydroxide neutralized waste under acid conditions may also be due to a slower oxidation rate, the accumulation of iron oxide and the iron hydroxide coatings on waste-rock fragments resulting from the suppressed activity of iron oxidizing bacteria (*thiobacillius ferrooxidans*) which cannot thrive above pH 4 (Lundgren and Silver, 1980; Arkesteyn, 1980). The existence of this bacterium at the Mount Washington mine has been confirmed by Errington and Ferguson (1987).

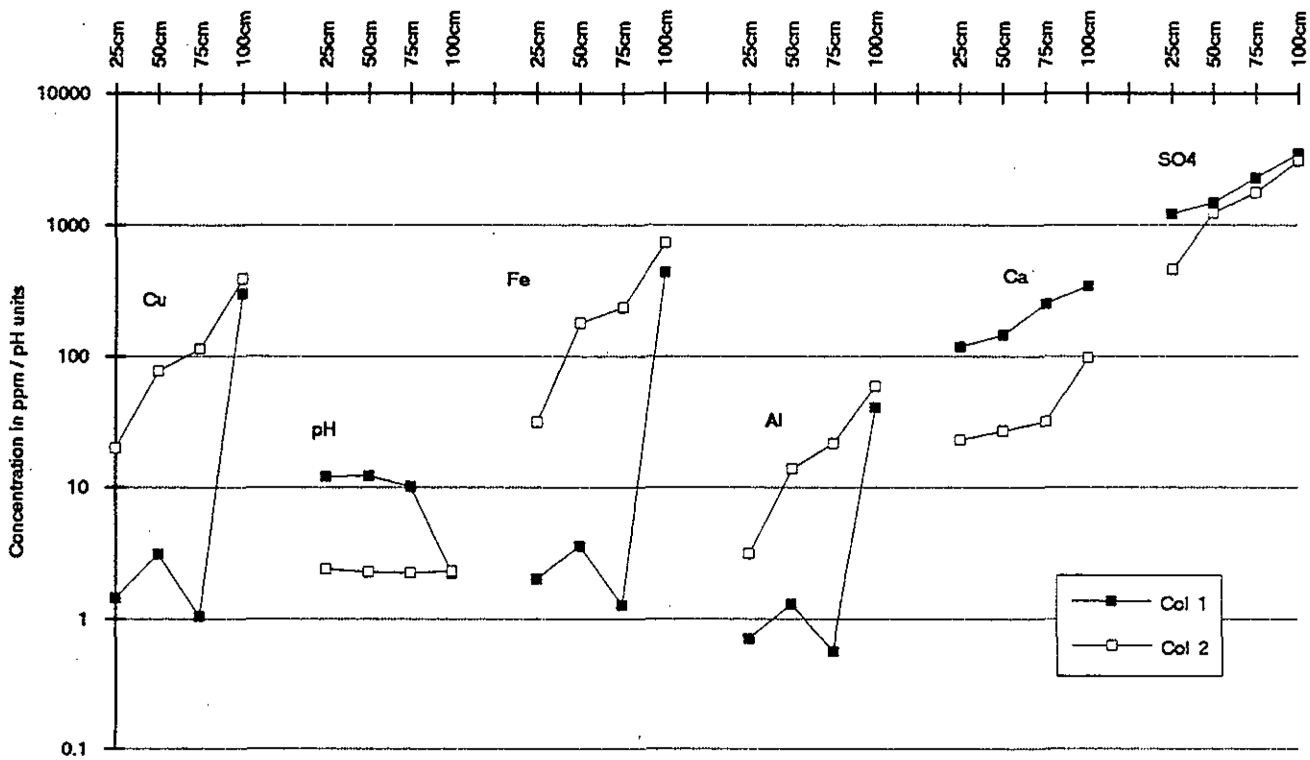

Figure 4. Columns 1 & 2 effluent chemistry, 9 Sept. 1991.

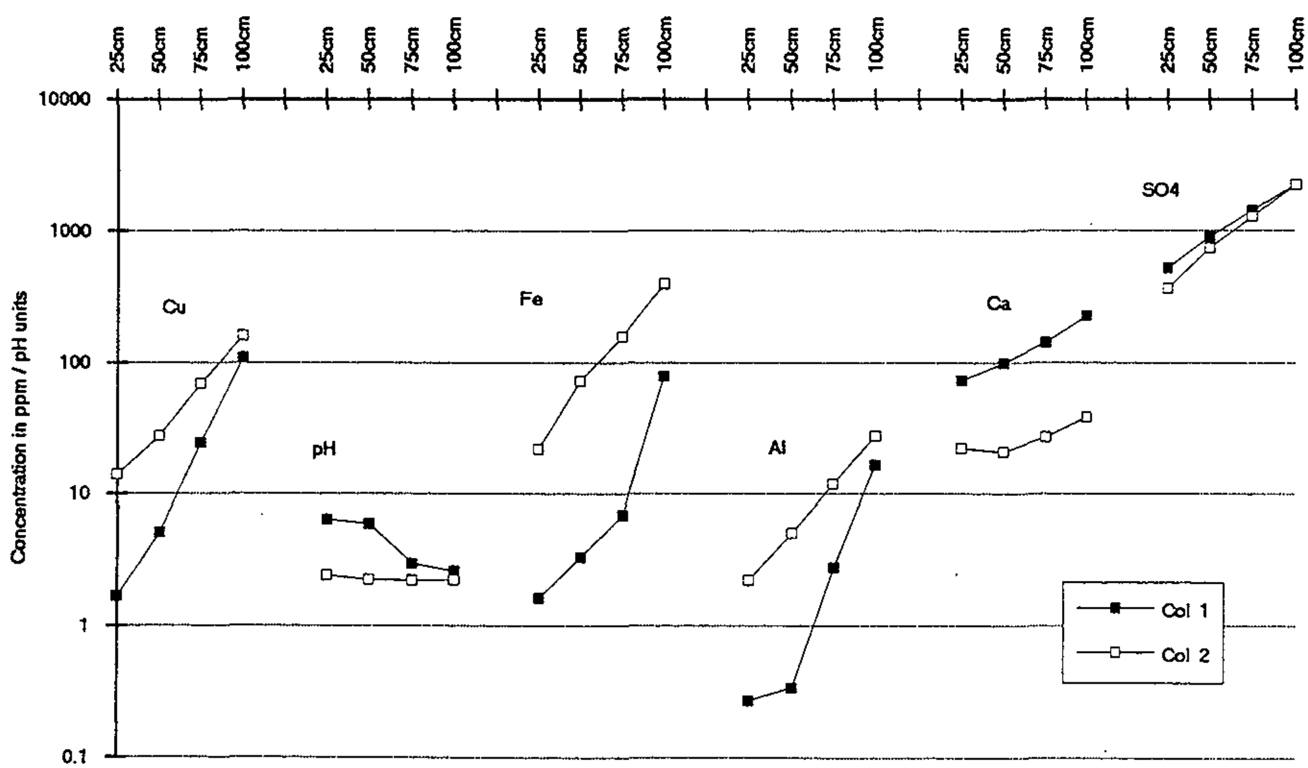

Figure 5. Columns 1 & 2 effluent chemistry, 12 Sept. 1991.

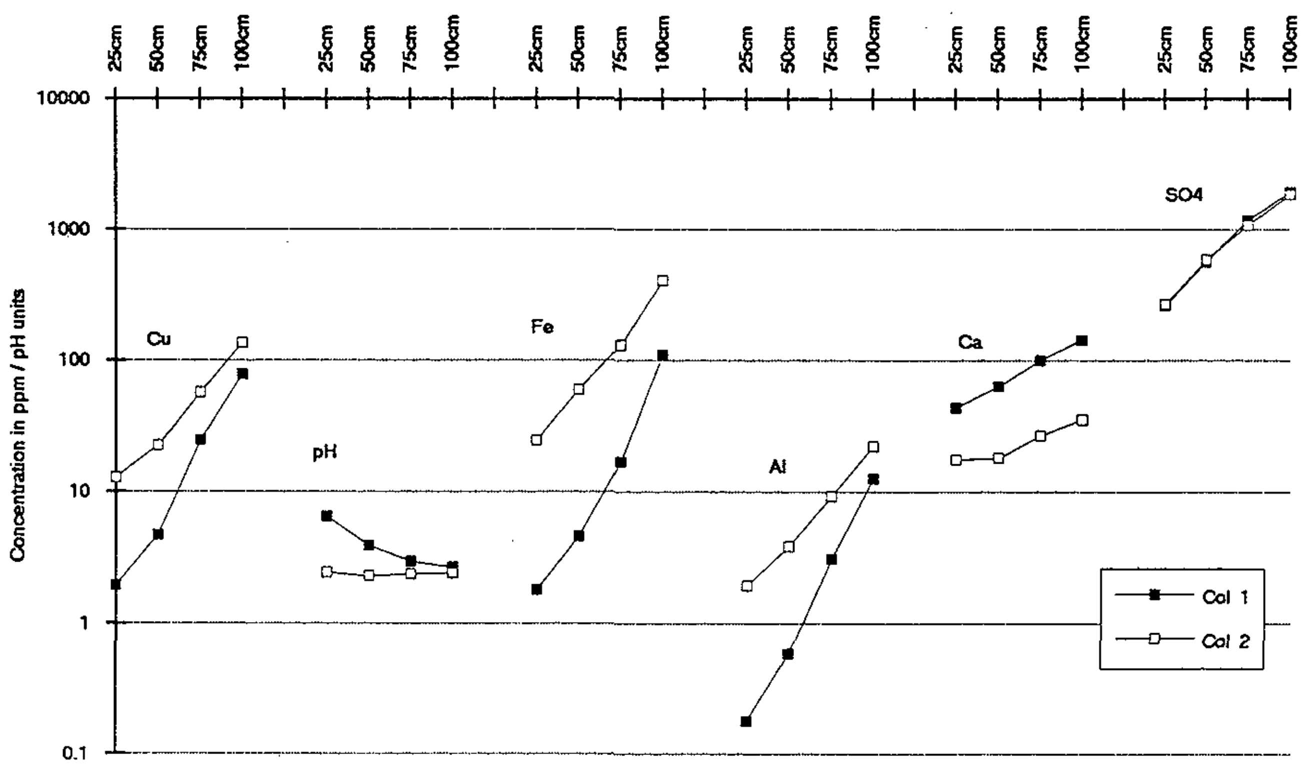

Figure 6. Columns 1 & 2 effluent chemistry, 16 Sept. 1991.

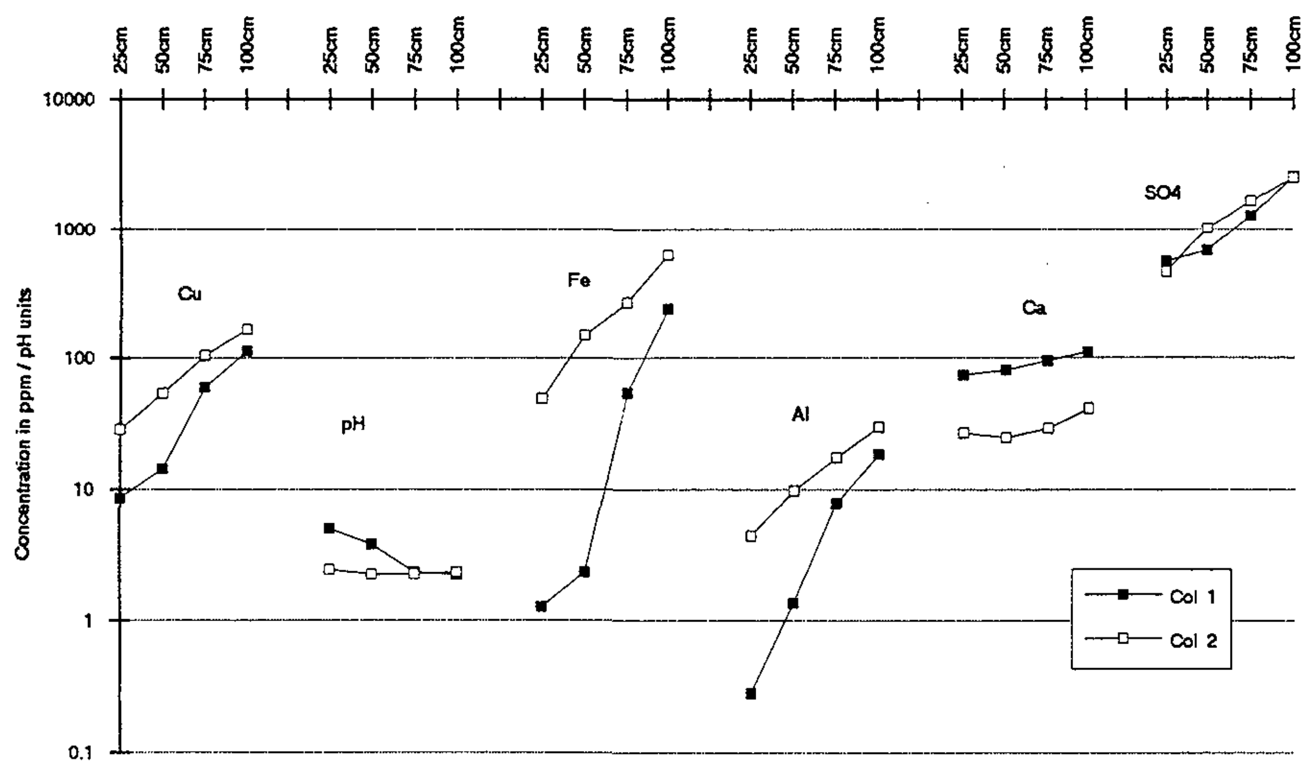

Figure 7. Columns 1 & 2 effluent chemistry, 23 Sept. 1991.

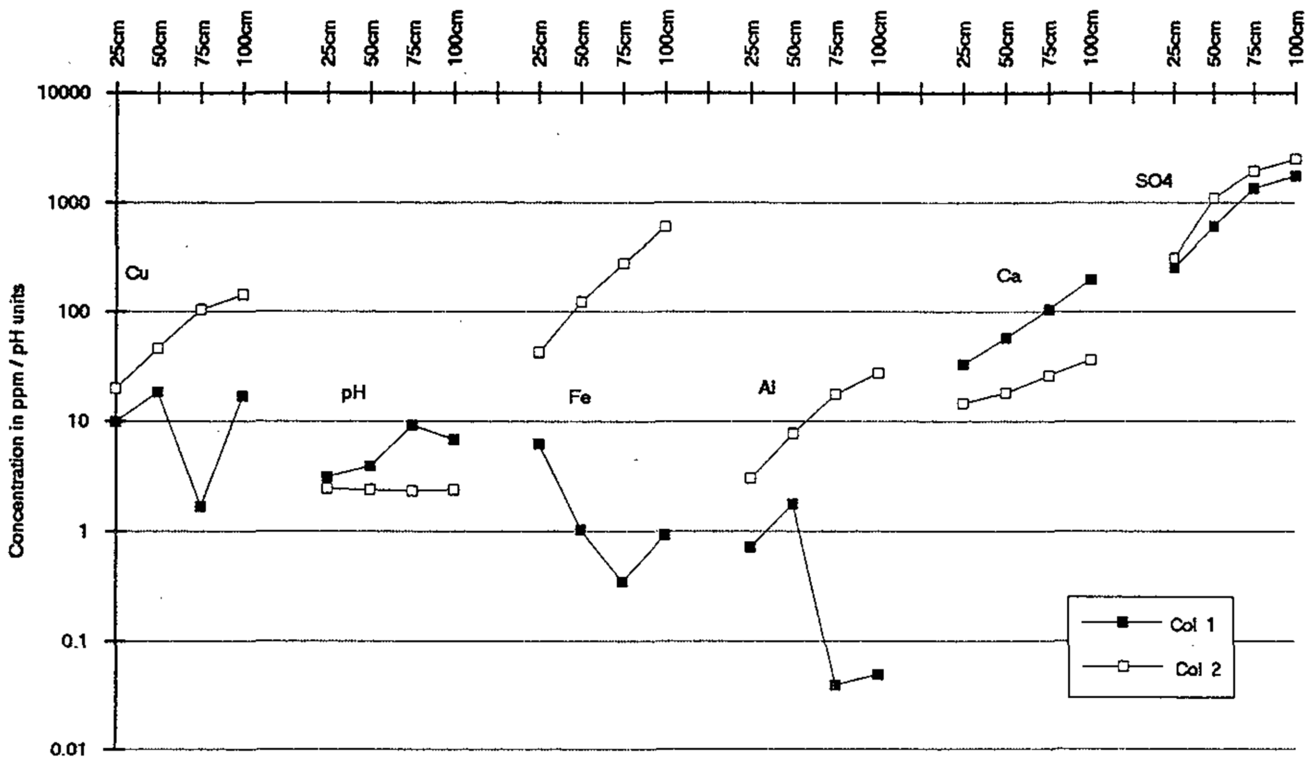

Figure 8. Columns 1 & 2 effluent chemistry, 7 Oct. 1991.

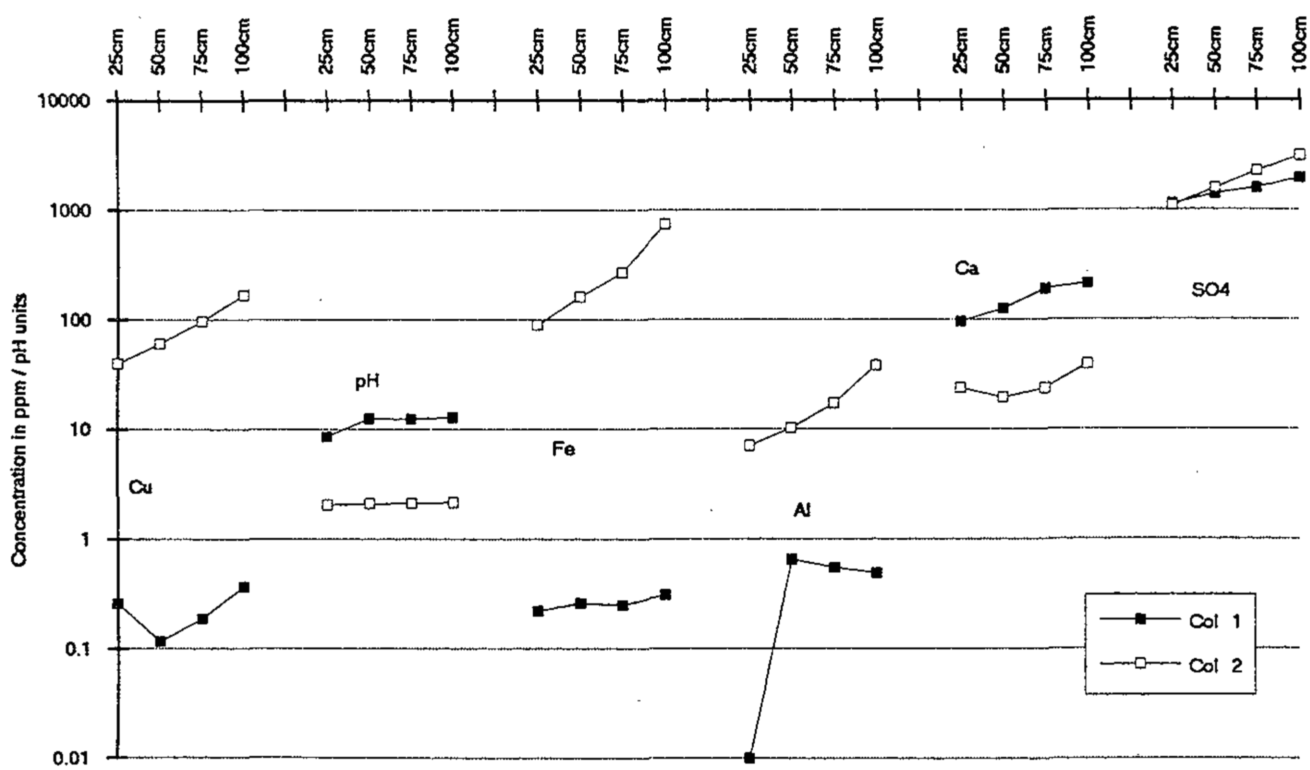

Figure 9. Columns 1 & 2 effluent chemistry, 15 Oct. 1991.

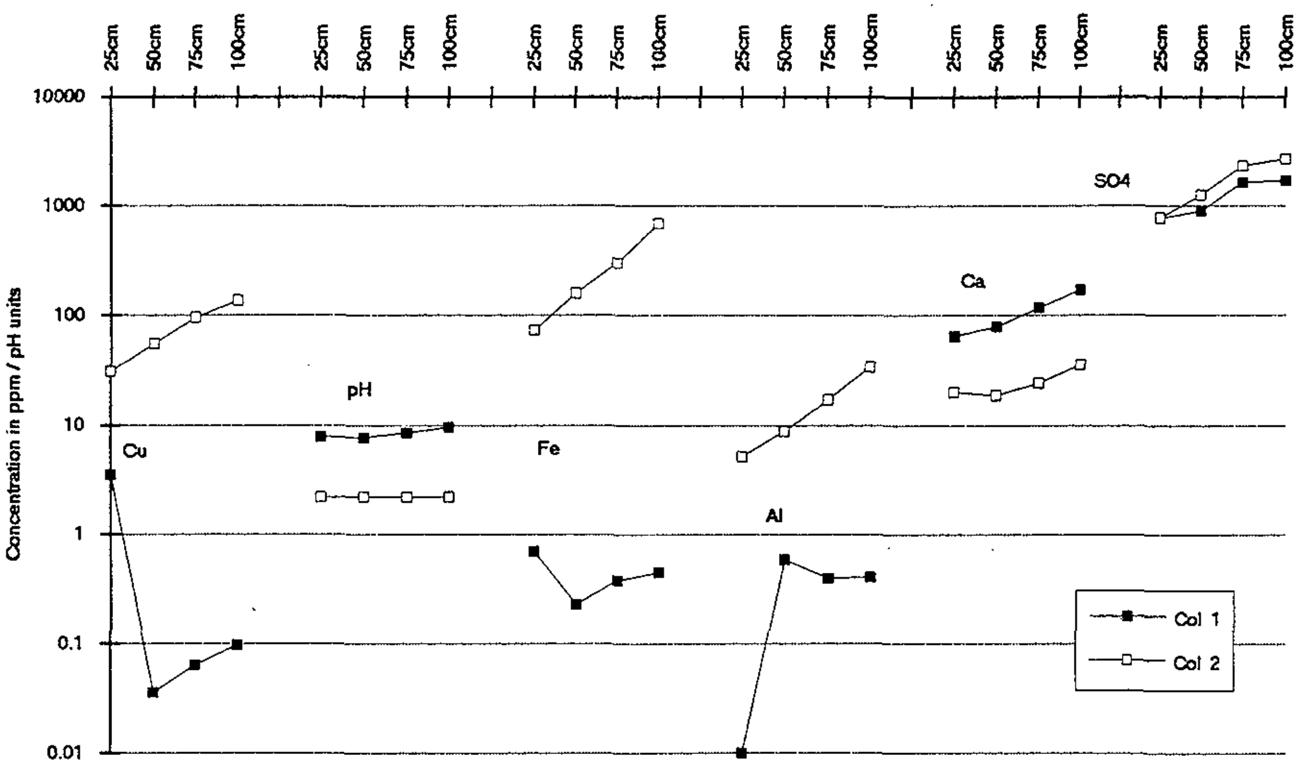

Figure 10. Columns 1 & 2 effluent chemistry, 21 Oct. 1991.

Although metal concentrations and pH changes in the 115-centimetre leachate can be explained by the effect of soluble salt dissolution at early stages of column flushing and depletion of soluble salts in later cycles, this simulation may not be a true representation of some field conditions where the length and frequency of the flushings vary with climatic conditions. However, in a prolonged flushing event (such as snow melt) the chemistry of the water draining the waste-rock piles (and in particular development of water chemistry stratification) is expected to resemble that observed in the columns.

The theoretical stability of aluminum, copper and iron minerals was examined by calculating relative saturation of minerals in solution from the October 15 column 1 leachate chemistry using WATEC, a thermodynamic equilibrium modeling program (Ball *et al.*, 1987). This particular leachate chemistry was selected because it was one of the few where Eh was measured in all samples. However, a more rigorous modeling of the water chemistry requires data for additional parameters such as sulphide, alkalinity and chloride. The saturation index (log equilibrium constant/thermodynamic constant) for column 1, October 15 (Figure 11) reveals a close relationship between pH and mineral saturation. WATEC modeling predicts that copper-iron minerals (*e.g.* cuprousferrite) and goethite are highly oversaturated throughout the column. Cuprite is undersaturated in the upper part of the column, but becomes oversaturated below 75 centimetres. Tenorite and diaspore become less saturated with depth, possibly due to the mildly reducing condition (Eh -0.088 Mv) in the 115-centimetre sample compared to oxidizing conditions (+ 44 mV) at 75 centimetres).

The exact relationship between pH and the solubility of minerals is important for operating acid-leachate neutralizing plants where the pH is generally maintained between 9.0 and 10.0. This is because this pH is considered the optimum for precipitation of copper, lead, iron and aluminum hydroxides (Goodwin, 1986; Monhemius, 1977). Arsenic, conversely, is precipitated from many of its soluble compounds, often very effectively, by coprecipitation with ferric hydroxide rather than as a discrete arsenic compound. The theoretical modeling shows that insoluble iron oxides and hydroxides would be stable under the conditions of the neutralizing column. While the precise nature of arsenic removal from solution was not investigated during this study, the removal is assumed to be in the form of an insoluble heavy metal arsenate, once the solution pH is sufficiently high for the arsenate ion to remain stable.

CONCLUSIONS

- Addition of 100 grams of calcium hydroxide slurry to the surface of sulphide-bearing waste-rock followed by repeated cycles of water immersion and drying, neutralizes the acid produced by oxidation of sul-

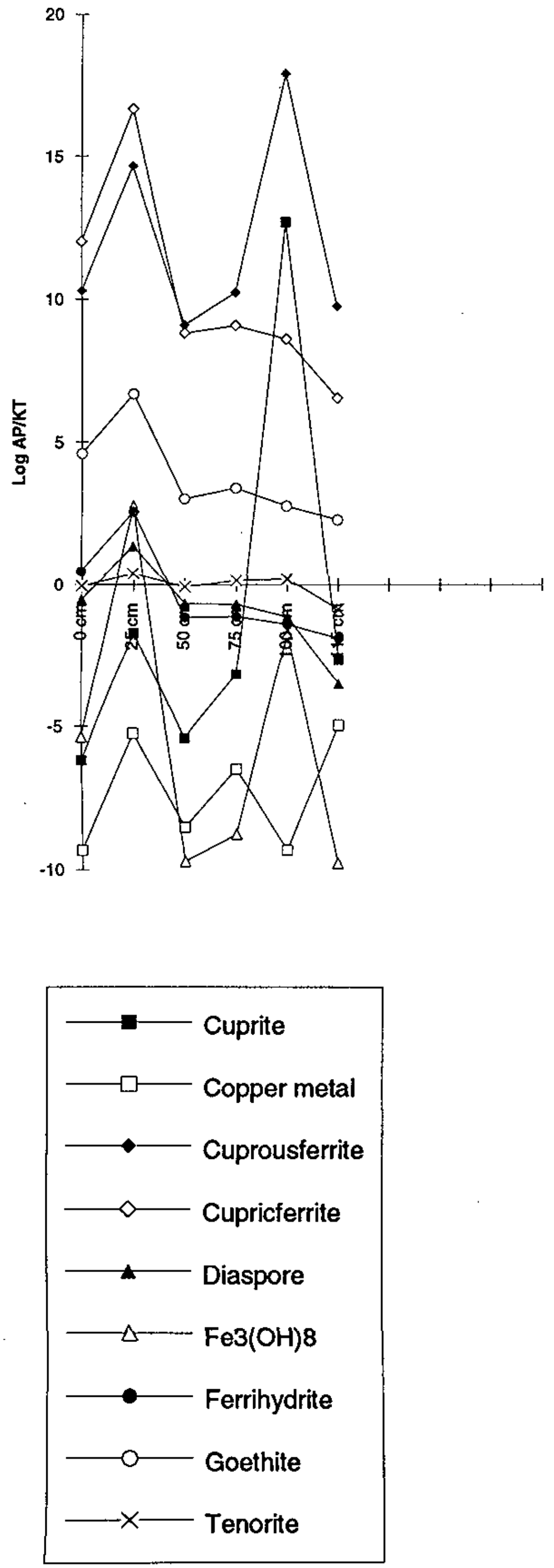

Figure 11. Solubility of minerals in Oct. 15 Column 1 leachate.

phides. The neutralization also decreases copper, lead and arsenic in the leachate from parts per million to parts per billion levels. The calcium hydroxide is consumed by the acid in about 20 days.

- 100 grams of calcium hydroxide slurry injected into the waste rock before repeated cycles of water immersion and drying also neutralizes the acid produced, suppresses the dispersion of heavy metals and improves the rate of neutralizer penetration throughout the waste-rock pile
- Even after acid conditions in the column indicate apparent exhaustion of the neutralizer, calcium hydroxide globules, protected by a hydroxide film, remain in the waste cavities. These globules inhibit dissolution of the early formed metal hydroxides and improve the efficiency of the neutralizer,
- Calcium hydroxide and other metal hydroxides accumulate as solid sludge at the bottom of the column. The high pH and increased amounts of copper in the leachate sampled from the base of the pile after repeated water immersion and drying of the waste suggests that amphoteric copper hydroxides are being remobilized and that copper can be progressively released into the leachate.
- The success of this base additive to control acid drainage is dependant on maintaining an alkaline interstitial water. Sustained control of acid drainage requires repeated application of the calcium hydroxide neutralizer. The sludge created during the process will no doubt alter the old established pathways of water and may give rise to new channels if the water flow through the rock pile is not reduced. Consequently, this process may effect the physical stability of the waste rock pile depending on its angle of repose.

DIRECTION OF FUTURE RESEARCH

These studies have shown that injection of a calcium hydroxide slurry into small, sulphide-bearing waste-rock pile is a promising, practical solution to the problem of acid rock drainage provided there are frequent additions of the neutralizer. However, more research is needed to examine the following aspects of the neutralizing mechanism.

- Extrapolation of the laboratory experiments to field studies where small waste pads are neutralized under conditions identical or similar to Mount Washington.
- The complex mineralogy of the precipitated minerals observed in column 1, and in particular, the composition of the calcium hydroxide clots. This will require detailed analysis using x-ray diffraction and possibly scanning electron microprobe.

- The effect of neutralizer applications on waste from mines mineralogically different from Mount Washington.

ACKNOWLEDGMENTS

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ASSESSMENT REPORTS
A SOURCE OF VALUABLE CURRENT AND HISTORIC MINERAL EXPLORATION DATA

By T.E. Kalnins and A.F. Wilcox

SUMMARY OF ASSESSMENT WORK, 1992

Results of mineral exploration programs are submitted by the industry to the Ministry in compliance with the Mineral Tenure Act Regulations and provide a valuable record of exploration data in British Columbia.

The number of assessment reports submitted and approved in 1992 totalled 616 with declared costs of $27 625 329, a 63% decrease in expenditures over year 1991. This mainly reflects decreased exploration activity throughout the province, particularly the Eskay Creek and Mount Milligan areas of northwestern and central British Columbia (Table 1, Figures 1, 2, and 3).

Drilling accounted for 46% of the expenditures, geochemistry 17%, physical work 10%, geophysics 9%, geology and prospecting 18% (Figure 4).

Assessment work, which is required for the maintenance of mineral claim tenure, comprises about half of the overall mineral exploration estimated at $50-60 million in the province.

Assessment work credits in excess of those applied to claim tenure may be recorded as Portable Assessment Credit (PAC) and used at a later date. Figure 5, Table 4 show that claim holders are taking advantage of these banked credits to maintain claim tenure during the current downturn in exploration activity.

Average exploration project costs by work type are shown in Tables 2 and 3. These values are based on clearly apportioned cost statements declared in 242 selected submissions, including labour, consulting, food, accommodation, transport, camp equipment rentals and supplies, laboratory analyses, report preparation, and direct administration and management of the project.

USING THE DATABASE

Assessment reports are the primary and most current source of detailed technical data available in the public domain. Data on exploration may be viewed or copies purchased after expiry of a confidentiality period (usually one year).

The Geological Survey Branch maintains a library of nearly 23 000 assessment reports dating from 1947. A computer index called ARIS (Assessment Report Indexing System) provides help to users wishing to locate specific information for planning new exploration programs, resource management - land use studies, or geoscience research.

Index maps on microfiche or paper at 1:250 000 scale (1:125 000 in southern B.C.) show the approximate centre of exploration reported. Page-size copies of these maps are included with the index printout. A basic bibliographic index printout is sorted by NTS map sheets. For each report the index provides latitude, longitude, UTM co-ordinates, claim names, operator, author, type of work reported and report year. The same data fields included in the paper index are organized as a series of flat ASCII files on diskettes to facilitate access by a variety of commercial software programs. The index is also available on

TABLE 1
SUMMARY OF ASSESSMENT WORK, 1992

NTS	No. of Assessment Reports	Value $	Geological (ha)	Geophysical Airborne (km)	Geophysical Ground (km)	Geochem. No. of Samples	Drilling Core (m)	Drilling Non-core (m)	Prospecting (ha)	Trenching (m)	Access Roads (km)	Line/grid (km)	Tunnelling (m)
82/83	162	5 159 099	48 851		807	24 481	30 287	1 375	9 929	4 414	10	487	480
92/102	207	6 707 310	67 853	531	1 054	37 199	35 269	2 090	9 928	6 134	7	439	
93	133	5 812 233	70 730	1 246	1 497	31 435	27 828	283	8 863	1 129	19	998	
94	29	3 051 036	15 075	1 040	623	13 408	13 024		6 825	390	20	397	
103	16	1 009 882	13 695	766	15	3 496	2 665		130			22	
104/114	69	5 885 769	41 138	2 332	277	18 852	17 083		10 735	413		254	
TOTALS													
1992	616	27 625 329	257 342	5 915	4 273	128 871	126 156	3 748	46 410	12 480	56	2 597	480
1991	1 304	74 379 878	326 022	61 357	9 076	320 505	235 267	22 379	112 943	35 891	170	4 920	1 680
1990	1 199	58 421 502	342 564	36 850	11 020	314 506	185 119	22 359	127 274	39 497	537	5 160	765

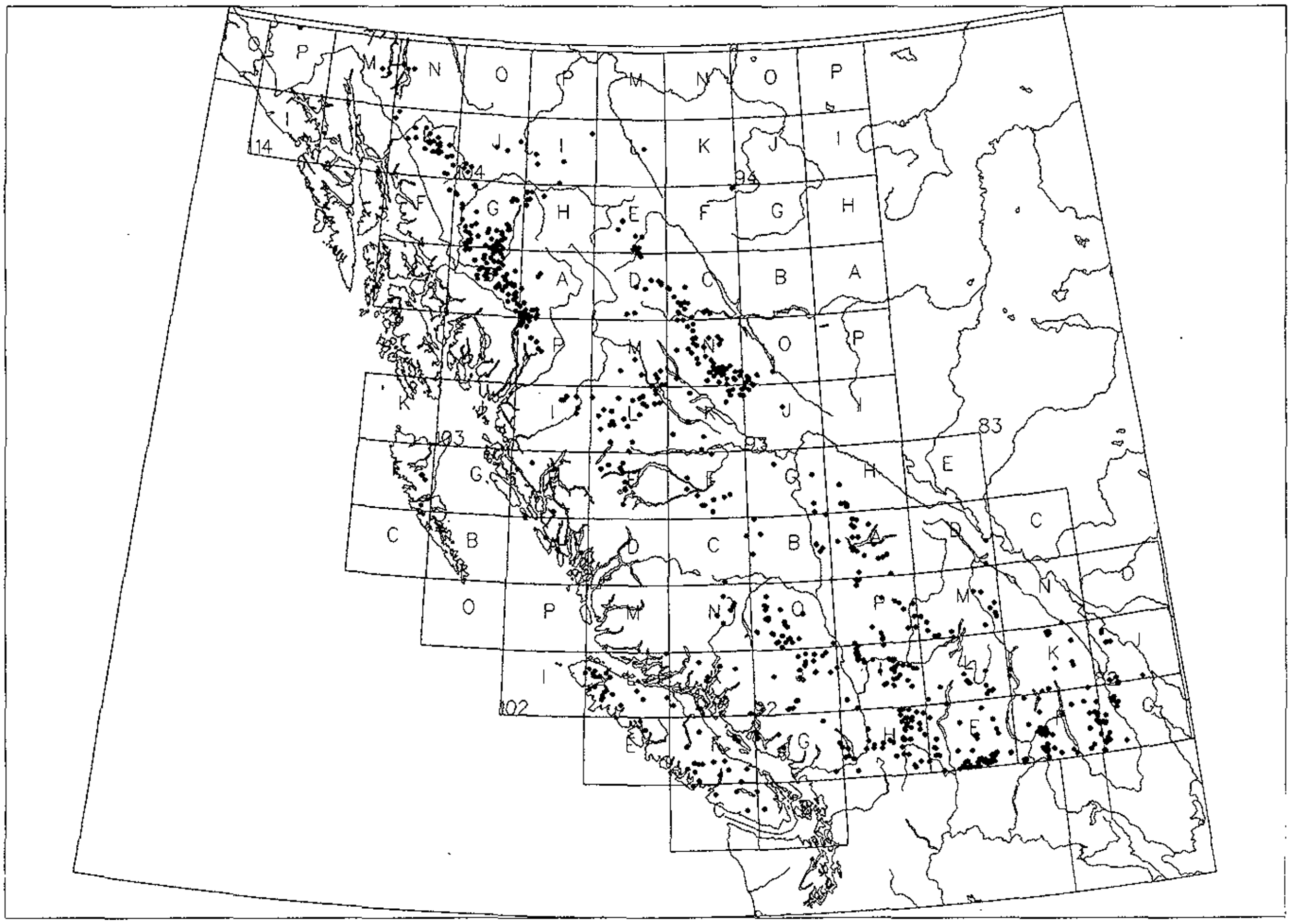

Figure 1. Assessment report distribution in B.C. - 1992.

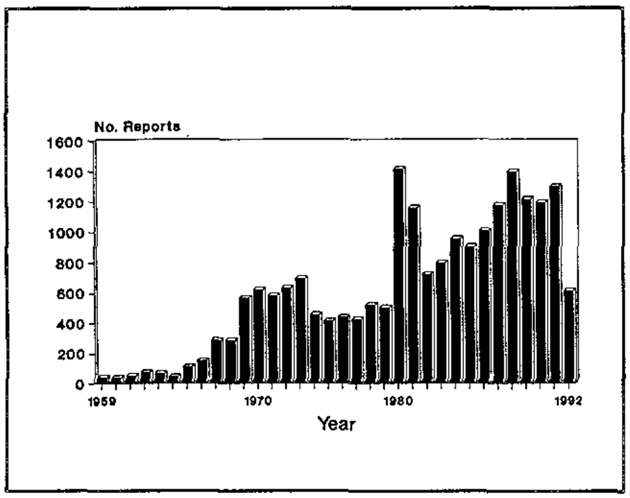

Figure 2. Assessment reports received.

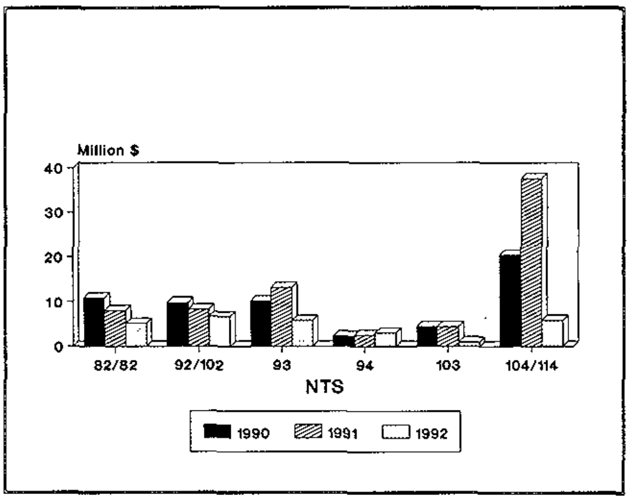

Figure 3. Assessment reports, value of exploration by NTS; 1990-1992.

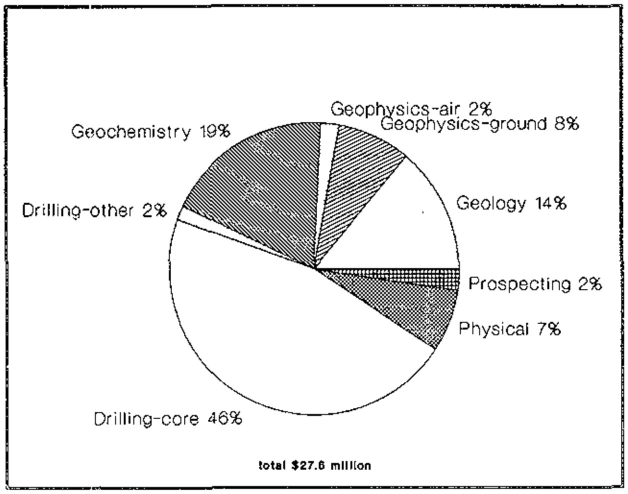

Figure 4. Value of exploration by work type; Assessment reports, 1992.

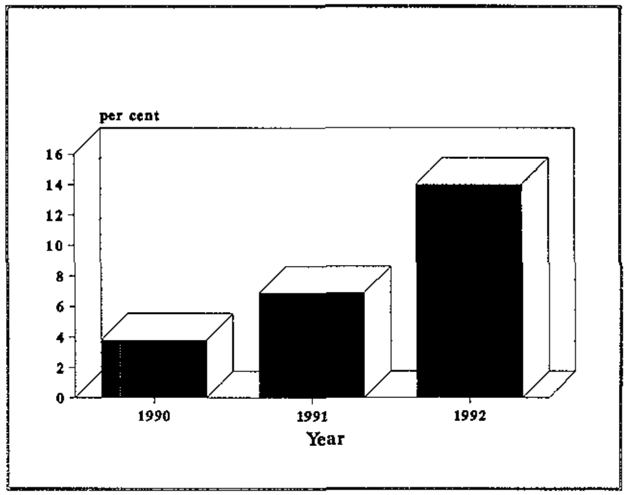

Figure 5. Portable assessment credits used; per cent of assessment work.

TABLE 2
EXPLORATION PROJECT COSTS, 1992

TYPE OF WORK	AMOUNT	UNITS	VALUE $	AVERAGE COST $		NO. OF SURVEYS
Geological mapping	109 401	ha	1 963 045	18	per ha	63
Petrography	85	samples	8 930	105	per sample	6
Magnetic, airborne	4 801	km	225 297	47	per km	9
Electromagnetic, airborne	4 436	km	225 274	51	per km	9
Magnetic, ground	795	km	194 897	245	per km	47
Electromagnetic, ground	565	km	268 041	474	per km	38
Induced polarization	494	km	541 766	1 098	per km	20
Self potential	30	km	23 220	784	per km	4
Soils	24 716	samples	877 709	36	per sample	66
Stream sediments	1 668	samples	136 393	82	per sample	24
Rock chips	2 186	samples	156 455	72	per sample	50
Sampling-assaying	26 479	samples	898 199	34	per sample	47
Core drilling	76 560	m	8 104 277	106	per m	43
Prospecting	22 270	ha	283 724	13	per ha	63
Line cutting, grid	1 325	km	729 396	550	per km	47
Road work	45	km	71 398	1 594	per km	7
Trenching	2 214	m	106 836	48	per m	8

TABLE 3
EXPLORATION PROJECT COSTS, 1990-1992
($ per unit of work)

Type of Work	1990	1991	1992
Geological mapping	11/ha	18/ha	18/ha
Petrographic	---	179/sample	105/sample
Mag./E.M., airborne	80/km	97/km	98/km
Magnetic, ground	170/km	138/km	245/km
Electromagnetic, ground	285/km	519/km	474/km
Induced polarization	1329/km	1258/km	1098/km
Self potential	---	---	784/km
Seismic	3969/km	---	---
Soils	32/sample	32/sample	36/sample
Stream sediments	115/sample	76/sample	82/sample
Rock chips	79/sample	72/sample	72/sample
Sampling-assaying	---	34/sample	34/sample
Drilling, core	109/m	128/m	106/m
Drilling, non-core	70/m	47/m	---
Prospecting	8/ha	10/ha	13/ha
Line cutting, grid	396/km	408/km	550/km
Trenching	---	38/m	48/m

TABLE 4
PORTABLE ASSESSMENT CREDITS (PAC)
1990-1992

Year	No. of Companies	No. of Entries	Total Debits	Credits	Work Debits	Title extension (PAC only)
1990	293	615	2 216 956	18 597 635	2 143 956	73 000
1991	355	799	5 110 808	32 519 024	4 795 008	315 800
1992	275	549	4 066 305	15 394 564	3 597 505	468 800

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