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Ministry of Energy, Mines and
Petroleum Resources
Hon. J. Weisgerber, Minister

MINERAL RESOURCES DIVISION
Geological Survey Branch

EXPLORATION
IN BRITISH COLUMBIA
1990

Part A - *Overview of Exploration Activity*

Part B - *Geological Descriptions of Properties*

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VICTORIA
BRITISH COLUMBIA
CANADA

JULY 1991

Eskay Creek Exploration Camp 1990, looking northeast.

FOREWORD

1990 has been a year of significant change for the mineral exploration and mining industry in British Columbia as the exploration industry adjusted to the termination of Flow Through Share financing for exploration. The Golden Bear mine officially reached commercial production in February, the Sullivan Pb-Zn mine reopened in November after a lengthy shutdown, and the Snip mine was closed to production at year end. Leading developments for the year included a new trend in metals exploration with a vigorous focus on copper-gold-porphyry systems such as Mount Milligan, Mount Polley and Galore Creek. In addition, continued encouraging results from the impressive Eskay Creek area in the Golden Triangle made this the busiest exploration area in the Province.

Claim staking in the province continued on an upward trend to exceed 96 000 units by the end of December, 1990. This is an increase of 3 per cent over 1989 and reflects, in large part, new activity in copper-gold-porphyry exploration. Exploration continued to emphasize precious metals but there is a growing interest in base metals, particularly copper and zinc.

The British Columbia Geological Survey Branch again had an active year of field surveying with projects in regional mapping, mineral deposits and regional geochemistry. Our new focus in the area of environmental and surficial geology is reflected in many of the papers in this issue of *Exploration in British Columbia*. The end of the 1985-1990 Canadian/British Columbia Mineral Development Agreement has brought to a completion many of the mapping and deposits research programs carried out under this program. This very successful program designed to assist and stimulate exploration and development in B.C. is expected to be renewed in 1991.

W.R. Smyth
Chief Geologist

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OVERVIEW OF EXPLORATION ACTIVITIES

BRITISH COLUMBIA EXPLORATION AND DEVELOPMENT HIGHLIGHTS FOR 1990

By V.A. Preto
Manager, District Geology and Coal Resources

INTRODUCTION

The year 1990 was one of new and significant developments in British Columbia. It was also one of transition for junior exploration companies and prospectors, the leading mine finders in the province, as they learned to adjust to life after flow-through.

Unlike 1989, which saw some of the most frantic activity ever, the junior-dominated Vancouver Stock Exchange was adversely affected by the termination of flow-through financing and continued negative publicity, and struggled through a very rough year. Its performance during September was the worst ever recorded.

New discoveries were few as most of the exploration activity was concentrated near exciting "hot spots", such as **Eskay Creek** and **Mount Milligan**, leaving the rest of the province, and particularly the southern half, much quieter.

Exploration expenditures are anticipated to total $143 million, only slightly lower than the $150 million spent in 1989. These expenditures, however, are very unevenly distributed across the province. It is anticipated that some $60 million has been spent in the Stewart - Iskut River area, British Columbia's Golden Triangle, $29 million of this at **Eskay Creek**, which continues to be accessible only by air. Another $25 million or so has been spent in a handful of other major projects in the northwest. Expenditures of $33 million are anticipated for the northern Quesnel trough because of the **Mount Milligan** success, leaving only $25 million, or roughly 16 per cent, for the remainder of the province. Most of these expenditures have been made by major companies which have

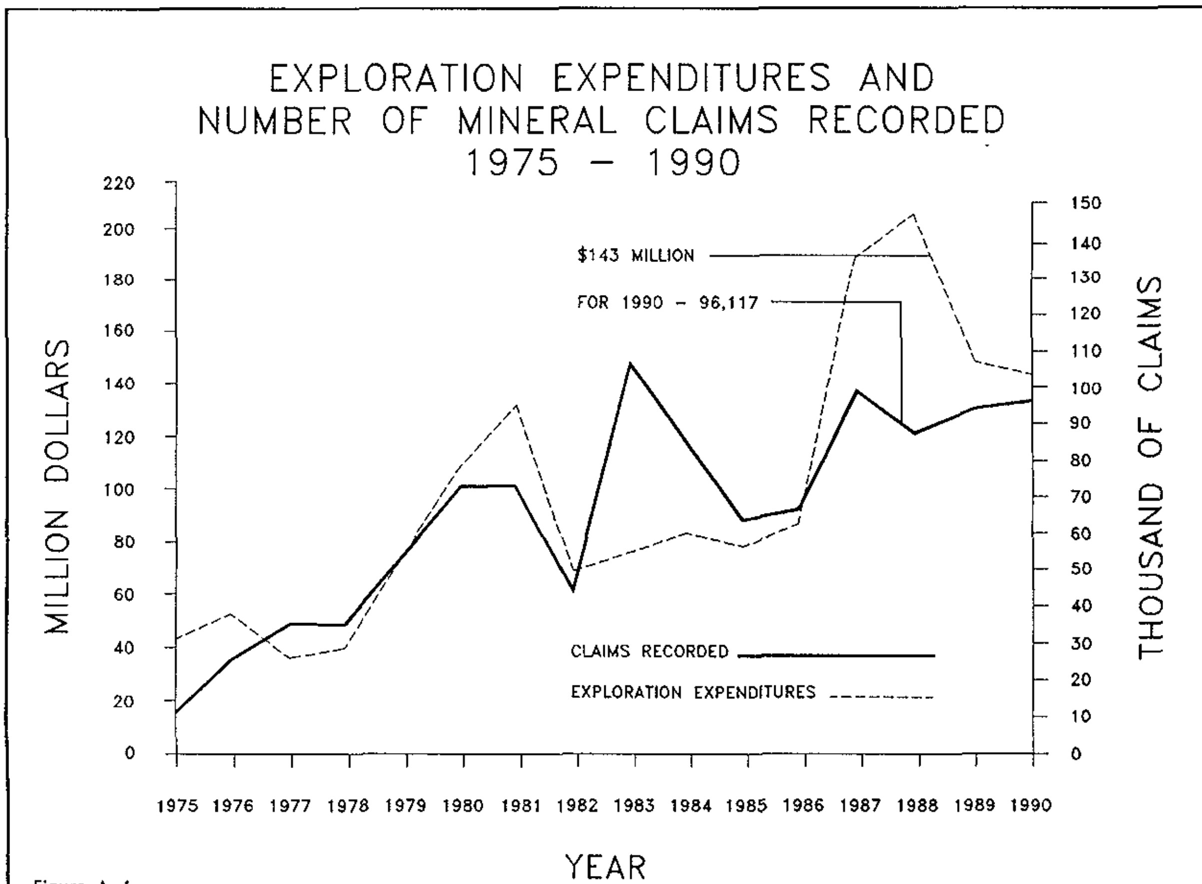
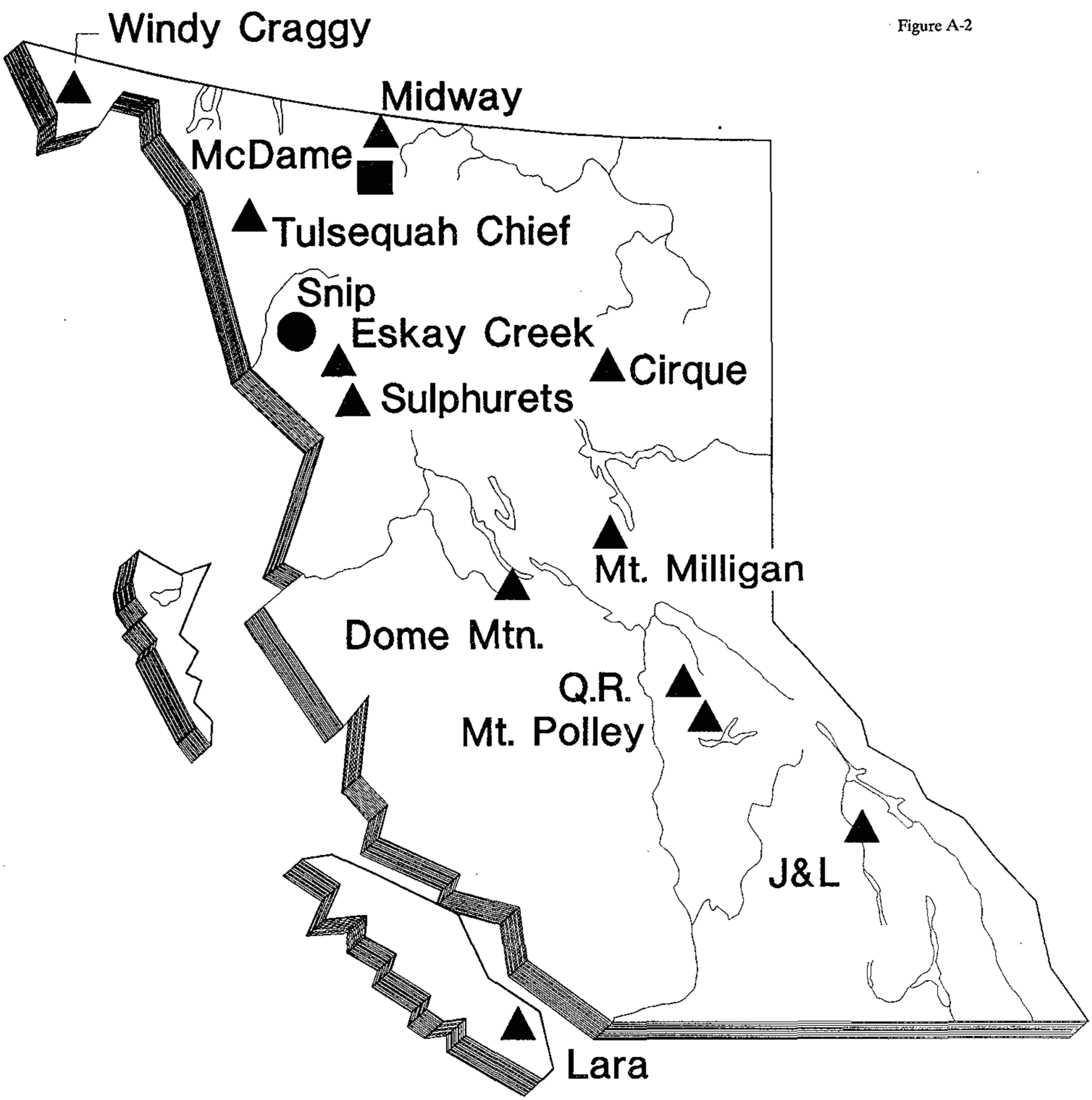


Figure A-1

Figure A-2



LOCATION OF PROJECTS

NEW MINES ■
DEVELOPMENT STAGE ●
ADVANCED EXPLORATION STAGE ▲

either acquired or increased control of some of the key properties such as **Eskay Creek, Snip, Tulsequah Chief,** and **Kerr.**

Mineral claims staking was up 3 per cent, to 96 117 units, by the end of December 1990 continuing the upward trend that began in 1989 . The busiest mining divisions continue to be Liard, Omineca and Skeena, all in the northern part of the province and all good areas for precious and base metals.

ADVANCED PROJECTS

In contrast with the difficulties experienced by the juniors' grass-roots programs, several large projects at the advanced exploration or prefeasibility stage, and financed primarily by major companies, reached significant milestones. In the extreme northwest corner of the province, a third, and new, copper zone, termed the Ridge zone, was discovered at the **Windy Craggy** copper-gold massive sulphide deposit of Geddes Resources Limited which is at Stage I in the Mine Development Review Process. Early in July, Cominco Ltd. formally announced the decision to proceed with the $65-million **Snip** gold project, held jointly with Prime Resources Group Inc. Production is expected to start in January 1991. Drilling and underground exploration at the rich **Eskay Creek** gold-silver deposit of Prime Resources Group and Corona Corporation continued, with positive results, and was highlighted in August by the spectacular intersection of the 21B zone in the decline. This project entered the Mine Development Review Process in April. An aggressive deep-drilling program by Cominco Ltd. and Redfern Resources Ltd. at the **Tulsequah Chief** volcanogenic massive sulphide deposit was rewarded with a spectacular 50-metre intersection which, together with other "hits", could significantly increase the reserve potential of this deposit. Continued drilling success at the **Sulphurets** gold-silver property of Newhawk Gold Mines Ltd. and Granduc Mines Ltd. brought this project to a feasibility study by Corona Corporation in October.

Control of the giant **Mount Milligan** gold-copper porphyry deposit of Continental Gold Corp. was formally taken over by Placer Dome Inc. in the fall. To November 1st, 1990, 758 holes had been drilled at this project which entered the Mine Development Review Process in February. Drilling continues at a reduced pace, pending a feasibility study and a production decision. A feasibility study of the **Mount Polley** copper-gold porphyry deposit of Imperial Metals Corporation and Corona Corporation concluded that this $131.5-million open-pit project would have a payback period of 3.6 years. The project is at Stage I in the Mine Development Review Process and awaiting financing. The $22-million **Q.R.** gold project of QPX Minerals Inc., received Approval-in-Principle by the Mine Development Review Committee and is also awaiting a production decision.

To facilitate exploration in the rugged Iskut River region, and to provide needed access to the developing **Snip** and **Eskay Creek** properties, the provincial government entered into a joint venture agreement with Cominco Ltd. and Prime Resources Group Inc. to proceed with planning and building a road to link the Stewart-Cassiar Highway with the two properties.

MINES

The total value of solid mineral production for 1990 is estimated at $3.265 billion, compared to $3.218 billion in 1989. In the metal sector, gold production is projected to be up approximately 10 per cent to 16.5 million grams (530 500 oz) reflecting new output from **Golden Bear**, and **Premier Gold**, as well as increased output from **Lawyers, Samatosum, Afton** and **Equity Silver.** Silver production is anticipated to be up 22 per cent to about 645 million grams (20.7 million oz) reflecting full production from **Samatosum** and increased output from **Equity Silver** and **Highland Valley Copper.** Copper remains the most important metal by far, with an anticipated production of approximately 335 000 tonnes, worth in excess of $1 billion, while coal continues to top the solid mineral production list with an anticipated output valued at $1.2 billion.

Although no new metal mines opened during 1990, the **Golden Bear** gold mine, of Golden Bear Operating Co. and Homestake Mining (B.C.) Ltd, which had opened late in 1989, officially reached commercial production in February, and the **Sullivan** lead-zinc mine of Cominco Ltd., reopened on November 1st after a 9-month shut down. In addition, the underground **McDame** asbestos mine of Cassiar Mining Corporation, opened as planned in November.

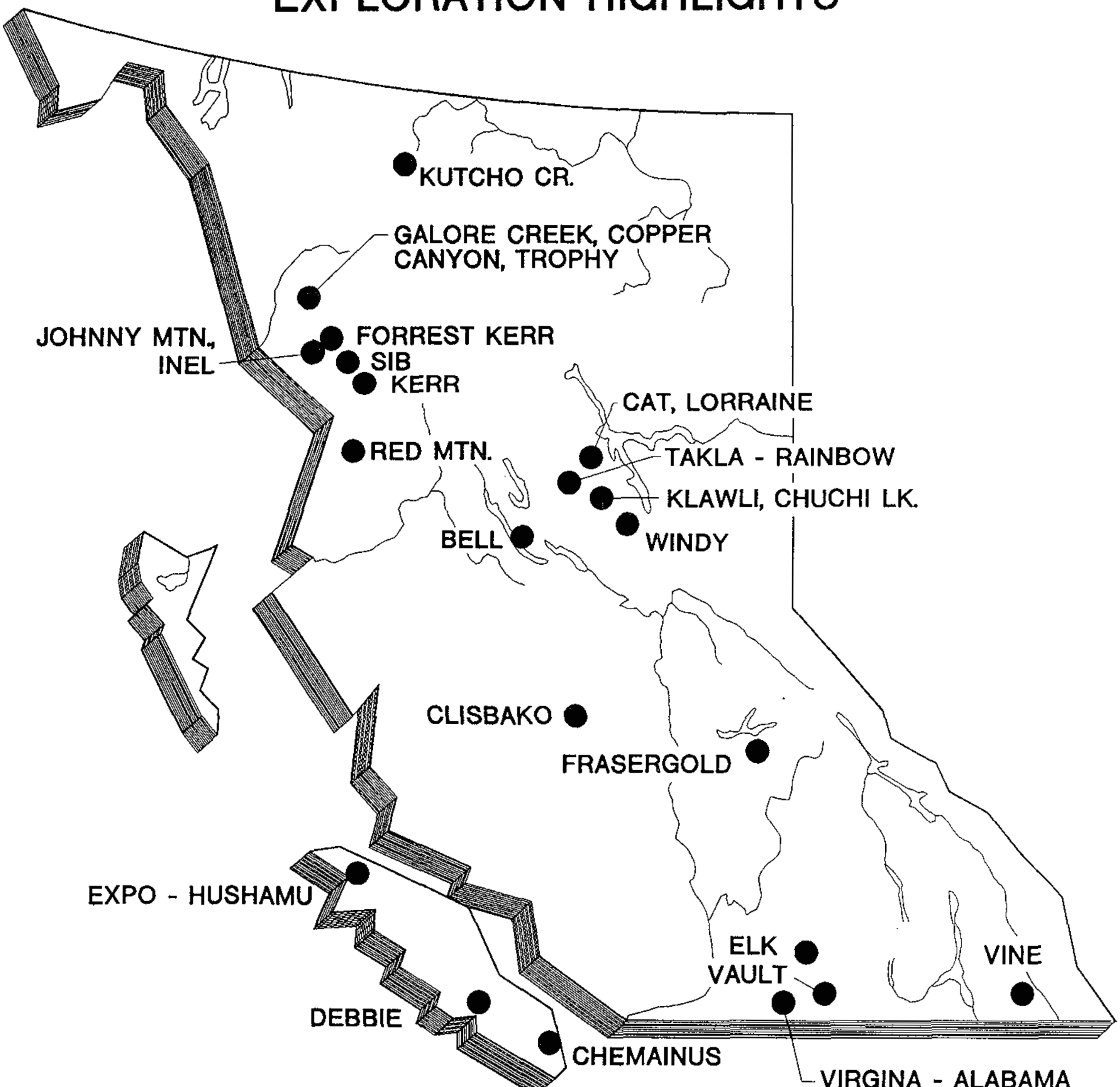
Following the trend that began in 1988-89, exploration interest continued to grow for deposits offering more than one recoverable product, such as volcanogenic massive sulphides and copper-gold porphyry deposits, while remaining strong for high-quality precious metal deposits. The targets that received most of the exploration attention are summarized below.

VOLCANOGENIC AND SEDIMENT-HOSTED MASSIVE SULPHIDE DEPOSITS

Volcanogenic massive sulphide targets in Paleozoic and Mesozoic submarine volcanic sequences continued

Figure A-3

1990
EXPLORATION HIGHLIGHTS



to receive the most attention because of the relatively high unit-value of these deposits, variety of metals contained, and most importantly, continuing success at key properties.

Perhaps the most significant exploration news of the year was the spectacular 50-metre intersection grading 2.92 per cent copper, 1.58 per cent lead, 9.09 per cent zinc, 3.83 grams per tonne gold and 170 grams per tonne silver reported by Cominco Ltd. and Redfern Resources Ltd. from Hole 90-22 at their **Tulsequah Chief** property. The focus of the year's program was deep drilling from newly created underground stations to test the possibility of a new ore lens (H) lying above the previously known "A" and "B" lenses. The intersection in Hole 90-22 and others from the same program could significantly increase the geologically indicated reserves of this deposit which in 1989 had been reported by Redfern Resources to be 5.27 million tonnes grading 1.6 per cent copper, 1.31 per cent lead, 7.03 per cent zinc, 2.74 grams per tonne gold and 100.46 grams per tonne silver.

In the extreme northwestern corner of the province, Geddes Resources Ltd. continued with a $15.5-million program on its **Windy Craggy** copper-gold deposit. This property is at Stage I in the Mine Development Review Process and much of the work done consisted of baseline environmental and engineering studies and drilling, as well as fill-in and test drilling in the area of the proposed open pit. During the course of this work a new copper zone, named the Ridge zone, was discovered. Other highlights of the 1990 program are the identification of an oxide capping, enriched in gold and silver, overlying the North zone, and confirmation of areas of higher zinc grades in the North zone. Shortly before the discovery of the Ridge zone, current probable and possible reserves had been recalculated at 210 million tonnes grading 1.59 per cent copper, 0.18 gram per tonne gold, 3.62 grams per tonne silver and 0.09 per cent cobalt at a 0.5 per cent copper cut-off.

In the north-central part of the province, approximately 80 kilometres southeast of Dease Lake, Homestake Explorations Ltd. and American Reserve Mining Corporation carried out a medium sized drilling program in the area of the **Kutcho Creek** deposit. This volcanogenic massive sulphide deposit, hosted by intensely deformed Upper Triassic felsic pyroclastic rocks, was discovered in the early 1970s. It has pittable reserves of 17 million tonnes grading 1.51 per cent copper, 2.16 per cent zinc and 27.3 grams per tonne silver.

In the busy Golden Triangle, a continuing major exploration effort at the **Eskay Creek** gold-silver deposits of Corona Corporation, Prime Resources Group Inc., Placer Dome Inc. and Adrian Resources Ltd., has shown that the bulk of the mineralization known to date is of a stratabound volcanogenic massive sulphide type (*e.g.* southern 21B deposit) while other deposits have distinct epithermal characteristics (*e.g.* 21A deposit and perhaps the northern 21B deposit). The Eskay Creek deposits were the object of $29 million surface and underground exploration programs, entirely supported by air. Much of the mineralization is hosted by argillaceous rocks of the lower member of the Middle Jurassic Salmon River Formation, while lesser, but still very important, amounts occur in underlying Lower Jurassic rhyolite of the Mount Dilworth Formation and dacite of the Betty Creek Formation.

Extensive surface and underground drilling and detailed mapping in the newly created underground workings are gradually improving our knowledge of these deposits. It is evident that the mineralization hosted in the argillite is of a sedimentary exhalative nature, as indicated by abundant thin laminations, slumps and other sedimentary features in the sulphide beds. A significant and rich part of the orebody, however, occurs in the footwall rhyolite sequence and is known to have classic epithermal features. Whether the Eskay Creek deposits should be classed as an epithermal or a volcanogenic-sedex system remains open. The sulphides are probably the product of a very shallow hydrothermal system which vented on the seafloor producing both exhalative volcanogenic and epithermal deposits. Some drill holes probing the deeper parts of the system have also indicated stockwork and porphyry-style mineralization, and it may well be that future work will outline significant reserves of this type in the roots of this truly world-class deposit. A recent reserve estimate for the main part of the deposits controlled by the Prime/Corona/Placer Dome interests, including the 21B Zone and parts of the 21C and Pumphouse Lake zones and calculated using a 3.42 grams per tonne gold cut-off yielded a geological reserve of 3.967 million tonnes grading 26.4 grams per tonne gold and 998.4 grams per tonne silver plus significant values in zinc and lead. Additional geological reserves in the order of 4.6 million grams of gold-equivalent have been indicated on the part of the 21B Zone and the TOK claim gap controlled by Adrian Resources Ltd. In addition, there is significant potential to increase reserves in at least seven zones. The Eskay Creek project entered the Mine Development Review Process earlier in the year and a Stage I report is scheduled for the spring of 1991.

American Fibre Corporation and Silver Butte Resources Ltd. continued exploration on the **SIB** deposit, located only 5 kilometres southwest of 21B Zone at Eskay Creek and discovered a new zone of gold, antimony and zinc mineralization hosted by graphitic mudstones interbedded in dacitic pyroclastics. This type of occurence is exciting because of its similarity and proximity to the 21B Zone at Eskay Creek.

Table A-1a
New Mines, Development and Advanced Exploration Projects

Project Status/ Company Name	Project Name	Commodity	Estimated Tonnes 1000's	Estimated Grade %, g/t	Estimated Employment
New Mines					
Cassiar Mining Corporation	McDame	Asbestos	16 000	--	145-170
Development (production decision announced)					
Cominco Ltd., Prime Resources Group Inc.	Snip	Au	936	30 g/t Au	150
Advanced Exploration					
Geddes Resources Ltd.	Windy-Craggy	Cu, Au, Ag, Co	210 000	1.59% Cu, 0.18 g/t Au. 3.62 g/t Ag, 0.09% Co	600
Teeshin Resources Ltd.	Dome Mtn.	Au, Ag	295	12.2 g/t Au, 80 g/t Ag	55
Curragh Resources Inc.	Cirque	Pb, Zn, Ag	34 600	2.1% Pb,7.8% Zn, 47 g/t Ag	200
Equinox Res. Ltd.	J & L	Au, Ag, Zn, Pb	808	7.2 g/t Au, 65.7 g/t Ag, 5.2% Zn, 2.5% Pb	80-90
Minnova Inc.	Lara	Au, Ag, Zn, Cu, Pb	529	4.73 g/t Au, 100.1 g/t Ag, 5.8% Zn, 1.01% Cu, 1.22% Pb	?
Corona Corp., Prime Resources	Eskay Creek	Au, Ag	3,967	26.4 g/t Au, 998.4 g/t Ag	200+
Placer Dome Inc.	Mt. Milligan	Cu, Au	400 000	0.2% Cu, 0.48 g/t Au	350+
Imperial Metals Corp., Corona Corp.	Mt. Polley	Cu, Au	48000	0.38% Cu, 0.548 g/t Au	250
Q.P.X Minerals Inc.	Q. R.	Au	1,200	5.22 g/t Au	75
Newhawk Gold Mines Ltd., Granduc Gold Mines Ltd.	Sulphurets	Au, Ag	500.8	14.33 g/t Au, 617 g/t Ag	50-60
Cominco Ltd., Redfern Resources Ltd.	Tulsequah Chief	Cu, Pb, Zn, Au, Ag	5,272 (Redfern Resources)	1.6% Cu, 1.31% Pb, 7.03% Zn, 2.74 g/t Au, 100.45 g/t Ag	?
Regional Resources Ltd.	Midway	Ag, Pb, Zn		7% Pb, 9.6% Zn, 410 g/t Ag	?

In the northeastern part of the province, Curragh Resources Inc. announced a $2-million program of underground exploration and bulk sampling on the **Cirque** sediment-hosted lead-zinc-silver massive sulphide deposit. The deposit is located 280 kilometres north of MacKenzie, the nearest railhead, and has geological reserves of 34.6 million tonnes grading 2.1 per cent lead, 7.8 per cent zinc and 47.0 grams per tonne silver.

In the south-central part of the province, the **J&L** deposit of Equinox Resources Ltd., located a short distance by road north of Revelstoke, was optioned by Cheni Gold Mines Inc. This deposit has drill-indicated reserves of 808 000 tonnes grading 7.2 grams per tonne gold, 65.7 grams per tonne silver, 5.2 per cent zinc, and 2.5 per cent lead.

On Vancouver Island, near Chemainus, Minnova Inc. continued with exploratory drilling on the **Lara** property which has indicated reserves of 529 000 tonnes grading 4.73 grams per tonne gold, 100.1 grams per tonne silver, 5.87 per cent zinc, 1.01 per cent copper and 1.22 per cent lead. Falconbridge Limited carried out a drilling program on adjacent claims, searching for similar massive sulphide targets. Both properties are underlain by Paleozoic volcanic rocks of the Sicker Group.

EPITHERMAL DEPOSITS

Interest in precious metal bearing epithermal systems in Mesozoic to Tertiary volcanic rocks continued high in several parts of the province. West of Quesnel, near Mount Dent, Eighty-eight Resources Ltd. carried out a surface exploration program on the **Clisbako** gold-silver deposit. Little is known at this time about this new discovery, other than it is epithermal in nature and hosted by Eocene Ootsa Lake volcanics.

In the south-central part of the province, 40 kilometres southeast of Merritt, Fairfield Minerals Ltd. and Placer Dome Inc. continued with an aggressive surface drilling and trenching program on the **Elk** property. This is a quartz-sulphide vein system of possible Tertiary age, hosted by the Jurassic Pennask granodiorite. The vein system has been traced on the surface continuously for a distance of 390 metres and intermittently for another 485 metres. It has been tested by 55 drill holes to a depth of 75 metres. Fifteen per cent of the drill holes have returned values greater than 7.9 grams per tonne gold across a true width of 2 metres, while 73 channel samples from a 390-metre continuous trench yielded an average of 17.4 grams per tonne gold across 2 metres true width.

In the southern Okanagan, Inco Gold Co. continued drilling on its **Vault** property, a gold epithermal system hosted in Eocene volcanic rocks.

PORPHYRY DEPOSITS

Driven by the success of the **Mount Milligan** and **Mount Polley** projects, and by reasonably strong copper prices, alkalic copper-gold porphyry systems hosted by Upper Triassic to Lower Jurassic volcanic sequences of the Intermontane Belt continued to be one of the most popular exploration targets in the province. The search for these was responsible for a sharp increase in activity and claim staking in the Quesnel trough, particularly north of Fort St. James, and in the Stikine region near the **Galore Creek** deposit. Gold-rich porphyry systems of the calcalkalic suite were the target of the largest exploration play on Vancouver Island, along what is known as the **North Island Copper Belt** west of the **Island Copper** mine.

In the **Galore Creek** camp Mingold Resources Inc. drilled a number of gold-copper-rich zones that are peripheral to the main alkalic porphyry system. Particular emphasis was put on the **Southwest zone** which also gave the best results and will undoubtedly receive further work. These peripheral zones have yielded intersections grading 3.5 to 10 grams per tonne gold and 1 to 2 per cent copper over 10 to 25 metres. The main Galore Creek deposit, discovered in the 1950s, has drill-indicated reserves of 113 million tonnes grading 1.06 per cent copper, 0.445 gram per tonne gold and 8.57 grams per tonne silver.

A short distance to the east of the Galore Creek deposit, Consolidated Rhodes Resources Ltd. intersected very significant widths of copper-gold porphyry mineralization in drilling the **Copper Canyon** property, an old prospect drilled by Amax Exploration Inc. in the late 1950s and early 1960s.

East of the Unuk River, Placer Dome Inc. carried out a major program, including 17 000 metres of drilling in 74 holes, on the **Kerr** property which was purchased late in 1989 from Western Canadian Mining Corporation and Sulphurets Gold Corporation. Drilling prior to 1990 indicated reserves of 114 million tonnes grading 0.61 per cent copper and 0.27 gram per tonne gold

The Quesnel trough, north of Fort St. James, was one of the most active areas of the province. The impetus was provided by the continued success of the **Mount Milligan** copper-gold project. This large alkalic porphyry system is hosted by Upper Triassic to Lower Jurassic volcanic and high-level intrusive rocks of the Takla Group. The property has been under continuous exploration by Continental Gold Corp. and B.P. Resources Canada Ltd. since 1986 and, as of November 1st, 1990, had been tested by 758 drill holes totalling 168 344 metres. In the fall of 1990 Placer Dome Inc. acquired the property and is now the sole owner and operator. Copper-gold mineralization occurs in a very large sulphide system, 10 square kilometres in area. Drilling to date has indicated a pittable reserve of 400 million tonnes grading 0.2 per cent copper and 0.480 gram per tonne gold in two deposits, **Mount Milligan** and **Southern Star**, clustered at the eastern end of the sulphide system. The Mount Milligan project entered the Mine Development Review Process in February, and drilling continues at a reduced pace, pending a feasibility study.

Drilling, and regional mapping by J.L. Nelson and K. Bellefontaine of the Geological Survey Branch, have shown that the Mount Milligan deposit occurs in a subvolcanic setting similar to that of other deposits of this type in southern and northern British Columbia. Furthermore, at least a dozen previously unrecognized small intrusions similar to those that created the Mount Milligan deposit were identified in the two 1:50 000 quadrangles that were mapped.

Work along the Mesozoic volcanic belt from Fort St. James north to the Osilinka River has involved a great many projects, most including drilling. Most notable amongst these are **Cat** of B.P. Resources Canada Inc. and

Table A-1b
EXPLORATION HIGHLIGHTS

Exploration Company Name	Name Project	Commodity	Estimated Tonnes 1000's	Estimated Grade %, g/t	Expenditures ($ Million)
Homestake Expln. Ltd.	Kutcho Ck.	Cu, Au, Ag	17,000	1.51% Cu, 2.16% Zn 27.3 g/t Ag	1.0
American Fibre Silver Butte Res.	Sib	Au, Zn	--	--	?
Bond Internatinal Gold Inc., Lac Minerals Ltd.	Red Mountain	Au	--	--	?
Eighty-eight Res. Ltd.	Clisbako	Au	--	--	?
Fairfield Minerals Ltd., Placer Dome Inc.	Elk	Au	--	--	0.75
Inco Gold Co., Ltd.	Vault	Au	--	--	1.1
Mingold Resources Inc.	Galore Ck.	Cu, Au, Ag	113 000	1.06% Cu, 0.445 g/t Au, 8.57 g/t Ag	?
Consolidated Rhodes Resources Ltd.	Copper Canyon	Cu, Au	--	--	?
Placer Dome Inc.	Kerr	Cu, Au	114 000	0.61% Cu, 0.27 g/t Au	2.8
B.P. Res. Canada Ltd., Lysander Gold Corp	Cat	Cu, Au,	--	--	?
Kennco Exploration	Lorraine	Cu, Au	--	--	?
Cathedral Gold Corp., Eastfield Resources Ltd.	Takla-Rainbow	Cu, Au	--	--	?
Rio Algom Expln., Ltd.	Klawli	Cu, Au	--	--	?
B.P. Res. Canada Ltd.	Chuchi Lake	Cu, Au	--	--	?
Placer Dome Inc.	Windy	Cu, Au	--	--	?
Princeton Mining Corp.	Virginia-Alabama (Copper Mtn.)	Cu, Au	23 000 (approx)	0.3-0.4% Cu, 0.2 g/t Au	2.2
Noranda Inc.	Bell Mine	Cu, Au	--	--	1.0
Moraga Resources Ltd.	Expo-Hushamu	Cu, Au, Mo	79,000	0.3% Cu, 0.34 g/t Au 0.023% Mo	1.0
Placer Dome Inc.	Johnny Mtn.	Au	--	--	2.5
Gulf International Minerals Ltd.	Inel	Au	--	--	2.5
Kokanee Explorations Ltd., Cominco Ltd.	Vine	Pb. Zn, Ag	--	--	1.1
Goldbelt Mines Inc., Gigi Resources Ltd.	Trophy	Au, Ag, Zn, Pb, Cu		--	--1.0
Avondale Resources Ltd.	Forrest Kerr	Cu, Au	--	--	1.5
Eureka Resources Ltd.	Frasergold	Au	20,000	2.5 g/t Au	1.4
Westmin Mines Ltd.	Debbie	Au	--	--	1.0
Falconbridge Ltd.	Chemainus	Au, Ag, Zn, Pb, Cu		--	--1.0

Lysander Gold Corporation, **Lorraine** of Kennco Exploration, **Takla-Rainbow** of Cathedral Gold Corporation and Eastfield Resources Ltd., **Klawli** of Rio Algom Exploration Inc., **Chuchi Lake** of B.P. Resources Canada Inc. and **Windy** of Placer Dome Inc.

In the southern Quesnel trough, near Likely, the **Mount Polley** project of Imperial Metals Corporation and Corona Corporation received a positive feasibility report. Open-pit reserves at this alkalic porphyry deposit are 48.8 million tonnes grading 0.38 per cent copper and 0.548 gram per tonne gold. This $131.5-million project is at Stage I in the Mine Development Review Process and is awaiting financing. The nearby **Q.R.** deposit of QPX Minerals Inc. has already received Approval-in-Principle by the Mine Development Review Committee. This smaller alkalic porphyry system is also hosted in Upper Triassic to Lower Jurassic Takla Group volcanic and sedimentary rocks and has pittable reserves of 1.2 million tonnes grading 5.22 grams per tonne gold.

In the south-central part of the province, Princeton Mining Corporation undertook an aggressive drilling program to test the **Virginia** and **Alabama** copper zones near its Similco open-pit mining operation at **Copper Mountain**. Its efforts were successful and should significantly extend mine life. New reserve figures are expected shortly. The Copper Mountain copper-gold alkalic porphyry camp produced from 1917 to 1962, and from 1972 to date, including the separate **Ingerbelle** mine. Current reserves are in the order of 180 million tonnes grading 0.4 per cent copper and 0.086 gram per tonne gold. If past production is added to the present reserves, the total inventory for this camp is in the order of 300 million tonnes.

In the Babine Lake area, northeast of Smithers, Noranda Minerals Inc. carried out a significant drilling program at its **Bell mine.** Reports are that the program was successful but the company has not yet stated whether or not reserves have been increased. The Bell deposit is a calcalkalic copper-gold system which since 1972 has produced approximately 65 million tonnes grading 0.48 per cent copper and 0.165 gram per tonne gold.

On Vancouver Island, Moraga Resources Ltd. carried out a large drill program on the **Hushamu** zone of its **Expo** property, west of the B.H.P. Utah Mines Ltd. **Island Copper** operation. This calcalkalic porphyry system has been recently reported to contain an initial pit reserve of 79 million tonnes grading 0.3 per cent copper, 0.34 gram per tonne gold and 0.023 per cent molybdenum at a stripping ratio of 0.8:1, with a much larger reserve potential at a stripping ratio of roughly 1.5:1.

MESOTHERMAL VEINS AND TRANSITIONAL DEPOSITS

Mesothermal veins and deposits that formed in a transitional setting between the classic epithermal environment and the deeper seated porphyry environment are another important target. Many of these deposits are found in British Columbia's Golden Triangle and include the **Snip** gold deposit of Cominco Ltd. and Prime Resources Group Inc. This $65-million project is under construction and production is expected to begin in January 1991 at 300 tonnes per day. Ore reserves at **Snip**, recalculated using a 12.5-metre drill spacing and a dilution factor of 20 per cent at zero grade, are 936 000 tonnes grading 30 grams per tonne gold. Immediately south of the Snip deposit, Placer Dome Inc. carried out a $2.5-million drilling program on the **Johnny Mountain (Reg)** gold deposit, under option from Skyline Gold Corporation. This mine suspended operations in September, due to exhausted ore reserves, after only two years of operation. A short distance to the southeast, at the head of Bronson Creek, Gulf International Minerals Ltd. carried out an underground drilling program of similar size to test the **Inel** gold deposit.

Located approximately 50 kilometres southeast of Snip is the **Sulphurets** deposit of Newhawk Gold Mines Ltd. and Granduc Gold Mines Ltd. Corona Corporation carried out a feasibility study on the **West zone** of this deposit and concluded that, based on a 320 tonne per day operation, the project would require an investment of $42.7 million to bring it on-stream and would incur direct operating costs of $265 per ounce gold-equivalent. Fully diluted mineable reserves for the West zone are 500 800 tonnes grading 14.33 grams per tonne gold and 617 grams per tonne silver. The Sulphurets deposit also has several other zones of very significant mineralization which have been explored less than the West zone.

Bond International Gold Inc. and Lac Minerals Ltd. carried out a major program using three drills on their **Red Mountain** gold property located 15 kilometres east of Stewart. Very little information is available about this property which was discovered in 1989. Preliminary indications are that this is a structurally controlled mesothermal vein system in a porphyry environment.

Teeshin Resources Ltd. announced late in the year that it had reached an agreement with Timmins Nickel Inc. to place the **Dome Mountain** gold property in production. Reserves at this deposit are reported at 295 000 tonnes grading 12.2 grams per tonne gold and 80 grams per tonne silver. Mining is planned at about 300 tonnes per day, with projected operating costs of $250 to $260 per ounce of gold.

Near Moyie, southwest of Cranbrook, Kokanee Explorations Ltd. and Cominco Ltd. carried out a substantial drilling program testing the **Vine** lead-zinc-silver vein system.

OTHER SIGNIFICANT DEPOSITS

A number of other precious and base metal deposits are definite highlights.

In the Rancheria area, Regional Resources Ltd. undertook a $7.2-million program of mine rehabilitation, underground drifting and drilling on the **Discovery zone** of the **Midway** silver-lead-zinc deposit. This is a manto-type replacement deposit consisting of laterally continuous pipes and pods of mineralization along the contact between a Devonian carbonate unit and overlying shale. Drill-indicated reserves are 1.19 million tonnes grading 7 per cent lead, 9.6 per cent zinc and 410 grams per tonne silver.

In the Stikine - Iskut - Unuk River area significant programs were completed on a variety of gold, silver and base metal deposits, some with skarn affinities, some replacements along faults and shears, and some breccias and replacements along faults, probably related to porphyry systems. These include the **Unuk River** project of Granges Exploration Ltd., the **Jack Wilson Creek** property of Bellex Mining Corporation and Quattro Resources Ltd., the **Trophy** breccia and skarn system of Goldbelt Mines Inc. and Gigi Resources Ltd., the **Forrest Kerr** property of Avondale Resources Ltd. and the **Bronson Creek** property of Cathedral Gold Corporation.

In the Quesnel Lake area, Eureka Resources Inc. carried out a large drilling program on the **Frasergold** deposit, where gold occurs in quartz-carbonate veins and pods in a black phyllite host. Geological reserves are 20 million tonnes grading 2.5 grams per tonne gold.

On Vancouver Island, near Port Alberni, Westmin Mines Ltd. is continuing to test the **Debbie** property with a program of surface and underground drilling and trenching. Gold mineralization occurs in veins and extensive quartz-carbonate-pyrite alteration zones associated with major north-trending faults as well as in a magnetite-jasper sulphide-bearing chert with quartz-vein stockwork in a footwall basalt.

SUMMARY AND A LOOK AT 1991

The year 1990 was one of sustained activity in British Columbia. Significant progress on major projects such as **Eskay Creek, Tulsequah Chief, Windy Craggy** and **Mount Milligan** reinforced the prospector's natural optimism and confidence that the province's mineral wealth is still largely untapped and holds great promise for the future. The majors, many of them base metal producers, continued to enjoy good profits, and used their cash flow to gain control of the best properties available.

The juniors and prospectors, the province's most successful mine finders, faced the challenge of learning to carry on their business after the end of flow-through financing and in a climate of persistently soft precious metal prices and increasingly stringent environmental controls and regulations.

Most importantly, however, the success of the four major projects mentioned above proved once again that British Columbia's mineral endowment is truly world class and that it can, and will, produce world class deposits. This is the fundamental reason why exploration expenditures decreased only very slightly in 1990 as compared to 1989, while claim staking increased by a very healthy 25 per cent. This performance is in sharp contrast with that of other major mineral-producing provinces and indicates once again that in British Columbia if one looks, one shall find.

TABLE A-2
MINE DEVELOPMENT REVIEW PROCESS (MDRP)
PROJECTS IN REVIEW, DECEMBER 1990

PROSPECTUS

PROJECT/COMPANY DEVELOPMENT REGION	COMMODITY/PRODUCTION RATE*/MINE LIFE	EMPLOYMENT (CONSTRUCTION/ OPERATION)/COMMUNITY	DEVELOPMENT SCHEDULE (STAGE/AIP**/PRODUCTION)
Harmer West Extension/ Westar Coal Kootenay	10 seam coal 4.8 million tpy	Existing employment Sparwood	Prospectus - Oct 1990 Review by Kootenay Mine Development Review Committee
Silback Premier SB Zone/ Westmin Resources Ltd. North Coast	Au, Ag 100 000 t total for 1 yr Feed for existing mill	Existing employment Stewart	Prospectus - Dec 1990 Review by Northwest Mine Development Review Committee
Sukunka/Canadian Coal Co. Inc. Northeast	Underground metallurgical coal 2.2 million tpy for 20 yrs	Constr: 175 Op: 239 Tumbler Ridge, Chetwynd, Dawson Creek	Prospectus - May 1990 Review on-going
Vine Property/Kokanee Explorations Ltd. Kootenay	Bulk sample 200 st Metallurgical testing	Cranbrook	Prospectus - Nov 1990 Review by Kootenay Mine Development Review Committee

STAGE I (OR EQUIVALENT)

PROJECT/COMPANY DEVELOPMENT REGION	COMMODITY/PRODUCTION RATE*/MINE LIFE	EMPLOYMENT (CONSTRUCTION/ OPERATION)/COMMUNITY	DEVELOPMENT SCHEDULE (STAGE/AIP**/PRODUCTION)
Byron Creek South Mine Extension/Byron Creek Collieries Kootenay	Thermal coal	Existing employment	Stage I - Nov 1990 Sparwood
Cirque/Curragh Resources Inc. Northeast	Pb, Zn, Ag 3500 tpd for 16+ yrs	Constr: 200 Op: 250 Fort St. John, Mackenzie, Prince George	Stage I - Spring 1991
Crystal Peak/Polestar Exploration Inc. Thompson-Okanagan	Garnet 100-200 stpd for 20 yrs	Total: To be determined Apex Village, Penticton	Stage I - Winter 1991
Equinox (J & L)/Equinox Resources Ltd., Pan American Minerals Corp.	Au, Ag, Pb, Zn 350 mtpd for 10 yrs	Constr: 50 person yrs Op: 80-90 Revelstoke	Stage I - 1991
Eskay Creek/ Corona Corp. North Coast	Au, Ag 750-1500 stpd for 10-12 yrs	Constr: 200-300 Op: 200-250 Smithers, Stewart, Terrace	Prospectus - April 1990 Stage I - March 1991
Golden Crown/ Attwood Gold Corp. Kootenay	Au, Cu 200 stpd for 2 yrs	Op: 20-30 Grand Forks	Stage I - 1990
Henretta Dragline/ Fording Coal Ltd. Kootenay	Metallurgical and thermal coal Existing production	Existing employment Elkford	Prospectus - March 1990 Stage I - Dec 1990

Mt. Milligan/ Continental Gold Corp., Placer Dome Inc. Nechako	Cu, Au 60 000 tpd for 15 yrs	Constr: 500 – 750 Op: 350 Fort St. James, Mackenzie, Prince George	Stage I - Spring 1991
Mount Polley/Imperial Metals Corp., Corona Corp. Cariboo	Cu, Au 13 700 tpd for 14 yrs	Constr: 153 person yrs Op: 162 Williams Lake	Stage I - Oct 1990 Review on-going
Windy Craggy/ Geddes Resources Ltd. Nechako	Cu, Co, Au, Ag 15 000 – 25 000 tpd for 30 + yrs	Constr: 500 Op: 618 B.C., Yukon, Alaska	Stage I - Jan 1990 Stage I Addendum - Nov 1990

STAGES II/III

PROJECT/COMPANY DEVELOPMENT REGION	COMMODITY/PRODUCTION RATE*/MINE LIFE	EMPLOYMENT (CONSTRUCTION/ OPERATION)/COMMUNITY	DEVELOPMENT SCHEDULE (STAGE/AIP**/PRODUCTION)
Canty (Nickel Plate Extension)/Corona Corp., Golden North Resource Corp. Thompson - Okanagan	Au 907 tpd for 15 months	Existing employment Penticton	Waste-dump rock drain approved by South Central Mine Development Review Committee - Nov 1990
Silbak Premier Province Zone/ Westmin Resources Ltd. North Coast	Au, Ag 252 000 t total for 2 yrs Feed for existing mill	Existing employment Stewart	Stage II - Aug 1989 Prod. - 1991 Approved by Northwest Mine Development Review Committee Aug 1990
Telkwa/Crowsnest Resources Ltd. Nechako	Thermal coal 800 000 tpy for 20 yrs	Constr: 130 Op: 185 Telkwa, Smithers	Stage II - March 1990 Stage II Addendum - Fall 1990

* *tonnes per day (tpd)*
tonnes per year (tpy)
Short tons per day (stpd)
** *Approval-In-Principle (AIP)*
SOURCE: Engineering and Inspection Branch

TABLE A-3
ACTIVE EXPLORATION PROPERTIES IN BRITISH COLUMBIA, 1990

Northwestern Distict

Property (Operator)	MINFILE Number	Mining Division	NTS	Commodity	Deposit Type	Work Done
4J's (Orequest Consultants Ltd.)	104B 128	Skeena	104B/8E	Zn, Pb, Ag, Au		5 ddh, 405 m; geochem; mapping
Albino Lake (Eurus Resource Corp.)		Skeena	104B/9W	Au		Initiating 8-10 ddh totalling 2500 m
Atlin Ruffner/Mount Vaughan (Homestake Mineral Dev. Co.)	104N 011	Atlin	104N/11W, 12E	Ag, Pb, Zn	Vein	15 ddh, 1166 m
Axe (Ascot) (Ascot Res. Ltd.)		Liard	104G/9,16	Au, Ag, Cu	Porphyry	1 ddh, 151 m; geochem; geophys
Axe (Beauchamp) (Ascot Res. Ltd.)		Liard	104G/9E	Au, Ag, Cu	Vein	3 ddh, 268 m; geophys; geochem
B1-North (Kestrel Res. Ltd.)		Liard	104B/15	Au		2 ddh, 340 m
Ball Creek (Placer Dome Expln. Inc.)	104G 042	Liard	104G/8W	Ag, Au, Cu	Vein	4 ddh, 330 m
Bar (Goldbank Ventures Inc.)		Atlin	114P/15W	Au, Cu, Pb, Zn	VMS	12 ddh, 1134 m; geophys; trenching; geochem
Bell Mine (Noranda Minerals Inc.)	093M 001	Omineca	093M/1E	Cu, Au, Ag	Porphyry	62 ddh, 20 919 m
Bob Creek (Equity Silver Mines Ltd.)	093L 005	Omineca	093L/7E	Au, Ag, Zn	Transitional	5 ddh, 988 m
Cam 5,6 (Crimsonstar Res. Ltd.)	104B 328	Liard	104B/10W	Au, Ag		4 ddh
Cheni Gold Mine/Lawyers (Cheni Gold Mines Inc.)	094E 066	Omineca	094E/6E	Au, Ag	Epithermal vein	74 ddh, sfc, u/g, 14 846 m; geophys; geochem; 2440 m drifting
Copper Canyon (Cons. Rhodes Res. Ltd.)	104G 017	Liard	104G/3W	Cu, Ag, Au	Porphyry	13 ddh
Coulter Creek (Swift Minerals Ltd.)		Skeena	104B/9,10	Au, Ag		5 ddh, 762 m
Dauntless (Westmin Res. Ltd.)		Skeena	104B/1E	Ag, Au	Vein	1 ddh, 412 m
Deer Horn Mine/Lindquist (Teck Expln. Ltd.)	093E 019	Omineca	093E/6W	Au, Ag, Cu, W	Vein	29 ddh, 2268 m
Del Norte (Orequest Consultants Ltd.)		Skeena	104A/4E,3W	Au, Ag, Cu, Pb, Zn	Vein	12 ddh, 3669 m; trenching; geochem; geophys; mapping
Dome Mountain (Teeshin Res. Ltd.)	093L 022	Omineca	093L/10E, 15E	Au, Ag, Pb, Zn	Vein	18 ddh, 2326 m
Equity Silver Mine (Equity Silver Mines Ltd.)	093L 001	Omineca	093L/1W	Ag, Au, Cu	Transitional	3 ddh, 1088 m
Eric (Equity Silver Mines Ltd.)		Omineca	093L/2E	Cu, Ag, Au	Stratabound	7 ddh, 1077 m; geophys; geochem
Erickson (Erickson Gold Mining Corp.)	104P 029	Liard	104P/4E,5E	Au	Mesothermal vein	43 ddh, 7941 m; geophys
Eskay Creek/Tok-Kay (Corona Corp./Prime Expln. Ltd.)	104B 008	Skeena	104B/9W	Au, Ag	VMS	485 ddh, 96 000 m; 1000 m drifting; bulk sample; geophys; mapping
Foremore (Cominco Ltd.)		Liard	104G/2W	Au, Pb, Zn	Massive sulphide?	5 ddh, 1349 m; geophys; mapping
Forrest Kerr (Pamicon Dev. Ltd.)		Liard	104B/15E	Au, Ag, Cu		24 ddh, 2500 m
Gab 9 (Pamicon Dev. Ltd.)		Liard	104B/10W	Au		5 ddh, 2523 m
Gab-Mon/Seagold (Kestrel Res. Ltd.)	104B 335	Liard	104B/15	Au, Ag, Zn	Vein	7 ddh, 640 m; air and grd geophys; geochem; mapping; trenching
Galore Creek/Stikine Copper (Mingold Res. Inc.)	104G 090	Liard	104G/3W,4E	Cu, Au, Ag	Porphyry	18 ddh, 1925 m
Georgia River (Bond Gold Canada Inc.)	103O 013	Skeena	103O/16W	Au, Ag, Pb, Zn, Cu	Vein	drilling
GJ (Ascot Res. Ltd.)		Liard	104G/9E	Cu, Au	Porphyry	9 ddh, 1656 m; geochem; geophys
GNC (Prime Equities Inc.)		Skeena	104B/9W	Au, Ag, Pb, Zn		19 ddh, 3028 m; geophys; geochem; mapping

Property (Operator)	MINFILE Number	Mining Division	NTS	Commodity	Deposit Type	Work Done
Goat (Integrated Res. Ltd.)		Liard	104G/13W	Au, Cu	Porphyry	1 ddh, 130 m; geochem; mapping; geophys
Golden Bear Mine (Golden Bear Oper. Co. Ltd.)	104K 079	Atlin	104K/1	Au	Vein	10 sfc, 9 u/g ddh, 2195 m; 40 m crosscut; geophys; geochem
Gossan/Khyber Pass (Western Canadian Mining Corp.)	104B 138	Liard	104B/10	Au, Ag, Cu, Zn	Vein	9 ddh, 1094 m; geophys; geochem
GOZ-RDN (Noranda Expln. Co. Ltd.)		Liard	104G/2E, 104B/15	Au, Ag, Cu, Pb		15 ddh, 1546 m; geochem grd& airborne geophys
Granisle (Noranda Minerals Inc.)	093L 146	Omineca	093L/16E	Cu, Au, Ag	Porphyry	38 ddh, 9629 m
Grouse Mountain/Copper Hill (Swift Minerals Ltd.)	093L 026	Omineca	093L/10E	Ag, Au	Vein	7 ddh, 1800 m, geochem, mapping
Hank (Carmac Res. Ltd.)	104G 107	Liard	104G/1,2	Au	Vein	5 ddh, 1464 m
Hearne Hill (Noranda Expln. Co. Ltd.)		Omineca	093M/1W	Cu	Porphyry	5 ddh, 856 m
High Ore (Westmin Res. Ltd.)	104B 056	Skeena	104B/1E	Au, Ag	Vein	5 ddh, 845 m; geochem; mapping
Ice (Nararre Res. Gp.)		Skeena	104B/8	Au, Ag, Zn		1 ddh, 98 m
Independence (Armeno Res. Inc.)	104A 038	Skeena	104A/4W	Au, Ag, Cu	Vein	6 ddh, 764 m
Indian (Westmin Mines Ltd.)	104B 031	Skeena	104A/4W	Ag, Au, Pb, Zn	Vein	5 ddh, 928 m; geochem; mapping
Inel (Gulf Int'l Min. Ltd.)	104B 113	Liard	104B/10W	Au, Ag, Cu, Pb, Zn	Vein	23 ddh, 2400 m; 375 m drifting
Iskut Joint Venture (Prime Expln. Ltd.)	104B 356	Liard	104B/11	Au	Vein	14 ddh, 1965 m; geochem
Jack Wilson Creek (Bellex Mining Corp.)		Liard	104G/4E	Cu, Au	Porphyry	5 ddh, 1392 m; geochem; geophys
Johnny Mountain (Skyline Gold Corp.)	104B 107	Liard	104B/11E	Au, Ag, Cu	Mesothermal vein	23 ddh, 4500 m; geophys; geochem; trenching; mapping
Kemess North (El Condor Res. Ltd.)	094E 021	Omineca	093E/2	Cu, Au	Porphyry	12 ddh, 2207 m
Kemess South/Ron-Du (El Condor Res. Ltd.)	094E 025	Omineca	094E/2, 094D/15	Cu, Au	Porphyry	17 ddh, 2686 m
Kerr (Placer Dome Expln. Inc.)	104B 191	Skeena	104B/8	Cu, Au	Porphyry	74 ddh, 17 000 m
Kits-Jade (Oliver Gold Corp.)	103P 233	Skeena	103P/11	Zn, Pb, Ag	Massive sulphide	mapping; geophys; geochem
KRL (Kestrel Res. Ltd.)		Liard	104B/10	Au	Vein	13 ddh, 1419 m
Kutcho (Homestake Mineral Dev. Co.)	104I 060	Liard	104I/1W	Cu, Pb, Zn, Au, Ag	VMS	28 ddh, 7050 m; geophys; geochem
Lakewater (Prime Expln. Ltd.)		Skeena	104B/9W	Au, Ag	Massive sulphide	9 ddh, 1650 m; geophys; geochem; mapping
Laredo Limestone/Aristazabal (Laredo Limestone Ltd.)	103A 001	Skeena	103A/11E	Ls	Sedimentary	2 ddh
Lefty (Equity Silver Mines Ltd.)		Omineca	093L/5E,6W	Cu, Ag, Au		7 ddh, 1100 m; geophys; geochem; mapping
McConnell Creek (Placer Dome Expln. Inc.)	094D 006	Omineca	094D/16W	Au, Cu	Vein	10 ddh, 1050 m; geochem; trenching
McLymont (Gulf Int'l Min. Ltd.)	104B 281	Liard	104B/15W	Au, Cu, Ag	Skarn	33 ddh, 4033 m; geophys; geochem; trenching; mapping
Midway (Strathcona Mineral Serv. Ltd.)	104O 038	Liard	104O/16W	Ag, Pb, Zn, Au, Sn, Cu	Manto	68 ddh, 9620 m; 765 m decline & drifting
Moonlight (High Frontier Res. Ltd.)	104A 005	Skeena	104A/5W	Au, Ag, Cu, Pb, Zn	Vein	8 ddh, 1059 m
New (Pamicon Dev. Ltd.)		Liard	104B/15	Au, Ag	Vein	10 ddh, 445 m
New Moon (Maple Resource Corp.)	093E 011	Omineca	093E/13	Au, Ag, Zn	Vein	7 ddh, 725 m; geochem; geophys
Newice (Pamicon Dev. Ltd.)		Liard	104B/14E, 15W	Au	Vein	4 ddh, 292 m
Nica (Ambergate Expln. Inc.)		Skeena	104B/8W	Au		3 ddh, 300 m; mapping
Nickel Mountain (Silver Standard Res. Inc.)	104B 006	Liard	104B/10E	Ni, Cu, Pt, Ag, Ti, Au		1 ddh, 134 m
North Star (Dolly Varden Minerals Inc.)	103P 189	Skeena	103P/11,12	Ag, Au, Pb, Zn, Cu	Massive sulphide	18 ddh, 7096 m
Packsack/Ecstall (Cominco Ltd.)	103H 013	Skeena	103H/14W, 13E	Cu, Zn, Ag, Au, Pb	VMS	3 ddh, 915 m; mapping

Property (Operator)	MINFILE Number	Mining Division	NTS	Commodity	Deposit Type	Work Done
Parrott Lakes, Fix, Lorne (Territorial Drilling Ltd.)		Omineca	093L/7E	Ag, Zn		30 pdh, 2280 m; geochem
Pavey (Lodestar Expln. Inc.)	104M 003	Atlin	104M/15W	Au, Ag, Cu	Vein	11 ddh; geophys; geochem; trenching; mapping
Paydirt (Pacific Century Expln. Ltd.)	104G 023	Liard	104G/4E	Au, Cu	Vein, porphyry	Mapping, linecutting, geochem, geophys
Pinelode (Noranda Expln. Co. Ltd.)		Atlin	104N/11W	Au	Mesothermal vein	3 rcdh, 160 m; geophys
Poker (Dryden Resource Corp.)	104G 001	Liard	104G/13W	Au, Cu	Porphyry	3 ddh, 379 m; geophys; mapping
Polaris-Taku (Orequest Consultants Ltd.)	104K 003	Atlin	104K/12E	Au, Ag, Cu, Sb	Vein	10 ddh, 2862 m; geochem; geophys; mapping
Premier Gold Mine (4G Zone) (Westmin Res. Ltd.)	104B 054	Skeena	104B/1E	Au, Ag, Pb, Zn	Epithermal vein	53 ddh, 3622 m; u/g rehabilitation
Quash Creek (Triumph Res. Ltd.)	104G 033	Liard	104G/16	Cu, Au	Porphyry	2 ddh, 377 m
Ram-Tut-Tot (Trans Atlantic Res. Inc.)	104K 097	Atlin	104K/8W	Au, Ag	Vein	4 ddh, 437 m; geophys; geochem; mapping
Red Mountain (Bond Gold Canada Inc.)	103P 086	Skeena	104P/13	Au, Ag	Massive sulphide?	drilling
Rhub-Barb (Alta Ventures Inc.)		Omineca	093F/11W, 12E	Au, Ag	Epithermal	6 ddh, 610 m; trenching
Rock and Roll (Thios Res. Ltd.)		Liard	104B/11E	Au, Ag, Pb, Zn, Cu	Vein?	9 ddh, 675 m
Rok/Rose (Cons. Carina Res. Corp.)	104H 001	Liard	104H/13W	Cu, Au	Porphyry?	3 ddh, 374 m; geophys; geochem
Shasta (Homestake Mineral Dev. Co.)	094E 050	Omineca	094E/2, 7W,3,6E	Au, Ag	Epithermal vein	27 ddh, 4777 m; geophys; geochem; u/g mapping & sampling
Sib (American Fibre Corp.)		Skeena	104B/9W, 10E	Au, Ag, Pb, Zn, Cu	Massive sulphide?	26 ddh, 1208 m; geophys
Silver Butte (Westmin Res. Ltd./Tenajon Res. Ltd.)	104B 150	Skeena	104B/1E	Ag, Au	Epithermal vein	96 ddh, 7404 m; 13 u/g, 16 sfc ddh, 3672 m
Silver Crown/Strike (Nararre Resource Corp.)	104A 061	Skeena	104A/4W	Au, Ag, Pb, Zn	Vein	930 m, ddh; geophys
Ski (Prime Expln. Ltd.)		Skeena	104B/9W	Au, Ag	VMS	35 ddh, 24 385 m; geophys
Snip (Cominco Ltd.)	104B 250	Liard	104B/11	Au, Ag	Mesothermal vein	2285 m development drifting
Spectrum/Red Dog (Columbia Gold Mines Ltd.)	104G 036	Liard	104G/9	Au, Ag, Cu, Pb, Zn	Vein, porphyry	20 ddh, 2412 m; geochem; trenching
Sphaler Creek/Pass Lake (Cons. Goldwest Res. Ltd.)		Liard	104B/13E, 14	Au, Ag, Cu, Zn		6 ddh, 1110 m; geophys; geochem; mapping
Stu (Kestrel Res. Ltd.)	104B 313	Liard	104B/10	Au, Ag, Cu	Skarn, vein	3 ddh, 457 m
Sul 1 & 2, Unuk 20 (Kenrich Mining Corp.)		Skeena	104B/8W	Au, Ag		5 ddh, 300 m; mapping
Sulphurets (Newhawk Gold Mines Ltd.)	104B 193	Skeena	104B/8E	Ag, Au	Epithermal vein	45 u/g ddh, 5800 m
Summit Lake Mine/Scottie Gold (Royal Scot Res. Ltd.)	104B 034	Skeena	104B/1E	Au, Ag, Cu, Pb, Zn	Mesothermal vein	3 sfc ddh, 172 m; 4 u/g ddh 546 m; geophys
Tide Lake (Somerville Geological Ltd.)	104B 251	Skeena	104B/8E	Au, Ag	Vein	ddh, geophys; geochem
Todd Creek/Fall Creek (Noranda Expln. Co. Ltd.)		Skeena	104A/5W	Cu, Au		10 ddh, 1249 m; aerial mag; geochem; mapping
TP/Teepee (Canada) (Cyprus Gold Ltd.)	104M 048	Atlin	104M/10,15	Au, Ag, Zn, Pb	Vein	11 ddh, 1336 m
Trophy Gold (Gigi Res. Ltd.)	104G 053	Liard	104G/3	Au, Cu	Vein	10 ddh, 1885 m; geochem; geophys; trenching; mapping
Tulsequah (Cominco Ltd.)	104K 002	Atlin	104K/12,11	Ag, Au, Pb, Zn, Cu	VMS	8 u/g ddh, 6706 m; u/g mapping; 183 m drifting
Unuk River (Granges Inc.)	104B 083	Skeena	104B/8,9,10	Au, Ag, Pb, Zn		16 ddh, 3000 m; mapping
Waratah (Big M Res. Ltd.)	104B204	Liard	104B/10W	Au, Ag, Cu	Mesothermal vein	4 ddh
Windy Craggy (Geddes Res. Ltd.)	114P 002	Atlin	114P/12E,W	Cu, Co, Au, Ag, Zn	VMS	16 869 m, sfc & u/g ddh; geotech; geophys; bulk sampling

Central District

Property (Operator)	MINFILE Number	Mining Division	NTS	Commodity	Deposit Type	Work Done
Ahdatay Lake (BP Res. Canada Ltd.)	93N 085	Omineca	93N/7W	Au, Cu	Alkali porphyry	6 ddh, 1068 m; geol; geophys

Property (Operator)	MINFILE Number	Mining Division	NTS	Commodity	Deposit Type	Work Done
Bio (Rio Algom Expln. Inc.)	93K 004	Omineca	93K/16	Au, Cu	Porphyry	geol; geochem
Cantin Creek (Placer Dome Expln. Inc.)	93B 027	Cariboo	93B/16	Au, Cu	Alkali porphyry	12 ddh, 1759 m; geophys
Cat (BP Res. Canada Ltd.)	94C 069	Omineca	94C/3W	Au, Cu	Alkali porphyry	14 ddh, 2590 m; geochem; geophys; trenches; road
Chuchi East (BP Res. Canada Ltd.)	93N 123	Omineca	93N/1W	Au, Cu	Alkali porphyry	geol; geochem; geophys; air geophys, 250 km
Chuchi Lake (BP Res. Canada Ltd.)	93N 159	Omineca	93N/7E,2E	Au, Cu	Alkali porphyry	29 ddh, 5240; geol; geochem; geophys; air geophys, 210 km; road, 5 km
Cirque (Canadian Mine Dev.)	94F 008	Omineca	94F/6	Pb, Zn, Ag	Sedex	u/g develop; 15 ddh; bulk sample; feasibility; road
Clisbako (Eighty-eight Res.)		Cariboo	93C/9	Au, Ag	Epithermal	geochem; 15 trenches; road, 2.5 km
Dominion Creek (Allan Raven)	93H 133	Cariboo	93H/6	Au, Ag, Pb, Zn	Replacement	pilot mill test
Doreen (Gibraltar Mines Ltd.)	93A 117	Cariboo	93A/7W	Au, Cu	Alkali porphyry	5 ddh, 1067 m; geophys; road, 2 km
Dorothy (Kennco Expln. (West) Ltd.)	93N 007	Omineca	93N/14W	Au, Cu	Alkali porphyry	geochem; geophys; road
Eagle (Noranda Expln. Co. Ltd.)	93N 092	Omineca	93N/2W	Au, Cu	Alkali porphyry	geol; geochem; geophys; road
Fog (Teck Corp.)		Cariboo	93A/15W	Pb, Zn, Ag	Replacement	ddh; geol; geochem; geophys; trenches; road
Frasergold (Eureka Res. Inc.)	93A 150	Cariboo	93A/7E	Au	Phyllite-hosted	25 ddh, 4687 m; 39 pdh, 4262 m; bulk sample
Gaspard Lake (Goldsmith Minerals Ltd.)		Clinton	92O/7,10	Au, Ag	Epithermal	6 ddh, 620 m; geophys
Hanson Lake (Cazador Expln. Ltd.)	93K 078	Omineca	93K/6	Au, Cu	Porphyry related	5 ddh; geol; geochem; geophys
Hawk (Cyprus Gold (Canada) Ltd.)		Omineca	94C/4	Au, Cu	Porphyry	8 ddh, 900 m; geol, geochem, geophys
Heath (Teck Expln. Ltd.)	93N 071	Omineca	93N/6E	Au, Cu	Alkali porphyry	2 ddh, 61 m; 18 trenches, 1700 m; geol; geochem; geophys
Heidi Lake (BP Res. Canada Ltd.)	93N 194	Omineca	93N/1E	Au, Cu	Alkali porphyry	10 ddh, 1427 m; geochem; geophys
J1 (Noble Metal Group Inc.)		Cariboo	93A/13,14	Au, Ag	Vein	4 ddh, 551 m; geophys; trenches; road
Klawli (Rio Algom Expln. Inc.)		Omineca	93N/7E,8W	Au, Cu	Alkali porphyry	5 ddh, 691 m; 5 trenches, 241 m; geochem; geophys, air geophys; road
Lorraine (Kennco Expln. (West) Ltd.)	93N 002	Omineca	93N/14W	Au, Cu	Alkali porphyry	geochem; geophys; road
Mitzi (Noranda Expln. Co. Ltd.)	93N 096	Omineca	93N/1W	Au, Cu	Alkali porphyry	10 ddh, 1050 m; geol; geochem; geophys; air geophys; road
Mt. Alcock (Triumph Res. Ltd.)	94F 015	Cariboo	94F/11W	Pb, Zn, Ag	Sedex	6 ddh, 1212 m; geol; geochem
Mt. Milligan (Placer Dome Inc.)	93N 194	Omineca	93N/1	Au, Cu	Alkali porphyry	387 ddh, 86 604 m; geotech; bulk sample; feasibility, MDRP prospectus
Mt. Sidney Williams (Viceroy Resource Corp.)	93K 039	Omineca	93K/14W	Cr, Au	Listwanite	7 ddh, 305 m; geol; geochem
Nina (Equinox Res. Ltd.)	93N 191	Omineca	93N/15	Au, Cu	Vein	14 ddh, 700 m
Pilot (Cominco Ltd.)		Cariboo	93J/12	Au	Alkali porphyry	ddh, 1000 m; geol; geochem; geophys
Porphyry Creek (Teck Expln. Ltd.)	94C 065	Omineca	94C/5,D/8	Au, Cu	Alkali porphyry	geol; geochem
Punt (Northair Mines Ltd.)	93C 011	Cariboo	93C/8E	Au, Ag	Epithermal	5 ddh, 368 m
Quintette (Quintette Coal Ltd.)	93P 019	Liard	93P/3W	coal	Sedimentary	6 ddh, 157 rdh, 20 000 m; road, 23 km; geophys
Redgold (Phelps Dodge Corp. of Canada)	93A 058	Cariboo	93A/6W	Au, Cu	Alkali porphyry	5 ddh, 537 m; geol; geochem; geophys
Steven (P.G. Paulson)	93G 024	Cariboo	93G/15E	W, Mo, Cu	Vein	3 ddh, 300 m
Sukunka (Canadian Coal Co.)	93P 011	Liard	93P/3W, 4W	coal	Sedimentary	reactivate production plans
Takla-Rainbow (Eastfield Res. Ltd.)	93N 082	Omineca	93N/11	Au, Cu	Alkali porphyry	8 ddh, 1242 m; 4 trenches, 200 m; geol; geochem; geophys; air geophys
Tam (Varitech Res. Ltd.)	93N 093	Omineca	94C/3,4	Au, Cu	Alkali porphyry	geol; geochem; geophys

Property (Operator)	MINFILE Number	Mining Division	NTS	Commodity	Deposit Type	Work Done
Taseko (Alpine Expln. Corp.)	93O 033	Clinton	92O/3W	Au, Cu	Porphyry	19 ddh, 11 480 m; geochem; geophys; air geophys
Tchentlo lake (Westmin Mines Ltd.)	93N 091	Omineca	93N/2	Au, Cu	Alkali porphyry	geol; geochem; 3 trenches, 500 m; road, 3.5 km
Tenakihi Creek (BP Res. Canada Ltd.)		Omineca	94C/3W	Au, Cu	Alkali porphyry	geol; geochem; geophys
Tez (Rio Algom Expln. Inc.)		Omineca	93K/15E	Au, Cu	Alkali porphyry	geochem; air geophys, 450 km
Tim (Liberty Gold Corp.)	92P 121	Clinton	92P/14E	Cu, Ag, Au	Porphyry	7 ddh; 12 pdh; geol
Trout (Goldrite Mining Corp.)	93F 044	Omineca	93F/10	Au, Ag	Epithermal	9 ddh, 1200 m; 4 pdh
WD (Cominco Ltd.)	93H 072	Cariboo	93H/6	Pb, Zn, Ag	Vein	3 ddh, 420 m; geophys
Webb (Moondust Ventures Inc.)		Omineca	93N/1W,1E	Au, Cu	Alkali porphyry	ddh; geol; geochem; geophys; air geophys; road
Wee (Cominco Ltd.)		Cariboo	93J/11	Pb, Zn, Ag	Replacement vein	2 ddh, 1000 m; geol; geochem; geophys
Windy (Placer Dome Inc.)	93J 024	Cariboo	93J/13	Au	Alkali porphyry	6 ddh, 684 m; 6 trenches, 365 m; geol; geochem; geophys; road, 3.5 km
Wingdam (Gold Ridge Res.)	93H 012	Cariboo	93H/4W	Au	Placer	decline; bulk sample
Witch (Rio Algom Expln. Inc.)	93N 164	Omineca	93N/1W,2E	Au, Cu	Alkali porphyry	geol; geochem; geophys

South Central District

Property (Operator)	MINFILE Number	Mining Division	NTS	Commodity	Deposit Type	Work Done
Abba (C. Hagel)		Nicola	92I/2E,2W	Au, Cu	Vein	3 ddh, 415 m; 6 trenches, 244 m; geophys
Add 8, 10 (A. Babiy)		Kamloops	92I/9E	Au, Cu	Porphyry	3 ddh, 251 m; 5 pdh, 305 m
Ajax (Afton Oper. Corp.)	092INE012	Kamloops	92I/9W	Cu, Au	Porphyry	13 ddh, 3504 m; geochem
B.S. (J. Hilton)		Vernon	82L/7W	Ag, Pb, Zn, Au	Shear	1 ddh, 194 m
Ban 1 (A. Babiy)		Kamloops	92I/9E	Au	Porphyry	1 pdh, 46 m
Betty Lou (Better Res. Ltd.)	092ISE173	Nicola	92I/2E	Cu, Fe	Skarn	2 ddh, 630 m
Birch (New Global Res. Ltd.)	082M 021	Kamloops	82M/12W	Pb, Zn, Au, Ag	Massive sulphide	9 ddh, 304 m; 4 trenches, 50 m; geochem
Birk Creek (Falconbridge Ltd.)	082M 219	Kamloops	82M/5W	Cu, Ag, Pb, Zn, Au	Massive sulphide	8 ddh, 2377 m; 4 trenches, 800 m; geochem; geophys, 60 km
Brett (Huntington Res. Inc.)	082LSW110	Vernon	82L/4E	Au	Epithermal	3 ddh, 379 m; geochem
Brew (Bethlehem Res./ Goldnev Res.)	082M 085	Revelstoke	82M/9W	Cu, Pb, Zn, Ag	Massive sulphide	2 ddh, 129 m; airborne geophys, 1263 km
Camp #1 (L. Mear)		Kamloops	92I/9E	Cu, Au	Porphyry	1 ddh, 61 m; geochem
Cana (Minnova Inc.)		Kamloops	82M/4W	Au, Ag, Cu, Pb, Zn	Massive sulphide	6 ddh, 1716 m; geochem
Carmi Moly (Placer Dome Inc.)	082ESW029	Greenwood	82E/11E, 6E	Mo	Porphyry	3 ddh, 311 m
Chu Chua (Minnova Inc.)	092P 140	Kamloops	92P/8E	Cu, Ag, Au, Zn	Massive sulphide	11 ddh, 2314 m; geochem; geophys, 100 km
Clifton (R. Yorke-Hardy)		Vernon	82L/10E	Marble		7 ddh, 320 m; 3 trenches, 500 m
CM (Minnova Inc.)	092P 101	Kamloops	92P/8E	Au, Ag, Cu, Zn, Pb	Massive sulphide	3 ddh, 581 m; geochem; geophys, 75 km
Copper Mountain (Similco Mines Ltd.)	092HSE013	Similkameen	92H/7E	Cu, Au	Porphyry	181 ddh, 28 601 m; 35 trenches, 1981 m; geochem; geophys, 35 km
Craigmont (Craigmont Mines Ltd.)	092ISE034	Nicola	92I/2E	Magnetite	Tailings	1 pdh, 32 m; 8 cph, 210 m
Crystal Peak (Polestar Expln. Inc.)	082ESW107	Osoyoos	82E/5W	Garnet	Skarn	18 ddh, 595 m; bulk sampling
Dayton (Crown Res. Corp.)	082ESW022	Greenwood	82E/3E	Au, Ag	Skarn	9 pdh, 1372 m; geochem; geophys, 5 km
Eagle 4&5 (A. Babiy)		Kamloops	92I/8W	Au, Cu	Porphyry	1 ddh, 84 m; 1 pdh, 61 m
Elk (Placer Dome Inc.)	092HNE134	Similkameen	92H/16W	Au	Epithermal	62 ddh, 5428 m; 18 trenches, 1.3 km; geochem; geophys, 50 km

Property (Operator)	MINFILE Number	Mining Division	NTS	Commodity	Deposit Type	Work Done
Fairview (Oliver Gold Corp.)	082ESW007	Osoyoos	82E/4E	Au, Ag	Vein	11 ddh, 2465 m; geochem
Ford (Teck Expln. Ltd.)		Kamloops	82M/4E, 82L/13E	Cu, Pb, Zn, Ag	Massive sulphide	4 ddh, 861 m; geochem; geophys, 1.6 km
G&G 1 (Iota Expln. Ltd.)	092ISE120	Nicola	92I/2E	Au, Ag, Cu	Vein	3 ddh, 183 m
Galaxy (Getchell Res. Inc.)	092INE007	Kamloops	92I/9W	Cu, Au	Porphyry	12 pdh, 847 m; geochem
Gold Bridge (Golden Rule Res. Ltd.)	092JNE045	Lillooet	92J/15W	Au, Ag	Vein	3 ddh, 478 m; geophys, 5 km
Gold Ridge (R. Lacombe)	092ISW055	Kamloops	92I/4E	Talc, magnesite		4 ddh, 244 m; 7 trenches, 78 m
Golden Loon (Corona Corp.)		Kamloops	92P/8W	Au, Cu, Pb	Vein/porphyry	7 ddh, 691 m; 29 trenches, 665 m; geochem; geophys, 5.3 km
Goldrop (M. Shewchuk)	092HSE124	Similkameen	92H/7E	Cu, Zn, Ag,	Vein/shear	2 ddh, 186 m
Goldstream (Bethlehem Res./ Goldnev Res.)	082M 141	Revelstoke	82M/9W	Cu, Zn, Ag	Massive sulphide	geochem; geophys, 398 km
Haida (Teck Expln. Ltd.)	092P 136	Kamloops	92P/9W	Cu, Au	Skarn/porphyry	14 ddh, 1952 m; geophys, 54.5 km; geochem
Hat Creek Bentonite (Pacific Bentonite Ltd.)		Kamloops	92I/13E	Bentonite		8 auger, 46 m
Hig-Wim (Gala Res. Ltd.)		Kamloops	82M/4E	Ag, Cu, Pb, Zn, Au	Massive sulphide	2 ddh, 227 m; geochem; geophys, 20 km
Highland Bell (Teck Corp.)	082ESW030	Greenwood	82E/6E	Ag, Au	Vein	62 u/g ddh, 3375 m
Highland Valley Copper (Highland Valley Copper)	*092ISE045*	*Kamloops*	*92I/11E*	Cu, Mo	Porphyry	11 ddh, 5303 m; geochem
Honeymoon (Minnova Inc.)		Kamloops	92P/9E,8E	Au, Ag, Cu, Zn, Pb	Massive sulphide	geochem; geophys, 90 km
J&J #5 (W. Groves)		Kamloops	92I/9W	Au, Cu	Porphyry	3 pdh, 183 m
J&L (Equinox Res. Ltd.)	082M 003	Revelstoke	82M/8E	Au, Ag, Pb, Zn	Sedex	250 m drifting; 10 ddh, 1500 m; geochem
Jewel (Corona Corp.)	082LSW065	Kamloops	82L/5E	Cu, Au	Porphyry	2 ddh, 258 m; geochem
JJ 4,7,8 (A. Babiy)		Kamloops	92I/9W	Au, Cu	Porphyry	3 pdh, 183 m; geochem
Kamad (Homestake Mining Canada Ltd.)	082M 025	Kamloops	82M/4W	Ag, Au, Cu, Pb, Zn	Massive sulphide	8 ddh, 2943 m; geophys, 500 m; geochem
Kamrose (C. Boitard)		Kamloops	92I/9W	Cu, Au	Porphyry	2 ddh, 221 m
Keystone (Bethlehem Res./ Goldnev Res.)	082M 088	Revelstoke	82M/8W	Cu, Zn, Pb, Ag	Massive sulphide	3 ddh, 572 m; geochem
Knut (Placer Dome Inc.)		*Kamloops*	*92I/9W*	*Cu, Au*	*Porphyry*	*9 ddh, 1205 m*
Last Chance (Minnova Inc.)	092INE062	Kamloops	92I/15W	Au, Ag, As, Hg	Epithermal	3 ddh, 614 m; 21 trenches, 454 m; geochem; geophys, 6 km
Lavington (B.P. Res. Canada Ltd.)		Vernon	82L/6E	Au, Ag, Pb, Zn	Shear	3 ddh, 396 m; road, 100 m
Lodestone (Tiffany Res. Inc.)	092HSE034	Similkameen	92H/7W	Pt, Fe	Magmatic	5 ddh, 610 m; trenching
Lucky Coon (Sirius Resource Corp.)	082M 012	Kamloops	82M/4E	Ag, Pb, Zn	Massive sulphide	13 ddh, 861 m
Lucky-Jura (Cominco Ltd.)	092HNE176	Similkameen	92H/9W	Cu, Au	Porphyry	17 pdh, 1469 m; geophys, 8 km
Lynx (Golden Sky Res. Inc.)	082LSE055	Vernon	82L/1W	Au	Vein	3 ddh, 183 m; geochem
Magna 1-10 (W. Spence)		Kamloops	82L/14W	Ag, Cu, Pb, Zn, Au	Massive sulphide	1 ddh, 152 m
Mam (Toba Gold Res. Ltd.)		Osoyoos	82E/4E	Au	Vein	15 m drifting; geochem
MC (Initial Developers Ltd.)		Kamloops	82M/12W	Cu, Pb, Zn	Massive sulphide	6 ddh, 630 m
Mica (Corona Corp.)	082M 190	Revelstoke	82M/15E	Ag, Pb, Zn, Cu	Massive sulphide	1 ddh, 67 m
Mila (Goldbank Ventures Inc.)	082M 151	Kamloops	82M/12E	Au, Ag, Cu, Pb, Zn	Massive sulphide	geochem; geophys, 35 km; linecutting, 20 km; 2 ddh, 366 m
Model Anne (Mad River Res. Inc.)	092INE039	Kamloops	92I/10W	Au	Epithermal	6 pdh, 479 m; geochem
Nickel Plate (Corona Corp.)	092HSE062	Osoyoos	92H/8E	Au	Skarn	45 ddh, 2850 m

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Nord 1 (A. Bably)		Kamloops	92I/9E	Au	Porphyry	1 pdh, 61 m
OK (J. Hilton)		Vernon	82L/7W	Ag, Cu, Pb, Zn, Au	Vein/shear	1 ddh, 61 m
Orofino Mountain (Orequest Consultants Ltd.)	082ESW113	Osoyoos	82E/4E,5E	Au, Ag	Vein	11 ddh, 730 m; 4 trenches, 50 m; geochem
Oz (Brenda Mines Ltd.)		Kamloops	92I/9W	Cu, Au	Porphyry	1 ddh, 305 m
Pooley Lake (Corona Corp.)		Kamloops	82L/12W, 92I/9E	Au	Vein/shear	2 pdh, 366 m; geochem
Rag-Happy-Days-Gs (Teck Corp.)	092INE045	Kamloops	92I/10E	Cu, Au	Porphyry	12 pdh, 872 m; geochem; geophys, 44 km
Rayfield (Brenda Mines Ltd.)	092P 005	Clinton	92P/6E	Cu, Au	Porphyry	12 ddh, 3340 m; geophys, 77 km
Richter (Minnova Inc.)		Osoyoos	82E/4E	Au, Ag	Vein	4 ddh, 466 m; geochem; geophys, 10 km
Rift (9041 Investments Ltd.)	082M 190	Revelstoke	82M/15E	Ag, Pb, Zn, Cu	Massive sulphide	7 ddh, 690 m; 2 trenches, 76 m; geochem
Road 4 (Naxos Res. Ltd.)		Kamloops	92I/9E	Au, Cu	Porphyry	6 pdh, 366 m
Rose (M. McElgunn)		Kamloops	92I/9E	Au	Porphyry	1 ddh, 46 m
RS-1 (Teck Expln. Ltd.)		Kamloops	82M/4E	Cu, Pb, Zn, Ag	Skarn	6 ddh, 766 m; 7 trenches, 382 m; geochem
Samatosum (Minnova Inc.)	082M 244	Kamloops	82M/4W	Ag, Cu, Pb, Zn, Au	Massive sulphide/ Vein	u/g devel; 47 ddh, 11 200 m; 22 pdh, 500 m; geochem
Sil (E. Carson)		Osoyoos	82E/4E	Marble		6 ddh, 180 m
Standard Creek (Armeno Res. Inc.)	092JNE015	Lillooet	92J/10E	Au, Ag	Vein	10 pdh, 1287 m; geochem; geophys, 6.1 km.
Stmp 1,2 (L. Mear)		Kamloops	92I/8W	Au	Porphyry	1 ddh, 91 m
Taweel Lake (Jaguar Equities Inc.)	092P 018	Kamloops	92P/9W	Au, Ag	Vein/shear	5 ddh, 396 m; geochem
Top (Commonwealth Gold Corp.)	082LSE017	Vernon	82L/2E	Au, Ag	Shear	110 m drifting; geochem
Tor (E. Wedekind/N. Proskin)		Similkameen	92H/10E	Au, Cu	Vein/shear	2 ddh, 305 m
Triple L (L. Loehr)		Kamloops	82L/12W,13W	Au	Vein	6 pdh, 67 m
Twin (Homestake Mining Canada Ltd.)	082M 020	Kamloops	82M/4W	Ag, Au, Cu, Zn, Pb	Massive sulphide	9 ddh, 3865 m; geophys, 2 km; geochem
Vault (Inco Gold Mgmt. Ltd.)	082ESW173	Osoyoos	82E/5E	Au, Ag	Epithermal	12 ddh, 2786 m; 2 trenches, 470 m
Whipsaw (Worldwide Minerals Ltd.)	092HSE073	Similkameen	92H/7E	Cu, Mo, Au	Porphyry/Vein	6 ddh, 683 m; geochem
Xen, Carol (Annax Ventures Inc.)		Vernon	82E/15E, 16W	Au, Ag, Pb, Zn	Vein/shear	6 ddh, 305 m; geochem; geophys, 5 km
Yalakom #2 (Consol Balsam Res. Corp.)		Lillooet	92O/2E	Au, Ag, Pb, Zn	Vein	1 ddh, 129 m
Zeb/Ed (Duchan Enterprises Ltd.)		Kamloops	82M/5E	Ag, Au, Cu, Zn, Pb	Massive sulphide	2 ddh, 335 m; 1 trench, 11 m; geochem; geophys, 5 km

Kootenay District

Property (Operator)	MINFILE Number	Mining Division	NTS	Commodity	Deposit Type	Work Done
4 Seam (Crows Nest Res. Ltd.)	082GNW055	Fort Steele	82G/15	Coal		2 rdh, 367 m
Alpine (Cove Res. Corp.)	082FNW127	Slocan	82F/11	Au, Ag	Vein	4 ddh, 520 m
Bar (Swift Minerals Ltd.)		Fort Steele	82G/5W	Cu, Au	Breccia	1 ddh
Bar (Goldpac Investments Ltd.)		Fort Steele	82G/5W	Zn, Pb, Ag	Sedex	1 ddh, 1900 m
Bluebird (South Quarry) (Speers Construction Ltd.)	082JSW009	Fort Steele	82J/4E	Gy	Evaporite	16 rdh, 750 m
Cash (Kokanee Expln. Ltd.)	082GNW018	Fort Steele	82G/11W	Pb, Zn, Cu, Ag	Skarn	17 ddh, 2550 m
Castle Mountain (Fording Coal Ltd.)	082JSW011	Fort Steele	82J/2W	Coal		21 rdh, 3820 m
Clearwater (P.M. Expln. Ltd.)	082FSW081	Nelson	82F/6E	Au, Ag	Vein	2 ddh, 100 m

Property (Operator)	MINFILE Number	Mining Division	NTS	Commodity	Deposit Type	Work Done
Clubine (Yellowjack Res. Ltd.)	082FSW200	Nelson	82F/3W	Au, Ag, Pb	Vein	7 ddh, 854 m; 6 trenches; geochem; geophys
Corbin (Byron Creek Collieries)	082GNE001	Fort Steele	82G/7	Coal		57 rdh, 7500 m
David/Lew (Bapty Research Ltd.)		Fort Steele	82F/8E	Au	Shear	34 ddh, 1000 m
Eng (Kokanee Expln. Ltd.)		Fort Steele	82F/1E	Ag, Cu	Sedex	5 ddh, 1550 m
Estella (Cominco Ltd. /Kootenay Expln.)	082GNW008	Fort Steele	82G/13E	Zn, Pb	Vein	3 ddh
Four-J, Two-T (Domtar Gypsum)	082JSW009	Fort Steele	82G/13E	Gypsum	Evaporite	30 rdh, 850 m
Gold Creek (Bapty Research Ltd.)	082GSW034	Fort Steele	82G/2	Au	Vein	10 ddh, 1220 m
Golden Crown-Crown II (Attwood Gold Corp.)	082ESE032	Greenwood	82E/2	Au, Cu	Vein	34 ddh, 2100 m
Great Western Star (Pacific Sentinel Gold Corp.)	082FSW083	Nelson	82F/6W	Au, Ag	Shear-related, porphyry	18 ddh, 4727 m; geochem; geophys
Hope (Kokanee Expln. Ltd.)	082FNW129	Slocan	82F/11W	Zn, Pb, Ag	Skarn	9 ddh, 255 m
Horseshoe Ridge (Crows Nest Res. Ltd.)	082GNWO55	Fort Steele	82G/15W	Coal		4 rdh, 736 m
Jake/Snake (Dragoon Res. Ltd.)		Fort Steele	82G/4E	Ag, Pb, Zn	Vein	16 ddh, 1000 m
Jo-Anne Property (Snowwater Res. Ltd.)	082FSW222	Nelson	82F/6	Au, Ag	Volcanogenic	N/A
Joe Property (Fairbank Eng. Ltd.)	082FSW207	Nelson	82F/3W	Au, Ag, Pb, Zn	Quartz vein	3 ddh, 130 m
Katie (Noranda Expln. Co. Ltd.)	082FSW291	Nelson	82F/3W	Au, Cu	Porphyry	7 ddh, 1692 m; geochem; geophys
Kena (Noramco Mining Corp.)	082FSW237	Nelson	82F/6W	Cu, Au	Porphyry	4 ddh, 1063 m; geochem; geophys
Lake Mountain Area (Fording Coal Ltd.)	082JSW011	Fort Steele	82J/2W	Coal		6 rdh, 518 m
Lookout (White Knight Res. Ltd.)		Fort Steele	82G/5W	Au, Ag, Pb, Zn	Vein	6 ddh, 1000 m; trenching; geochem geophys
Lower Henretta Creek (Fording Coal Ltd.)	082JSW011	Fort Steele	82J/2W	Coal		38 rdh, 3625 m
Lower South Pit East (Crows Nest Res. Ltd.)	082GNW055	Fort Steele	82G/15W	Coal		5 rdh, 392 m
McNeil (Bapty Research Ltd.)	082GSW038	Fort Steele	82G/5W	Pb, Zn	Sedex	2 ddh, 915 m
Midnight Mine (Al Matovich)	082FSW130	Trail Creek	82F/4	Au	Vein	1500 t shipped to mill at Northport, U.S.A.
Millie Mack (Bapty Research Ltd.)	082KSW051	Slocan	82K/4	Ag, Pb	Shear	3 ddh, 457 m
MSA North (Crows Nest Res. Ltd.)	082GNW055	Fort Steele	82G/15W	Coal		14 rdh, 2228 m
MSA North Extension (Crows Nest Res. Ltd.)	082GNW055	Fort Steele	82G/15W	Coal		9 rdh, 2051 m
Nevada Royal Canadian Group (Winchester Dev.)	082FSW088	Nelson	82F/6E	Au, Ag, W	Vein	2 ddh, 130 m (each?)
Ore Hill-Sumit (Yellowjack Res. Ltd.)	082FSW053	Nelson	82F/3E	Au, Ag, Pb, Zn	Replacement?	3 ddh, 613 m; geochem
Pine (Victoria Res. Corp.)		Fort Steele	82G/12W	Au, Cu	Vein	4 ddh, 575 m; geochem
Player Group (Formosa Res. Corp.)	082FSW085	Nelson	82F/6W	Cu, Au, Ag	Shear-related	14 ddh, 1800 m
Price (Kokanee Expln. Ltd.)	082FNE056	Fort Steele	82F/9E	Au	Vein, breccia	7 ddh, 300 m
Rainbow - Tam O'Shanter (Minnova Inc.)	082ESE130	Greenwood	82E/2W	Au, Ag	Epithermal?	7 ddh, 1171 m; trenching; geochem; geophys
Rely (Pegasus Gold Inc.)	082FSW266	Nelson	82F/3	Au	Vein	5 ddh, 710 m; geochem; geophys
Roo (Teck Expln. Ltd.)	O82GSW020	Fort Steele	82G/2W	Cu	Vein	8 ddh, 600 m
Rossland Claims (Bluebird) (Antelope Res. Inc.)	082FSW122	Trail Creek	82F/4W	Au	Vein	7 ddh, 1220 m
Shaft (Noramco Mining Corp.)	082FSW331	Nelson	82F/6	Au, Cu	Shear-related, porphyry	6 ddh, 1653 m; geochem
Silvana Mine (Treminco Res. Ltd.)	082FNW050	Slocan	82F/14	Ag, Pb, Zn, Cd	Vein	2 ddh, 1046 m; 6 u/g ddh, 1098 m

Property (Operator)	MINFILE Number	Mining Division	NTS	Commodity	Deposit Type	Work Done
Silver Dawn (Rock Creek Res. Ltd.)	082ESE113	Greenwood	82E/2W	Pb, Zn, Ag	Replacement	30 ddh, 2030 m
Star (Barkhor Res. Inc.)	082FSE089	Nelson	82F/1E	Ag, Pb, Zn	Sedex/vein	9 ddh, 4082 m
Steeples (Bull River Mine) (R.H. Stanfield Group)	082GNW002	Fort Steele	82G/11W	Cu, Ag, Au	Vein	12 ddh, 5550 m; rtd, 1200 m
Strawberry Flats (Cameco)		Trail Creek	82F/4W	Au	Skarn	5 ddh, 430 m; 8 trenches; geochem
Sullivan Two (White Knight Res.)	082FSE077	Nelson	82F/2E	Pb, Zn, Ag	Sedex	9 ddh, 1500 m
Surelock (Mountain Minerals Co. Ltd.)		Golden	82K/9W	Ba	Fault breccia	bulk sample; exploration adit; mapping; geochem
Taylor Pit (Fording Coal Ltd.)	082JSE009	Fort Steele	82J/2W	Coal		9 rdh, 1808 m
True Blue (Minequest Expln. Assoc. Ltd.)	082FNE002	Slocan	82F/15W	Cu, Ag, Zn, Au	Stratabound massive sulphide	1ddh
Vine (Kokanee Expln. Ltd.)	082GSW035	Fort Steele	82G/5W	Pb, Zn, Cu	Vein	39 ddh, 8000 m
Whitewater (Teck Corp.)	082FSW222	Nelson	82F/6W	Au	Breccia	5 ddh, 650 m; geochem; geophys
Wilds Creek (Kokanee Expln. Ltd.)	082FSE005	Nelson	82F/2E	Zn	Stratabound	5 ddh, 1464 m

Southwestern District

Property (Operator)	MINFILE Number	Mining Division	NTS	Commodity	Deposit Type	Work Done
Bruno (Doromin Res. Ltd.)	092L 229	Nanaimo	92L/1E	Cu, Ag, Au	Veins	11 ddh, 1400 m
Chemainus/Holyoak (Falconbridge Ltd.)	092B 037	Victoria	92B/13W, 92C16E	Au, Ag, Zn, Cu, Pb	VMS	24 ddh, 7202 m; geophys
Cimadoro (Doromin Res. Ltd.)	103F 052	Skeena	103F/1E, W	Zn, Pb, Cu, Au, Ag	Sedex?	9 ddh
Debbie (Westmin Res. Ltd.)	092F 078	Alberni	92F/2E, 7E	Au, Ag	Shears, Qtz-vein stockwork	4 ddh, 240 m; trenching; geophys
Expo(Hushamu) (Moraga Res. Ltd.)	092L 185	Nanaimo	92L/12W	Cu, Mo, Au	Porphyry	18 ddh, 4267 m; geophys; geochem; mapping
Harrison Gold(Abo) (Bema Gold Corp.)	092HSW092	New West.	92H/5E, W	Au	Vein stockwork	7 ddh, 2106 m
Lara (Minnova Inc.)	092B 110	Victoria	92B/13W	Au, Ag, Zn, Pb, Ag	VMS	49 ddh, 11 167 m; geophys; geochem
Merry Widow (Noranda Expln. Co. Ltd.)	092L 044	Nanaimo	92L/6E, W	Au, Ag, Cu	Skarn, manto	geophys; geochem; mapping 4ddh, 386 m;
Mount Sicker (Minnova Inc.)	092B 001	Victoria	92B/13E, 13W	Cu, Au, Ag, Pb, Zn	VMS	14 ddh, 2400 m
Mount Washington (Better Res. Ltd.)	092F 116	Nanaimo	92F/11E, W; 14W	Au, Ag, Cu	Epithermal veins, breccias	6 ddh, 284.4 m
Quet (Noranda Expln. Co. Ltd.)	092GNE027	New West.	92G/9W, 16W	Au, Ag, Zn, Pb, Cu	Veins, replacement	7 ddh, 1251.9 m; geophys; geochem; mapping
Red Dog (Moraga Res. Ltd.)	092L 200	Nanaimo	92L/12W	Cu, Au, Mo	Porphyry	10 ddh, 1890 m
Seneca (Minnova Inc.)	092HSW013	New West.	92H/5W	Cu, Zn, Pb, Au, Ag	VMS	geochem; mapping; drilling
Southeaster (Clear Creek Res. Ltd.)	103G 004	Skeena	103F/8E, 103G/5	Au, Ag	Epithermal Veins, breccias	18 ddh, 940 m; trenching
Spud Valley (McAdam Res. Inc.)	092L 211	Alberni	92L/2W	Au, Ag	Veins	u/g drifting; bulk sampling; pilot mill
Tsable River (Western Canadian Mining Corp.)	092F 333	Nanaimo	92F/7W, 10W	Coal	Sedimentary	drilling
Wann (Moraga Res. Ltd.)	092L 087	Nanaimo	92L/12E, W	Cu, Mo, Au	Porphyry	17 rcdh, 1867 m

pcdh = percussion-drill hole
rcdh = reverse circulation drill hole
rdh = rotary-drill hole
ddh = diamond-drill hole
VMS = Volcanogenic massive sulphide
grd = ground
u/g = underground
sfc = surface

NORTHWESTERN DISTRICT

By D.V. Lefebure and M.L. Malott
District Geology, Smithers

INTRODUCTION

Northwestern British Columbia was one of the most active mineral exploration areas in the country in 1990, with expenditures in excess of $110 million. This amounts to more than 60 per cent of all the dollars spent on exploration in the province. More encouraging results from the **Eskay Creek** property generated much of the action as 34 companies exploring in the Stewart - Iskut River area spent more than $51 million. The current surge of mineral exploration has lasted four years and has found numerous new mineral occurrences and defined new deposits.

The number of exploration programs increased in most areas throughout the Northwestern District. More companies were active in the region extending north from the Iskut River to the Galore Creek and Kiniskan Lake areas. Precious metal veins continued to be the principal target with some companies searching for polymetallic porphyry and volcanogenic massive sulphide deposits.

Construction of the surface facilities and development of the underground workings for the **Snip** gold deposit of Cominco Ltd. were almost complete by the end of the year. Mining of this deposit will start in early 1991. **Windy Craggy** and **Sulphurets** were the other two most advanced, active projects.

Eight mines continued production and one operation closed in 1990. The **Bell, Equity Silver, Cheni Gold, Shasta, Premier Gold, Golden Bear** and **Cassiar** mines operated throughout the year. Cassiar Mining Corporation removed the last ore from its open pit in June and by November had begun underground mining of asbestos fibre from the newly developed **McDame** deposit. The depletion of ore reserves at the **Johnny Mountain** gold mine led to its closure in September.

Crows Nest Resources Limited proposed mining plans for the Telkwa coal deposits; however, late in the year the company announced it was planning to sell its coal assets. The number of placer mining operations in the district declined 20 per cent from 1989, continuing a trend which started in 1988.

HIGHLIGHTS

- Geddes Resources Ltd. spent $11 million on the **Windy Craggy** copper deposit to complete a drilling program, mine planning studies and bulk sampling.
- At the **Midway** silver-lead-zinc deposit Regional Resources Ltd. extended the workings to the Discovery zone and carried out an underground drilling program.
- Cassiar Mining Corporation completed the development of the **McDame asbestos orebody** and started underground mining.
- Drilling on the **Tulsequah Chief property** resulted in a 50-metre intersection of precious metal rich massive sulphides in the H lens.
- For the first time since the early 1970s, a large drilling program was completed on the **Galore Creek copper-gold deposit.**
- Cominco Ltd. started construction and underground development at the **Snip gold deposit** with production planned for early 1991.
- On the **Eskay Creek property** Calpine Resources Inc. spent $27 million to complete 485 diamond-drill holes, underground development and bulk sampling, with only helicopter access to the claims.
- Polymetallic mineralization was found on the **Ski, GNC and Sib properties** which are adjacent to Eskay Creek.
- Placer Dome Exploration Ltd. drilled 65 holes on the **Kerr porphyry copper-gold deposit.**
- Feasibility studies completed on the **Sulphurets gold-silver property** indicated the West zone is not economically attractive at current metal prices.
- Westmin Mining Ltd. signed a joint venture agreement with Tenajon Resources Corporation concerning the **Silver Butte deposit.**
- Underground development and exploration on the Cliff Creek zone at the **Cheni Gold mine** proved disappointing as ore reserves in the zone were reduced by 45 per cent.
- Exploration by Noranda Minerals Inc. at the **Bell mine and Granisle pit** outlined mineralization which

Plate A-1. Geddes Resources Ltd. continued to work on developing the huge Windy Craggy copper deposit. The company completed numerous studies to assess the impact of a mine in this remote location, including field tests on the potential for developing acid drainage shown in the picture above.

could significantly increase the reserves available for the Bell mill.

TRENDS

The mineral industry in northern British Columbia underwent a number of changes in 1990.

- Major companies became much more active.
- Companies developing major mines have kept the public more completely informed about their activities.
- Land-use issues proliferated and their potential impact on mineral exploration increased dramatically.

In the late 1980s mineral exploration was dominated by junior companies while the major companies played a secondary role. This year there was a marked change as major companies, such as Cominco Ltd., Homestake Mineral Development Co., Noranda Inc., Placer Dome Inc. and Westmin Resources Limited completed large exploration programs. In the 1990s it would appear that the major companies will play a larger role in exploring for mineral deposits and developing new mines.

In 1990, for the first time in British Columbia, a company, Geddes Resources Ltd., toured the province to explain its mining plans for the Windy Craggy copper deposit. While many projects do not require this level of public discussion, it is anticipated that in the next decade there will be increasing demands for information from mineral industry companies about proposed mine developments.

The pressure on British Columbia's land base also began to show in 1990, with a wide variety of new areas proposed for consideration as Wilderness Areas, Local Resource Use Plans, Recreation Corridors, Parks and other designations. Most of these initiatives will not alienate the land from mineral exploration. They will, however, place more constraints on how mineral exploration and mining can be carried out. During the next decade the mineral industry will be increasingly asked to participate in land-use decisions.

The regional infrastructure in northwestern British Columbia continued to improve with the completion of the Bob Quinn airstrip in August. Numerous companies were using the strip by the end of the field season and as many as five helicopters were based there. Nearby Bob Quinn Lake will be the starting point for the 92-kilometre

Plate A-2. Located near the Yukon border, a $7.5-million underground development and drilling program was completed on the Discovery Zone of the Midway manto deposit.

Plate A-3. Underground development at Eskay Creek started in June and include mining of a bulk sample (pictured above) for metallurgical tests.

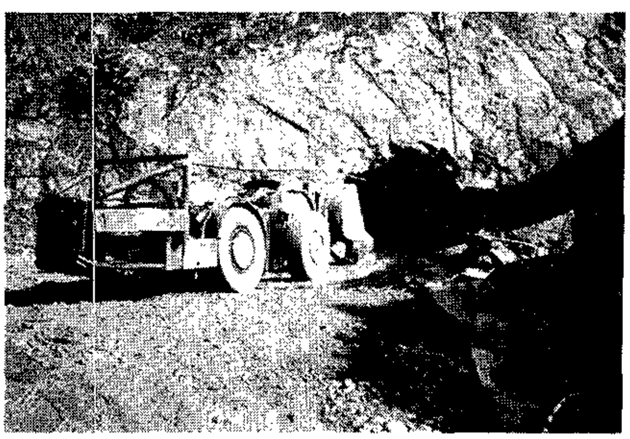


Plate A-4. In the Toodoggone, Sable Resources Ltd. shifted to underground mining of the JM and Creek zones from two underground levels. The portal to the Creek zone is shown above.

Iskut road. Field studies for this road were completed in October. It will follow the Iskut River to the Bronson Creek airstrip (near Cominco's Snip project) with a spur along Volcano Creek to provide access to the Eskay Creek property. Construction of the Iskut Road is planned to start in 1991.

OPPORTUNITIES

Areas with excellent exploration potential are still open for staking throughout the Northwestern District. Some of the more attractive exploration targets are the porphyry copper-gold deposits in the Stikine and Quesnel terranes, volcanogenic massive sulphide deposits in the Alexander and Stikine terranes and mesothermal gold deposits in the Alexander Terrane.

Porphyry copper-gold deposits, such as Galore Creek, Kerr and the Bell orebody, are found throughout the Stikine Terrane. Current exploration is focused on the Quesnel trough and northern part of the Stikine Terrane. There is excellent potential in southern Stikinia, particularly in the Babine Lake area. The northern extension of the Quesnel Terrane into the Dease Lake area also holds some promise.

A number of volcanic belts in the Northwestern District are underexplored for volcanogenic massive sulphide deposits. Recent exploration results at Windy Craggy and the Tulsequah Chief mine, as well as the development of the Greens Creek mine in Alaska, have generated more interest in this deposit type. Areas with massive sulphide potential include the Tatshenshini River, Cry Lake, Dundas Island and Ecstall River districts.

Current work on the Eskay Creek deposit suggests it is primarily a volcanogenic massive sulphide deposit with very high precious metal contents. Exploration for similar deposits in the Stikine Terrane is attracting a lot of funding. Middle Jurassic submarine strata elsewhere within this terrane are prospective for similar deposits.

The North Coast was again one of the quietest areas in the province with respect to mineral exploration, despite the potential to find major mesothermal gold veins.

MINERAL EXPLORATION

Mineral exploration expenditures for the Northwestern District soared to $110 million, more than 60 per cent of the provincial total (Figure A-4). More than $51 million was spent in the Stewart - Iskut River "Golden Triangle", where the focus was on the $29-million **Eskay Creek** program. Except for the **Windy Craggy** project, virtually all the other large projects were located within the Stikine Terrane. Excluding the Eskay Creek and Windy Craggy projects, the average expenditure for a project with drilling or underground development was $644 000.

A total of 622 Notices of Work were submitted in 1990 for mineral exploration, up 40 per cent from 1989 (Figure 2-5). Eight per cent of the Notices were revisions to previously submitted programs. A total of 99 properties in the district were explored by drilling, underground development or major surface programs (Figure 2-6). A complete list of all the major exploration programs is presented in Table A-4 and Figures A-7 and A-8. The following material is a review of the 1990 exploration activity in the various parts of the Northwestern District. The descriptions start with properties located in the northwest and move generally to the southeast.

TATSHENSHINI RIVER AREA

In the extreme northwestern corner of the province a $12-million program was completed on the **Windy Craggy** property of Geddes Resources Ltd. Windy Craggy is a volcanogenic massive sulphide deposit with similarities to both the Besshi and Cyprus types. The mineralization is hosted by Triassic clastic sediments and mafic flows and sills. It occurs near the transition from a predominantly clastic host to overlying mafic volcanic rocks. The North and the South orebodies have a combined strike length of 1.6 kilometres and extend 600 metres below the surface. Each of the zones has a surface expression of supergene copper sulphide enrichment overlain by gossan caps rich in gold and silver. Reserves are currently estimated at 210 million tonnes of 1.59 per cent copper at a 0.5 per cent copper cut-off (Table A-4).

Environmental and geotechnical studies necessary for mine planning, as well as drifting and drilling, were completed in 1990. Drilling between the North and South zones located the new Ridge zone which has been traced along strike for 390 metres. Geddes Resources has revised its Stage 1 report for the provincial government to better address several issues, including potential acid rock-drainage.

Seventy kilometres northeast of Windy Craggy, Goldbank Ventures Ltd. outlined a volcanogenic massive sulphide target on the **Bar** property. The baritic zone contains auriferous pyrite, sphalerite, chalcopyrite, galena and argentite mineralization.

ATLIN

On the **Atlin Ruffner** property of Homestake Mineral Development Company, exploration focused on the South Vulcan zone and #6 vein. Both these zones are hosted by the Fourth of July Creek batholith. The South Vulcan Creek zone is characterized by quartz veins and stockworks in quartz-sericite-altered granodiorite of the Fourth of July Creek batholith. One mineralized interval returned values of 260.2 grams per tonne silver over 0.45 metre. Silicified, chloritized and sheared mafic dikes host the #6 vein which has a strike length exceeding 1600 metres. The best assay from the eastern extension of the vein is an intercept grading 36.3 grams per tonne silver, 20.5 per cent lead and 6.5 per cent zinc over a true width of 0.6 metre.

Noranda Exploration Company, Limited explored for lode gold on the **Pinelode** property on Pine Creek, an important placer gold producer. The property is believed to be underlain by gold-bearing listwanitic alteration zones which occur at a contact between ultramafic intrusive rocks and andesitic volcanic rocks. Unfortunately the drilling intersected only barren ultramafic rocks.

Northwest of Atlin, between Bennett and Tutshi lakes, Lodestar Explorations Inc. discovered two large hydrothermally altered zones in metamorphic rocks of the Yukon Group on the **Pavey** property. Called the Skarn and Cowboy zones, they were drilled and returned assays ranging from 1.23 grams per tonne gold over 29.9 metres to 9.09 grams per tonne gold over 2.99 metres.

Approximately 45 kilometres west of Atlin, on the **TP (Teepee)** property, Cyprus Gold Ltd. drilled several veins cutting Proterozoic-Paleozoic metamorphic rocks close to the Llewellyn fault.

CASSIAR

In the Cassiar mining camp **Total Energold Corporation** used geophysical surveys over its extensive property holdings to trace thrust contacts between argillite and volcanic-chert units within the Sylvester allocthon. These thrust faults were systematically drilled to identify alteration zones and find hidden ore zones. The Bain vein, discovered in 1989, was extended another 300 metres, for a total of strike length of 500 metres, and remains open to the east. Drilling located two other weakly mineralized veins on the Erickson property.

The **Midway** manto deposit is located just south of the Yukon border and 85 kilometres west of Watson Lake. The 1990 exploration program consisted of extending the underground workings by a decline from the Silver Creek zone to the Discovery zone, to provide access for more than 5000 metres of underground drilling. The deposit is hosted by McDame Group carbonates and occurs up to 30 metres below the contact with the overlying Earn Group shale. Mineralization consists of an irregular system of pipes filled with pyrite, sphalerite, galena, pyrrhotite, friebergite, arsenopyrite, pyrargyrite and tin and lead sulphosalts. The geology is disrupted by north-trending faults and several new mineralized zones were intersected by drilling. Drilling in the early 1980s resulted in estimated geological reserves of 1.185 million tonnes grading

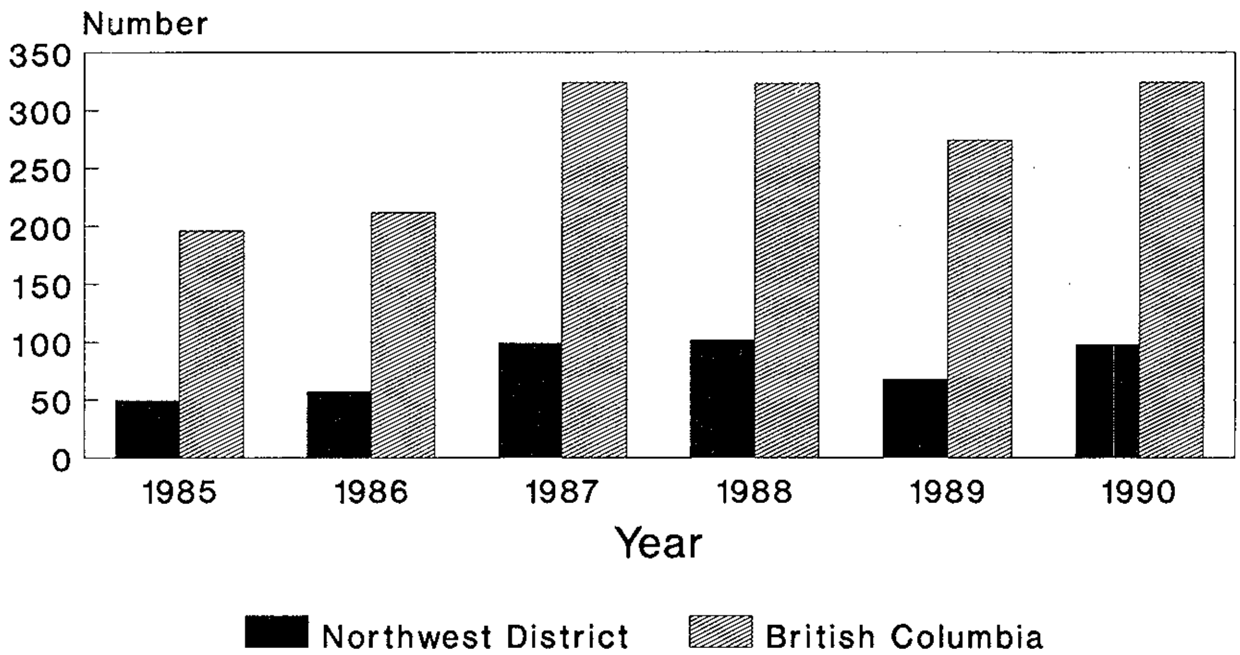


Figure A-6. Major exploration programs.

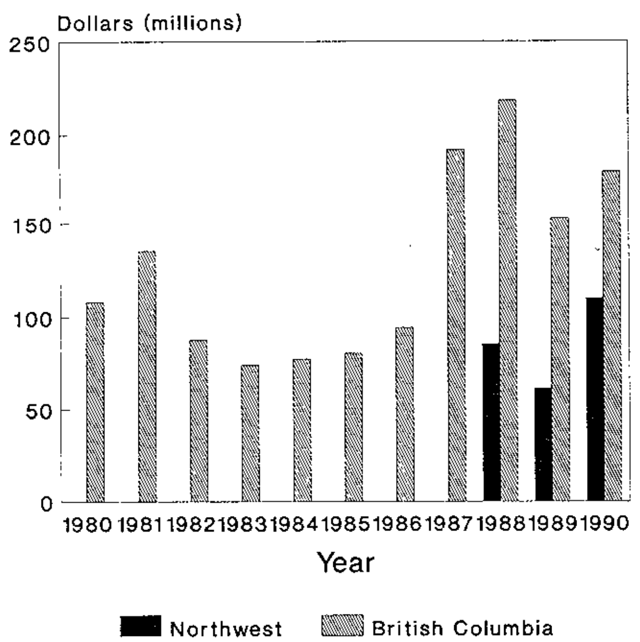


Figure A-4. Provincial figures for 1980 to 1989 provided by B.C. and Yukon Chamber. 1990 figure from District Geologists. Separate statistics for Northwestern District are not available prior to 1988.

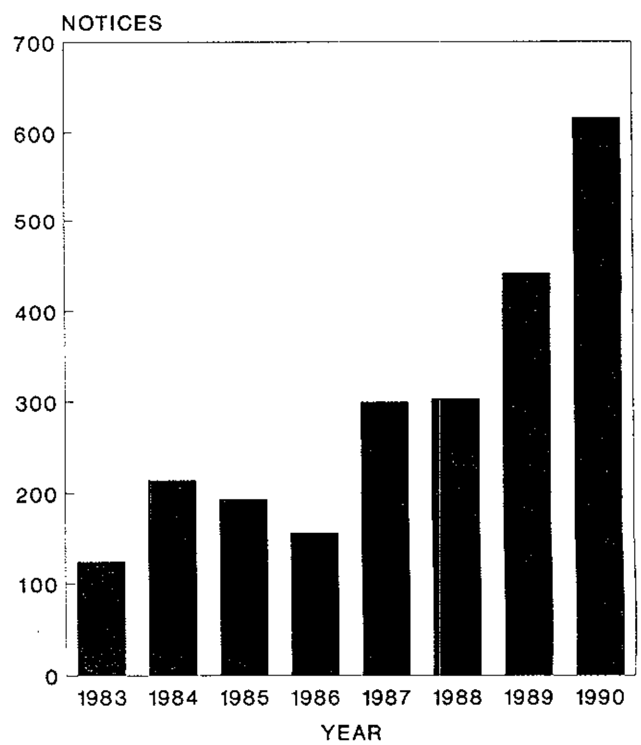


Figure A-5. Mineral Notices of Work, Northwestern British Columbia.

Figure A-7

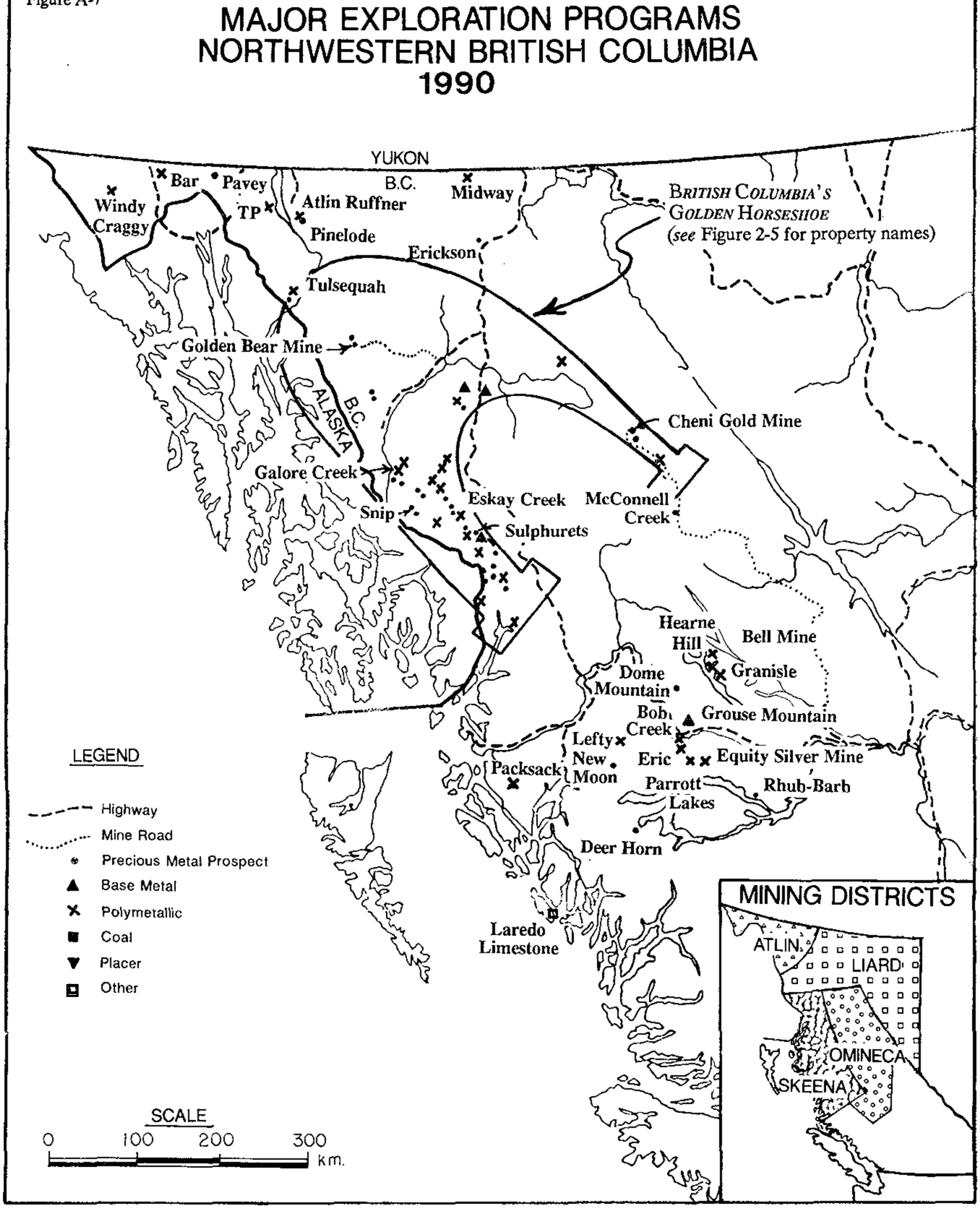

MAJOR EXPLORATION PROGRAMS
NORTHWESTERN BRITISH COLUMBIA
1990
YUKON
B.C.
Windy Craggy
Bar
Pavey
TP
Atlin Ruffner
Pinelode
Midway
Erickson
Tulsequah
Golden Bear Mine
ALASKA
B.C.
BRITISH COLUMBIA'S GOLDEN HORSESHOE
(see Figure 2-5 for property names)
Cheni Gold Mine
Galore Creek
Snip
Eskay Creek
McConnell Creek
Sulphurets
Hearne Hill
Bell Mine
Granisle
Dome Mountain
Bob Creek
Grouse Mountain
Lefty
New Moon
Eric
Equity Silver Mine
Packsack
Parrott Lakes
Rhub-Barb
Deer Horn
Laredo Limestone
LEGEND
Highway
Mine Road
Precious Metal Prospect
Base Metal
Polymetallic
Coal
Placer
Other
SCALE
0 100 200 300 km.
MINING DISTRICTS
ATLIN
LIARD
OMINECA
SKEENA

TABLE A-4
DEVELOPMENT STAGE PROJECTS
NORTHWESTERN DISTRICT, BRITISH COLUMBIA

PROJECT	COMPANY	ORE RESERVES
Windy Craggy	Geddes Resources Ltd.	143 Mt; 1.69% Cu, 0.084% Co, 0.2 g/t Au 3.41 g/t Ag (proven and probable)
Eskay Creek	Corona Corp., Placer Dome Inc.	3.967 Mt; 26.4 g/t Au 998.4 g/t Ag, Pb,Zn,Cu (probable and possible)
Silver Butte	Tenajon Resources Corp., Westmin Mining. Ltd.	279.4 kt; 17.31 g/t Au 36.68 g/t Ag
Telkwa Coal	Shell Canada Ltd.	South Telkwa: 21.8 Mt North Telkwa: 13.2 Mt bituminous coal

410 grams per tonne silver, 9.6 per cent zinc and 7 per cent lead within the Discovery and Silver Creek zones.

BRITISH COLUMBIA'S "GOLDEN HORSESHOE"

The Stewart - Iskut River and Toodoggone River areas are only part of the northern Stikine Terrane which has potential for major precious metal deposits related to island-arc volcanic centres. The Galore Creek, Kiniskan Lake and other areas have well-demonstrated potential for large gold, copper and silver deposits. This area can be considered to be British Columbia's "Golden Horseshoe" because northern Stikinia forms a horseshoe-shaped border to the Bowser basin (Figure A-7). This area includes the much smaller "Golden Triangle" which has Johnny Mountain, Sulpurets and Stewart at the corners.

Exploration programs in the Tulsequah River, Tatsamenie Lake, Dease Lake, Mount Edziza, Galore Creek, Forrest Kerr, Iskut River, Eskay Creek, Unuk River, Sulphurets, Stewart, Alice Arm and Toodoggone areas all lie within the Golden Horseshoe. Expenditures on 77 major exploration programs within the Horseshoe were in excess of $83 million in 1990.

TULSEQUAH RIVER - TATSAMENIE LAKE AREA

The **Tulsequah Chief** property of Cominco Ltd. and Redfern Resources Ltd. is located 65 kilometres northeast of Juneau, Alaska. The 1990 drilling program was designed to test for the new H ore lens lying above the previously known A and B lenses. Drill intersections of the ore horizons were approximately 300 metres deeper than last year's drilling. In July, Cominco intersected 50 metres of massive sulphides grading 2.92 per cent copper, 1.58 per cent lead, 9.09 per cent zinc, 3.83 grams per tonne gold and 170 grams per tonne silver in the H lens. Other massive sulphide intersections were made during the program, although in many cases they were partially displaced by a diorite dike. The 1990 results are expected to boost the geologically indicated reserves reported by Redfern Resources in 1989 (*see* Table A-5).

Just across the Tulsequah river, at the old **Polaris-Taku** gold mine, Suntac Minerals Corporation completed a drilling program in early 1990 which was followed up later in the year with surface surveys by Estey Agencies Ltd. The early program tested the strike and down-dip continuity of the east-trending C vein, a quartz-carbonate shear zone containing veins impregnated with auriferous arsenopyrite. Reported assay results from drill intersections varied between 2.16 grams per tonne gold over 9 metres to 51.02 grams per tonne gold over 3 metres. The drilling added 332 000 tonnes to the reserves which now total 803 765 tonnes (probable and possible) grading 16.11 grams gold per tonne.

At the **Golden Bear** mine there was drilling north and south of the Bear main zone to locate extensions to the orebody. Results indicate that the host structure extends a considerable distance to the south. This area is largely untested. Drill results to the north indicate the potential for significant mineralization hosted in an en echelon fault which parallels the Bear Mine fault. Approximately 10 kilometres northwest of the Golden Bear mine, Armeno Resources Inc. investigated a zone of silicification and brecciation extending 1.5 kilometres along a limestone-phyllite contact on the **Tut** property. Strongly anomalous gold, silver, arsenic and antimony values were

EXPLORATION PROGRAMS COMPLETED IN THE "GOLDEN HORSESHOE"

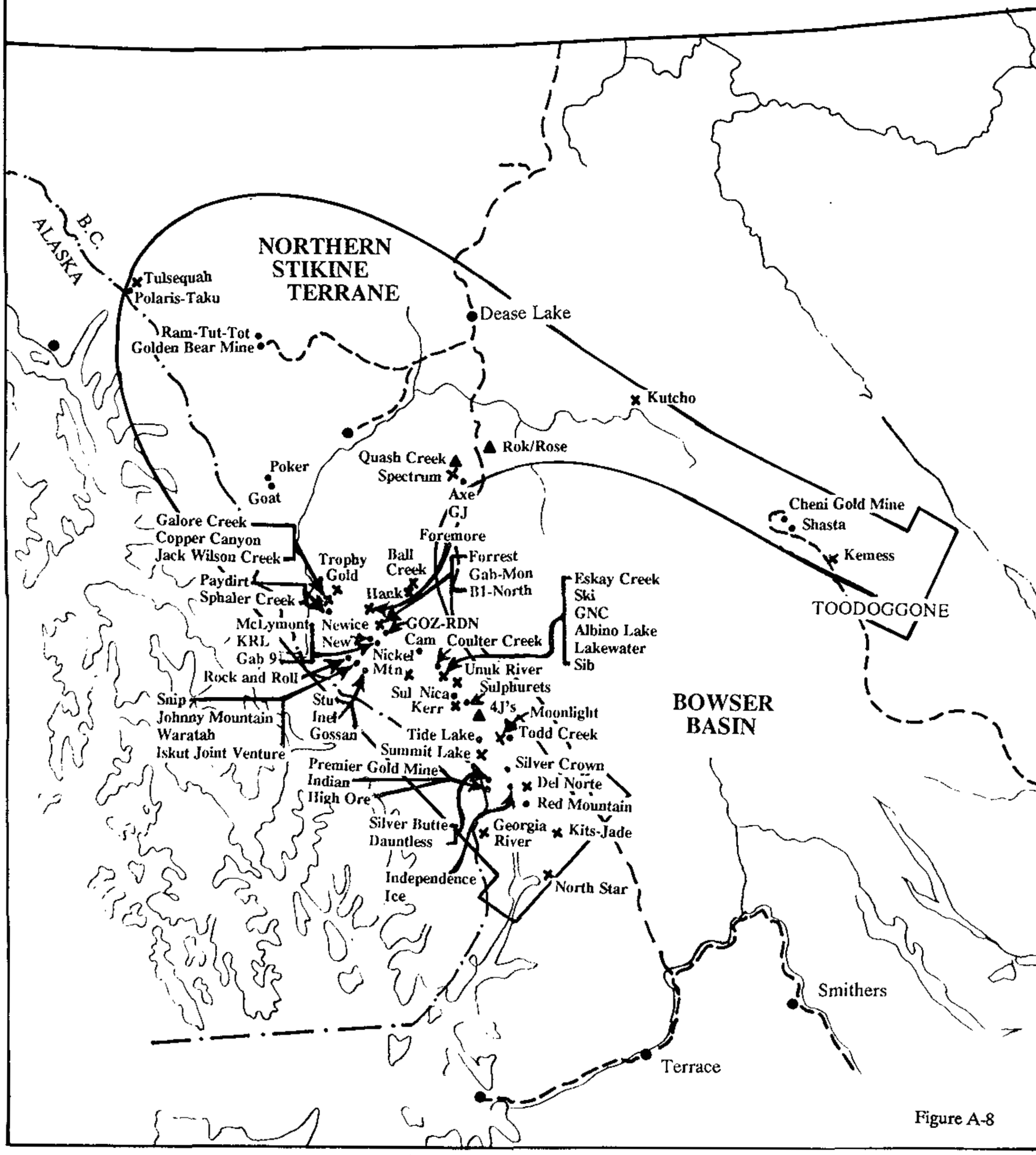


Figure A-8

TABLE A-5
ADVANCED EXPLORATION PROJECTS,
NORTHWESTERN DISTRICT, BRITISH COLUMBIA

PROJECT	COMPANY	ORE RESERVES
Midway	Regional Resources Ltd.	1 185 Mt; 410 g/t Ag, 7.0 % Pb, 9.6 % Zn
Tulsequah	Cominco Ltd., Redfern Resources Ltd.	5.26 Mt; 1.6% Cu, 1.31% Pb, 7.03% Zn, 2.74 g/t Au, 100.5 g/t Ag
Erickson Gold	Total Energold Corp.	Erickson:18.3 kt; 14.1 g/t Au Cusac, Michelle Ext.: 25 kt; 34.29 g/t Au, 12.3 g/t Ag
Kerr	Western Canadian Mining Corp., Sulphurets Gold Corp.	114.3 Mt (drill inferred); 0.61% Cu, 0.27 g/t Au, 1.71 g/t Ag
Dome Mountain	Teeshin Resources Ltd. Canadian-United Minerals Inc.	293.9 kt; 12.17 g/t Au, 80.23 g/t Ag

returned from the silicified zone which is up to 50 metres thick.

In the Barrington River area, two projects were completed in an area underlain by interlayered volcanics and sediments of the Stuhini Group. These conformable units have been intruded by a multiphase syenitic stock which is enveloped by a large hornfels zone. The syenite has a variety of associated mineral occurrences, including porphyry copper-gold mineralization. On the **Poker** property, surveys were completed by Dryden Resource Corporation to try to locate the source of glacial boulders found below Limpoke Glacier. Drill holes testing UTEM and magnetic anomalies on the south side of the valley produced no significant results. On the nearby **Goat** property the exploration program concentrated on known showings. Fifteen zones have significant concentrations of gold-copper mineralization, while numerous lenses of massive arsenopyrite and pyrrhotite with high gold values over narrow widths were found in other areas.

DEASE LAKE - MOUNT EDZIZA AREA

At the **Kutcho** property, located approximately 100 kilometres southeast of Dease Lake, Homestake Mineral Development Company completed a major drilling program over virtually an entire greenstone belt. The target was volcanogenic massive sulphide deposits similar to the **Kutcho Creek** deposit. Favourable hydrothermal alteration was found at numerous locations on the property, however, a pyrite bed 1 to 2 metres thick was the only new horizon discovered. It was intersected in four holes over a 3.5-kilometre strike length along the southwestern side of the property. No new base metal sulphide lenses were defined.

There were a number of exploration programs in the Kiniskan Lake area. Near Eddontenajon, Manchester Resources Corporation drilled the Main showing on the **Rok** property. The third hole intersected chalcopyrite mineralization near the top of the hole, including a 6.0-metre interval of 4.25 per cent copper and 7.13 grams gold per tonne. Farther to the west, on Teck Corporation's **Quash Creek** property, drilling was focused on a strong copper-gold soil anomaly in the vicinity of a porphyritic stock intruding Stuhini Group volcanics.

On the nearby **Spectrum** property, the target is porphyry gold-copper mineralization associated with an altered zone in Stuhini Group volcanics and sediments. Previous work on the property was concentrated on the Red Dog zone where earlier drilling had outlined 1.8 million tonnes grading 1.37 grams per tonne gold. In 1990, initial drilling by Columbia Gold Mines Ltd. tested the 500 Colour, Porphyry and QC zones. These zones trend northerly and dip steeply. They are associated with a large system of intensely silicified and carbonatized andesitic tuffs containing pyrite, arsenopyrite and visible gold.

Adjoining the Quash property to the south are the **Axe** claims of Ascot Resources Ltd., and farther south, the **Axe** property of Beauchamps Exploration Inc. The Axe properties cover Upper Triassic volcanics and coeval subvolcanic intrusives. Positive results were obtained on the Ascot property where high-grade copper mineralization with significant gold and arsenic values was discovered over an area 500 by 400 metres at Trevor Peak. Nearby, on the **GJ** property, a similar copper-gold porphyry target, with diorite to latite dikes and subvolcanic plugs, is hosted by coeval upper Triassic volcanics and cherts to siltstones of possible Paleozoic age. The drilling, by Ascot Resources Ltd., tested along strike from known mineralization as well as several new targets. Results were considerably poorer than in earlier drilling programs, with the best interval grading 0.18 per cent copper and 0.34 gram per tonne gold over 27 metres.

Galore Creek Area

The Galore Creek district was an active area with exploration for porphyry and vein deposits continuing. A two-phase drilling program was completed by Mingold Resources Inc. on the **Galore Creek** deposit. Initial drilling tested several gold targets peripheral to the main deposits. The second phase was concentrated on the Southwest zone.

The Copper Canyon showing, immediately to the east of Galore Creek, was drilled by Consolidated Rhodes Resources Ltd. Preliminary reserves of 29 million tons grading 0.7 per cent copper, 9.33 grams per tonne silver and 0.311 gram per tonne gold were outlined in 1957. The 1990 drilling repeated some of the old holes and returned similar values over widths of tens to hundreds of metres. Other holes stepped out to define the margins of the deposits.

On the **Trophy Gold** property, drilling tested the Ptarmigan zone and the N110 Grid, a large copper-gold soil anomaly coincident with induced polarization chargeability highs. Gigi Resources Ltd. reported gold and silver values from the Ptarmigan zone over widths of approximately 1 metre. Low-grade gold mineralization was intersected on the N110 Grid.

The **Jack Wilson Creek** property is located west of Galore Creek. It is underlain by strongly sheared, Triassic Stuhini volcanics and dioritic intrusives which are pervasively altered to chlorite and epidote, and locally to quartz, anhydrite and potassium feldspar. The strongest copper-gold mineralization appears to be at the intersection of fractures, faults and shears. The mineralization and associated alteration appear consistent with a high-level copper-gold porphyry model. The best copper-gold values found to date are in the Central zone where a 45-metre section grades 0.237 per cent copper and 0.377 gram per tonne gold .

On the fringes and south of the Galore Creek area the **Paydirt** and **Sphaler Creek** properties were explored for veins. At Sphaler Creek, Pass Lake Resources Ltd. drilled on coincident geophysical and geochemical anomalies on the Deluxe zone without intersecting any significant mineralization. Silver Standard Resources Inc. carried out an extensive mapping, geochemical and geophysical program on the Paydirt property.

Forrest Kerr Area

The **Ball Creek** property covers a porphyry copper-gold system in an Upper Triassic package of andesitic tuffs, flows and epiclastics intruded by a swarm of subparallel, north-trending Late Triassic monzonite dikes. A circular hypabyssal monzonite stock is also believed to underlie the property. Alteration consists of a potassic core (Camp zone) grading outwards into concentric phyllic and then propylitic shells. Earlier drilling outlined a large area of promising gold and copper values. The 1990 drilling tested geophysical and geochemical targets, unfortunately results were not encouraging.

On the nearby **Hank** property, owned by Lac Minerals Ltd., the lower alteration zone was tested along strike for the extension of the broad pervasive area of pyritic alteration with quartz stringers and veins containing galena, sphalerite, chalcopyrite and pyrite which characterizes the zone. No significant zones of gold mineralization were found.

Massive sulphide boulders in the **More Creek** area generated considerable excitement as several companies searched for their source. Cominco Ltd. followed up on its 1989 surface exploration program and drilled five holes through Foremore Glacier. The holes were to test for the bedrock source of massive sulphide boulders at both toes of the glacier. The stratigraphic sequence (from top to bottom) intersected in drilling is: gabbro, laminated argillite, limy tuff, graphitic schist, chert, maroon and green intermediate pyroclastics with interfoliated quartz-sericite-pyrite schist. The sequence has undergone two periods of penetrative deformation and is thought to be Devono-Mississippian in age. On the adjoining **GOZ-RDN** property to the south, Noranda Exploration Company, Limited followed up another boulder train. Drill testing of selected targets yielded mixed results which ranged from 7.89 grams per tonne gold over 7.85 metres to 11.6 grams per tonne gold over 4.4 metres.

Avondale Resources Ltd. continued work on a number of prospects on the **Forrest Kerr** property, including the Creek showing. The latter is a large area of gold-silver-copper mineralization within a quartz stockwork. Twenty-four holes were drilled on eight targets.

Five gold-bearing zones were explored on the **Gab-Mon** property of Consolidated Seagold Ltd., including the extension of the Northwest zone on the **McLymont** property. On the Northwest zone, low gold values were obtained in fractures in Mississippian volcanics, but no limestone units were found. The **Arseno/Sulphide** zone was the only prospect drilled, with the best intersection containing 5.07 grams per tonne gold over 2.2 metres.

Kestrel Resources Ltd. drilled two holes to test a geophysical anomaly on the nearby **B1-North** property. No significant mineralization was encountered.

NEWMONT LAKE AREA

The Northwest zone of the **McLymont** property was drilled extensively by Gulf International Minerals Ltd. It is now believed to be a gold-enriched retrograde-altered skarn. Jasper, hematite, carbonate, quartz and rare remnants of andradite garnet with associated gold have replaced units of coarse crinoidal marble. Galena-lead isotope analyses indicate an Early Jurassic, or older age. Zones with similar alteration patterns have been identified elsewhere on the property.

On the adjacent **Gab 9** claims, held by Jazzman Resources Inc., a thick succession of Mississippian volcanic, volcaniclastic and bioclastic rocks underlies the property. The exploration target is a gently dipping crinoidal limestone occurring near steeply dipping faults associated with the regional McLymont fault. Dolomitization, silicification and chlorite alteration are associated with widespread pyrite. Gold is primarily confined to silicified and sericitized zones in recrystallized limestone as seen on the adjoining McLymont property. The most significant results include an assay of 11.6 grams per tonne gold over 1 metre within a strong geochemically anomalous zone 80 metres thick.

On the **KRL** property, located near the McLymont property, Kestrel Resources Ltd. drill-tested a series of quartz veins carrying visible gold. A number of drill holes cut short sections assaying up to 34 grams per tonne gold. Northwest of the McLymont area, Ticker Tape Resources Inc., on the **Newice** property, and Adrian Resources Ltd., on the **New** claims, drilled a series of gold-bearing quartz veins. They report no significant results.

ISKUT RIVER AREA

The **Rock and Roll** property of Thios Resources Ltd. is centred on some rocky knolls near the confluence of the Craig and Iskut rivers. The Black Dog zone has massive pyrite, galena, sphalerite and chalcopyrite mineralization in a subvertical shear zone. Immediately to the east, on ground controlled by the Iskut Joint Venture, gold occurs in variably carbonate-altered and sheared pyritic volcanic rocks and narrow quartz-carbonate veins. Drilling tested three zones in two phases. The best result was an intersection assaying 8.98 grams per tonne gold over 1.37 metres in the Gregor zone.

Underground development and surface construction continued at Cominco Ltd.'s **Snip** deposit, in preparation for the commencement of mining operations in 1991 (*see* section on Development Projects). On nearby Johnny Mountain, a large exploration program was completed by Skyline Gold Corporation on the **Johnny Mountain Flats** area. High gold values were found in a 1.5-metre quartz vein at the C1 zone and in a mineralized shear zone called the Burnie. In addition Skyline worked with Placer Dome Exploration Inc. in a joint venture covering the **Reg** claims which cover the Bronson Creek and Bonanza West prospects. Polymetallic mineralization was discovered in a shear zone (the Bonanza zone) which lies along the extension of the structural zone hosting the Snip deposit.

Big M Resources Ltd. worked on the **Waratah** property, located just east of the confluence of the Iskut River and Bronson Creek. The program consisted of surface trenching and drilling on the Cooper occurrence, a gold-bearing shear zone.

To the south, on the **Inel** property, Gulf International Minerals Ltd. completed an underground development and drilling program on the AK zone, in conjunction with Avondale Resources Inc. The pyrite, sphalerite, galena, chalcopyrite and arsenopyrite mineralization is hosted by a syenitic intrusive breccia. The mineralized breccia was traced over a strike length of about 150 metres. Two of the best drill-hole intersections were 7.4 metres grading 41.14 grams per tonne gold and 9.2 metres grading 18.17 grams per tonne gold. The highest gold values seem to be concentrated along one horizon at about the 1690-metre elevation.

On the nearby **Stu** property, Kestrel Resources Ltd. drilled high-grade veins in two separate areas. To the east, on the adjoining **Cam** claims of Crimsonstar Resources Ltd. and Florin Resources Inc., pyrite, pyrrhotite, chalcopyrite and arsenopyrite, with magnetite and hematite, were intersected in drilling on a strong geochemical anomaly. The mineralization may be similar to skarns found on the adjacent **Josh** claims.

The **Gossan** claims in the Khyber Pass area, south of Inel, are underlain by sediments and volcanics of the Lower Jurassic Betty Creek and Unuk River formations. These units have been intruded by megacrystic feldspar-porphyritic diorite and an equigranular monzonite. Vector Industries International Inc. drill-tested the Pyramid Hill skarn, Zinc Hill and 'A' zones. The A zone, first drilled in 1985, is interpreted to be a conformable horizon at the base of an andesitic unit and overlying a siltstone. The Zinc Hill zone is located northeast of the A zone and has a similar style of mineralization. A 54.4-metre intersection on the A zone returned values of 1.10 grams gold and 10.29 grams per tonne silver, 0.05 per cent copper and 0.42 per cent zinc.

A 1988 airborne magnetometer survey over the **Nickel Mountain** property of Silver Standard Resources Inc. was followed up late in 1990 by a short drilling program testing two pronounced anomalies. Swift Miner-

Plate A-5. Exploration in rugged northwestern British Columbia continued at a record pace in 1990. On the Eskay Creek property more than $25 million dollars was spent on this rich gold-silver deposit which is accessible only by helicopter.

als Ltd. drilled five holes on the nearby **Coulter Creek** property.

ESKAY CREEK AREA

Exploration continued at full bore on the **Eskay Creek** property with expenditures in excess of $25 million, the biggest program in British Columbia in 1990. Work was concentrated on infill drilling on the 21B zone, previously known as the Central zone, and its strike extension to the north. A step-out drilling program tested mineralization discovered on the 'C' and Pump zones to the west and east of the 21B zone, respectively. During the second half of the year an underground program included 1000 metres of drifting, and two crosscuts in ore, providing a bulk sample for metallurgical testing. The project entered the Mine Development Review Process with submission of a Prospectus in April. During 1990 road access and environmental studies were undertaken for a Stage I report which is scheduled to be submitted in the spring of 1991.

Current estimated tonnages for the 21B and parts of the 21C and Pumphouse Lake zones, using a 3.42 grams per tonne gold cut off, are a geological reserve of 3.967 million tonnes grading 26.4 grams per tonne gold and 998.4 grams per tonne silver plus significant zinc and lead values. The deposits are hosted by argillaceous sedimentary rocks within the lowest member of the Salmon River Formation and partly within a footwall sequence of rhyolites of the Mount Dillworth Formation. The 21B zone is now recognized as a volcanogenic massive sulphide deposit.

Drilling by Adrian Resources Ltd. further defined reserves on the **Tok** claim "gap" which is surrounded by the Eskay Creek property. These reserves are part of the 21B deposit but are reported separately as 153 314 tonnes grading 22.63 grams gold and 598.98 grams silver per tonne at a 3.42 grams gold cut off. Adrian Resources also drilled on its **Ski** property to the north and east of the Eskay Creek project. Lower grade mineralization was traced along strike from the 21B zone for several hundred metres onto this property. The zone is deeper toward the northeast.

On the **GNC** claims, which are located to the east and west of the Eskay Creek property, Prime Resources Group Inc. focused its drilling on the Tip Top and Porphyry showings. The latter is a base metal zone with gold and silver values, adjacent to a feldspar porphyry intrusion. Adjoining the GNC property to the west, the **Lakewater** holdings of Tymar Resources Inc. were also drilled for possible down-dip extensions of the Eskay Creek deposit.

The **Albino Lake** project of Eurus Resources Corp. abuts the Eskay Creek property on the northwest. A winter drilling program is testing for the down-dip extensions of the 21C and 21B zones. The **Sib** property of

American Fibre Corporation adjoins the Eskay property to the southwest. Intensely altered volcanic rocks host stockwork and vein-breccia mineralization within the 4.2-kilometre-long gossanous Central anomalous zone. Drilling cut numerous intercepts grading 0.34 to 3.09 grams per tonne gold. Two hundred and fifty metres west of the Central zone and five kilometres south of the Eskay Creek property, an intersection in the Lulu zone averaged 14.43 grams gold and 1059.85 grams silver per tonne over 14.3 metres. The mineralization is in a graphitic mudstone interbedded with felsic volcanics.

SULPHURETS CREEK AREA

Granges Inc. worked its large Unuk River property south of the Eskay Creek area which covers a number of prospects. Exploration focused on the **R grid, Zone 1/AP zone, U2 grid** and **Beedee zone**. Thirteen holes were completed on Zone 1 and three holes on the R grid. Short, subeconomic, polymetallic mineralized intervals were encountered in brecciated welded tuffs in the Zone 1/AP zone. No significant mineralization was encountered in R-grid drill holes which intersected minor felsic tuffs in a dominantly argillitic and andesitic sequence.

In the Sulphurets Creek area, drilling on the **Nica** claims by Ambergate Explorations Inc. produced little encouragement. Exploration on the nearby **Sul** claims by Kenrich Mining Corporation also did not find any significant showings.

On the **Kerr** property, more than 17 000 metres of drilling was done, on a porphyry target, by Placer Dome Exploration Inc. Mineralization and alteration occur in Triassic volcanics and sediments intruded by subvolcanic alkaline stocks. Disseminations and veinlets of chalcopyrite with lesser chalcocite, tenantite and bornite occur in a shear zone 90 to 100 metres wide within a north-trending sericitic alteration zone. Average grades of 0.8 per cent copper and 0.034 gram per tonne gold have been traced for a strike length of 1 kilometre and to a depth of 400 metres. Reserves based on 1989 information are quoted as 114.3 million tonnes grading 0.61 per cent copper, 0.27 gram gold and 1.71 grams silver per tonne.

Immediately to the east, on the **Sulphurets** property, Newhawk Gold Mines Ltd. completed underground drilling during the winter which extended the R8 vein system to the south and at depth, and the West zone deeper and to the north.

STEWART MINING CAMP

Teuton Resources Ltd. discovered a 600 by 200-metre gold anomaly in soils on the 4Js property, 50 kilometres north of Stewart. Drilling beneath the anomaly intersected mineralization containing from 2.37 grams gold per tonne over 7.2 metres to 7.82 grams gold per tonne over 1 metre. At **Tide Lake**, Tenajon Resources Ltd. trenched and drilled the 73-metre-long 'A' structure. Surface chip samples averaged 20.5 grams gold and 6.86 grams silver per tonne over a width of 1.16 metres.

At the **Summit** property, the former Scottie Gold mine, Royal Scot Resources Ltd. conducted a surface and underground program testing the E, C and M zones. Continuity of the M zone was confirmed below the 3000 Level.

A zone of vein-breccia replacement with polymetallic sulphides, 600 metres long, occurs on the **Silver Crown** property of Nararne Resource Corporation. The mineralization is hosted by what are believed to be mid-Jurassic siltstones and greywackes overlying well-stratified epiclastics of the Mount Dillworth felsic volcanic sequence.

Tenajon Resources Ltd. completed a drilling program which extended and confirmed the continuity of the Kansas and West Kansas zones on the **Silver Butte** property. Sulphide mineralization occurs in a quartz-carbonate stockwork hosted by Hazelton Group andesites. In October, Tenajon Resources and Westmin Mining Limited signed a joint venture agreement on the property, which is situated a kilometre southwest of the **Big Missouri minesite**. Milling the high-grade ore from the Silver Butte is expected to improve the overall economics of the **Premier Gold mine** operation. Westmin is currently evaluating data on the Facecut and West Kansas zones provided by a drilling program completed in September and October. Data from drilling on the **Dauntless** claim, adjacent to the Silver Butte, are also being evaluated.

Westmin continued to explore for new ore reserves. On the **Silbak Premier** deposit, the 4G area of the 4 level was rehabilitated and an extensive underground drilling program undertaken. Westmin also drilled the **Indian** and **High Ore** properties.

In the Mount Shorty Stevenson area, Armeno Resources Inc. drilled north and south of the workings on the main structure of the **Independence** property. To the north, the silver mineralization was tested at depth and along strike. Testing to the south was for gold mineralization at depth.

On the **Ice** claims the target is a brecciated vein with quartz and sulphides, hosted by Lower Jurassic Unuk River Formation volcaniclastics and intercalated tuffaceous sandstones. Core from 50 centimetres of one hole assayed 1.79 grams gold and 343.0 grams silver per tonne, and 9.24 per cent zinc.

In the Todd Creek drainage, Noranda Exploration Company, Limited drilled coincident induced polarization and geochemical anomalies on the **Fall Creek** zone. The zone is a hydrothermally altered and mineralized area within a felsic volcanic and volcaniclastic package believed to be part of the Mount Dillworth Formation. On the **Moonlight** property, a few kilometres to the west, High Frontier Resources Ltd. drilled a quartz vein within a mineralized zone at the contact of volcanic and sedimentary rocks of what is believed to be the Lower Jurassic Unuk River Formation.

Approximately 15 kilometres east of Stewart, Teuton Resources Corporation evaluated a series of base and precious metal zones characterized by metal-rich veins and gold-copper-rich replacement horizons. The hostrocks are thought to be Middle Jurassic volcaniclastic and epiclastic rocks of the Betty Creek Formation which are flanked on either side by Salmon River Formation sedimentary rocks. Both units are intruded by a plagioclase hornblende porphyry. The mineralization appears to occur at the sediment-volcanic contact.

Bond Gold Canada Inc. drilled near **Red Mountain**. Although little information is available about this property, preliminary data suggest that this is a mesothermal vein system, possibly related to a porphyry system. Approximately 25 kilometres south of Stewart, Bond Gold Canada also undertook a program on the **Georgia River** property.

Alice Arm Area

At the head of the Kitsault valley, Oliver Gold Corporation conducted a large geophysical and geochemical program on the **Kits-Jade** property. The focus of exploration has moved from narrow, high-grade lead-silver shear veins to large-tonnage, stratiform zinc-lead-silver targets. Broad zones of porphyry copper-gold mineralization have also been outlined.

Dolly Varden Minerals Inc. drilled for massive sulphides in a wide area of conformable barite mineralization. The sporadic zinc-copper-lead-gold values encountered are interpreted by Dolly Varden Minerals geologists as a distal facies of a sulphide lens.

North Coast

Cominco Ltd. drilled the **Packsack** property in the Ecstall River area to test continuity of the known massive sulphide horizon at depth.

The limestone quarry on **Aristazabal Island**, owned by Laredo Limestone Ltd., was drilled to confirm reserves and limestone quality.

Todoggone River Area

Epithermal gold-silver veins hosted by Triassic Takla Group and Lower Jurassic Toodoggone volcanics (equivalent to the Hazelton Group) have remained the focus of exploration in the area. On the southeastern border of the camp porphyry copper-gold mineralization is the target.

Cheni Gold Mines Inc. conducted an extensive exploration program on the **Lawyers** property. The AGB zone was drilled in the West and Blasthole segments. The deposit contains a hematite zone grading into a silicic then propylitic zone with depth. The Duke's Ridge zone was tested for a down-dip extension of the structure. The entire Cliff Creek zone was drilled. Both the South and Mid areas within the Cliff Creek zone are more complicated than originally thought. The mineralization is associated with narrow breccia zones which seem to act as conduits for ore-forming fluids. The veins appear to be tension gashes between the breccia zones.

On the **Shasta** property, mineralization is hosted predominantly by feldspar quartz crystal-lapilli tuffs informally named the "pyroclastic series" of the Toodoggone Formation. Volcaniclastics overlying the pyroclastic series appear to postdate the mineralization. The mineralization can be characterized as tabular to curviplanar quartz-calcite breccia zones within an area of variable alteration and stockwork veining. Drilling results on the Creek zone were encouraging for Homestake Minerals Ltd.; it was extended along strike and now has a 1000-metre length, 200-metre down-dip extent and an average thickness of 6 metres.

South of the Toodoggone and east of Thutade Lake, El Condor Resources Ltd. explored for porphyry copper-gold mineralization on the **North** and **South Kemess** properties. The **North Kemess** property, east of Duncan Lake, was drilled to test mineralization in intensely hydrothermally altered diorite plutons and Takla volcanics. These rocks host auriferous porphyry copper mineralization within phyllic and potassic alteration zones that are surrounded by extensive propylitic alteration. Drilling on the **South Kemess**, which is south of Duncan Lake, gave encouraging results ranging from 0.03 gram per tonne gold and 0.19 per cent copper over 40.6 metres to 0.83 gram per tonne gold and 0.31 per cent copper over 161.72 metres. The host stock, a complex monzonite-diorite that is variably quartz bearing and strongly altered and quartz veined, intrudes Takla volcanics and interbedded sediments.

Babine Lake Area

Noranda Minerals Inc. carried out three exploration programs in the Babine Lake area. At the **Bell minesite**, Noranda drilled 52 holes within and adjacent to the pit in

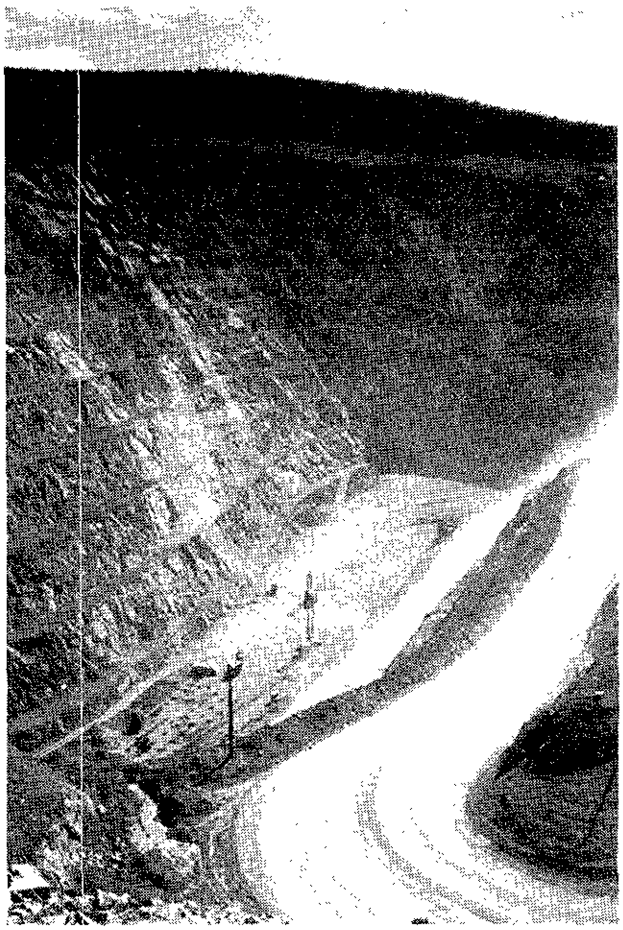


Plate A-6. At the Equity Silver Mine mining operations focused on the Main Zone pit (shown above) with development and initial mining of the Waterline Zone pit. Current ore reserves at Equity Silver are projected to be exhausted by late 1992.

order to better define ore and waste zones. An additional 10 holes were drilled to the north and west of the pit to define areas suitable for future waste-rock dumps. For the first time in a number of years, Noranda Minerals worked on the **Granisle property**. Drilling was to confirm the grade and tonnage calculations determined from drill and blasthole data collected prior to the closure of the Granisle mine, and also to define waste zones within the core of the deposit. A few holes tested the possibility of pushing back the north wall of the pit. On the **Hearne Hill** property, drilling by Noranda for the last two years has been targeted on an altered, chalcopyrite-bearing breccia pipe within a Tertiary biotite feldspar porphyry. Part of a larger zone of low-grade, fracture-controlled mineralization, the pipe extends to 120 metres below surface where it is cut off by a postmineral quartz feldspar porphyry dike.

SMITHERS - HOUSTON AREA

Drilling on the **Dome Mountain** property of Teeshin Resources Ltd., 25 kilometres east of Smithers, outlined a continuation of the main ore zone and increased the length of the Boulder shear zone. Significant intersections were encountered throughout the 350-metre extension of the Boulder zone. In November, Teeshin Resources announced the signing of a joint venture agreement with Timmins Nickel Inc. whereby the latter company is to bring the property into production.

North of Houston, copper showings on the **Grouse Mountain** property were drilled by Swift Minerals Ltd.

Equity Silver Mines Ltd. explored both at the minesite south of Houston and on a number of properties within the region. At the minesite, drilling the down-dip extension of the southern end of the Main zone, intersected several narrow intervals of erratic high-grade copper-silver-gold mineralization. Ten kilometres south of Houston, Equity Silver drilled an alteration zone on the northeast side of **Bob Creek**. Four holes intersected strongly clay-altered zones with weak mineralization averaging 0.3 gram per tonne gold with assays sporadically reaching 2.9 grams per tonne gold. The **Eric** copper-silver showing in a Lower Jurassic Hazelton Group lapilli tuff was the drill target of another Equity Silver program south of Houston. The stratabound mineralization consists of pyrite, tetrahedrite, galena and traces of chalcopyrite and sphalerite within the tuff.

On the **Parrott Lakes** project, south of Houston, Territorial Drilling Ltd. drill tested a zone of zinc-silver mineralization.

On the northeast side of Ootsa Lake, Mingold Resources Inc. intersected several epithermal zones of intense silicification and brecciation in drilling on the **Rhub-Barb** property. The hostrocks are Lower Tertiary Ootsa Lake Group volcanics. Assay values are up to 1.37 grams per tonne gold over 0.70 metre.

In the Burnie Lakes area Equity Silver Mines Ltd. drilled several copper-silver-gold showings hosted in rhyolitic flows and andesites of the Lower Jurassic Hazelton Group on the **Lefty** Property. The mineralization consists of disseminations of chalcopyrite, tetrahedrite and sphalerite.

Eighty kilometres southwest of Houston, Maple Resource Corporation conducted follow-up drilling on two mineralized areas on the **New Moon** property. Silicification and shearing at, or close to, the contact between rhyolite and andesite flows returned values up to 12.89 grams per tonne gold across 2 metres. The Main zone of stringer to semimassive base and precious metals mineralization was also tested.

WHITESAIL LAKE AREA

Although there are a number of known porphyry deposits in the Whitesail region, major exploration activity in the area has been limited for the past several years.

Golden Knight Resources Inc. completed the last half of a $1-million program to assess the potential of the old **Deer Horn mine** situated within the Tweedsmuir Recreation Area.

COAL

The **Telkwa** property of Crows Nest Resources Limited was the only active coal project in the Northwestern District in 1990. Crows Nest submitted a revised Stage 2 report early in the year. The mine plan focuses on the bituminous coal deposits on the north side of the Telkwa River in the vicinity of Pine Creek. Plans were outlined to develop the deposits near Goathorn Creek on the south side of the Telkwa River towards the end of the life of the mine. In December, the company announced plans to phase out its coal operations and closed its office in Smithers.

PLACER

Placer activity decreased 20 per cent from the preceeding year, to 59 Notices of Work for the Northwestern District. Thirty-three of the notices were from the **Atlin** Mining Division, including 26 from the Atlin placer camp. The busiest area was **Spruce Creek** with six operations. In the Liard Mining Division there were 29 placer Notices of Work filed with three operators on each of **Dease**, **McDame** and **Rosella** creeks.

DEVELOPMENT PROJECTS

A number of projects were in the provincial government's **Mine Development Review Process** at the end of 1990. Active projects were Eskay Creek, Silver Butte, Snip, Sulphurets, Telkwa Coal and Windy Craggy (Table A-6). The Snip deposit was the only project for which the company had announced a production decision. Telkwa Coal has already been discussed in the section dealing with coal.

The **Snip** gold mine of Cominco Ltd. was under construction in late 1990 with startup planned for early 1991. The government Approval-in-Principle was granted in January 1990. Onsite construction started in June, although several buildings had been completed the previous year. The work included driving a 1-kilometre haulage adit at the 130 level and preparing the tailings impoundment area. A refitted 300 tonne per day mill was barged to the site. The mill will recover gold and silver metals from a gravity separation circuit and in concentrate from a sulphide floatation circuit. Many supplies for the mine site have been shipped in from Wrangell by hovercraft which will carry concentrate to Wrangell on the return trips after the mine opens.

Newhawk Gold Mines Ltd. completed a winter drilling program on the **Sulphurets** property. The drilling followed the West and R8 zones along strike and deeper. Cominco Engineering Services Ltd. and Fluor Daniel Wright Engineers Ltd. both completed feasibility studies. The latter study determined that a 317 tonne per day operation would entail a capital cost of $42.7 million with estimated direct operating costs of $130 per tonne. At current metal prices the Sulphurets project was not deemed to be economic by Fluor Daniel Wright Engineers. The project has completed Stage I of the Mine Development Review process; the next step would be Stage III.

During the summer Geddes Resources Ltd. completed a large program, costing more than $10 million, to facilitate mine planning for the Windy Craggy deposit. A major drilling program located the Ridge ore zone, a new discovery, between the North and South orebodies. Engineering, environmental and glaciology studies were completed. There were also ongoing studies to assess the acid-generation potential of the waste rock. A Stage I report was submitted to the Mine Development Review Committee in January, 1990. It was followed by a revised mine plan for the Stage I proposal in November. Two series of open-house meetings for the general public were organized by the company to help disseminate information about the proposed mine. The meetings were held in communities in British Columbia, Alaska and the Yukon in May and November.

An extensive exploration program, costing approximately $29 million, was completed on the **Eskay Creek** property by Prime Resources Group Inc. (*see* description above). A prospectus was submitted to the Mine Development Review Committee in April, 1990. A variety of terrain, engineering and environmental studies were carried out during the summer to establish mill and tailings pond locations. A 10-kilometre road route, which would link the property to the proposed Iskut road, was surveyed. A takeover battle for ownership of the property ended with Corona Corporation in charge and Placer Dome Inc. the other major owner. The Mine Development Review Committee was told to expect a Stage I report in the spring of 1991.

Exploration on the **Silver Butte** property has outlined 279 400 tonnes grading 17.14 grams gold and 36.7 grams silver per tonne. In October, Westmin Mines Limited entered into a joint venture with the owner Tenajon Resources Ltd. to develop the orebody to provide feed for the Premier mill.

OPERATING MINES

During 1990 the nine mines operating in the Northwestern District employed over 1450 people and played

TABLE A-6
ACTIVE MINES IN THE NORTHWEST DISTRICT, 1990

PROPERTY NAME (OWNER)	TONNES MILLED (000s)	RATED CAPACITY (tpd)	%ANNUAL RATED CAPACITY	DEPOSIT TYPE	RESERVES/PRODUCTION
Golden Bear (Golden Bear Op. Co.)	61.2	360	50	Vein Au	488 706 grams Au; for period Jan. to Nov.
Cassiar Mine (Cassiar Min. Corp.)	960	3600	91	Ultramafic asbestos	Mined out in June 1990; produced 2 603 692 tonnes of asbestos fibre from 1953 to 1990. Underground mining started on the McDame deposit in November.
Johnny Mountain (Skyline Gold Corp.)	96.9	350	92	Mesothermal vein Au-Ag-Cu	Suspended operations in August; 1 188 079 grams Au, 1 699 118 grams Ag, 271.5 tonnes Cu; for for period Jan. to Aug.
Premier Gold (Westmin Mines Ltd.)	620.5	2000	100	Epithermal vein Au-Ag	1284 kg Au, 14 825 kg Ag; for period Jan. to Oct.
Lawyers (Cheni Gold Mines Ltd.)	175.3	500	100	Epithermal vein Au-Ag	1488 kg Au, 33 455 kg Ag for period Jan. to Nov.
Shasta (Sable Resources Ltd.)	53.6	181	89	Epithermal vein Au-Ag	237 kg Au, 11 784 kg Ag for period Jan.-Nov.
Bell Mine (Noranda Minerals Inc.)	4957	14402	93	Porphyry Cu-Au	825 kg Au, 2989 kg Ag 19 748 722 kg Cu
Equity Silver (Equity Silver Mines Ltd.)	2621.6	9000	96	Transitional Ag-Au-Cu	200 530 kg Ag, 1797 kg Au 5 293 200 kg Cu for period Jan. to Oct.

a very important economic role in northwestern communities (Figure A-9). The base metal open-pit mines enjoyed high copper prices for a second straight year; however, the gold mines suffered soft gold and silver prices throughout 1990. The McDame underground deposit at Cassiar was the only new mine to open.

Cassiar Asbestos closed open-pit operations in June 1990 after operating since 1953. Ore from the pit was stockpiled for milling until the McDame underground deposit came on stream in November. The change from open-pit to underground mining has resulted in some additions to the work force. At McDame, preparations for underground production continued all year, including the relocation of the tramline. Numerous faults in the serpentinite host of the asbestos fibre produce very unstable mining conditions. Working headings in the ore zones require shotcreting round by round, which adds considerably to costs. Markets for the asbestos fibre remained strong throughout the year.

The **Golden Bear mine** experienced a number of start-up problems in 1990. An innovative mill system has required an extended tune-up period. Difficulties with the dry-grind process have been resolved, but problems with the roaster system were still being addressed late in the year. Most of the feed was lower grade oxide ore from the open pit which could bypass the roaster. The objective is to feed the mill equally from both underground and open pit operations. A stockpile from summer mining in the open pit is used during the winter months. Capital costs, initially estimated at $36 million, have now reached $82 million.

The **Johnny Mountain mine** suspended operations in September 1990 because ore reserves were depleted. Skyline Gold Corporation found that the high costs of operating a fly-in operation, coupled with the lower than predicted head grades for the mill, necessitated shutting down the operation. Annual transportation costs were estimated to be $2.4 million. The 318 tonne per day mill has produced 2333 kilograms of gold, 3826 kilograms of

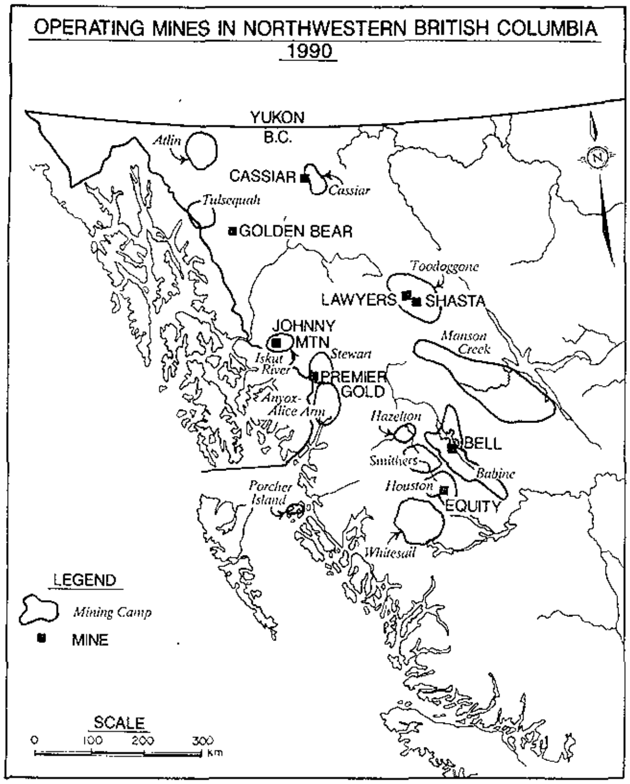


Figure A-9

silver and 88 984 kilograms of copper from the Stonehouse deposit since beginning production in August 1988.

The **Premier Gold project** mined ore from the Dago, S-1, Province and Silbak Premier pits in 1990. Persistent problems with dilution of ore by lower grade rock have affected this operation's profitability. In the second quarter, tonnages were up and the average head grade had kept pace, however, third quarter production slipped. Westmin Mining Limited announced in December that due to persistent adverse technical and economic factors it had been forced to reduce the ore reserves in the Silbak Premier deposit. This will result in reducing both the mill rate from 2300 to 1500 tonnes per day, and the number on staff from 165 to 100 early in 1991. Investigation of potential new ore sources and reconfirmation of existing ore reserves are ongoing.

On the **Lawyers property** in the Toodoggone, Cheni Gold Mines Inc. carried out an aggressive exploration program on the Cliff Creek zone, continued mining the AGB zone, completed a decline on the Cliff Creek zone and built a tote road to the nearby Al property. The AGB zone is expected to be mined out in the spring of 1991. Grades on this zone have been 12 per cent higher than predicted. Underground development of the Cliff Creek zone has been ongoing in order to bring it onstream with depletion of the AGB. Due to differences in sulphide content, ore from the two zones will not be blended. Exploration on the southern extension of the Cliff Creek zone indicated that deposit was smaller than originally thought. As a result Cheni announced in September that it had reduced the Cliff Creek reserves to 755 000 tons of probable and 472 000 tonnes of possible ore.

Nearby, on the **Shasta deposit**, Sable Resources Ltd. began underground development on two levels in order to access both the JM and Creek zones. During the summer ore was trucked about 10 kilometres to the old Baker millsite where it is stockpiled to feed the mill year round. The Baker mill has been modified to run at a reduced rate of 180 tonnes per day with an average head grade of 5.14 grams per tonne gold.

On Newman peninsula in Babine Lake, Noranda Minerals Inc. maintained production at the **Bell mine** near the capacity level of 13 500 tonnes per day with an average head grade of 0.48 per cent copper. Encouraging results from 1990 exploration drilling on the southeast side of the pit are expected to extend the mine life. Drilling at the nearby Granisle pit may lead to the identification of additional reserves for the Noranda Minerals Inc. mill.

At the **Equity Silver Mine** southeast of Houston, production continued at a rate of 8600 tonnes milled per day with an average head grade of 12.10 grams per tonne silver, 1.15 grams per tonne gold and 0.29 per cent copper. Mining continued on the Main zone and, to a small extent, on the Waterline zone. Equity Silver Mines Ltd. has been actively exploring for new reserves within the region as a closure of open-pit operations is anticipated in the fall of 1992. Acid rock-drainage is an ongoing problem being addressed by the company. A site-reclamation bond has been posted with the provincial government and negotiations are proceeding to determine the final amount of the bond.

CENTRAL DISTRICT

By E.L. Faulkner and B.E. Madu
District Geology, Prince George

INTRODUCTION

The number of projects in the Central District set a new record in 1990. Mineral exploration expenditures were estimated at $35 million, down from $40 million in 1989, due to greatly reduced spending by junior companies. Placer operations were down 13 per cent from 1989, due to continued increases in costs that were not offset by higher gold prices.

Alkali porphyry and porphyry-related copper-gold deposits were again the dominant exploration targets in the district, especially in the northern Quesnel trough. There was some interest in base metal targets with precious metal credits, mostly by major companies with long-term interest in base metal mining. Interest in industrial minerals picked up, especially among small operators, due to the more attractive status of such properties under the Mineral Tenure Act. The Canadian Coal Co. Ltd. revived plans for production from the Sukunka deposit, otherwise there was little coal exploration outside established mining areas.

HIGHLIGHTS

- Placer Dome Inc. gained control of the Mount Milligan deposit and is fast-tracking it to feasibility study.
- The Mount Polley deposit received a positive feasibility decision.
- The QR deposit received Approval-in-Principle for production.
- Underground development resumed at the Cirque deposit.
- Canadian Coal Co. Ltd. revived plans to mine the Sukunka deposit.

TRENDS AND OPPORTUNITIES

Figure A-10 shows the growth in interest in the Omineca Mining Division over the past few years. This is the result of success at Mount Milligan, and rapidly improving access to the area due to logging activity.

Major companies were responsible for most of the spending in this and other parts of the Central District,

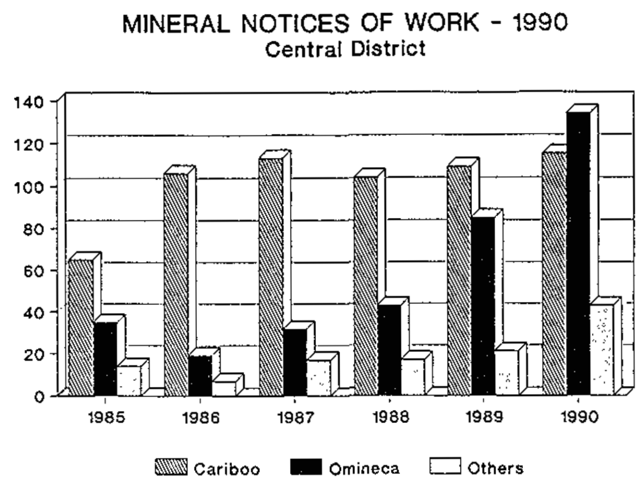


Figure A-10

led by Placer Dome Inc., BP Resources Canada Ltd., Rio Algom Exploration Inc. Noranda Exploration Company Limited and Cominco Resources International Limited. A number of other major companies were either new to the district, or had greatly increased budgets for 1990, including: Asarco Exploration Company of Canada Ltd., Kennco Explorations (Canada) Ltd., Inco Ltd., Teck Corporation and Westmin Resources Limited. Majors are expected to dominate the exploration scene again this year, but possibly with lower budgets than in 1990. The outlook for junior company spending at other than assessment work levels is bleak.

There was modest interest in base metal targets with precious metal values, but curiously most of the interest was in the Barkerville - Cariboo Mountains area, and not in the Gataga-Muskwa ranges. There were only two major programs in this Devonian shale belt. Access to this area is improving more rapidly than is generally realized, and there is open ground with excellent exploration potential.

Increased costs again reduced the number of placer operations in 1990, and sharply increased fuel prices are likely to accelerate this trend during the coming year. Opportunities for exploiting interglacial or Tertiary channels exist in the Cariboo for experienced operators.

MINERAL EXPLORATION

Mineral Notices of Work totalled 284, up 32 per cent from 1989, again setting new records for the district (Figure A-10). There were 20 major projects with

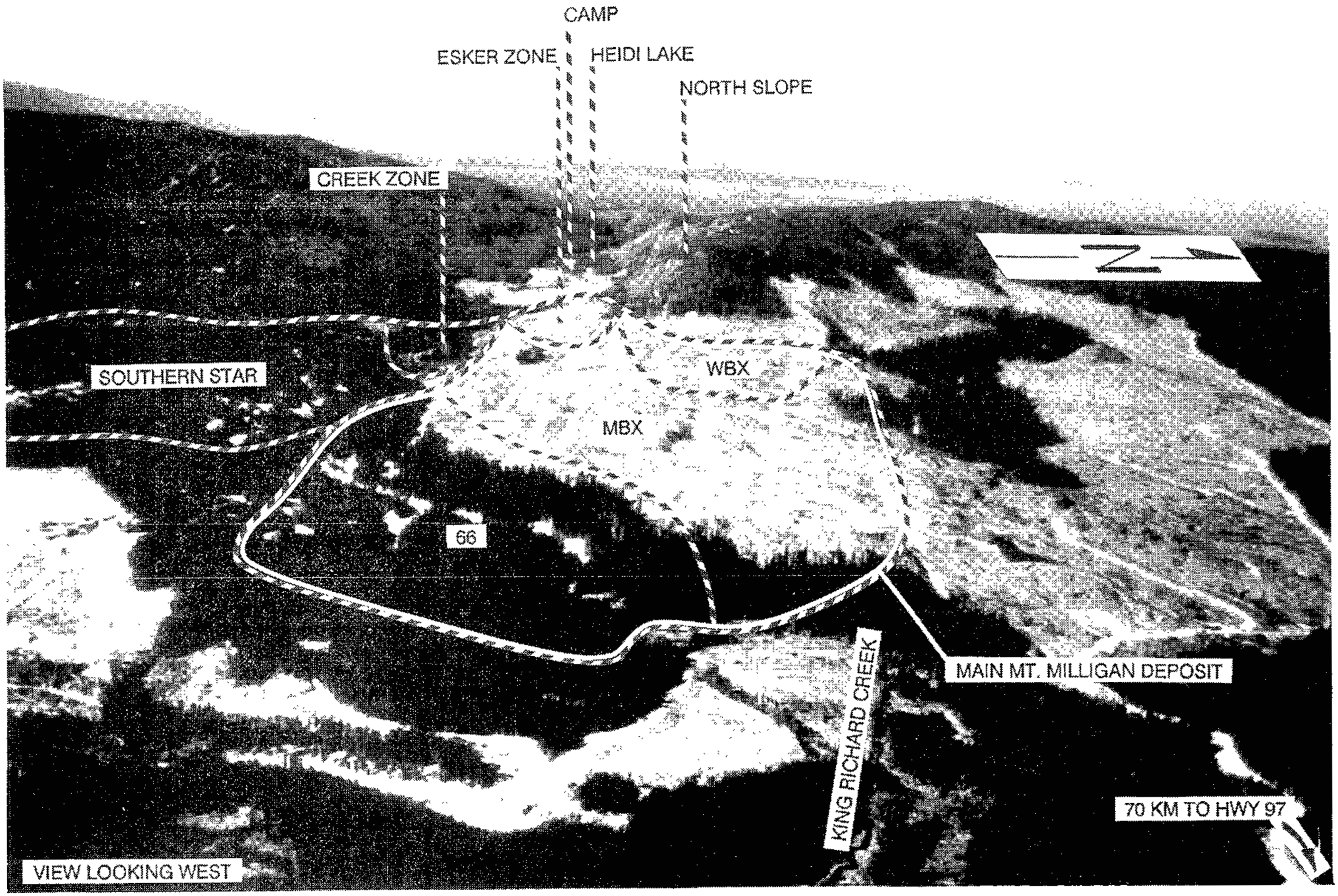

CAMP
ESKER ZONE
HEIDI LAKE
NORTH SLOPE
CREEK ZONE
N
SOUTHERN STAR
WBX
MBX
66
MAIN MT. MILLIGAN DEPOSIT
KING RICHARD CREEK
70 KM TO HWY 97
VIEW LOOKING WEST

Figure A-11

TABLE A-7
OPERATING MINES IN CENTRAL DISTRICT, 1990

MINE (OWNER)	TONNES MILLED (000s)	RATED CAPACITY (tpd)	%ANNUAL RATED CAPACITY	DEPOSIT TYPE	RESERVES/PRODUCTION
Endako (Placer Dome Inc.)	6900	29 600	63	Porphyry Mo	Reserves: 142.5 Mt @ 0.081% Mo
Gibraltar (Gibraltar Mines Ltd.)	13 245	38 100	75	Porphyry	Reserves: 183 Mt @ 0.31% Cu, 0.009% Mo Production: 27 kt Cu in concentrates and 4.5 kt cathode Cu from electrowinning plant
Blackdome (Blackdome Min. Corp.)	70.4	200	115	Epithermal	Reserves exhausted late 1990 Production: Au 1230 kg
Bullmoose (Bullmoose Op. Co.)	1800	6300	77	Coal	Reserves: 64.7 Mt Production: 1.8 Mt metallurgical coal
Quintette (Quintette Coal Ltd.)	4200	17 260	74	Coal	Reserves: 222.1 Mt. 4.45 Mt thermal coal Production: 4.7 Mt metallurgical coal

expenditures of $250 000 or more, up slightly from 1989. Details of major drill, surface, or underground exploration programs are given in Table A-7, and the locations are shown on Figure A-12.

NORTHERN QUESNEL TROUGH

Steady staking activity took place in the **Mount Milligan** area and along the eastern margin of the Hogem batholith from late 1989 to the summer of 1990. Many properties that received their first examination in 1988 or 1989 progressed to the drilling stage in 1990, and encouraging results were reported from several, particularly along the south and east margins of the batholith. Mapping by J.L. Nelson and K. Bellefontaine of the British Columbia Geological Survey Branch in the Mount Milligan area has identified a number of previously unrecorded plutons with geological settings similar to the intrusions at Mount Milligan, and hence the possibility for other copper-gold deposits. Work by D. Kerr, also of the Geological Survey Branch, at Mount Milligan showed the potential value of surficial geological studies in interpreting soil geochemical results in areas of extensive overburden which is common to much of the northern Quesnel trough.

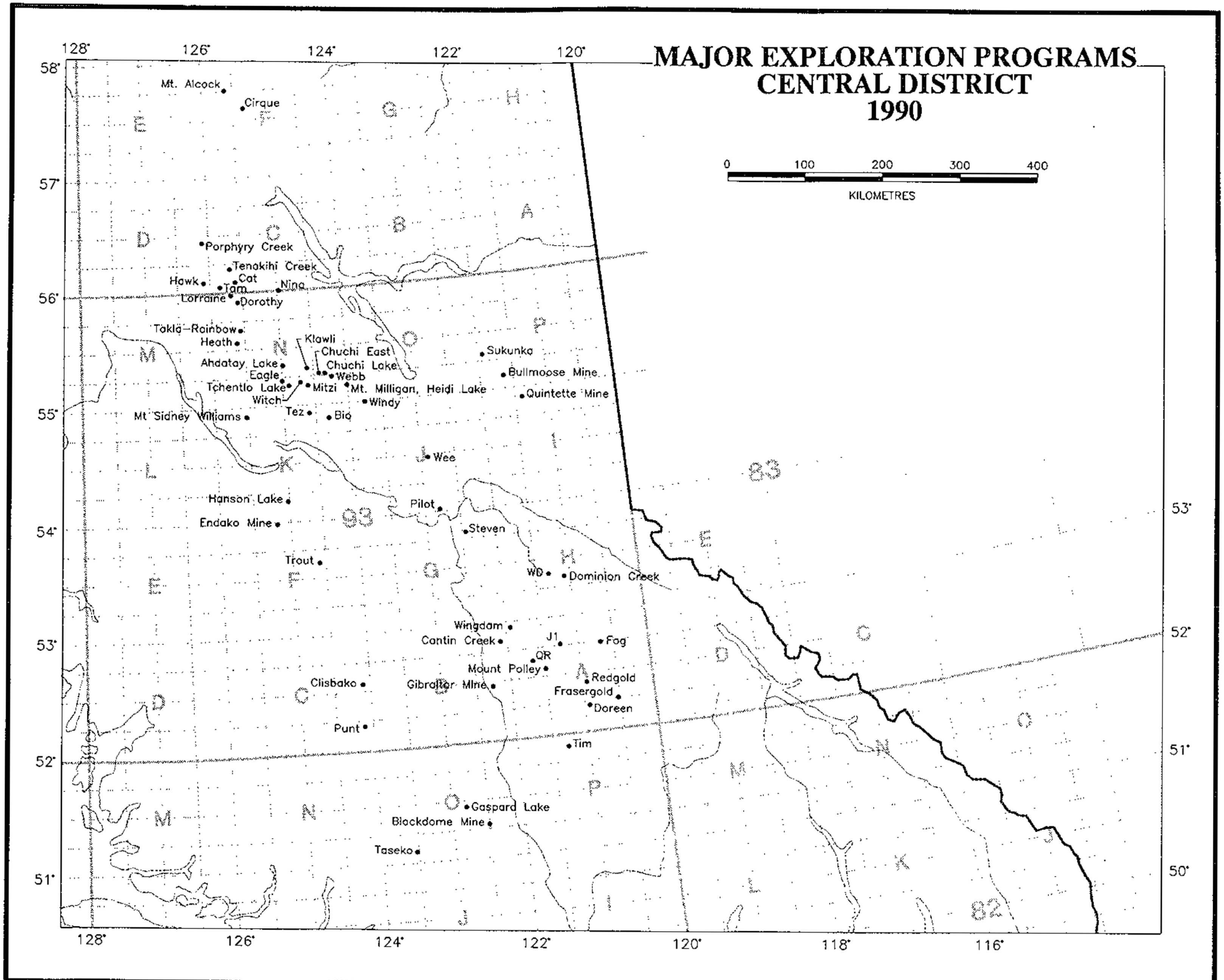
The question of which major company would gain control of the Mount Milligan deposit (Figure A-11), was settled when Placer Dome Inc. purchased BP Resources Canada Ltd.'s 30 per cent interest, and made a successful offer to shareholders of Continental Gold Corp. for the remaining interest. The total acquisition cost was close to $260 million. More than 380 holes totalling 86 000 metres were drilled by Continental Gold and Placer Dome to delimit the **Mount Milligan** and **Southern Star** orebodies and provide information for the feasibility study. Placer Dome intends to fast-track the property to a feasibility decision and, if favourable, construction is planned for late this year. Ore reserves are currently 400 million tonnes grading 0.2 per cent copper and 0.48 gram per tonne gold. Ore of higher grade in both deposits appears suitable for a starter pit.

Near Mount Milligan, drilling programs were conducted on the **Webb** property by Moondust Ventures Inc., on the **Heidi Lake** property by BP Resources Canada Ltd., and on the **Mitzi** property by Noranda Exploration Company Limited. All reported mixed to encouraging results.

South of Mount Milligan, Placer Dome continued exploration of the **Windy** property and reported mixed results. Patchy gold and copper mineralization continue to be found in strongly sheared and altered volcanic rocks.

A large number of companies were active on alkaliporphyry targets along the eastern margin of the Hogem batholith. In the Witch Lake - Chuchi Lake area, companies typically reported encouraging results, with widespread coincident magnetic and soil geochemical anomalies, often with altered and sometimes mineralized volcanic and intrusive float in areas of generally heavy drift cover.

BP Resources Canada was active on several properties, including **Ahdatay Lake**, **Chuchi East** and **Chuchi Lake**. At Chuchi Lake, porphyry copper-gold mineralization of variable grade is associated with magnetite in a monzonite porphyry. Typical grades of 0.2 to 0.3 per cent copper and 0.2 to 0.4 gram per tonne gold were reported



MAJOR EXPLORATION PROGRAMS
CENTRAL DISTRICT
1990
0 100 200 300 400
KILOMETRES
128° 126° 124° 122° 120°
58° 57° 56° 55° 54° 53° 52° 51°
53° 52° 51° 50°
128° 126° 124° 122° 120° 118° 116°
93
83
82
Mt. Alcock
Cirque
Porphyry Creek
Tenakihi Creek
Hawk
Cat
Tam
Nina
Lorraine
Dorothy
Takla-Rainbow
Heath
Klawli
Chuchi East
Chuchi Lake
Ahdatay Lake
Eagle
Webb
Tchentlo Lake
Mitzi
Mt. Milligan, Heidi Lake
Witch
Windy
Sukunka
Bullmoose Mine
Quintette Mine
Mt Sidney Williams
Tez
Bio
Wee
Hanson Lake
Pilot
Endako Mine
Steven
Trout
WD
Dominion Creek
Wingdam
Cantin Creek
J1
Fog
QR
Mount Polley
Redgold
Clisbako
Gibraltar Mine
Frasergold
Doreen
Punt
Tim
Gaspard Lake
Blackdome Mine
Taseko

Figure A-12

in intersections from 10 to more than 200 metres. Rio Algom Exploration Inc. reported mixed results from initial drilling of heavily altered volcanics on the nearby **Klawli** property and identified a number of drill targets on the **Witch** property. In this same area, Noranda prepared access to the **Eagle** property for drilling in 1991. Other companies reporting encouraging results were Westmin on the **Tchentlo Lake** and Teck Corporation on the **Heath** properties.

Farther north along the eastern margin of the Hogem batholith, where exposures are generally better, many of the properties examined were old porphyry targets. Kennco rehabilitated access to the **Lorraine** deposit and nearby **Dorothy** property, and commenced surface work to re-evaluate the potential of this area. Eastfield Resources Ltd. drilled targets on the **Takla-Rainbow** property with some good intersections of low-grade copper mineralization and spotty gold values occurring mostly in a border phase of the batholith.

At the northern end of the Hogem batholith, B.P. Resources Canada continued drilling and surface work on the **Cat** property where a number of syenite and monzonite bodies intrude volcaniclastic rocks in north-trending fault slices. Some good copper-gold mineralization was outlined in one of these on the south face of Cat Mountain, and a number of other promising target areas have been identified. A Major General Resources - Varitech Resources Ltd. joint venture found several coincident induced polarization and soil geochemical anomalies with outcropping mineralization at the **Tam** property and plan to drill three of them. Teck Corporation was also encouraged by surface work on its claims in the **Porphyry Creek** area, and Cyprus Gold (Canada) Ltd. reported erratic but encouraging copper and gold values in shear zones and stockwork veins intersected by drilling on the **Hawk** property.

SOUTHERN QUESNEL TROUGH

Activity in the southern Quesnel trough was again confined to established properties or old target areas. Placer Dome continued work on the **Cantin Creek** property. The geological setting is similar to the nearby **QR** deposit but the alteration is more extensive and more drilling is planned. Phelps Dodge Corporation of Canada Ltd. has outlined a large porphyry target in surface work and initial drilling at the **Redgold** property. Gibraltar Mines Ltd. drilled the **Doreen** property with disappointing results. Despite promising surface indications, copper mineralization at depth was confined to narrow intersections.

In the Canim Lake area, Liberty Gold Corporation found widespread, fine-grained, native copper and cuprite with erratic and occasionally high silver values in altered tuffs on the **Tim** property. The property is on the flanks of the Timothy Mountain stock where a number of porphyry-style prospects occur.

Eureka Resources Inc. continued work on the **Frasergold** property where gold is associated with secondary quartz veining in basal phyllites of the Quesnel trough. Lateral extensions of the areas of known mineralization, as indicated by soil geochemical anomalies, were generally confirmed in a $1.4-million program of stepout and infill drilling, with several reported intersections of 10 to 20 metres grading 2 grams per tonne gold or better. New bulk samples from the adit confirmed grades of 2.3 grams per tonne gold reported from earlier bulk sampling. Another major drilling program is planned for 1991.

BARKERVILLE - CARIBOO MOUNTAINS

Work was concentrated in the Cariboo Lake area, where replacement base metal and silver mineralization occurs in limestones and marbles of the Cunningham Formation at the contact with phyllites of the overlying Isaac Formation. Drilling by Cominco on the **WD** property and drilling and trenching by Teck on the **Fog** property suggests that a considerable part of this contact may be mineralized. However, the lateral continuity of this style of mineralization, has been erratic in the area tested to date.

FRASER PLATEAU

Epithermal gold-silver targets in altered Ootsa Lake Group basalts on the Fraser Plateau were explored by a few companies in 1990, with mostly mixed to poor results. Goldrite Mining Corporation reported generally poor results from drilling the **Trout** property. Goldsmith Minerals Ltd. reported mixed results from the **Gaspard Lake** area where some good grade but very shallow gold-bearing quartz veins had been found in 1989. Only Eighty-eight Resources Ltd. reported encouraging results and these were from a trenching program on the **Clisbako** property.

OTHER AREAS

In the Muskwa Devonian shale belt, only two companies were active with major programs. Curragh Resources Inc. resumed underground exploration, drilling, and bulk sampling at the **Cirque** property with a feasibility decision expected this year. At the nearby **Mount Alcock** property, drilling and surface work by Triumph Resources Ltd. showed that the mineralization continues down dip rather than along strike, and deeper drilling is planned.

On the large **Hanson Lake** property, Cazador Explorations Limited, continued to outline promising target areas despite delays in financing. Porphyry copper-gold mineralization, often with significant base metal sulphides, occurs in several zones.

Westpine Metals Ltd. drilled more than 11 000 metres at the **Taseko** property where copper-gold mineralization occurs in zones of intense advanced argillic alteration in Kingsvale volcanics at the contact with the Coast Range batholith. Grades of more than 1 per cent copper and 1 gram per tonne gold have been reported in several good but deep intersections in mixed quartz and quartz-andalusite zones.

PLACER

Placer Notices of Work totalled 358, down 13 per cent from 1989. Most of the decrease occurred in mechanized and the number of hand operations now exceeds mechanized mines in the Cariboo. As stated earlier, significantly higher fuel prices are expected to reduce the number of mechanized operations again this year, and historic increases in placer production associated with down-turns in the economy may not be realized.

Of note in new placer workings this year, Gold Ridge Resources Inc. began a decline in bedrock to reach the rich, buried, Tertiary gravels of Lightning Creek at **Wingdam**. Two previous underground mines at this site recovered gravels grading up to 4 ounces of gold per yard before severe water problems and inflow of mud forced their closure.

COAL

There was little exploration for coal beyond the established operating areas in 1990. Quintette Coal Ltd. continued detailed exploration in the **Mesa** and **Wolverine valley** areas with more than 20 000 metres of rotary and diamond drilling. Canadian Coal Company Ltd. reactivated production plans for the **Sukunka deposit** where reserves of 103 million tonnes of low-ash coal have been defined. A dispute over the ownership of the coal rights remains to be settled and this could delay production plans.

MINE DEVELOPMENT REVIEW

Details of projects in the Mine Development Review process are given Table A-2.

The **QR** property received Approval-in-Principle for construction, but financing arrangements had not been decided by the end of the year. Imperial Metals Corporation submitted a Stage I report for the **Mount Polley** property, with Approval-in-Principle expected early 1991. As indicated earlier, Curragh Resources resumed work on the **Cirque** deposit after being inactive for much of the year. Two new projects entered the Mine Development process; Continental Gold Corp. submitted a Prospectus for the **Mount Milligan** deposit, and Canadian Coal Co. submitted a revised prospectus for the **Sukunka** deposit.

OPERATING MINES

Details of operating mines in the Central District are given in Table A-7. Output of coal from **the Bullmoose** and **Quintette mines** was not significantly affected by a rail strike late in 1990, however, Quintette had not managed to restructure its debt financing at the time of writing.

Endako mine continued to refine its ultimate pit design and **Gibraltar mine**, as a consequence of continued firm copper prices, revised its ore reserves upward. Ore reserves at **Blackdome mine** were exhausted late in the year and the mill closed. The potential for discovering new reserves remains good and the company hopes to continue with an exploration program.

SOUTH CENTRAL DISTRICT

R.E. Meyers and T.B. Hubner
District Geology, Kamloops

INTRODUCTION

Exploration in south-central British Columbia continued at lower than usual levels during 1990. The competition for exploration dollars has been high, particularly for junior company projects. Weak gold prices and a scarcity of project funding severely hampered many projects that were very active in the 1987-89 period. Announcements of mine closures at Brenda and Beaverdell, and diminishing reserves at other operations added to an already subdued economic outlook in the exploration and mining industry in the southern Interior (Figure A-14).

Fortunately, a contrastingly strong base metal market has partially off-set the slump in precious metals oriented junior company activity. As a result, exploration and development at operating mines has had the effect of counteracting the negative trends in the region and has contributed to maintaining a stable and secure production environment for the established base metal producers.

Total estimated exploration and development expenditures in the district for 1990 dropped to about $36.5 million, from some $70 million spent in 1989 (Table A-8). Approximately 49 per cent of the total, amounting to $18.01 million, was spent on exploration projects (Figure A-13). This figure includes nearly $4.4 million (or 24 per cent) devoted to exploration around active mining operations. Compared to the estimated $20 million spent in 1989, a 7.5 per cent drop in exploration funding in south-central B.C. is indicated for 1990.

Mine development expenditures in the district (Table A-9) were also substantially lower for 1990, totalling $18.5

TABLE A-8
SUMMARY OF EXPLORATION & DEVELOPMENT EXPENDITURES

	($Millions) 1990	1989
Exploration (all projects)	$18.01	$20.0
Development (operating mines)	$18.50	$50.0
Total	$36.51	$70.0

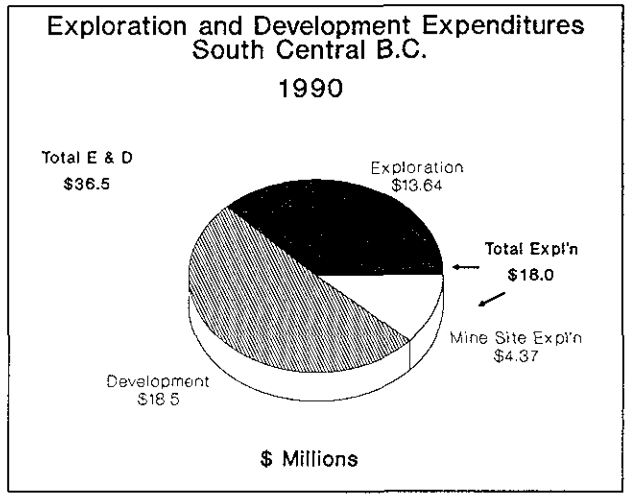
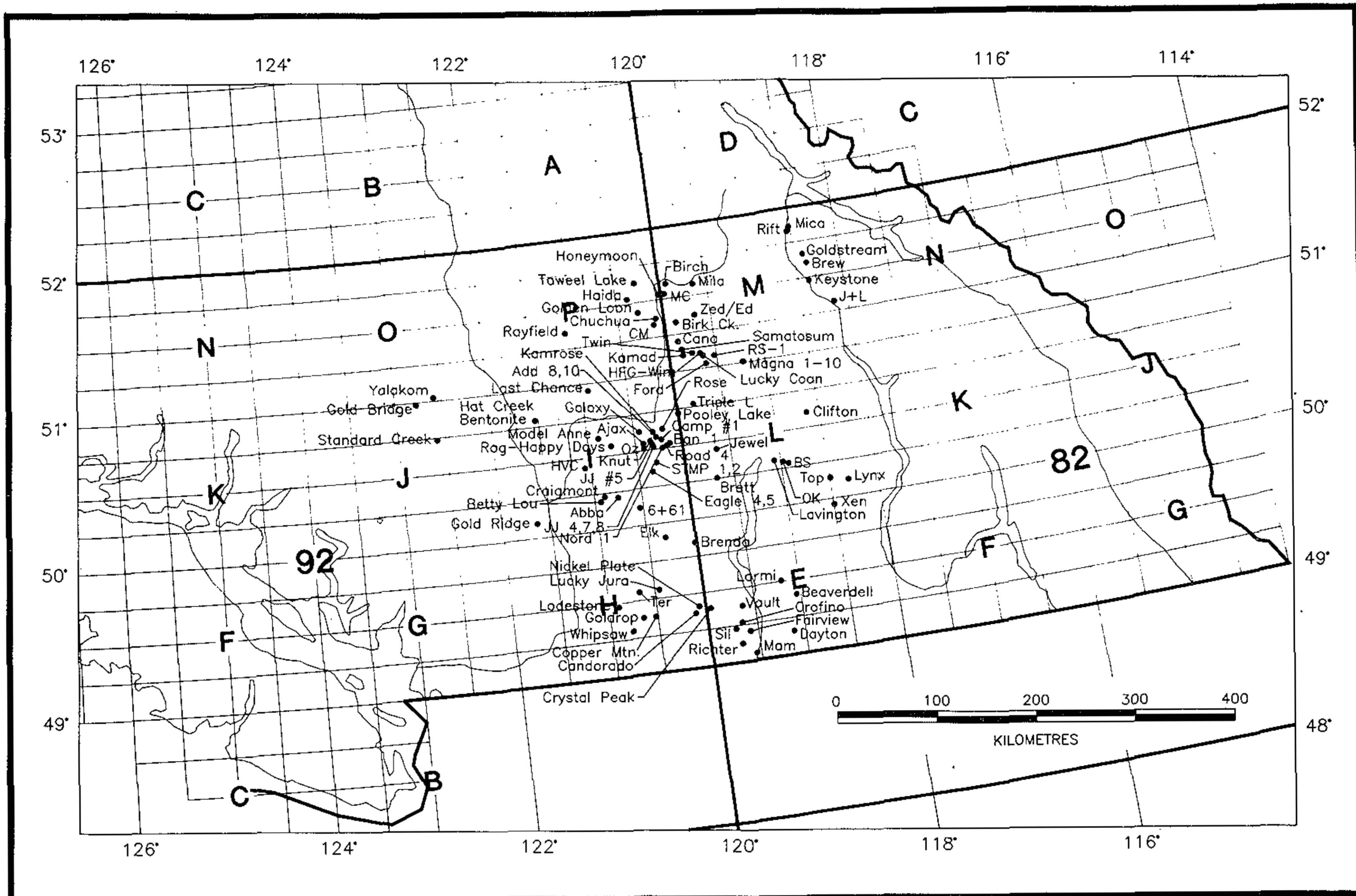


Figure A-13

TABLE A-9
SOUTH CENTRAL DISTRICT
EXPLORATION & DEVELOPMENT EXPENDITURES
AT OPERATING MINES

Mine	($Millions) Exploration	Development
Highland Valley Copper	$0.7	$14.1
Afton/Ajax	$0.17	--
Similco	$2.0	$1.5
Samatosum	$1.2	$1.0
Nickel Plate/Canty	$0.18	$1.2
Highland Bell (Beaverdell)	$0.12	$0.2
Brenda	Closed June 1990	
Candorado	--	$0.5
Totals	$4.37	$18.5



126° 124° 122° 120° 118° 116° 114°
53° 52° 51° 50° 49° 48°
92
82
A B C D C N O K J F G E H I L M P
Rift Mica
Goldstream
Brew
Keystone
J+L
Honeymoon
Birch
Taweel Lake
Mila
Haida
MC
Zed/Ed
Chuchua
Birk Ck.
Rayfield
CM
Cana
Samatosum
Twin
RS-1
Kamrose
Kamad
Magna 1-10
Add 8,10
HFG-Win
Lucky Coon
Last Chance
Ford
Rose
Yalakom
Triple L
Gold Bridge
Hat Creek
Pooley Lake
Bentonite
Galaxy
Clifton
Camp #1
Ajax
Model Anne
Ban 1
Standard Creek
Jewel
Rog-Happy Days
Oz
Road 4
HVC
Knut
BS
STMP 1,2
Top
Lynx
JJ #5
Brett
Craigmont
Eagle 4,5
OK
Xen
Betty Lou
Abba
6+61
Lavington
Gold Ridge
JJ 4,7,8
Nord 1
Elk
Brenda
Nickel Plate
Lucky Jura
Lormi
Beaverdell
Ter
Lodestone
Vault
Orofino
Goldrop
Fairview
Whipsaw
Sil
Dayton
Copper Mtn.
Richter
Mam
Candorado
Crystal Peak
0 100 200 300 400
KILOMETRES

Figure A-14

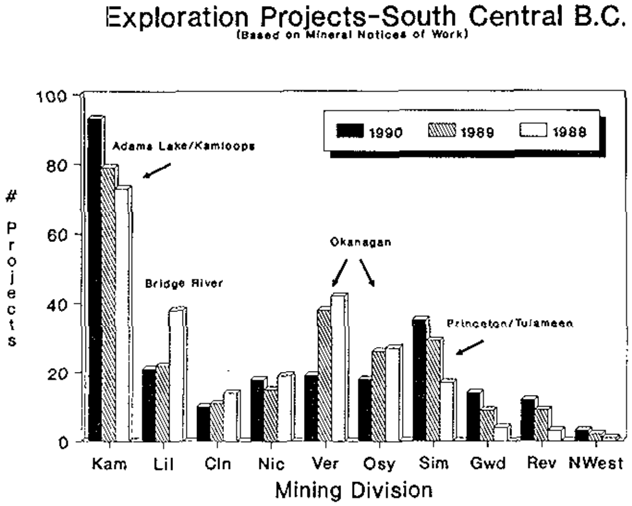


Figure A-15

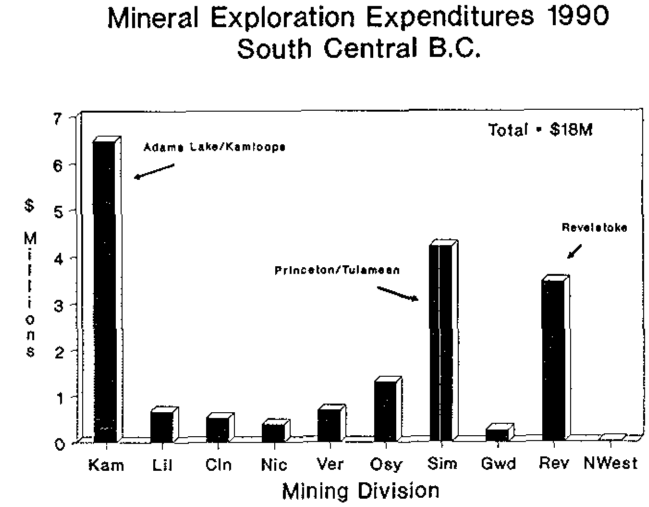


Figure A-16

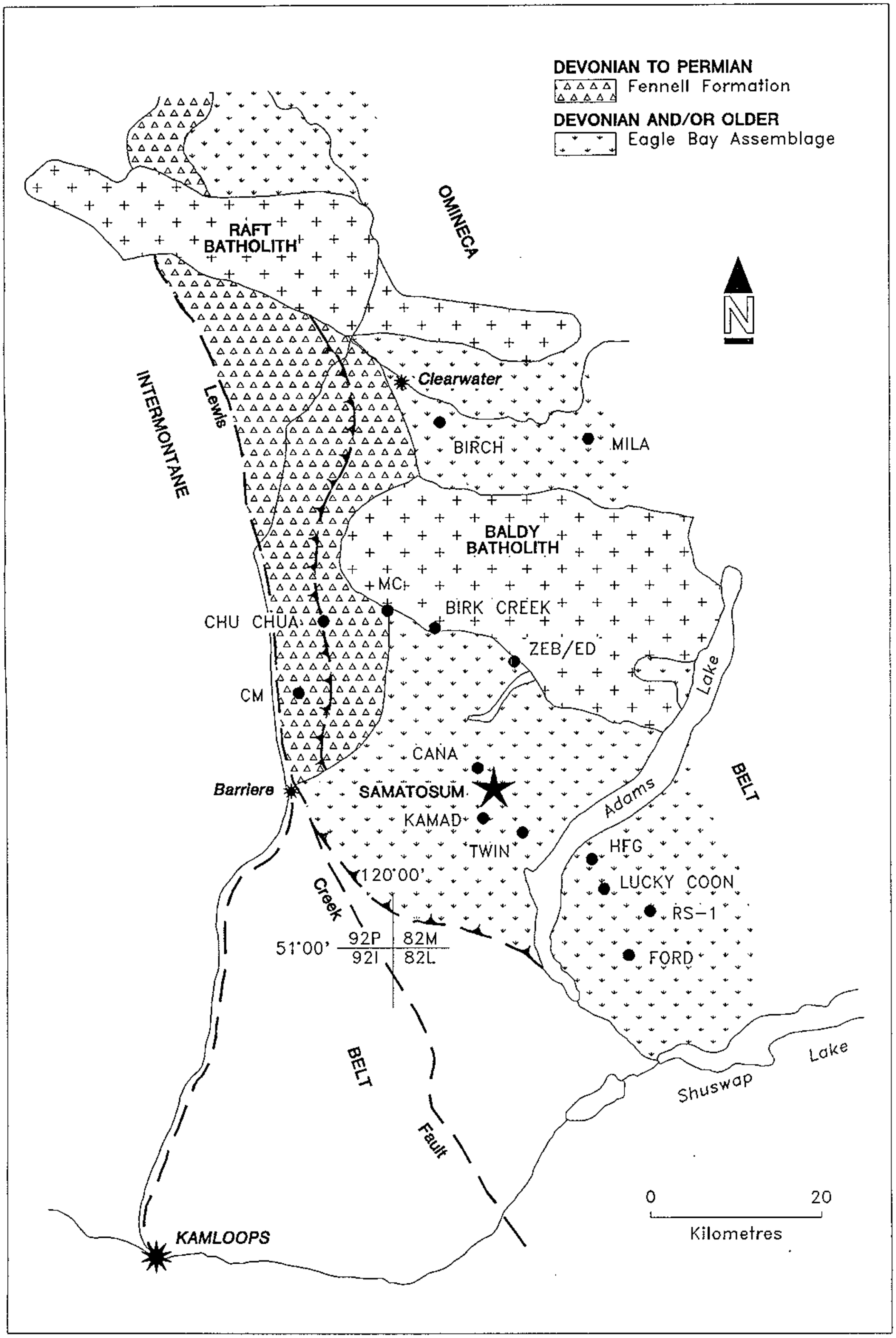
million, compared with $50 million estimated for 1989. However, the 1989 figure included development costs for two new mines, Afton Operating Corporation's **Ajax** deposit and Minnova's **Samatosum** mine. The bulk of the 1990 development budget went to general construction and expansion at Highland Valley Copper.

Regionally, the Adams Lake and Kamloops areas far surpass the rest of the district in exploration activity (Figure A-15), exhibiting a steady increase over the past three years. The Princeton-Tulameen area is a somewhat distant second, but also shows increased activity, due in large part, to major programs near Siwash Lake and at Copper Mountain. The Revelstoke and Greenwood areas have had modest, but notable increases in the numbers of projects, over previous years. However, in spite of the relatively few operators, exploration expenditures for the Revelstoke area rank third in the district (Figure A-16), primarily due to the advanced stage of the **J & L** project. This factor illustrates the impact that just one advanced-stage project can have on a region. By contrast, the steady decline of exploration activity and the lack of major projects in the Okanagan and Bridge River areas have seriously changed the industry picture in these two exploration camps in only two years.

On a parallel trend with steadily increasing activity in the Adams Lake, Kamloops and Revelstoke areas, the progressive shift toward base metals oriented projects in the region is another reflection of strengthening base metal markets, particularly for copper and zinc. In the intermediate term, these areas are likely to capture an increased share of exploration funding, particularly if gold and silver prices remain weak. The decline in activity in the Okanagan, Hedley and Bridge River areas also reflects an overall decreasing focus on vein and skarn precious metals targets.

HIGHLIGHTS

- **ADAMS LAKE** - The Eagle Bay asemblage and Fennell Formation near Adams Lake continue to draw the highest level of exploration activity, stimulated by the success of the **Samatosum** polymetallic mine operated by Minnova Inc. and Rea Gold Corporation. Major projects, such as those operated by Minnova, Homestake Mining Canada Ltd. and others in the area, continued to focus on the "Sam" and "Rea" horizons and on comparable geological environments in Eagle Bay rocks. Minnova also expended considerable effort on areas within the Fennell Formation, associated with the Chu Chua copper-iron massive sulphide deposit.
- **SIWASH LAKE** - In the Siwash Lake area, northeast of Princeton, the potential of the **Elk** gold project was substantially upgraded as Fairfield Minerals Ltd. and Placer Dome Inc. completed a second successful year. Detailed drilling on the Siwash North zone increased both the lateral and down-dip extent of the deposit and expanded work on other prospects on the property suggests that a major area-wide gold-quartz vein system may be present.
- **COPPER MOUNTAIN** - An aggressive exploration drilling program at Similco's **Copper Mountain** deposit has outlined two new zones in the Lost Horse Gulch area. The **Virginia and Alabama** deposits will add nearly 25 million tonnes of potentially mineable copper-gold ore to the mine's reserves.
- **REVELSTOKE** - Exploration activity in the area north of Revelstoke increased over previous years, with the main focus on Early Paleozoic rocks hosting the **J & L** and **Goldstream** deposits. Equinox Resources Ltd. and Cheni Gold Mines Inc. joined ef-



DEVONIAN TO PERMIAN
Fennell Formation
DEVONIAN AND/OR OLDER
Eagle Bay Assemblage
RAFT BATHOLITH
OMINECA
INTERMONTANE
Lewis
Clearwater
BIRCH
MILA
BALDY BATHOLITH
MC
CHU CHUA
BIRK CREEK
ZEB/ED
CM
Lake
CANA
Barriere
SAMATOSUM
KAMAD
TWIN
Adams
BELT
HFG
LUCKY COON
RS-1
FORD
120°00'
Creek
51°00'
92P
82M
92I
82L
BELT
Fault
Shuswap
Lake
0
20
Kilometres
KAMLOOPS

Figure A-17

forts at J & L to expand and develop mineable reserves in the deposit. Recent reports that funding may soon be in place to return the Goldstream mine to production are positive indications that exploration and mining in the Revelstoke area are in an upward trend.

- **OKANAGAN** - The Okanagan was considerably quieter during 1990 than in the 1987-89 period. A number of small to mid-size precious metals projects were operated in spite of the strain of poor financing. Work at the **Vault** epithermal gold project was maintained, albeit under pressure. Closure of the **Brenda** operations and news that the **Highland Bell** silver mine would close early in 1991 dampened the economic outlook for the Okanagan and marked the end of 90 years of continuous production at Beaverdell.
- **HEDLEY** - At Hedley, Corona Corporation has indicated that without an improved reserves picture, the **Nickel Plate** operations will likely end in late 1991.
- **BRIDGE RIVER** - The area experiencing the greatest downturn in mineral exploration in the region was the Bridge River district, where, except for the **Standard Creek** property, only minimal work was completed on very few projects.
- **ECONOMIC IMPACT** - The downturn in exploration, resulting largely from the lack of project funding, has created significant economic stress on the exploration-related service sector of the South Central District. Drilling companies, assay laboratories, staking and line-cutting contractors and equipment suppliers have all felt the effects in the form of drastic reductions in contracts and clientele. The withdrawal from activity by many project operators has forced a few companies to temporarily close their doors due to insufficient business. In other situations, work-sharing and lay-offs are becoming reality, whereas in previous years, sufficient work was available to carry a nearly full compliment of staff through to the next exploration season.

MINERAL EXPLORATION

ADAMS LAKE AREA

The Eagle Bay assemblage and Fennell Formation in the Adams Lake area continue to be the prime focus of exploration in south-central British Columbia (Figure A-17). Influenced by the highly successful Samatosum project, the industry expended more than 20 per cent of the total district exploration budget in this region. In total, 15 drilling projects and associated surface programs were carried out for Samatosum-type and Rea-type precious metal rich polymetallic sulphide deposits.

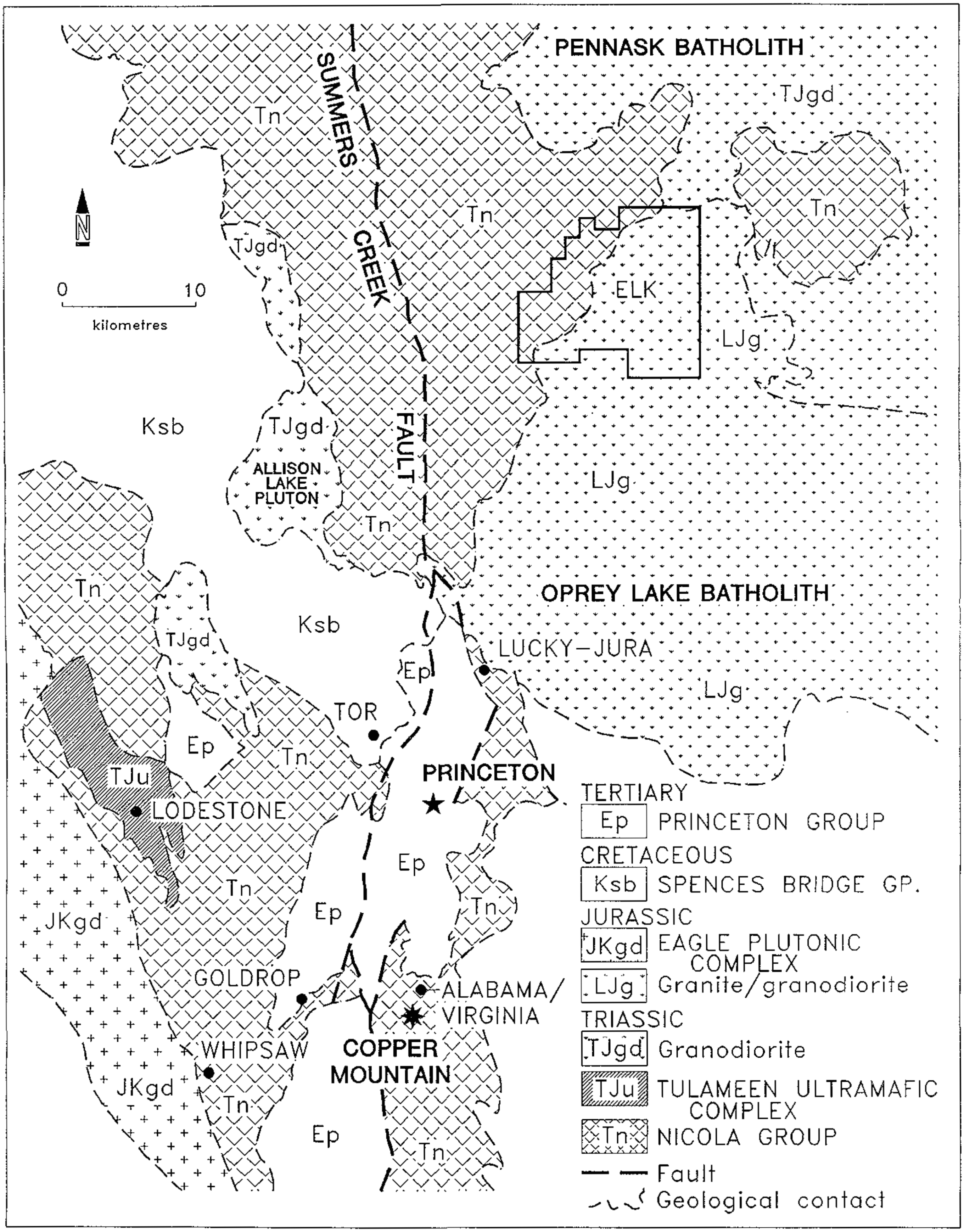
At the **Samatosum mine**, Minnova Inc. continued to operate exploration drilling programs throughout the year, concentrating primarily on the horizons hosting the Samatosum and Rea Gold deposits. A 200-metre exploration adit was commenced early in the fall, to explore the lower sections of the deposit in preparation for underground mine planning. The company has also begun a comprehensive research project with McGill University to evaluate the genesis of the deposit. Immediately to the north, Minnova also drilled the **Cana** property. The mine stratigraphic sequence continues into this area, but is overlain by a substantial thickness of Tertiary basalt, which seriously hampers exploration. Previous drilling by Homestake Mining Canada Ltd. and Esso Resources intersected weak sulphide mineralization.

Two new prospects were discovered in the Adams Lake region during 1990, by prospecting outcrops created along recently constructed logging roads; the **Mila** property, east of Vavenby, and the **McLellan** prospect, south of North Barriere Lake. At the north end of the area, on the Mila claims, Goldbank Ventures Ltd. and International Suneva Resources Ltd. exposed significant massive sulphide mineralization which carries encouraging values in zinc, copper and gold. The mineralization occurs in a sequence of Lower Paleozoic quartz-chlorite-sericite schists and phyllites of the Eagle Bay assemblage. At the McLellan property, which is under option to Rea Gold Corporation, only preliminary surface work has been carried out.

Minnova Inc. continued work at the **Chu Chua** property, under option from owners International Vestor Resources Ltd., Quinterra Resources Inc. and Pacific Cassiar Limited. The 1990 drilling program was aimed at testing a newly outlined geophysical anomaly, located about 2 kilometres south of the main deposit. Minnova carried out airborne geophysical surveys in the region earlier in the summer. South of Chu Chua Mountain, on the **Chinook Mountain (CM)** property, Minnova completed extensive geochemical and geophysical surveys, followed up by diamond drilling.

At the **Birk Creek** property, Falconbridge Limited concentrated exploration on a number of showings, as well as geochemical and geophysical (IP) targets. The main showing of interest is the **Uki** prospect, a high-grade polymetallic zone occurring in Eagle Bay chlorite-sericite schist and phyllite. Sampling in 1989 returned values as high as 5 per cent lead, 4.5 per cent zinc, 0.66 per cent copper, 0.35 grams per tonne silver and 1 gram per tonne gold.

On the **Honeymoon** property east of Clearwater, Minnova completed extensive geophysical and geochemical surveys. The property is underlain by Paleozoic


PENNASK BATHOLITH
TJgd
Tn
SUMMERS CREEK FAULT
Tn
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N
0 10
kilometres
TJgd
ELK
LJg
Ksb
TJgd
ALLISON LAKE PLUTON
LJg
Tn
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OPREY LAKE BATHOLITH
Ksb
TJgd
LUCKY-JURA
Ep
LJg
TOR
Ep
Tn
PRINCETON
TJu
LODESTONE
Ep
Tn
Ep
Tn
JKgd
GOLDROP
ALABAMA/
VIRGINIA
WHIPSAW
COPPER MOUNTAIN
JKgd
Tn
Ep
Tn
TERTIARY
Ep PRINCETON GROUP
CRETACEOUS
Ksb SPENCES BRIDGE GP.
JURASSIC
JKgd EAGLE PLUTONIC COMPLEX
LJg Granite/granodiorite
TRIASSIC
TJgd Granodiorite
TJu TULAMEEN ULTRAMAFIC COMPLEX
Tn NICOLA GROUP
Fault
Geological contact

Figure A-18

metasedimentary and volcanic rocks of the Fennell Formation. Adjacent to this ground, to the east, Initial Developers Ltd. drilled the **MC** property and a few kilometres to the northeast, New Global Resources Ltd. drilled the **Birch** massive sulphide prospect. Targets on both properties are polymetallic zinc-lead-silver occurrences in Eagle Bay and Fennell rocks. On the **Zeb** property, near Saskum Mountain, Duchan Enterprises Ltd. carried out surface surveys, trenching and a small drilling program to test a strong EM conductor. A thin shear-hosted sulphide lens was intersected, but returned low precious metals values.

Homestake Mining Canada Ltd. continued with a major diamond drilling program on the adjacent **Twin** and **Kamad** properties. The two properties are underlain by Eagle Bay rocks, including quartz-sericite schists and ankeritic mafic volcanic rocks which collectively incorporate the southeastern extension of the stratigraphic horizons hosting both the Samatosum and Rea Gold deposits. In 1987, drilling on the Twin 3 claim delineated a gold-bearing massive sulphide lens and in 1988 Esso discovered the **K-7** massive sulphide lens on the Kamad 7 claim, which lies on the "Rea" zone.

The Eagle Bay assemblage was also explored on the Adams Plateau, east of Adams Lake. Teck Explorations Ltd. continued with trenching and diamond drilling on the **RS-1** claim, optioned from Kamad Silver Co. Ltd. Polymetallic sulphide mineralization occurs with garnet-diopside-epidote skarn zones hosted in Eagle Bay metavolcanic rocks and phyllites. The sequence is cut by small diorite intrusions believed to be the most likely cause of skarn alteration. Teck Exploration also completed surface surveys and drilling on the **Ford** property, where minor copper and silver mineralization occurs in sericitic and chloritic schists. The results from both programs were generally discouraging and Teck plans to return the properties to their owners.

Early in the year, Sirius Resource Corporation completed drilling on the **Lucky Coon** prospect to extend a mineralized zone outlined in an earlier program. The work met with only limited success and the company has since dropped its interest in the property. West of the Lucky Coon, Gala Resources Ltd. drilled the **HFG-WIM** claims to test geochemical and geophysical anomalies outlined in previous work. On the **Magna** claims, to the east of Scotch Creek, W. Spence drill-tested geochemical and geophysical anomalies in Eagle Bay rocks.

KAMLOOPS - BONAPARTE AREA

The **Rayfield River** property, northwest of Vidette Lake, was worked by Brenda Mines Ltd. (Discovery Consultants), who completed geophysical surveys and a diamond-drilling program. The program targeted porphyry copper-gold mineralization associated with syenite, monzonite and granodiorite of the Early Jurassic Thuya batholith, exposed in a window within Miocene plateau basalts. Although weak copper mineralization in the form of chalcopyrite, bornite and native copper is widespread on the property, grades encountered were very low, with only geochemically anomalous gold values.

At the **Taweel Lake** gold prospect, west of Clearwater, Jaguar Equities Inc. completed geochemical surveys and diamond drilling in an attempt to outline a gold-anomalous quartz-carbonate alteration and vein system hosted in Nicola volcanic and sedimentary rocks. Drill results were not encouraging in that they did not substantiate the results of previous surface sampling.

Teck Explorations Ltd. continued work on the **Haida** property northwest of Little Fort. Diamond drilling outlined magnetite-pyrrhotite-copper mineralization associated with diopside-garnet skarn in limy Nicola rocks which are intruded by pyroxene gabbro and feldspar porphyry dikes. Weak porphyry-style copper mineralization was also found on the property. On the **Golden Loon** property, west of Little Fort, Corona Corporation completed trenching and drilling on gold geochemical anomalies underlain by felsic to intermediate intrusives and ultramafic rocks of the Thuya batholith. Minnova Inc. drilled the **Last Chance** property near Chris Creek. Epithermal gold mineralization is the target, associated with structures cutting Jurassic Ashcroft conglomerate where it is overlain by Tertiary basalts.

On the south side of the Late Triassic Iron Mask batholith, Afton Operating Corporation drilled several holes at the southern edge of the **Ajax West** deposit to determine the lower limits of ore reserves for the Stage II pit. The northeast extension of the East pit was also drilled off to explore the possibility of a north-wall pushback. East of the Ajax mine, Placer Dome Inc. completed nine drill holes for 1200 metres on the **Knut** alkaline porphyry copper-gold property. The program tested coincident chargeability and gold geochemical anomalies, also in Iron Mask rocks. Northwest of the Ajax mine, Getchell Resources Inc. completed a drilling program on the **Galaxy** property, another porphyry copper-gold deposit. Work on this property in the 1960s outlined approximately 3.2 million tonnes grading 0.65 per cent copper. Intersections from 1990 drilling returned weighted averages of 0.74 per cent copper and 3.4 grams per tonne gold.

KAMLOOPS - NICOLA BELT

East of Kamloops, near Monte Creek, Corona Corporation drilled the **Pooley Lake** property, a precious metals prospect associated with epigenetic vein mineralization. North of this property, L. Loehr drilled the **Triple L** claim, another precious metals vein prospect.

In the Shumway Lake area, south of Kamloops, Naxos Resources Ltd. completed a second phase of drilling on the **Road 4** claims. The target is bulk-tonnage, low-grade gold mineralization reported to be associated with mafic rocks intruding Upper Triassic Nicola volcanic stratigraphy. A number of properties in the same area, including the **Nord, Add, JJ, Ban, Camp** and **Rose**, are underlain by similar geology. These properties were drilled by several junior companies associated with A. Babiy, L. Mear and M. McElgunn. To the south, near Stump Lake, the **Eagle** and the **Stmp** claims were also drilled by the same interests.

Several small to mid-size drilling programs were also completed in Nicola rocks south of the Iron Mask batholith, between Kamloops and Merritt. At Greenstone Mountain, Teck Explorations Ltd. drilled the **Rag/Happy Days** property to test low-grade gold potential. The prospect is an alkaline porphyry copper-gold occurrence associated with Early Jurassic monzonite-diorite rocks intruding Nicola andesite. Previous work by Cominco Ltd. reported widespread, but low grade copper and minor gold mineralization on the property. To the northwest, Mad River Resources Inc. completed geochemical surveys and drilling on the **Model Anne** prospect. This is a structurally hosted epithermal precious metals target associated with widespread cinnabar mineralization and Tertiary faults. Brenda Mines Ltd. drilled the **Oz** copper-gold property, but obtained discouraging results and has since dropped the property. On the **Kamrose** property, east of Knutsford, C. Boitard drill-tested an induced polarization anomaly related to widespread pyrite mineralization. South of Swakum Mountain, C. Hagel carried out geophysical surveys, trenching and drilling on the **Abba** prospect, where copper and gold vein mineralization occurs in Nicola volcanic rocks and Jurassic Ashcroft conglomerate. At Nicola Lake, Iota Explorations Ltd. drilled the **G&G 1** claim, a copper-gold prospect associated with dioritic rocks intruding Nicola volcanics. West of the Craigmont mine, near Merritt, Better Resources Ltd. continued work on the **Betty-Lou** property, where Craigmont-type copper-iron skarn mineralization is the target. On the Craigmont property, Craigmont Mines Ltd. (M-7 Industries Ltd.) has initiated a project to recover magnetite from the mine tailings for use in the coal industry. The project has been submitted to the Mine Development Steering Committee.

In the Guichon Creek batholith, a drilling program was carried out at the **Highland Valley Copper mine** to explore a potential southern extension of the Valley orebody. Significant new copper-molybdenum mineralization was encountered and is being evaluated.

PRINCETON - TULAMEEN AREA

This area encompasses most of the Similkameen region, west of the Okanagan Valley, and extends north to the Aspen Grove area, in the Nicola volcanic belt (Figure A-18). Two major projects are highlighted; one in the north, at Siwash Lake and one in the south, at the Copper Mountain mine. Several other drilling programs were carried out on properties distributed throughout the area.

At Siwash Lake, east of Aspen Grove, Fairfield Minerals Ltd. and Placer Dome Inc. completed the second major program on the Elk property, which consisted of surface surveys, trenching and extensive diamond drilling. The property is underlain by the mid-Jurassic Osprey Lake granodiorite at its contact with Nicola volcanic rocks. Fairfield discovered the **Siwash North** gold zone during early surface work in 1988. A detailed trenching program was completed in 1989, followed by drilling, which has continued through 1990. Gold mineralization in the Siwash North zone is a structurally controlled shallow-dipping quartz-vein system that has been traced on surface for about 1.5 kilometres and intersected in drill holes for about 500 metres along strike and to 250 metres depth. There are at least four other gold-anomalous areas on the property remaining to be explored in detail. Significant gold mineralization was intersected on the **Lake zone**, following a trenching and drilling program in that area.

Similco Mines Ltd. undertook an aggressive exploration program at the **Copper Mountain** mine south of Princeton. More than 180 drill holes were completed, the majority of which were in the Lost Horse Gulch area, north of the main open-pit operations. As a result, two adjacent, potentially mineable copper-gold zones were delineated in 1990, in an area originally planned for waste-rock storage. The **Virginia** zone contains an estimated 14 million tonnes grading 0.4 per cent copper and the **Alabama** zone has about 9 million tonnes of 0.32 per cent copper. The precious metals grade of both zones is about 2.5 times the average mine grade and has the effect of enhancing copper grades by about 25 per cent (copper equivalent). Similco is reviewing plans to incorporate the Virginia deposit into 1991 mining plans.

Southwest of the Copper Mountain area, two small projects were operated near Whipsaw Creek. World Wide Minerals Ltd. drilled the **Whipsaw** property, a copper-molybdenum porphyry prospect with associated gold-bearing quartz veins. M. Shewchuk drilled the **Goldrop** claim to the northeast, where copper and zinc mineralization are associated with quartz-carbonate veins and alteration.

Elsewhere in the area, Cominco Ltd. drilled the **Lucky-Jura** claims, north of Princeton. Copper-gold mineralization occurs in intermediate volcanic rocks of the Upper Triassic Nicola Group. The program met with limited technical success. In the same area, E. Wedekind and associates drilled the **Tor** claims, a shear-hosted copper-gold prospect. To the east, in the Tulameen ultramafic complex, Tiffany Resources Inc. continued work on the **Lodestone** property. Magnetite and minor chromite occur as magmatic segregations in pyroxenitic rocks, with reported values averaging about 17 per cent iron and traces of platinum.

HEDLEY AREA

Exploration in the Hedley area was relatively quiet during 1990, with only two major projects operated. Corona Corporation completed extensive diamond drilling in the North and South pit areas of the **Nickel Plate** mine. Additional gold-bearing skarn mineralization was outlined in the North pit and the feasibility of a limited expansion of that zone is under review. At Mount Riordan, work continued on the Polestar Exploration Inc. **Crystal Peak** industrial garnet project (*see* INDUSTRIAL MINERALS). A limited program of diamond drilling, reclamation and geotechnical work was carried out and an agreement for project financing was announced. The program continues under close observation from local environmental interest groups.

OKANAGAN REGION

VERNON MINING DIVISION

Several small to mid-size drilling projects were carried out in the North Okanagan, near Vernon. B.P. Resources Canada Ltd. drilled the **Lavington** property, where anomalous gold values occur in an altered and pyritized shear zone within Devonian Eagle Bay schists. Unfortunately, the area has become the focus of environmental issues which have hampered exploration progress and the company plans to terminate its interest. To the east, near Lumby, J. Hilton drilled the **B.S.** and **OK** properties, both of which are shear-hosted gold prospects in Late Triassic Sicamous rocks.

South of Cherryville, Commonwealth Gold Corporation completed 110 metres of underground drifting and sampling on the **Top** gold prospect. Gold-bearing quartz veins and shear zones occur in Late Cretaceous Whatshan Peak granodiorite. Farther to the south, two intrusive-hosted gold vein prospects were drilled; both occur in mid-Jurassic Nelson granodiorite. Golden Sky Resources Inc. drilled the **Lynx** property and Annax Ventures Inc. drilled the **Xen/Carol** (Winnifred Creek) prospect.

West of Okanagan Lake, in the Whiteman Creek area, Huntington Resources Inc. completed additional surface sampling and a small drilling program on the **Brett** property. The Brett is an epithermal gold deposit, which was extensively explored during 1987-89, but the project was hampered by a lack of funding in 1990. To the north, near Falkland, Corona Corporation drilled the **Jewel** property, a copper-gold prospect associated with diorite intruding late Paleozoic to early Mesozoic sedimentary rocks.

OSOYOOS AND GREENWOOD MINING DIVISIONS

The South Okanagan was again the focus of a number of small to mid-size exploration programs. At Okanagan Falls, Inco Gold Management Ltd. continued with another substantial drilling program on the **Vault** epithermal gold deposit. Two zones were drilled during 1990. East and west extensions of the North vein were tested and additional holes were drilled in the Central (main) zone. The North vein, which extends to surface, was estimated in 1989 to contain some 152 000 tonnes grading 14 grams per tonne gold. The Central zone is a much larger, but deeper and more complex zone with typically lower gold grades. The project was hampered in 1990 by a Section 35 claim dispute and by corporate problems of joint venture partners Seven Mile High Group. Both issues were resolved in favour of the project. Elsewhere in the region, Oliver Gold Corporation drilled extensions of the **Fairview** vein system. Northwest of Fairview, Orequest Consultants Ltd. completed a comprehensive trenching and drilling program at the **Orofino Mountain** lode gold prospect. South of Oliver, at Mount Kobau, Minnova Inc. carried out geochemical and geophysical surveys and diamond drilling on the **Richter** gold project. Targets here are silicified shears and quartz veins cutting Carboniferous metasedimentary rocks of the Kobau Group. West of Osoyoos, the **Mam** gold prospect was explored by Toba Gold Resources Ltd., which completed minor underground development and sampling. Mineralization occurs as precious and base metal bearing quartz veins within the Jurassic Osoyoos granodiorite. In the Camp McKinney area, Crown Resources Corporation carried out geochemical and geophysical surveys and percussion drilling on the **Dayton** property. Targets are structurally controlled gold-silver occurrences in late Paleozoic Anarchist Group rocks.

At the **Highland Bell** silver mine, near Beaverdell, Teck Corporation carried out extensive underground drilling in an attempt to improve the ore reserve picture. Late in the year, however, the company announced that the mine would cease operations early in 1991. To the

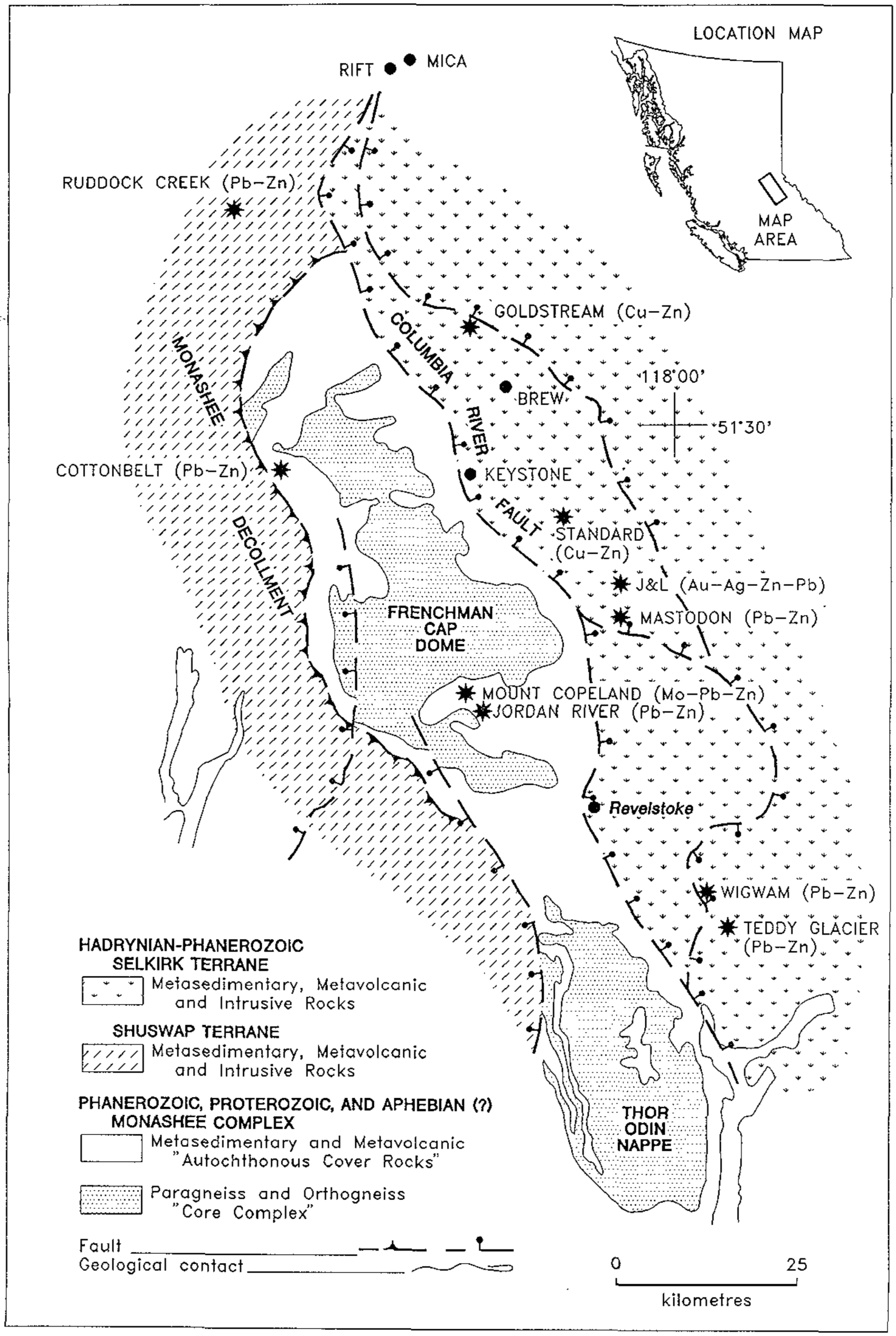

LOCATION MAP
MAP AREA
RIFT
MICA
RUDDOCK CREEK (Pb-Zn)
GOLDSTREAM (Cu-Zn)
COLUMBIA RIVER FAULT
MONASHEE DECOLLMENT
118°00'
BREW
51°30'
COTTONBELT (Pb-Zn)
KEYSTONE
STANDARD (Cu-Zn)
J&L (Au-Ag-Zn-Pb)
MASTODON (Pb-Zn)
FRENCHMAN CAP DOME
MOUNT COPELAND (Mo-Pb-Zn)
JORDAN RIVER (Pb-Zn)
Revelstoke
WIGWAM (Pb-Zn)
TEDDY GLACIER (Pb-Zn)
THOR ODIN NAPPE
HADRYNIAN-PHANEROZOIC
SELKIRK TERRANE
Metasedimentary, Metavolcanic and Intrusive Rocks
SHUSWAP TERRANE
Metasedimentary, Metavolcanic and Intrusive Rocks
PHANEROZOIC, PROTEROZOIC, AND APHEBIAN (?)
MONASHEE COMPLEX
Metasedimentary and Metavolcanic "Autochthonous Cover Rocks"
Paragneiss and Orthogneiss "Core Complex"
Fault
Geological contact
0
25
kilometres

Figure A-19

north, Placer Dome Inc. drilled the **Carmi Moly** property, to confirm earlier data and obtain structural information. A 1988 reserves study reported on the deposit for owners International Vestor Resources Ltd. and Dymac Oil Ltd., estimated approximately 21 million tonnes grading 0.106 per cent molybdenite.

REVELSTOKE AREA

Exploration for stratiform base and precious metal deposits in Paleozoic metasedimentary and metavolcanic rocks was continued north of Revelstoke, in the area east of the Columbia River (Figure A-19). The **J & L** project, operated by Equinox Resources Ltd., continues to be the largest and most comprehensive of the area. The property was inactive for much of the year, following completion of metallurgical test work begun late in 1989. In the fall of 1990, Equinox entered into an agreement with Cheni Gold Mines Inc., whereby Cheni will fund a major underground exploration program to expand the current reserves. Cheni can earn a 60 per cent interest in the property by funding all exploration work, a feasibility study and all capital costs required to bring the property to commercial production. The current work is expected to continue until early in 1991.

Near the Goldstream deposit, Orequest Consultants Ltd. operated programs on the **Goldstream** and **Brew** properties controlled by Bethlehem Resources Corporation and Goldnev Resources Inc. Airborne geophysical surveys were completed on and adjacent to the **Goldstream** mine, with follow-up ground geophysical and geochemical surveys. A short drilling program was also completed on the **Brew/Montgomery** property. The results of the 1990 work will be used to generate drill targets for future programs. Bethlehem Resources also completed limited drilling on the **Keystone** property, south of the Goldstream area. The work was designed to test the extension of several sulphide horizons and soil geochemical anomalies outlined in 1989. At year-end Bethlehem and Goldnev entered negotiations toward an agreement with Nippon Mining Co. Ltd. and Sumitomo Corporation to fund the rehabilitation and development of the Goldstream mine and mill complex. Pending completion of financing, the operation could be put into production later in 1991. Reserves for the planned operation are currently reported at 1.86 million tonnes grading 4.81 per cent copper and 3.06 per cent zinc, using a 3 per cent copper cut-off grade.

Farther north on the Columbia River, the **Mica** and **Rift** prospects were separately explored by Corona Corporation and 9041 Investments Ltd. (Beaumont Logging). Corona's drilling attempted to extend massive sulphide mineralization on the Mica showing, a 2-metre-thick zinc-lead horizon discovered in 1985. The prospect is about 400 metres southeast of the Rift prospect, where a number of thin zinc and lead-bearing pyritic zones occur in lower Paleozoic calcsilicates and marbles. On the Rift prospect, trenching, geochemical sampling and drilling were completed by 9041 Investments Ltd., which controls only the base metal rights on the property. Corona Corporation owns the precious metals rights on the Rift, as well as a 100 per cent interest in the Mica property.

BRIDGE RIVER AREA

The Bralorne and Gold Bridge areas were again fairly quiet, with only three major projects. Armeno Resources Ltd. completed geochemical and geophysical surveys and percussion drilling on the **Standard Creek** gold prospect. The 1990 drilling was done near Piebiter Creek where 1987 work outlined encouraging gold and minor copper values over substantial widths.

Golden Rule Resources Ltd. drilled the **Gold Bridge** property, north of Carpenter Lake. Precious and base metal mineralization occurs as sulphide-rich veins associated with felsic dikes cutting Paleozoic ribbon cherts of the Fergusson Group (Bridge River Complex). Consolidated Balsam Resources Corporation carried out minor drilling at the **Yalakom** property, near the north end of the Shulaps ultramafic complex. Gold-bearing quartz veins are hosted in porphyritic quartz diorite that intrudes serpentinites of the complex. Sulphide mineralization in the form of pyrite, arsenopyrite, chalcopyrite, galena, sphalerite and pyrrhotite, occurs the quartz vein system.

INDUSTRIAL MINERALS

Industrial minerals projects typically account for a relatively small portion of exploration activity in the South Central District. The main commodities and products of interest in 1990 include abrasives, limestone, silica and gypsum for cement and other industrial uses, flagstone and tile, clay products for absorbants and thickeners, and magnesite and talc.

Several industrial minerals operations were active during the year. East of Kamloops, Lafarge Canada Inc. produces cement products from the Harper Ranch limestone quarry. The operation also uses silica from the nearby Buse Lake property and gypsum from the quarry at Falkland. West of Cache Creek, at Pavillion Lake, Continental Lime Ltd. produces limestone, primarily for use in the construction industry. Flagstone and tile products are produced from several locations in the district; south of Revelstoke, at the Revelstoke Flagstone quarry (mica schist), the Mighty White Dolomite Ltd. quarry at Rock Creek and the Beaverdell Granite quarry at Beaverdell. Dimension stone is also produced at the

Beaverdell operation, as well as at the Gazdar granite quarry on Cayoosh Creek, southwest of Lillooet.

The largest industrial minerals exploration project in the region in 1990 is the **Crystal Peak** industrial garnet property operated by Polestar Exploration Inc. at Mount Riordan. Drilling during 1990 was directed toward detailed definition of the main ore zone, as well as geotechnical work for the millsite. Work is also progressing on a Stage I Report for the Mine Development Steering Committee. Late in 1990, the company entered into an agreement with Hawkeye Developments Ltd. to finance a feasibility study for the project. Drill-indicated reserves are currently estimated at 35 million tonnes grading 78 per cent andradite garnet.

At **Red Lake**, northwest of Kamloops, Western Industrial Clay Products Ltd. began limited production from a diatomaceous earth deposit in altered Eocene Kamloops Group volcanic rocks. The material is trucked to the company's Kamloops processing plant for manufacturing of industrial and domestic absorbants.

Northeast of Vernon, at Mabel Lake, R. Yorke-Hardy trenched and drilled a marble unit on the **Clifton** property. This unit occurs in gneisses correlated with the Paleozoic Eagle Bay assemblage, and is potentially a commercial source of flagstone and tile material. In the South Okanagan, E. Carson drilled the **Sil** limestone/marble property, east of Keremeos. The property is underlain by limestones of the Carboniferous Blind Creek Formation, with estimated reserves of 40 million tonnes. Flagstone and tile are the targeted market products.

At the **Hat Creek** bentonite deposit, west of Cache Creek, Pacific Bentonite Ltd. carried out a small auger-drilling program. The work tested peripheral areas of the deposit for extensions of bentonitic horizons discovered during exploration and development for the Hat Creek coal project. Piezometric studies in drill holes have also been initiated. South of Lytton, R. Lacombe drilled the **Gold Ridge** talc-magnesite prospect. The property is underlain by serpentinized ultramafic rocks intruding Late Triassic Nicola Group rocks. The property was formerly explored for gold.

OPERATING MINES

INTRODUCTION

Mining operations in the South Central District experienced a series of highs and lows during 1990. The industry was buoyed by generally strong copper and zinc prices, but was hurt by falling silver prices and generally low gold prices. Mine production for 1989 and 1990 are compared in Table A-10. Production tonnage was higher at four operations and lower at two. **Highland Valley Copper** was back in full production following a major strike and reduction in output in 1989. Production at **Copper Mountain** fell slightly due to a major pit development, but the discovery of two new ore zones has improved the ore reserves picture. **Samatosum, Ajax** and **Candorado** all completed their first full year of operations. British Columbia's silver production increased substantially during 1989-90 due largely to the opening of the **Samatosum** mine.

On the down side, the **Brenda** mine was shut down by mid-year due to exhausted reserves, resulting in less than half of its normal output of copper and molybdenum. The **Beaverdell** and **Blackdome** (*see* Central District) mines were both scheduled for closure and dwindling reserves at **Nickel Plate** all serve to emphasize the region's critical need for new mineral resource development.

HIGHLAND VALLEY COPPER: The Highland Valley Copper joint venture operations mined 96.92 million tonnes of material in 1990, which included 47.09 million tonnes of ore grading 0.429 per cent copper and 0.0078 per cent molybdenum, and 49.83 million tonnes of waste. The Valley Copper pit supplied 36.78 million tonnes of ore, with the balance of 10.31 million tonnes mined from the Lornex pit. The daily milling rate for the year averaged 129 000 tonnes per day. Ore reserves at year end were estimated as: proven, 729.4 million tonnes grading 0.41 per cent copper and 0.007 per cent molybdenum; probable, 101.31 million tonnes grading 0.36 per cent copper and 0.007 per cent molybdenum. The joint venture spent more than $14 million on development that included relocation of an in-pit crusher, raising the tailings dam, powerline and road construction, mill expansion and general improvements. An exploration drilling program was also carried out on the south extension of the Valley Copper orebody.

SIMILCO: Production at the Princeton Mining Ltd. Copper Mountain mine totalled 6 913 836 tonnes of ore grading 0.495 per cent copper, with significant gold content. Currently estimated reserves are: proven, 29 745 700 tonnes grading 0.477 per cent copper; probable and possible, 111 584 000 tonnes grading 0.39 per cent copper. Similco's aggressive exploration program in 1990 (see Princeton-Tulameen area), outlined two new zones of copper-gold mineralization in the Lost Horse Gulch area. One of the new zones, the Virginia deposit, may be included in 1991 mining plans. The company also carried out a $1.5-million expansion of the milling operation, which has increased copper recoveries by about 2.5 per cent.

AFTON/AJAX: Production continued throughout 1990 at Afton Operating Corporation's Ajax copper-gold deposit south of Kamloops, with an average milling rate of 7332 tonnes per day. Total production was 2 676 195 tonnes

TABLE A-10
MINE PRODUCTION AND RESERVES
1989-1990
SOUTH CENTRAL DISTRICT

	PRODUCTION				RESERVES (End 1990)	
MINE	1990 TONNES (000s)	GRADE	1989 TONNES (000s)	GRADE	TONNES (000s)	GRADE
Highland Valley Copper	47 090	0.429% Cu 0.007% Mo	33 000	0.43% Cu 0.01% Mo	776 500	0.41% Cu 0.007% Mo
Similco	6 194	0.495% Cu	7500	0.449% Cu	29 746	0.477% Cu
Samatosum	164.7	830 g/t Ag 0.9% Cu, 1.0% Pb 1.6% Zn 1.0 g/t Au	102.8	808 g/t Ag 1.1% Cu 2.8% Pb 3.6% Zn 1.6 g/t Au	460.4	679 g/t Ag 0.8% Cu 1.0% Pb 1.7% Zn 1.0 g/t Au
Afton/Ajax	2 676	0.55% Cu 0.39 g/t Au	2597	0.42% Cu 0.21 g/t Au	20 865	0.44% Cu 0.32g/t Au
Nickel Plate	1 141	2.502 g/t Au	936.4	2.88 g/t Au	938	2.605 g/t Au
Brenda	4 282	0.14% Cu 0.029% Mo	11 563	0.14% Cu 0.028% Mo	----	----
Highland Bell	36.3	311 g/t Ag	36.3	308 g/t Ag	----	----
Candorado	372	0.79 g/t Au	97.3	0.85 g/t Au	810	0.79 g/t Au

grading 0.55 per cent copper and 0.39 gram per tonne gold, which included 2 104 669 tonnes from the west pit and 571 526 tonnes from the east pit. The operating rate was slightly below the rated capacity of 8165 tonnes per day. Afton completed a short diamond-drilling program in the pit area to further delineate ore-zone boundaries. All preproduction development costs for the two pits were reported in 1989.

SAMATOSUM: The Minnova Inc. Samatosum operation continued throughout 1990, with production and recovery rates better than anticipated at start-up. British Columbia's silver production showed a significant increase for 1989-90 following the commencement of mining at Samatosum in mid-1989. The mine produced 164 723 tonnes of ore grading 830 grams per tonne silver, 0.9 per cent copper, 1.6 per cent zinc, 1.0 per cent lead and 1.0 gram per tonne gold. A comprehensive exploration program was on-going throughout the year. Late in the fall, an exploration adit was collared in the open pit to explore the lower part of the ore zone, in preparation for the later phase of underground production. Year-end reserves are estimated at 460 436 tonnes grading 679 grams per tonne silver, 0.8 per cent copper, 1.7 per cent zinc, 1.0 per cent lead and 1.0 gram per tonne gold.

NICKEL PLATE: Mine production at the Corona Corporation Nickel Plate mine was increased from 2900 to about 4000 tonnes per day for a total 1990 throughput of 1 141 255 tonnes grading 2.502 grams per tonne gold. Production from the Canty deposit began in October, 1990 and has proceeded with grades and recoveries as predicted. Reserves for the Canty are 435 000 tonnes grading 3.4 grams per tonne gold. Current overall reserves for the mine are 937 666 tonnes grading 2.605 grams per tonne gold and are expected to be exhausted by late 1991. However, 1990 exploration in the North pit outlined potentially mineable gold mineralization but would require substantial pit expansion. An additional mineral inventory of approximately 6 million tonnes, grading 2.57 grams per tonne gold may also be mined, depending on economic conditions. If this tonnage is developed and added to reserves, the operation would continue well into the future.

BRENDA: Production at the Brenda mine ceased, slightly ahead of schedule, on June 8th, 1990, following a major pit-wall failure. Mill throughput for the year (January to August, including stockpiles) totalled 4 281 870 tonnes averaging 0.14 per cent copper, 0.03 per cent molybdenum, 0.001 gram per tonne gold and 0.077 gram per tonne silver. The mine operated from 1970 to 1990 with two shutdowns due to low metal prices; from October 1983 to May 1984 and again from December 1984 to September 1985. Total production for the life of the mine is 181 787 700 tonnes averaging 0.15 per cent copper, 0.036 per cent molybdenum, 0.001 gram per tonne gold and 0.062 gram per tonne silver.

HIGHLAND BELL: Teck Corporation's Beaverdell silver mine remained in production throughout 1990 at 100 tonnes of ore per day, to produce 36 300 tonnes grading 311 grams per tonne silver, 0.103 gram per tonne gold and 1 per cent combined lead-zinc. After 90 years of continuous operation the mine will close at the end of February 1991 due to serious operating losses, falling silver grades and weak silver prices.

CANDORADO: Gold recovery from mine tailings at the Candorado Mines Ltd. leach plant continued throughout the year. The leach pad was expanded from a capacity of 100 000 tonnes to 410 000 tonnes. Expected recovery from the existing pad is about 286 kilograms (9200 ounces) of gold. The operation is now processing at a marginal rate due to low gold prices. Reserves of unprocessed tailings are estimated at 810 000 tonnes grading 0.79 gram per tonne, sufficient for about two more years of operation. The current source of tailings is located east of Hedley and originates from historical mining at the Nickel Plate mine. The company is reviewing the feasibility of processing tailings from the former Hedley Mascot mine, which are situated north of the town of Hedley. This would provide an additional supply of about 631 000 tonnes of material.

KOOTENAY DISTRICT

By Andrew Legun and Carlo Buttner
District Geology, Nelson

INTRODUCTION

As in the previous year, 1990 saw a broad spectrum of exploration activity directed toward precious and base metals, industrial minerals and coal. Over 300 Notices of Work were filed, compared to about 250 in 1989. About 60 of these programs involved significant expenditures. A number of proposed programs were cancelled due to problems with financing. Gold was the focus of metal activity but silver, lead, zinc and copper were also sought. Deposit types sought included sedimentary exhalative, vein, skarn, alkalic porphyry and shear-related deposits. The more active camps were Purcell, Nelson-Ymir and Greenwood. No new metal deposits entered the Mine Development Review Process. Cominco's Sullivan mine closed January 31, 1990 but reopened November 1 with a new production plan for the remaining reserves.

Coal exploration activity was at about the same level as 1989, with three of the five coal mines conducting programs. In spite of improving prices for metallurgical and thermal coal, two mines, Byron Creek Collieries and Line Creek were put up for sale by their parent petroleum companies Esso Resources Canada Limited and Crows Nest Resources Limited.

Industrial minerals programs were directed principally toward gypsum, barite and phosphate (with emphasis on rare-earth content).

As in 1989 prospectors led the way in finding new prospects in the Kootenay District.

TRENDS AND OPPORTUNITIES

Though the northwest of the province has been the focus of recent exploration activity, spurred on by discoveries such as Eskay Creek and at Tulsequah Chief, the cost of exploration is reportedly 2 to 2.5 times less expensive in areas of good infrastructure such as the Kootenays. In 1991 the release of data for the 1990 Regional Geochemical Survey of map sheets 82G and 82J, and the release of gold and 26 other previously undetermined elements from archived stream-sediment pulps for map sheets 82E, F, K, M and L will give explorationists an opportunity to get the best "bang for their buck" in the Kootenay District (Figure A-20).

The district is also excellent hunting ground for industrial minerals. Over the last few years good prospects with respectable tonnage potential have been found for barite, gypsum, wollastonite and magnesite. In some cases the mineral occurrence was locally known. The new Mineral Act facilitates exploration and development of industrial mineral properties.

TRENDS IN THE EAST KOOTENAYS

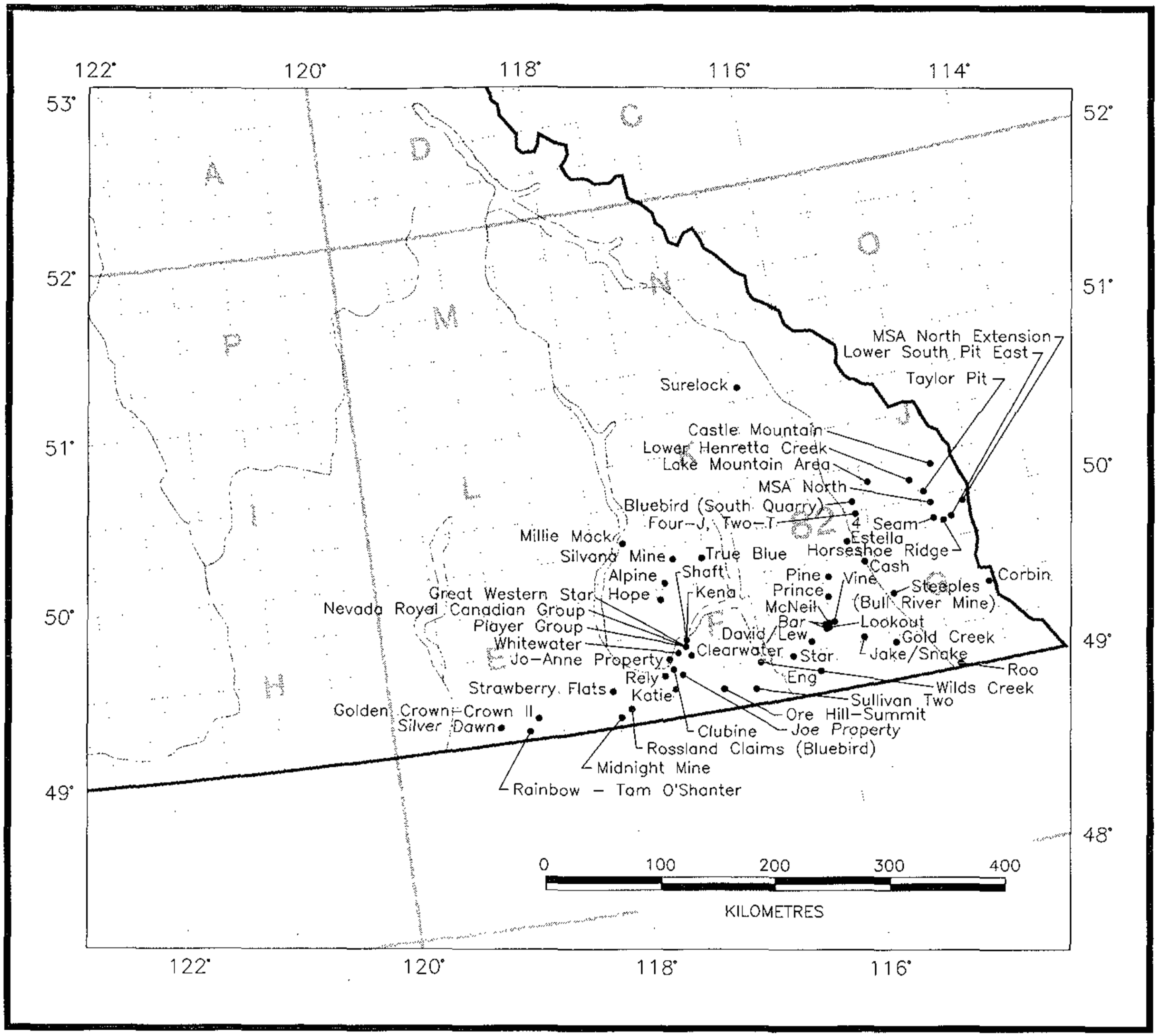
In the East Kootenays metal exploration activity increased for the third year in a row. General areas of activity include the Cranbrook-Yahk area, the east margin of the Rocky Mountain trench and Creston.

CRANBROOK-YAHK AREA

In the Cranbrook-Yahk area exploration was directed toward the following:

- Base metal "sedex" (Sullivan-type) targets in the Aldridge Formation (*e.g.* **McNeil**, **Eng**, **Star**, **Bar** properties).
- Base metal veins (the **Vine**, its northwest extension and the southeast extension of the past-producing **St. Eugene** mine).
- Gold mineralization associated with generally north-northeast to northeast-trending faults. Associated with these faults are mineralized shears and dilatant zones plugged by quartz, breccias and, occasionally, altered felsic intrusions (**Bar**, **David/Lew**, **Price** properties).

Though the Sullivan time-horizon is still the principal target for sedex exploration, the thousand metres of overlying stratigraphy is receiving some attention, based on the presence of thin sulphide bands, disseminated mineralization and Sullivan-type features such as tourmalinite and fragmental zones. Exploration work is facilitated by better knowledge and correlation of thin turbidite marker horizons in the Aldridge Formation. Initial intersections of quartz sulphides on the **Star** property by Barkhor Resources Inc. at "Munroe marker time" provided the impetus for exploration on surrounding properties. Some geologists perceive there is a relationship between Moyie


122°
120°
118°
116°
114°
53°
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K
H
E
F
G
82
Surelock
MSA North Extension
Lower South Pit East
Taylor Pit
Castle Mountain
Lower Henretta Creek
Lake Mountain Area
MSA North
Bluebird (South Quarry)
Four-J, Two-T
4 Seam
Estella
Horseshoe Ridge
Millie Mack
Silvana Mine
True Blue
Cash
Corbin
Alpine
Shaft
Pine
Vine
Steeples
Great Western Star
Hope
Kena
Prince
(Bull River Mine)
Nevada Royal Canadian Group
McNeil
Lookout
Player Group
Bar
David
Lew
Gold Creek
Whitewater
Clearwater
Star
Jake/Snake
Jo-Anne Property
Roo
Rely
Eng
Wilds Creek
Strawberry Flats
Katie
Sullivan Two
Golden Crown-Crown II
Ore Hill-Summit
Silver Dawn
Joe Property
Clubine
Rossland Claims (Bluebird)
Midnight Mine
Rainbow - Tam O'Shanter
0
100
200
300
400
KILOMETRES

Figure A-20

dikes and sills, structurally controlled vein deposits and stratabound sulphides.

ROCKY MOUNTAIN TRENCH AND EAST

Exploration in this area included drilling the peripheries of past-producing vein deposits in the Aldridge Formation (**Estella, Bull River**) and assessing the potential of old and new prospects related to monzonitic-syenitic intrusives within and east of the Rocky Mountain Trench (*e.g.* **Cash** property). The petrology of the intrusions within and east of the trench is not well known.

CRESTON AREA

Exploration in the Creston area focused on stratabound targets in the Middle Proterozoic Aldridge Formation (**Sullivan Two** property) and in the Upper Proterozoic Dutch Creek Formation (**Wilds Creek** property).

OPPORTUNITIES IN THE EAST KOOTENAYS

The combination of deep-seated faults and intrusive activity appears to provide good prospective ground in the East Kootenays.

Upper Proterozoic rocks on the west margin of the Purcell anticlinorium have some potential for sedex deposits based on volcanic horizons, intervals of black shale and the stratigraphic proximity of exhalative minerals such as barite in the geologic section (Mt. Nelson Formation).

TRENDS IN THE WEST KOOTENAYS

NELSON-SALMO-ROSSLAND AREA

Exploration activity in the Nelson-Salmo-Rossland area remained high. Efforts were focused on shear-related gold in the Elise Formation volcanic-intrusive suite, precious and base metal veins in the larger stratigraphic package of Jurassic volcanics and sediments, and alkaline porphyry copper-gold potential in dioritic to monzonitic intrusions within the Rossland Group.

Exploration continued on several intrusive-hosted gold-bearing quartz veins in the area. These included the **Alpine** of Cove Resources Corporation and the **Nevada Royal Canadian** of Winchester Developments. These gold-quartz veins interestingly also carry some scheelite together with carbonate and pyrite.

GREENWOOD AREA

Interest in the Greenwood area increased in 1990 and there was significant staking based on activity immediately south of the international border. Work focused on finding gold-bearing skarns near known copper-skarn prospects and past producers. There were also programs investigating the listwanite-gold association and precious metal mineralization associated with quartz veins and Tertiary gravity faults.

The discovery of a gold-bearing skarn in Knob Hill Group oceanic rocks (**Buckhorn** deposit) in Washingston State is providing impetus for staking similar aged rocks on the Canadian side of the border as well as re-evaluation of the known Triassic copper skarns (*e.g.* Phoenix) for the presence of gold halos.

Listwanite-related targets are basically of two types. In the first, gold-bearing quartz veins which are spatially associated with serpentinites contain erratic but occasionally spectacular pockets of precious metal mineralization (*e.g.* **Velvet, Skylark, Midnight, Golden Crown**). In the second, pervasively altered country rocks are prospective for precious metal bearing zones (*e.g.* **Rainbow - Tam O'Shanter, Silver Dawn**).

OPPORTUNITIES IN THE WEST KOOTENAYS

Historically the area is known for its vein deposits. Old prospects should be re-examined in the light of new ideas. Some of the old showings may in fact represent parts of larger systems such as skarns, stockworks or porphyries. More attention needs to be paid to the potential for low-grade, large-tonnage stratabound deposits which may have been overlooked given the focus on veins.

According to Bill Howard and other prospectors, outliers of the Rossland Group within Nelson plutonic suite are not mapped in some areas including southeast of Castlegar. If true, these areas are prospective for deposits similar to the **Tillicum** or **Willa.**

In the Nelson area the **Silver King** shear zone appears to persist into the Nelson pseudodiorite, making the area to the northwest prospective ground.

The Rossland camp should be assessed for its gold skarn potential given that the veins of the Rossland camp were associated with some skarn minerals. Recent petrographic studies of gold-bearing (5.31 g/t) alteration zones from the **Rossland claims** of Antelope Resources Inc. confirm skarn features such as development of garnet.

In the Nelson area prospectors have identified a number of zones of intense silica flooding and brecciation within Nelson plutonic rocks. The alteration is quartz-carbonate-sericite with minor vugs and chalcedonic banding. Most quartz breccias are barren of sulphides, low in trace metals and areally restricted, but a few carry copper-lead-zinc mineralization with anomalous gold and are more extensive. They appear to have few counterparts in the record of mining in the area although the vuggy and crustiform quartz breccias of the **Mollie Gibson** vein, a past producer may be an analogue.

In the Slocan camp workings on high-grade zinc veins abandoned at the turn of the century may be worthwhile to pursue.

The Greenwood camp appears to have been neglected for copper-gold porphyry potential compared to the Nelson camp, even though it is closer to the Intermontane Belt that hosts these deposit types. Known porphyry prospects in the Greenwood camp include the **Lexington.**

MINERAL EXPLORATION

GREENWOOD AREA

Battle Mountain (Canada) Inc. has started a major re-evaluation of the immediate area of the **Phoenix** copper pit for gold. In 1990 a 135-kilometre grid was established, 3400 soil samples taken and ground magnetometer survey completed. Drilling will be conducted in 1991 under an agreement with Kettle River Resources Ltd.

On the **Silver Dawn** property (old **Imperial and Emiline** Crown Grants) of Rock Creek Resources Ltd. silver-rich lenses occur within a siliceous (chalcedonic?) breccia that is intercalated with quartz-carbonate rock (listwanite?). Mineralization consists of native silver with fine-grained pyrite, galena and sphalerite. The mineralized zone is reported to be open along strike, flat lying and near surface.

On the **Rainbow** property Minnova Inc. has drilled mineralization hosted by flat-lying silicified and phyllic-altered quartz porphyry sills intercalated with carbonatized ultramafic rocks.

On the **Golden Crown** property south of the Phoenix pit, Attwood Gold Corporation did further drilling to increase existing reserves of 57 000 tonnes grading 14.21 grams per tonne gold and 0.70 per cent copper. It conducted a re-evaluation of work to date and concluded that the mineralized zone is continuous between the **Winnipeg** and Golden Crown workings.

NELSON-SALMO-ROSSLAND AREA

ROSSLAND GROUP (INTRUSIVE AND SHEAR RELATED GOLD-COPPER)

On the **Player** property Formosa Resources Corporation completed 1525 metres of drilling in two areas on a northwest-trending polymetallic shear in Elise Formation volcanics. The mineralization is hosted in carbonatized and silicified tuffs and is present up to widths of 8 metres running 0.4 to 0.5 per cent copper, a few per cent combined lead and zinc and 3.12 to 6.24 grams per tonne gold. Further fill-in drilling will include testing the peripheral area of a small monzonitic intrusion.

In the adjacent **Great Western Star** property, Pacific Sentinel Gold Corporation drilled several targets along a 4900-metre mineralized trend early in the year. Three of the targets (**Ron**, **Eureka**, **Star**) are copper-gold prospects hosted by altered and fractured monzonite which underlies the northwest part of the property. The **Alma N** showing is at the monzonite-volcanic contact and consists of gold with pyrite. Drilling to the southeast, at the **Toughnut** claims, explored altered volcanics along the Silver King shear.

Noramco Mining Corporation examined the **Kena** property for alkalic porphyry copper-gold mineralization. The area is marked by sericitic and siliceous shear zones parallel to the regional foliation and by zones of moderate to intense fracturing. Chalcopyrite and pyrite occur principally in synvolcanic diorites and to a lesser extent in Elise Formation tuffs.

Drilling on the **Shaft** property by Noramco was generally disappointing except for one area at the contact of Silver King porphyry with adjacent tuffs where anomalous gold, lead, zinc, copper and arsenic warrant further work.

A step-out hole by Noranda Exploration Company Limited on the **Katie** property near Salmo returned a 120-metre intersection of 0.15 per cent copper and 0.16 gram per tonne gold, indicating potential for a low-grade, large-tonnage porphyry deposit. The property is underlain by hornblende diorite, Elise Formation tuffs, agglomerate and feldspar porphyry. Alteration is variably propylitic, pyritic, silicic and potassic. The mineralogy consists of pyrite, chalcopyrite and magnetite but magnetite is not coincident with sulphides. Chalcopyrite occurs in stringers and as disseminations, often with calcite or quartz. Further drilling is expected to test the extent of low-grade mineralization.

VEINS

At the southern border of Kokanee Glacier Park, Cove Resources Corporation drilled the eastern extension of the **Alpine** vein and a subparallel vein, the **Gold Crown**, to the south. Immediately west of Nelson, Winchester Developments drilled the **Nevada** vein.

Quartz veins related to shears were also drilled on the **Clearwater** and **Joe** properties. One hole on the Clearwater returned 13.4 grams per tonne gold over 2.3 metres.

On the **Clubine Comstock** property on the east side of the Hall syncline, north of Salmo, Yellowjack Resources Ltd. exposed a 0.3-metre vein in trenches; the best assay ran 55 per cent lead and 2185 grams per tonne silver. This high-grade vein, hosted by the Hall Formation, will be drilled in 1991. Earlier drilling had followed a quartz vein.

On the **Rely** property, between Nelson and Castlegar, gold occurs with pyrite and pyrrhotite in erratic vein-like zones within a section of hornfelsed Archibald Formation siltstones and interbedded felsic to intermediate volcanics. Pegasus Gold Inc. drilled an induced polarization anomaly but with less encouraging results than in 1989 when a 6.1 metre intercept assayed 8.74 grams per tonne gold.

On the **Whitewater** property, Teck Corporation drilled a breccia in Rossland Group rocks, near the contact with Nelson intrusive rocks, with inconclusive results.

In the Rossland camp Antelope Resources renewed drilling on the **Rossland** claims late in the year, focusing on the **Bluebird** and **New North** areas in the south belt. A large (62-metre) interval of lead-zinc mineralization was intersected in one hole and a narrow high-grade gold-silver zone in another (0.37 metres of 376 grams per tonne silver, 14.5 per cent lead, 7.5 per cent zinc and 10.3 grams per tonne gold). Traditional mineralization on this claim block consists of massive pyrrhotite-chalcopyrite shoots in altered monzonite and Elise Formation volcanics. Interestingly, gold occurs with arsenopyrite but not necessarily with the massive sulphides.

Southwest of Rossland, at the **Midnight** mine, underground development continued on quartz veins and about 1500 tonnes of ore was hauled to a mill in Northport, Washington.

SKARN

North of Nancy Greene Park, in an area underlain by Mount Roberts Formation, CAMECO drill-tested two areas in which trenching had exposed massive pyrite-pyrrhotite mineralization with elevated gold values in skarn.

OTHER

In the Salmo camp, Yellowjack Resources Ltd. explored for gold in Lower Paleozoic limestones and phyllites on the **Ore Hill-Summit** property. Sulphides, including sphalerite, galena and minor chalcopyrite, and free gold are present in crackle zones confined to the more carbonate-rich facies. Mineralized intercepts in three holes returned values of 6.24 to 12.48 grams per tonne gold in intervals of 2 to 3 metres. Old mine workings nearby exploited a rich polymetallic quartz-siderite vein.

SLOCAN AREA (KASLO - NEW DENVER - SLOCAN)

At the **Silvana** silver-lead-zinc mine, drilling from surface and underground explored for the faulted western extension of the lode structure and tested the ground between the Silvana mine and Carnation workings without much success.

Avril Explorations Ltd. opened up, mapped and sampled levels 2, 3, 5 and 5A on the **Grey Copper** vein (a high-grade zinc vein) located near the former mining town of Cody.

Kokanee Explorations Ltd. drilled the **Hope** prospect which consists of a skarned pendant of the Slocan Group surrounded by rocks of the Nelson plutonic suite. Potential for extension of modest reserves is limited.

The **Millie Mack** property, site of an extensive program in 1989 by Dragoon Resources Ltd., underwent limited drilling without much success.

The **True Blue** massive sulphide prospect, hosted by the Upper Paleozoic Milford Group, was tested by a single hole drilled by QPX Minerals Inc. This prospect of banded massive pyrite-pyrrhotite-chalcopyrite up to 1.2 metres thick warrants further work.

CRESTON AREA

Kokanee Explorations Ltd. drilled the **Wilds Creek** property near Wyndell, where sphalerite occurs in two apparently stratabound units within the Dutch Creek Formation. The Dutch Creek Formation consists of interbedded green, quartz phyllite, black phyllite (with magnetite) and argillaceous limestone together with a very thin volcanic unit. The sphalerite occurs with coarse-banded pyrite.

West of Creston, White Knight Resources Ltd. explored bedded sulphide zones in metamorphosed Aldridge rocks on the **Sullivan Two** property.

CRANBROOK-YAHK AREA

Kokanee Explorations Ltd.'s **Vine** prospect near Cranbrook has been tested for 375 metres along strike and for a depth of 800 metres. Polymetallic mineralization in a siliceous or calcitic gangue occurs in veins, primarily on the hangingwall and footwall of a steeply dipping gabbroic dike which occupies a northwest-trending fault. A hangingwall vein is most persistent, up to 4 metres wide but averaging 2 metres. The mineralogy is galena, sphalerite, pyrrhotite, pyrite and gold-bearing arsenopyrite. Drilling to date totals 16 385 metres in 54 holes with three principal mineable zones having been defined. A decline and bulk sampling is planned for 1991.

On the **Price** claims near Perry Creek Kokanee drilled quartz veins and breccias associated with a northeast-trending structure.

On the **Lookout** property, operated by White Knight Resources Ltd., continuity of the Vine vein structure to the northwest was established. Lead-zinc-silver-gold mineralization was found to be irregular due to the presence of a gabbro dike within the structure. The structure is believed to be the faulted northwest extension of the Vine occurrence.

On the **Star** property of Barkhor Resources Inc., sulphides (galena, sphalerite, pyrrhotite, chalcopyrite) are enclosed in coarse quartz bands. Some suggestion of contorted sulphide bands is present and some quartz bands are quite continuous. Sulphides are also associated with more erratic quartz veining. Nine drillholes of about 300 metres each have been completed. The property has large areas of alteration (tourmalinization) and the style of mineralization is not yet well understood.

A deep hole was drilled on the **Bar** property of Goldpac Investments Ltd. to intersect the Sullivan time-horizon within the favorable mineral trend known as the "Sullivan corridor". The 1900-metre hole intersected a large gabbroic body.

On the **Bar** property near Cranbrook, Swift Minerals Ltd. intersected 37.82 metres of copper mineralization (0.2 to 0.54% range) with anomalous gold in four intervals over a length of 129.3 metres. Hostrocks include two syenite dikes separated by a quartz and quartz-breccia zone that occupies a zone of dilation along the Cranbrook fault. Drilling was conducted at the north end of an area drilled by Chapleau Resources Ltd. in 1988.

Bapty Research Ltd. drilled a gold-bearing shear with quartz on the **David/Lew** property. Shearing may be related to the nearby Old Baldy fault. Values of 6.24 grams per tonne gold across 2.4 metres are reported for a tested strike length of 150 metres.

ROCKY MOUNTAIN TRENCH AND EAST

On the east side of the Rocky Mountain Trench, at the site of the **Bull River** mine, the R.H. Stanfield Group drilled a copper vein-system southeast of previous surface workings. The veins, including mineralized quartz-carbonate breccias, are 1 to 3 metres wide and are enclosed in prospective shear envelopes of up to 10 metres in width. The principal sulphide is disseminated chalcopyrite but the veins carry minor silver and an undefined amount of gold.

Near the east fork of the **Wildhorse River**, Kokanee Explorations Ltd. explored copper-skarn mineralization at the contact of a small monzonitic plug and lead-zinc in nearby Cambrian Jubilee Formation brecciated limestone.

In the south, near the United States border at Roosville, Teck reports that drilling at the **Roo** property, a red-bed copper prospect in the Proterozoic Sheppard Formation, was inconclusive. Anomalous silver values remain unexplained.

Drilling at the **Estella** mine suggests graphitic Aldridge rocks may be responsible for the geophysical anomalies.

COAL

Coal exploration programs were undertaken at **Line Creek** and **Fording River** operations and **Coal Mountain.**

At **Line Creek** exploration drilling was conducted at Horseshoe Ridge, Mine Services Area North, and 3-4 seam area. Exploration became focused on Mine Services Area North, straddling the north boundary of Mine Lease 4. A coal seam 30 metres thick occurs in a low strip-ratio setting. Drilling continued into late fall.

At **Coal Mountain**, Byron Creek Collieries completed 57 rotary-drill holes in the Corbin area, adjacent to its active pit. Reserves were increased, principally due to a structurally thickened 30-metre seam which has weak coking-coal properties. Exploration and development work will continue in 1991 and the paperwork for extending the mine lease is in hand.

At **Fording Coal** further drilling in the Lower Henretta valley brought this area one step closer to mine development. Drilling in Taylor pit defined the base of coals against a basal thrust. South of the mine area, drilling confirmed a coal resource on Castle Mountain. To the west, in the area of the Greenhills syncline at Lake Mountain, drilling and bulk sampling were conducted in preparation for a dragline mining operation in 1992.

The area of the Fernie basin has attracted attention from oil and gas companies investigating its potential for coalbed methane generation. Basic research and background engineering studies are in progress.

INDUSTRIAL MINERALS

Domtar Inc. drilled its south quarry which is scheduled for gypsum production in 1991 and drill-tested a new area north of the northern quarry (**Four J, Two-T**). Mountain Minerals Co. Ltd. drove an exploration adit and bulk sampled a fault-controlled barite deposit at the **Surelock** property.

Formosa Resources Corporation located additional phosphate prospects in the basal Fernie Formation on the **Barnes** property.

OPERATING MINES

The **Sullivan** mine closed in January but reopened November 1 after 2.5 months of development work. The mine has an expected life of 8 years and annual production is expected to be 2 million short tons.

Byron Creek Collieries increased production to 1.6 million tonnes but was put up for sale by Esso Resources. Toward the end of the year the **Line Creek** mine was also on the auction block.

At the **Silvana** mine about 3050 metres of development drilling was completed. Total reserves (including pillars) stood at about 41 000 tonnes running 356 grams per tonne silver, 4.1 per cent lead and 5.1 per cent zinc in July 1990. Additional tonnage is available from the **Hinckley** mine but at a lower ratio of silver to lead and zinc.

Westroc Industries Ltd. plans to deplete its gypsum reserves at the **Windermere** 3 quarry and switch back to the **Elkhorn 1** quarry which was the site of operations before 1989. An adjacent pit, **Elkhorn 2** is scheduled for production later. Westroc mines about 410 000 tonnes of gypsum annually.

About 150 000 tonnes of silica were mined in the Kootenay District in 1990. Silica for production of silicon metal is mined at Nicholson south of Golden by Bert Miller Contracting Ltd. while silica sand is produced from a friable quartz sandstone mined by Mountain Minerals just north of Golden. Silica for the Cominco smelter at Trail comes from a quarry south of Salmo, operated by 331670 B.C. Ltd.

Over 170 000 tonnes of high-grade magnesite was produced at the **Mount Brussilof** deposit of Baymag Mines Ltd.

At the **Moyie River placer operations** of Queenstake Resources Ltd., 37 631 cubic metres of gravel were processed to yield roughly 52 kilograms of fine gold.

TABLE A-11
OPERATING MINES IN KOOTENAY DISTRICT, 1990

MINE (OWNER)	TONNES MILLED (000s)	RATED CAPACITY (tpd)	%ANNUAL RATED CAPACITY	DEPOSIT TYPE	RESERVES/PRODUCTION
Line Creek (Crows Nest Res. Ltd.)	2 072	10 400	55	Coal	Production: 1.8 Mt metallurgical and thermal coal
Balmer (Wester Mining Ltd.)	5 939	26 000	68	Coal	Production: 5.4 Mt metallurgical coal, 200 kt thermal coal
Coal Mountain (Byron Creek Collieries)	1 587	4 930	57	Coal	Production: 1.6 Mt thermal coal
Greenhills (Westar Mining Ltd.)	3 032	9 900	85	Coal	Production: 2.7 Mt metallurgical coal
Fording River (Fording Coal Ltd.)	6 860	15 900	104	Coal	Production: 5.0 Mt metallurgical coal, 0.9 Mt thermal coal
Sullivan (Cominco Ltd.)	460	8 000	76	Sedex Zn-Pb-Ag	Reserves: 23 Mt @ 7.1% Zn, 4.6% Pb, 29 g/t Ag
Silvana (Treminco Res. Ltd.)	34.6	110	84	Vein Ag-Pb-Zn-Cd	Reserves: 41 kt including pillars @ 356 g/t Ag, 4.1% Pb, 5.1% Zn
Mt. Brussilof (Baymag Mines Ltd.)				Replacement	Production: 170 kt magnesite
Lussier River (Domtar Gypsum Inc.)				Evaporite	Production: 135 kt gypsum
Moberley Silica				Sedimentary	Production: 90 kt silica
Parson (Mountain Minerals Co. Ltd.)				Vein	Production of barite N/A
Nicholson (Bert Miller Contracting Ltd.)				Sedimentary	Production: 36 kt silica
Crawford Bay (IMASCO)				Sedimentary	Production: 32-36 kt dolomite
Sirdar Granite (IMASCO)				Granite	Production: 2.8 kt granite
Lost Creek (IMASCO)				Sedimentary	Production: 6-7 kt limestone
Salmo Quartzite (Kootenay Stone Centre)				Sedimentary	Production: Several thousand tonnes flagstone from 3 quarries
Queenstake Moyie River (Queenstake Res. Ltd.)				Placer Au	Production: 52 kg fine Au from 37 631 cubic metres of gravel
Windermere (Westroc Industries Ltd.)				Evaporite	Production: 410 kt gypsum

SOUTHWESTERN DISTRICT

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District Geology, Victoria

INTRODUCTION

A reduction in the level of exploration activity in the Southwestern District, which began in 1989, accelerated significantly in 1990 and appears likely to continue into 1991. The total number of Notices of Work filed was down by approximately 15 per cent compared to the same period in 1989. More specifically, Notices on mineral properties were down by 13 per cent while placer Notices dropped by 82 per cent. The pace of activity was significantly reduced on Vancouver Island, particularly in the Victoria Mining Division, and showed a major reduction on the Queen Charlotte Islands. In contrast, activity as measured by the number of active projects, showed a slight increase in the southwestern mainland. However, most of those projects had small, low-budget programs. The total number of advanced exploration projects in the district, defined as those which involved drilling or underground exploration (*see* Table A-3), was down by exactly 50 per cent from 1989. Of those advanced projects which were active in 1990, several were operating with reduced budgets compared to previous seasons. Only three companies (Minnova Inc. at the Lara project, Falconbridge Limited at Chemainus and Moraga Resources Limited west of Port Hardy) spent close to or slightly more than $1 million on projects in the district. In the case of Moraga, the expenditure was divided among several separate properties. There were no project expenditures in excess of $1 million.

The main focus of exploration interest was on the porphyry copper camp west of the Island Copper mine on northern Vancouver Island where Moraga Resources Limited, and several affiliated junior companies, drilled three properties and carried out preliminary programs on several others. Near Chemainus, both Minnova Inc. and Falconbridge Limited again completed major drilling programs searching for volcanogenic massive sulphides in the Sicker Group. Potentially important drilling programs were started late in the year at the **Merry Widow** gold-copper skarn prospect, optioned by Noranda Exploration Company, Limited from Taywin Resources Ltd., and on the **Tsable River** coal licences where Western Canadian Mining Corporation is the operator. Other properties with potential for generating interest in 1991 include the **Quet** gold and base metal property north of Harrison Lake, optioned by Noranda from Aranlee Resources Ltd.; the **Seneca** volcanogenic massive sulphide prospect on the Chehalis River where Minnova Inc. mounted a late-season drilling program; the **Ladner Creek** project where Anglo Swiss Mining Corporation hopes to increase reserves at the former Carolin mine; and the **Southeaster** gold prospect of Worthington Resources Corporation on Graham Island (Figure A-21).

Several advanced properties at which gold is the main or only significant commodity saw limited exploration programs, or none at all, as both major and junior companies found it increasingly difficult to raise exploration funding for exclusively precious metal projects. Among those properties were **Spud Valley**, **Debbie** and **Mount Washington**.

The three operating mines in the district continued full-scale operation through 1990. Westmin Mines Limited at **Buttle Lake** and BHP-Utah Mines Ltd. at the **Island Copper** mine both maintained large-budget exploration programs in an attempt to increase the lives of their respective mines beyond the end of the century. The **Quinsam** thermal coal mine of Brinco Coal Corporation made or initiated several operating improvements, including a test underground operation, in 1990 and appears to be an increasingly healthy producing mine.

MINERAL EXPLORATION

VANCOUVER ISLAND

The project on Vancouver island where most interest was focused in 1990 is the **Expo** property optioned by Moraga Resources Ltd. from BHP-Utah Mines Ltd., operator of the nearby Island Copper mine. Prior to Moraga's current program the **Hushamu** porphyry copper-gold deposit on the Expo property, located 26 kilometres west of Island Copper, had published reserves of 52.2 million tonnes grading 0.32 per cent copper, 0.008 per cent molybdenum and 0.41 gram per tonne gold, with a further geological inventory of 159 million tonnes of similar grade. Moraga's objective was to improve the measured reserves and to demonstrate the existence of a mineable deposit in the Hushamu zone with a stripping ratio more favorable than the 2.2:1 previously calculated by BHP-Utah Mines. In 1991 Moraga completed 18 drill holes totalling 4267 metres. The most recent published

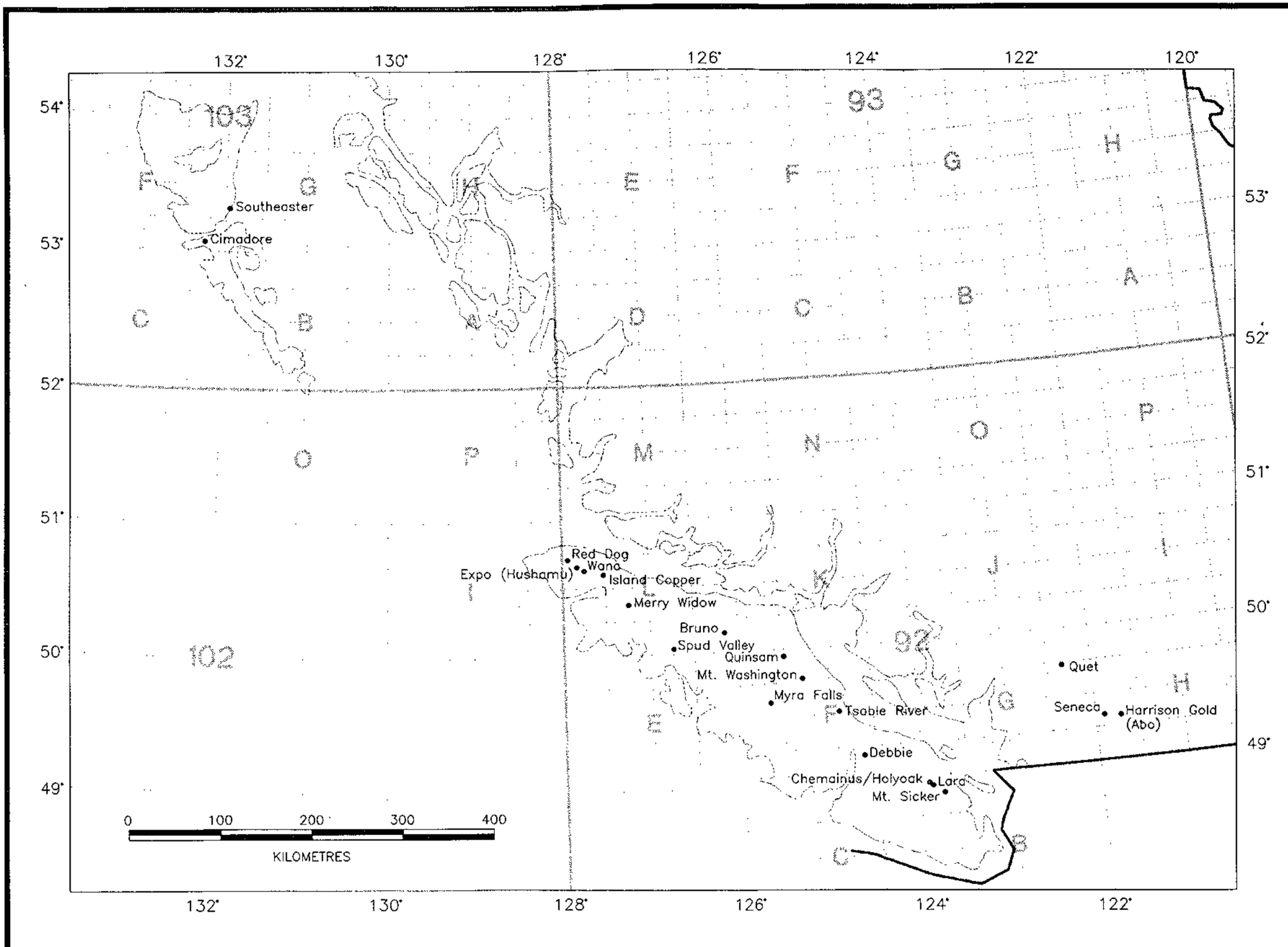
132° 130° 128° 126° 124° 122° 120°
54° 53° 52° 51° 50° 49°
103
93
102
92
Southeaster
Cimadore
Red Dog
Wano
Expo (Hushamu)
Island Copper
Merry Widow
Bruno
Spud Valley
Quinsam
Mt. Washington
Myra Falls
Tsable River
Quet
Seneca
Harrison Gold (Abo)
Debbie
Chemainus/Holyoak
Lara
Mt. Sicker
0 100 200 300 400
KILOMETRES

Figure A-21

estimate of indicated reserves is 79 million tonnes at 0.30 per cent copper, 0.010 per cent molybdenum and 0.34 grams per tonne gold, at a stripping ratio of 0.8:1 and with a possible total resource inventory of as much as 414 million tonnes in the Hushamu zone.

In addition to the major drilling program on the Expo property, Moraga drilled 10 holes totalling 1890 metres at the adjacent **Red Dog** property located near Holberg and optioned from Crew Natural Resources Ltd. The 1990 drilling confirmed previously estimated reserves of 45.4 million tonnes grading 0.32 per cent copper and 0.41 gram per tonne gold, with an exceptionally favorable stripping ratio of 0.36:1. Moraga also completed a drilling program consisting of 17 reverse-circulation holes totalling 1867 metres on the **Wann** property optioned from Acheron Resources Ltd. and located in the Wanokana Creek area west of Coal Harbour. This preliminary program tested several anomalous zones and intersected encouraging alteration assemblages but, so far, no ore-grade mineralization. Elsewhere in the northern Vancouver Island copper belt, Moraga Resources and several affiliated junior companies, as well as major companies including Placer Dome Inc., completed reconnaissance-scale programs on a large number of claim groups, in many cases following up on anomalous results from the 1989 Regional Geochemical Survey release.

The only other concentration of large-budget drilling programs on Vancouver Island was in the Chemainus River area at the eastern end of the Cowichan uplift of Sicker Group rocks. Both Minnova Inc. and Falconbridge Limited completed major drilling programs there in the ongoing search for additional volcanogenic massive sulphide mineralization in Paleozoic felsic volcanics. At the **Lara** property, which is owned by Laramide Resources Ltd., Minnova drilled a total of 11 167 metres in 49 holes, mainly to test a new mineralized zone called the 262 which is stratigraphically distinct from the previously explored Coronation zone. The 262 horizon has now been traced along strike for about 4 kilometres. Minnova also drilled 14 holes totalling 2400 metres on the separate, wholly-owned **Mount Sicker** property. Falconbridge drilled a total of 7202 metres in 24 holes on its **Chemainus - Holyoak** property, which adjoins both the east and west sides of the Lara property, and provides potential targets on strike with the Coronation zone and the former producers on Mount Sicker. No results have yet been released for any of these Chemainus-area projects.

The only other advanced project in the Sicker belt of southern Vancouver Island was the **Debbie** project of Westmin Resources Limited on McLaughlin Ridge southeast of Port Alberni. This large property with three significant mineralized zones, all involving epigenetic, shear and vein-related gold mineralization, had attracted considerable attention in recent years as the flagship for new styles of mineralization in the Sicker belt. In 1990 Westmin mounted a program with a much-reduced budget. The only drilling involved four short holes to test a new gold zone west of the high-grade 900 zone. The junior joint venture partner, Pacific Gold Corporation (formerly Nexus Resources), did not participate in the 1990 program and did no work on its self-managed **Yellow** claim.

At the end of 1989 McAdam Resources Inc. seemed well on its way to developing a new gold producer at its **Spud Valley** property in the Zeballos gold camp. Early in 1990, underground drifting and sampling was in progress and was feeding bulk-sample material to a newly opened pilot mill on the property. Unfortunately, the head grade to the mill was only a small fraction of the average ore grade, apparently due to severe dilution in the mining process. The company reported that gold produced from the mill was insufficient to pay for continued mining. By mid-year the exploration budget, financed mainly by an associated company, McNickel Inc., had been exhausted, McAdam Resources was in financial difficulty, and all work on the property ceased.

Another highlight property in 1989 was the **Merry Widow** skarn-related gold-copper prospect of Taywin Resources Ltd. near Benson Lake. In September of 1990, it was announced that Noranda Exploration Company Limited had signed an otion agreement with Taywin granting it an option to earn 51 per cent interest by spending $1.5 million in two years. Late in the year, a Noranda crew completed mapping, geophysics and geochemistry over most of a 20-kilometre grid and, early in December, began drill-testing several promising geophysical/geological targets.

Other advanced mineral exploration properties on Vancouver Island which received some work in 1990 included the **Mount Washington** epithermal gold prospect where Better Resources Ltd. drilled six holes totalling 284 metres to test the southward extent of the **Lakeview** gold-silver-copper deposit, and the **Bruno** property of Doromin Resources Ltd. in the White River area south of Sayward, where 11 holes totalling 1400 metres were drilled to test a fault-related copper-bearing quartz vein in suspected Paleozoic volcanic rocks.

SOUTHWESTERN MAINLAND

Although the total number of Notices of Work from the southwestern mainland part of the district was marginally higher than in 1989, advanced projects and highlights were few. The highlight project in 1989 was the **Giant Copper** prospect of Bethlehem Resources Corporation southeast of Hope. The project was essentially dormant in 1990 as the company waited for some political resolution of the status of Skagit Recreation Area where an essential portion of the mineral resource inventory of the property is reported to occur.

The most intriguing, and potentially most interesting, new development was at the **Quet** property of Aranlee Resources Ltd., located on Sloquet Creek northwest of Harrison Lake. Noranda Exploration Company Limited optioned the property from Aranlee and, after completing extensive surface surveys, drilled a fence of seven holes totalling 1252 metres, to test stratabound mineralization in a felsic fragmental unit of the Fire Lake volcanics. The mineralized zone, characterized by coincident induced polarization and strong multi-element soil geochemical anomalies, is believed to be a result of intense hydrothermal alteration and veining of a receptive horizon, rather than syngenetic mineralization as originally believed. The drilling results were encouraging and indicate potential for a large-tonnage, low-grade precious metal deposit. At the **Harrison Gold** project of Bema Gold Corporation and Abo Resources Corporation near Harrison Hot Springs, Bema drilled a total of 2106 metres in seven holes to evaluate the gold potential of the Hill stock and a nearby hydrothermal breccia body. A separate deposit on the property, confined to the Jenner quartz diorite stock, had previously been determined to contain indicated and inferred reserves totalling 2.2 million tonnes grading 4.1 grams per tonne gold. Assays reported from the 1990 drilling were substantially below the average grade of the Jenner deposit, but Bema has not yet commented on the overall results of the 1990 program.

Minnova Inc., which had been systematically exploring volcanogenic massive sulphide potential throughout the Britannia volcanic belt for several years, was not active in that area in 1990. However, it did option the **Seneca** property on the Chehalis River near Harrison Lake from International Curator Resources Ltd. and Chevron Minerals Ltd., the target being massive sulphides in Harrison Lake Formation volcanics. After reviewing existing data and completing limited surface surveys, Minnova began a drilling program late in the year. At Ladner Creek northeast of Hope, Anglo Swiss Mining Corporation expects to resume underground drilling at the **Idaho zone** of the former **Carolin** mine in order to improve on the present underground mineral inventory of 898 000 tonnes containing 4.3 grams per tonne gold. Earlier in the year the company completed a trenching program at the **McMaster zone**, located 1 kilometre north of the Idaho zone, where drilling in 1989 produced very encouraging results.

Queen Charlotte Islands

The year 1990 saw a major reduction in the number of Notices of Work received for properties on the Queen Charlotte Islands, indicating a continued decline in exploration interest in this politically sensitive area. The highlight property on the islands in the previous decade was the **Cinola** deposit with a measured reserve of 24.8 million tonnes of low-grade gold mineralization. In May of 1990, City Resources (Canada) Corporation announced that the latest feasibility study had indicated that the deposit was uneconomic at current gold prices and no further work would be done to develop a mine at Cinola in the foreseeable future. In spite of that negative development, Worthington Resources Corporation remains optimistic about the potential of its **Southeaster** epithermal gold prospect near Skidegate. An aggressive program consisting of 18 holes totalling 940 metres, plus trenching of newly discovered zones, was completed early in the year. Erratic but locally high-grade gold values were intersected in quartz veins and siliceous breccias associated with a regional fault system parallel to the major Sandspit fault which controls the mineralization at Cinola.

At the **Cimadoro** massive sulphide prospect of Doromin Resources Limited on Deena Creek, northern Moresby Island, Teck Corporation dropped its option after failing to locate additional mineralization in a drilling program in late 1989. Doromin Resources then drilled nine short holes in the vicinity of the original surface showing and reported several narrow intervals of good-grade polymetallic mineralization. The surface showings consist of lenses of sheared lead-zinc-silver sulphides with minor gold, copper and locally high barium in a package of cherts, argillites and limestones which appears to underlie the Karmutsen formation. There are also layers of cherty siltstone in the section which contain finely disseminated pyrite, sphalerite and galena with zinc assays up to 1.5 per cent. Although the geology of the deposits is still poorly understood, due to complex folding, shearing and faulting, it is the opinion of this observer that they most closely resemble sedex deposits. There is also growing evidence that the mineralization and its host stratigraphy are Paleozoic in age and may herald a new type of exploration target on the Queen Charlotte Islands. A Geological Survey of Canada mapping crew has reported the discovery of very similar stratigraphy elsewhere on northwestern Moresby Island containing Permian conodonts (*see* J. Hesthammer *et al.*, G.S.C. Current Research, Part A, Paper 91-1A).

COAL

The first Notice of Work on a coal exploration property in almost two years was filed late in 1990 by Western Canadian Mining Corporation, a company affiliated with Consolidated Brinco Limited, owner of the Quinsam Coal mine near Campbell River. Western Canadian started drilling in December on the **Tsable River** coal licences south of Comox Lake, owned partly by Weldwood of Canada Limited and partly by Esquimalt and Nanaimo Railway Ltd. A total of 5000 metres in 28 large-diameter diamond-drill holes is planned in the initial phase of drilling to be concluded early in 1991.

INDUSTRIAL MINERALS

There were no major industrial mineral developments or exploration projects reported from the Southwestern District in 1990. A new granite quarry, operated by Pacific Granistone Corp. near Squamish, is reported to have begun cutting and selling granite blocks. Near Sechelt, Tri-Sil Minerals Inc. continues to sample, test and solicit markets for wollastonite, garnet, and "black granite" from its multi-commodity industrial mineral properties.

PLACER

Placer activity in the Southwestern District has become almost dormant. In 1990 only two placer Notices were received, one from the **Leech River** area and the other from **Amai Inlet** on Vancouver Island. There is no reported activity anywhere on the lower Fraser River or its tributaries.

PRODUCING MINES

There are two producing metal mines and one producing coal mine in the Southwestern District and no new mines currently being developed. There are also three producing limestone quarries on Texada Island and a few claystone and marl producers on Vancouver Island and in the Fraser Valley.

At Myra Falls on Vancouver Island, Westmin Mines Limited continued production from the **H-W** and **Lynx** mines with a daily milling rate close to 3600 tonnes. Published reserves at the start of 1990, totalling all categories in all orebodies, were 12.1 million tonnes averaging 2.5 grams per tonne gold, 34.5 grams per tonne silver, 2.3 per cent copper, 0.4 per cent lead and 5.2 per cent zinc. The slow and expensive process of exploring underground for new reserves continued through 1990 with an exploration budget reported to be $7.8 million. Several potentially significant new massive sulphide zones throughout the mine lease are being evaluated.

BHP-Utah Mines Ltd. continued to mine and mill ore at a rate of approximately 50 000 tonnes per day from its **Island Copper** porphyry copper-gold-molybdenum deposit at Rupert Inlet near Port Hardy. Current recoverable reserves are estimated to be sufficient to maintain production until late 1996 or early 1997. Meanwhile exploration drilling of several possible sources of additional reserves on the mine property is continuing, with a 1990 exploration budget of approximately $700 000.

At Middle Quinsam Lake near Campbell River, Brinco Coal Corporation operates the **Quinsam** open-pit coal mine with an anticipated total production in 1990 of 250 000 tonnes of thermal coal. A test underground mining operation in 1990 is considered to have been quite successful and the company is hoping to soon double its annual production by opening an underground mine while maintaining steady production from the open pit. Reserves at the Quinsam mine were estimated in mid-1990 to be of 23.3 million tonnes of surface-mineable coal and 19.9 million tonnes of underground reserves.

1990-91 BRITISH COLUMBIA PROSPECTORS ASSISTANCE PROGRAM

By J. Pardy, Prospectors Assistance Program

INTRODUCTION

The 1990-91 British Columbia Prospectors Assistance Program is a $500 000 one-year program to promote prospecting activity in the province by providing training, financial and technical assistance to prospectors. Financial assistance is available through the prospector grant program which is designed to provide part of the risk capital required by prospectors in their search for mineral deposits. Sound, well-conceived prospecting programs are supported with grants up to a maximum of $7500 per year. Prospecting targets eligible for assistance include lode and placer deposits of metallic and industrial minerals (except sand and gravel), and coal deposits. Prospectors have access to technical assistance in the field from staff of the Ministry of Energy, Mines and Petroleum Resources active throughout the province. Training consists of the delivery or support of three levels of courses: introductory level courses, the annual Advanced Prospecting Course and the highest level course, Petrology for Prospectors.

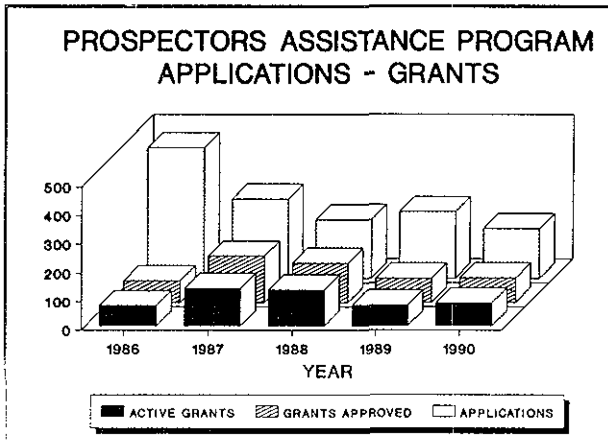

Figure A-22

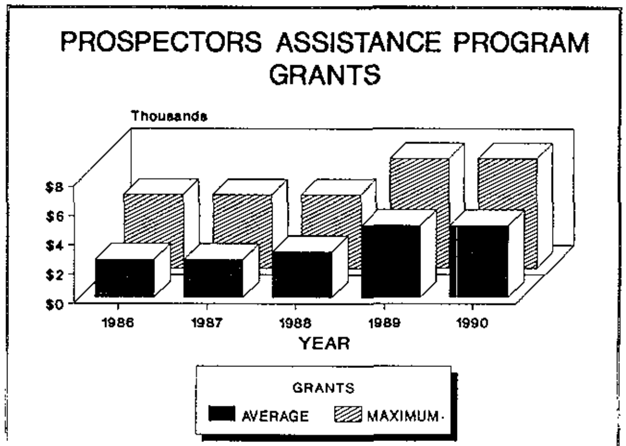

Figure A-23

FINANCIAL ASSISTANCE

For the 1990-91 program, applications received by April 6, 1990 were considered for the initial allotment of grant funds. Grants were awarded as follows (Figures A-22, 23):

Applications received	174
Grants awarded	86
Maximum grant	$7500
Average grant	$4884

Fifty per cent of the grant awarded is payable on approval of the applications, with the remainder on receipt of a satisfactory prospecting report by January 31, 1991. Grantee prospectors are required to submit a prospecting report consisting of two parts: part A, a summary of prospecting activities and expenditures and part B, a technical report of activities. Final payment of the grant is made upon approval of the report. The technical reports received are released to the public domain after a 5-year confidentiality period.

A total of 161 prospecting programs were proposed by the 86 grantee prospectors. Only the most significant of these were used to plot the 136 locations on Figure A-24.

Most of the assisted programs are concentrated in areas of active exploration and good access (Figure A-24) and are fairly evenly distributed in the geologically significant areas of the southern two-thirds of the province. The gradual northward shift in the location of assisted programs that started in 1988-89 has continued through to this year.

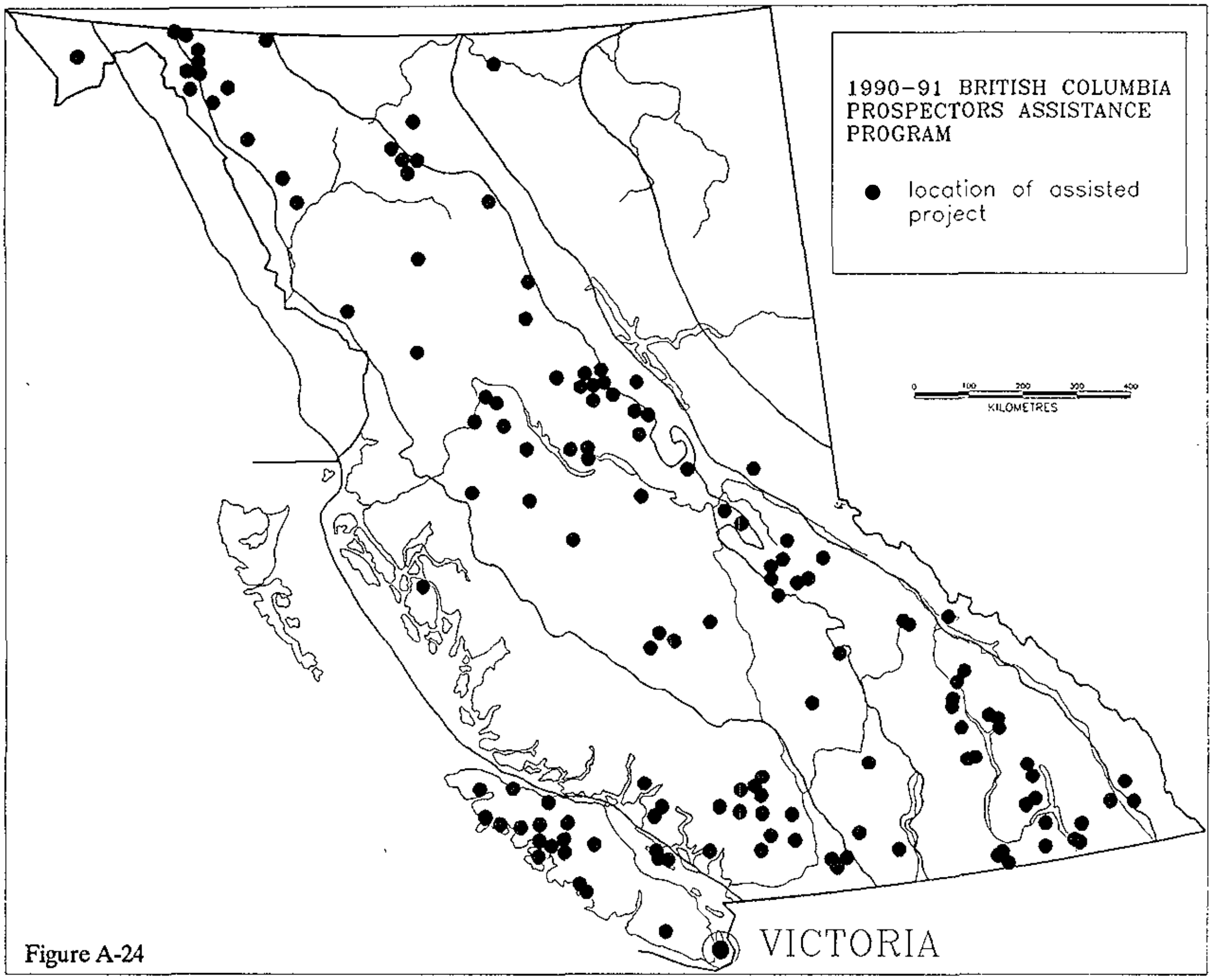

Figure A-24

The percentage of assisted programs by primary target commodity is as follows:

Industrial minerals	2%
Base metals	3%
Placer gold	7%
Precious metals	28%
Base/precious metals	60%

Changes in primary target commodity from the 1989-90 program include decreases in placer gold projects (9% to 7%), hard-rock precious metal projects (39% to 28%), base metal projects (4% to 3%) and industrial mineral projects (9% to 2%) and an increased interest in polymetallic targets (39% to 60%). The trend over the past several years has been a significant reduction in the number of precious metal projects and an increased interest in polymetallic targets.

Each year the prospecting activity under the grant program generates prospects that warrant further exploration. These prospects are optioned by mining or mineral exploration companies which carry out larger and more expensive exploration programs that usually are beyond the means of individual prospectors. The effectiveness of the prospecting activity will ultimately be measured by future developments of properties generated under the program. The cumulative value of work commitments made by exploration companies on mineral prospects worked on under the grant program always exceeds the total value of funds committed to grants.

One of the most significant prospects generated by grantees is the Fireweed silver-lead-zinc-copper-gold occurrence located on the west side of Babine Lake. Disseminated sulphides, massive sulphides and sulphides in breccia zones occur in sedimentary rocks thought to belong to the Cretaceous Skeena Group. Mineralized outcrops were discovered in 1987 after following up float containing anomalous gold and the property was subsequently optioned by Mansfield Minerals (formerly Canadian United Minerals Inc.). In excess of $1 million was spent on the property and interesting targets have been defined by ground surveys and drilling. Minnova Inc. has recently optioned the property from Mansfield Minerals and plans to conduct additional ground surveys and complete further drilling.

Under the 1988-89 program prospector Charles Kowall discovered significant gold-silver mineralization on Willoughby Creek east of Stewart and optioned the property to Bond International Gold Inc. The company subsequently acquired additional claims and conducted an exploration program which resulted in a drill intersection of 20.5 metres averaging 24.98 grams per tonne gold and 184.21 grams per tonne silver at the Willoughby gossan and a drill intersection of 66 metres averaging 9.88 grams per tonne gold and 49.29 grams grams per tonne silver 6 kilometres west of Red Mountain. Further work was conducted by the company in the 1990 exploration season.

TRAINING

Introductory prospecting courses, offered in British Columbia on an annual or fairly regularly scheduled basis, are sponsored by the Ministry of Energy, Mines and Petroleum Resources, the British Columbia & Yukon Chamber of Mines, the Chamber of Mines of Eastern British Columbia, community colleges and prospector associations. Most of these courses are delivered through community college facilities. The Prospectors Assistance Program sponsors a minimum of two courses annually and supports other courses through contributions and, up to this year, provided the essential learning resource of the prospecting courses by producing and selling high-quality rock and mineral sets at very reasonable cost. The British Columbia Museum of Mining now produces and sells the rock and mineral sets. Centres where courses are available annually include: Victoria, Nanaimo, Vancouver, Nelson and Smithers. Courses are less frequently offered in Prince George, Chilliwack and Kelowna. Other introductory courses are offered at selected times and locations on a cyclical or as-needed basis.

The 14th Annual Advanced Prospecting Course (APC) was successfully delivered during the period of April 24 to May 11, 1990. The fourteen sessions of the course held since 1977 have produced 422 graduates. The APC is an 18-day, live-in course comprising practical instruction in geological, geochemical and geophysical prospecting methods, held in the Cowichan Lake area on Vancouver Island. Other topics include mining law, metallurgy and provincial government acts and regulations. The class is limited to a maximum of 32 students. The course is jointly sponsored by the Ministry of Energy, Mines and Petroleum Resources and the Ministry of Advanced Education, Training and Technology and is administered through Malaspina College, Nanaimo. In-class instruction and accommodations are provided at the Ministry of Forests, Cowichan Lake Research Station. Most of the in-field instruction and exercises are conducted at Mount Sicker, 30 kilometres, east of the station. The curriculum is divided into two parts: part one, ten days long, deals with geology and general prospecting methods while part two, seven days long, reviews geochemistry and geophysics. A day of rest separates the two parts. The 15th annual APC was held from May 7 to May 24, 1991.

The most advanced course, introduced in 1990, Petrology for Prospectors, is a continuing education course for those who have training and experience at or above the Advanced Prospecting Course level. The course lasts seven days and examines rock and rock-alteration assemblages as they relate to some of the most important mineral deposit types in British Columbia. Laboratory study of rock suites is the basis of the course. It was offered for the first time from March 26 to April 1, 1990 in Smithers, in cooperation with the Smithers Exploration Group. The second edition was offered in Kamloops in April 1991 in cooperation with the Kamloops Exploration Group and Dr. Tom Richards.

PART B

GEOLOGICAL DESCRIPTION
OF
SELECTED PROPERTIES

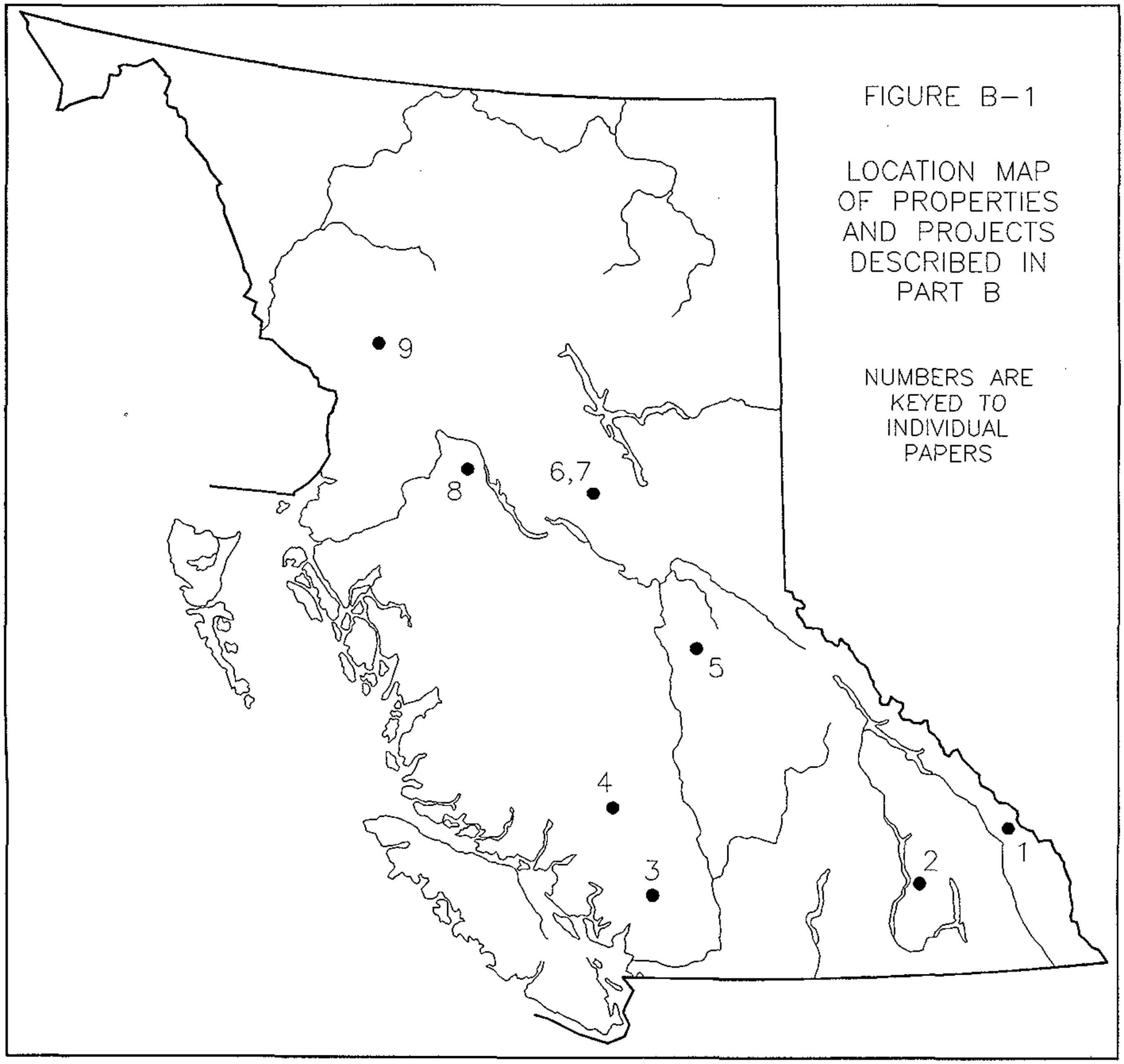

FIGURE B–1

LOCATION MAP OF PROPERTIES AND PROJECTS DESCRIBED IN PART B

NUMBERS ARE KEYED TO INDIVIDUAL PAPERS

QUICK FIELD METHOD FOR IDENTIFICATION OF MAGNESITE-BEARING ROCKS IN MOUNT BRUSSILOF AREA, SOUTHEASTERN BRITISH COLUMBIA (82J/12, 13)

(Fig. B1, No. 1)

By George J. Simandl, Kirk D. Hancock, Suzanne Paradis, Jana Simandl,

INTRODUCTION

All of the common carbonates are characterized by rhombohedral cleavage; most are either translucent or transparent. Their hardness varies from 3 to 5 on the Moh's scale and their density varies from 2.71 to 3.96 grams per cubic centimetre. They may form cryptocrystalline, compact masses, granular cleavable masses or sparry masses. In many cases they cannot be distinguished by crystal form. Their colour varies from white, grey, yellow-brown to black and, in most cases, is not a diagnostic feature.

Calcite ($CaCO_3$), dolomite $CaMg(CO_3)_2$, siderite ($FeCO_3$) and magnesite ($MgCO_3$) are the most common and widely distributed carbonates in sedimentary rocks. These minerals are conveniently represented on a triangular phase diagram (Figure B-1-1). Calcite, dolomite, and magnesite-siderite solid solution may coexist in equilibrium, as shown schematically by the shaded triangle. The position of the triangle is temperature dependent. With increasing temperature the iron content of the magnesite-siderite solid solution coexisting with calcite and dolomite increases (Rosenberg, 1967; Goldsmith, 1983). At low temperatures, a pure, low-iron end-member of the siderite-magnesite solid solution does not coexist in equilibrium with pure calcite. Siderite-magnesite solid solution reacts with calcite to form dolomite.

Field observations from the Mount Brussilof area are in agreement with these thermodynamic considerations. Calcite within the sparry magnesite rocks of the Mount Brussilof deposit occurs either in late veins or as late open-space fillings. Fine-grained, calcite-bearing dolomitic lenses enclosed by sparry magnesite ore have selvages of calcite-free dolomite (Simandl and Hancock, 1991).

In the field, calcite fragments can be distinguished from dolomite fragments. They effervesce strongly in 5 per cent cold hydrochloric acid. However, the relative proportions of calcite and dolomite in carbonate rock are difficult to estimate.

Large dolomite fragments dissolve slowly in cold 5 per cent hydrochloric acid, whereas powdered dolomite dissolves with effervescence. In contrast, magnesite does not react visibly with weak hydrochloric acid at room temperature, even if powdered. Proportions of dolomite and magnesite may be roughly estimated by observing the amount of effervescence of crushed dolomite-magnesite rock in weak acid. However, the amount of effervescence also depends on the grain size of the powdered rock.

Modern magnesite-exploration programs rely on costly chemical analyses to identify magnesite-bearing rocks. In many cases, the results of chemical analyses are not available until the exploration field season is over. In the past, geologists used staining techniques and specific gravity determinations to reduce laboratory expense and the time-lapse between sampling and receiving analytical results.

Staining methods are well described by Allman and Lawrence (1972). Staining is time consuming, requires many chemicals, and does not work well on hand specimens unless they are sawn and/or polished.

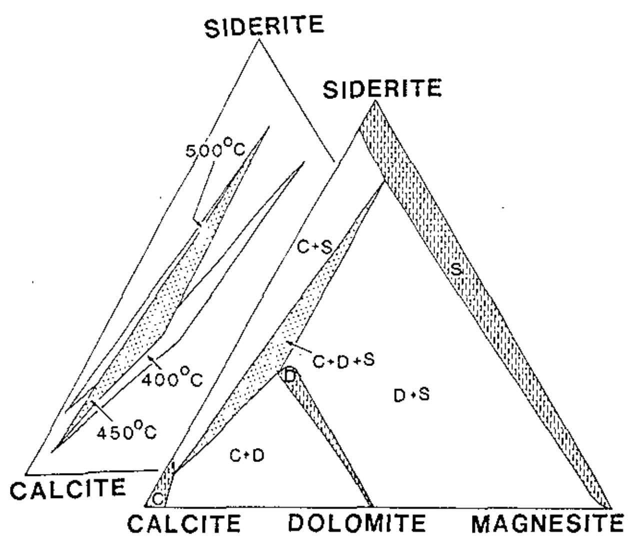

Figure B-1-1. Calcite-magnesite-siderite phase diagram. Valid for temperature of 450°C. D = dolomite, C = calcite, S = siderite - magnesite solid solution. Background diagram shows the position of the three-phase (C+D+S) triangles for temperatures of 400°C, 450°C and 500°C (after Rosenberg 1967).

Sensitive torsion and Joly balances used to determine specific gravity are expensive and generally unsuitable for field use. Beam balances are rugged and relatively precise for measuring the density of large specimens. However, they are not practical because large specimens free of cracks, cavities and impurities are rare.

In the early 1980s, most of the traditionally used heavy liquids were proven toxic, cancer causing or incompatible with environmental regulations (Sax and Lewis, 1989). As a result, prospectors ceased to use heavy liquids. In early 1980, SOMETU introduced sodium polytungstate on the market as a water-soluble, nontoxic, heavy agent which can be discarded safely. It was recommended as a "safe way to carry out effective heavy mineral separations by the geoscientific community" (Callahan, 1987). Up until now, the use of sodium polytungstate has been largely restricted to mineral or fossil separations. The density of sodium polytungstate solution can be effectively controlled in the range of 1 to 3.1 grams per cubic centimetre. Consequently, it can be effective in magnesite and other exploration programs where density variations in the same range can be used to identify economic minerals.

In the future, portable x-ray fluorescence (XRF) machines that have been introduced recently in exploration for metalliferous deposits, will probably render the use of heavy liquids in magnesite exploration obsolete. However, for various technical reasons, none of the portable XRF units presently on the market can be effectively applied to magnesite exploration.

In the Mount Brussilof area, a large, high-grade, sparry magnesite deposit is hosted by a dolomite of the Middle Cambrian Cathedral Formation (Simandl and Hancock, 1991; Simandl *et al.*, 1991). Traditional prospecting and boulder tracing remain the two most useful field techniques for magnesite exploration.

PROPERTIES OF SODIUM POLYTUNGSTATE AND OTHER DENSITY AGENTS

The chemical composition of sodium polytungstate was expressed as $3Na_2WO_4 \cdot 9WO_3 \cdot H_2O$ in SOMETU's marketing literature (Anonymous, 1988). A chemical with the same chemical formula was also described as sodium metatungstate by Krukowski (1988). It is promoted as a nontoxic, recyclable, water-soluble inorganic salt, that is stable in a pH-range of 2 to 14. Marketing literature indicates that small quantities of sodium polytungstate enhance plant growth, and if ingested, all of it is excreted within 24 hours (Anonymous, 1988).

Due to the lack of independent studies conducted on sodium polytungstate, it is not possible to verify these claims. Sax and Lewis (1989) do not list sodium polytungstate ($Na_6H_2W_{12}O_{40}$) but only sodium tungstate and other heavy liquids previously used for density determinations. Their information is summarized below:

- **Bromoform** ($CHBr_3$) has a hazard rating of 3. It is a poison by ingestion and it can cause serious liver damage or death.It is mutagenic, reacts explosively with crown ethers or potassium hydroxide, reacts violently with acetone or bases and emits toxic bromine fumes when heated to decomposition (Sax and Lewis, 1989).
- **Methylene iodide** (CH_2I_2) has a hazard rating of 3. It is moderately toxic by subcutaneous routes. Potentially explosive reactions occur with diethyl zinc in the presence of alkenes, and a violent reaction takes places with copper-zinc alloys in the presence of ether. It forms very shock-sensitive explosive mixtures with potassium, potassium-sodium alloys and lithium. It emits toxic iodine fumes when heated to decomposition (Sax and Lewis, 1989).
- **Tetrabromoethane** ($C_2H_2Br_4$) has a hazard rating of 3. It is poisonous by inhalation and ingestion and irritates eyes and skin. It is narcotic, mutagenic and emits highly toxic fumes of carbonyl bromide and bromine when heated (Sax and Lewis, 1989).
- **Sodium tungstate** (Na_2WO_4) has a hazard rating of 3. It is poisonous if ingested, and mutagenic. When heated to decomposition it emits toxic fumes of Na_2O (Sax and Lewis, 1989).

Unlike the heavy liquids used for mineral separation in the past, sodium tungstate does not participate in explosive reactions and, being water soluble, does not require the use of potentially harmful dilutants such as acetone or carbon tetrachloride.

Hill *et al.* (1990) studied the toxicity and anti-viral activity of a range of polyoxometalates, including sodium polytungstate. They established that the toxicity of most polyoxometalates is not very high. Their experiments were conducted on human blood cells. The difficulty in obtaining physiological data stems from the chemistry of these compounds. As shown by Day and Klemperer (1985), many polyoxometalate structures are unstable in water and physiological systems; they degradate and rearrange.

According to Krukowski (1988), no special protective measures are required for the use, maintenance and storage of sodium polytungstate, although inhalation of the powdered solid may cause irritation.

Although sodium polytungstate appears to be less harmful than other heavy liquids commonly used for mineral separations, caution is recommended. Until more information is available, this substance should be handled with protective gloves and users should wash their hands before eating. Although the chemical has been used on an open bench (Savage, 1988), use in enclosed areas without a fume hood is not recommended.

SODIUM POLYTUNGSTATE IN MAGNESITE EXPLORATION

The density of the heavy liquid depends on the quantity of sodium polytungstate powder dissolved in the water. The density of the solution may be increased by allowing water to evaporate, or decreased by diluting with water. The density of the solution can be controlled from 1.0 to 3.1 grams per cubic centimetre, so it is suitable for distinguishing between calcite (2.71 g/cm^3), dolomite (2.85 g/cm^3), magnesite (3.0 to 3.2 g/cm^3) and pure siderite (3.96 g/cm^3). Whether the sample floats, is suspended, or sinks depends on whether the tested specimen is of lower, equal or higher density, than the calibrated sodium polytungstate solution.

SAMPLING PROCEDURE

Samples of fresh carbonate rock are collected from outcrops. The rock chips selected for gravity testing should be from 0.5 to 1.0 cubic centimetre in size. It is recommended that at least three chips from each outcrop be collected and stored together in prenumbered paper envelopes. Samples should not contain obvious impurities, such as sulphide grains, fractures or cavities that may affect the density of the sample. If color, textural or other variations are encountered, representative samples should be stored in separate envelopes and tested individually.

HARDWARE, CHEMICAL REAGENTS AND PREPARATION OF POLYTUNGSTATE SOLUTION

Hardware and chemical reagents required for systematic testing are given in Table B-1-1. Although plastic is preferred, glass or stainless steel equipment could be used.

The process is more efficient if sodium polytungstate solutions of known density are prepared in the laboratory before leaving for the field. Solutions of desired density are produced by mixing appropriate proportions of sodium polytungstate and deionized water. Fine adjustments can be done in the field camp by evaporation or by dilution of the solution.

TABLE B-1-1
FIELD HARDWARE AND REAGENTS

500 g of sodium polytungstate*
100 ml of hydrogen peroxide
4 transparent plastic or glass (100 to 200 m) beakers
1 pair of plastic pincers
1 glass mixing rod
1 set of plastic, density calibrating chips, varying from 2.6 g/cm^3 to 3.1 g/cm^3
1 plastic funnel
6 plastic (150 to 500 m) bottles that can be hermetically sealed
1 L of 5% HCl
1 roll of masking tape
1 glass or Teflon plate (60 X 50 cm)
5 L of deionized water
1 box of plastic disposable gloves

* In 1988, the price of 10 kg of sodium polytungstate was $1374. The supplier of the product was SOMETU, Berlin, Germany.

ANALYTICAL PROCEDURE

It is recommended that samples be processed in batches of 30 to 60 samples. The analytical procedure is illustrated using the original orientation survey from the Mount Brussilof area. A set of 34 samples, representative of a wide spectrum of carbonate rocks, was collected and analyzed.

- **Step 1:** Visually check each sample to ensure that no minerals other than carbonates are present
- **Step 2:** Submerge each sample in 5 to 10 per cent cold hydrochloric acid for a few seconds (Plate B-1-1), then rinse with deionized water using a plastic dispenser (Plate B-1-2). This process eliminates small particles and any dissolved calcium. Deposit the clean samples in a numbered "pigeon hole" on a clean sheet of glass (Plate B-1-3). The "pigeon holes" were outlined with masking tape.
  Failure to eliminate dust-sized particles from the chips will render the solution cloudy with repeated use and filtering will be required. Further, the failure to remove the calcium ions from the sample surface results in formation of insoluble calcium polytungstate (Anonymous, 1988).
- **Step 3:** The clean and dry samples are placed one at a time into a small beaker containing polytungstate solution of known density. For the Mount Brussilof samples, the initial solution used had a density 2.85 grams per cubic centimetre (d1). Samples that float in this solution have a specific gravity less than 2.85 and consist of calcite or a calcite-dolomite mixture. Floating samples are recorded and no longer needed.
  If the sample remains submerged but does not lie on the bottom of the beaker, its specific gravity is 2.85 and the chip consists of dolomite. Samples which sink are denser than 2.85 grams per cubic centimetre and consist of a magnesite or dolomite-magnesite mixture.
  Each sample is extracted from the solution using pincers and washed again in deionized water. The purpose of washing with deionized water is three-fold: to recover sodium polytungstate; to prevent coating of the sample by sodium polytungstate, which would affect the sample density during the next stage of the testing

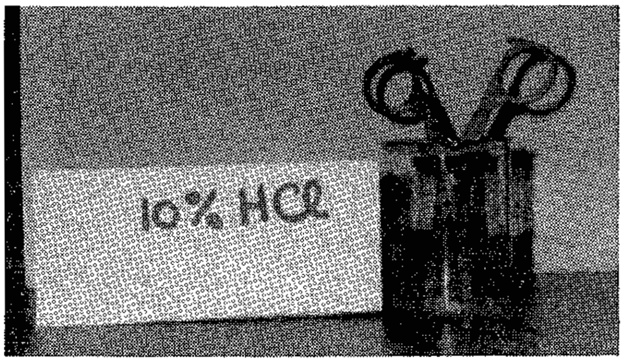

Plate B-1-1. Washing a sample in 10 per cent hydrochloric acid.

Plate B-1-2. Washing a sample with deionized water.

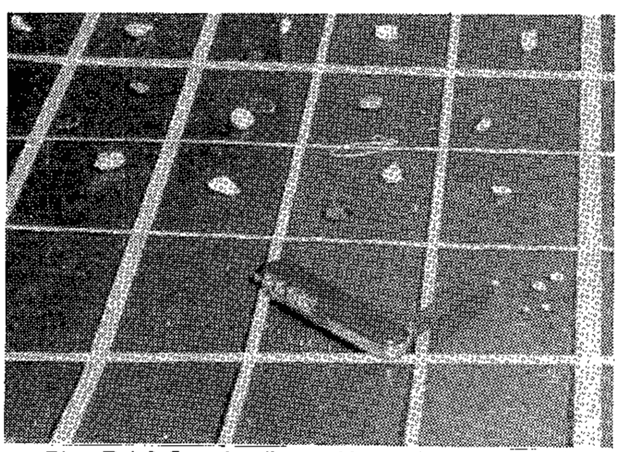

Plate B-1-3. Samples disposed in numbered "pigeon holes" on a clean sheet of glass.

or change the density of the solution; and to prevent crystallization of cement-like sodium polytungstate residue which would bond the sample to the glass surface.

Samples denser than the solution are returned to their "pigeon hole" and washed samples of the density equal or lower than the solution are discarded.

- **Step 4:** The procedure described in Step 3 is repeated using progressively denser solutions. In the Mount Brussilof example, the second polytungstate solution had a specific gravity between 2.89 and 2.94. Samples denser then 2.94 grams per cubic centimetre consist mainly of magnesite and are of definite economic interest. In our example, six of the 34 samples were left (Figure B-1-2).
- **Step 5** (optional): In the Mount Brussilof orientation survey, samples denser than 2.94 grams per cubic centimetre were tested using a solution with a specific gravity between 2.94 and 3.08. None of the samples were denser than 3.08 grams per cubic centimetre. This optional test indicated that magnesite from the Mount Brussilof area is probably a pure end-member of the magnesium-iron carbonate solid solution series, as shown in Figure B-1-1. These results were confirmed by subsequent chemical analyses.

SENSITIVITY AND SPEED OF THE METHOD

Chemical analyses confirmed the effectiveness of this method. Nineteen samples of magnesite and dolomite-bearing rocks were analyzed for MgO, CaO, FeO, SiO_2 and Al_2O_3 using atomic absorption. The major constituents are MgO and CaO, which are negatively correlated (Figure B-1-2). The magnesium content of these samples

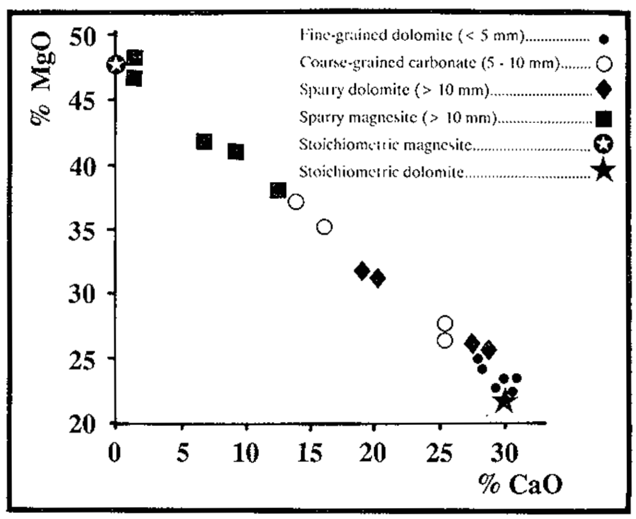

Figure B-1-2. Relationship between MgO and CaO content of carbonate rocks, Mount Brussilof area. The distribution of the data confirms that representative samples were collected (after Simandl and Hancock, 1991).

varies continuously from stoichiometric dolomite to stoichiometric magnesite. Densities determined by sodium polytungstate method, correlated well with the magnesia content obtained from chemical analyses (Figure B-1-3). The sensitivity of the method can be increased if the samples are tested in more successive stages, using solutions with small density intervals. This was not considered necessary in our study, because the sodium polytungstate method was used to confirm the acid "fizz test" results and to screen the samples for chemical analysis. As with all exploration methods, the effectiveness is heavily dependent upon the sampling procedure.

The method is quick. On a sunny summer day, when samples dry quickly after each washing, 60 samples were processed in less than 90 minutes by one person. This was accomplished by having four prepared sodium polytungstate solutions of appropriate densities stored in hermetically sealed plastic containers and ready for use.

PRECAUTIONS AND RECOMMENDATIONS

- During testing the density of the sodium polytungstate solution may increase due to evaporation, or decrease due to dilution if the washed chips are not completely dry before they are submerged in the solution. The density of the solution can be continuously monitored by leaving one calibrating chip of slightly higher density and another of slightly lower density, floating in the fluid during testing.
- Very small air bubbles adhering to a chip may prevent the sample from sinking, even if the chip is denser than the solution. The bubbles can be eliminated by stirring the solution with a glass rod.

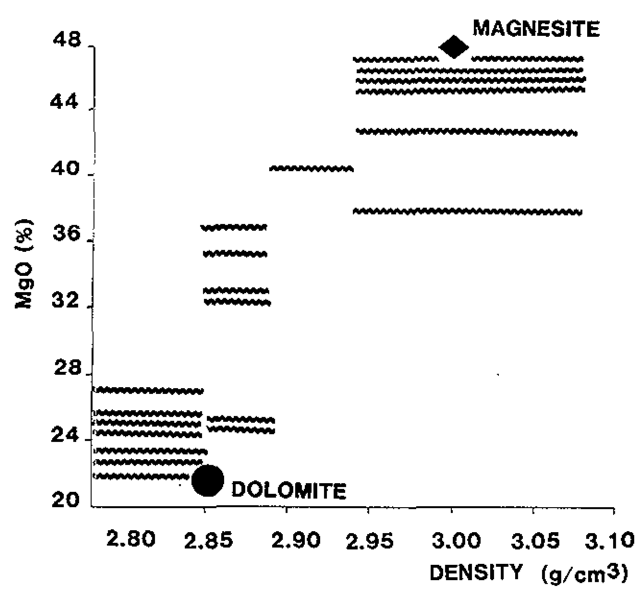

Figure B-1-3. The relationship between density and MgO content of carbonate rocks in the Mount Brussilof area.

- It is recommended that the water used to wash samples between successive density determinations be collected in a clean container flushed with deionized water. The wash-water can then be evaporated and almost all of the sodium polytungstate recovered for reuse.
- Accidental contact of sodium polytungstate solution with reducing agents will colour the solution blue. This does not affect the density and the coloration can generally be eliminated by the addition of a few droplets of hydrogen peroxide (Anonymous, 1988).
- If the solution becomes cloudy due to concentration of dust-size particles, it can be cleaned by filtration.

SUMMARY AND CONCLUSIONS

This screening method is effective in exploration for magnesite hosted by sedimentary rocks. It confirms the traditional acid "fizz-test" and permits accurate and objective screening of samples to decide if they require chemical analysis. As with any geochemical or geophysical method, an orientation survey is recommended prior to large scale application in new geological environments. It is a quick, easy method. As almost all the sodium polytungstate can be recycled, the method is also environmentally-friendly and cost effective.

Another major advantage is that results are available in the field, permitting rapid identification of favorable areas for follow-up work. It may save helicopter time in less accessible areas, particularly if fly camps are used. No special sample preparation such as cutting, polishing or crushing is required.

According to the manufacturer, the chemical is non-toxic (Anonymous, 1988). However, there is limited independent information concerning sodium polytungstate in publications dealing with toxic substances. Consequently, precautions in handling it are recommended.

ACKNOWLEDGMENTS

We wish to thank W.J. McMillan, B. Grant, P. Matysek and V. Vilkos of the B.C. Geological Survey Branch, B.C. Ministry of Energy, Mines and Petroleum Resources for constructive reviews of earlier versions of this paper.

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MILLIE MACK (82K)

By A. Legun

(Fig. B1, No. 2)

LOCATION:	Lat. 50°02'30" Long. 117°43'12" (82K/4) SLOCAN MINING DIVISION. On Blue Grouse Mountain, east of Burton, on the east side of Upper Arrow Lake. MILLIE MACK, BLACK BEAR, BILLIE P and GREAT WESTERN Crown Grants.
ACCESS:	East from Burton along 12 kilometres of well-graded logging road following Caribou Creek to the base of Blue Grouse Mountain. The last 4 kilometres of switchback road ascends over 850 metres to the showings.
OWNER:	Wayne Smith
OPERATOR (1990):	BAPTY RESEARCH LTD.
COMMODITIES:	Silver, lead, zinc, gold.
MINFILE:	082KSW051

EXPLORATION HISTORY

The Millie Mack property was first staked in 1896 and the area of Blue Grouse Mountain covered by nine crown crants. The first shipment of hand-picked ore was made in 1897. Independent operators worked the claims intermittently for the next 70 years. Most work was in the area of the Millie Mack Crown Grant and included underground development of about 800 metres of drifting and raising. A light tramway was built in 1919 to bring down the ore. Minor underground development was also done on the Black Bear Crown Grant.

Since 1967, successive companies have carried out more regional programs involving geochemical and geophysical grid-surveys and limited bulk sampling. In 1967 Richwood Silver Mines Ltd. systematically sampled four outcrop faces. In 1979, 70 tonnes of hand-picked ore grading 288.0 grams per tonne silver, 7.2 grams per tonne gold and 2 per cent lead were mined. In 1980, Semper Resources Inc. completed 54 rotary and five diamond-drill holes in the area of the Millie Mack claim. In 1981, David Minerals Limited extended surveys to the western portion of the claim group and stripped the Billie P, Great Western, Millie Mack and Black Bear showings for additional bulk sampling. A 450-tonne bulk sample was concentrated at the company's mill at Ainsworth. Five shipments of lead concentrate were made to the Trail smelter. The net assay of the entire shipment was 6.35 per cent zinc, 3.17 per cent lead, 999 grams per tonne silver, 0.18 per cent copper, 3.36 per cent arsenic and 6.6 grams per tonne gold. In 1988 the property was sold to Greenstone Resources Ltd. In the same year a 3100-tonne bulk sample was mined from four faces. In 1989 a major program was undertaken with Dragoon Resources Ltd. as operator. This program involved additional road construction, exposure of the mineralized shear in five wide cuts, more than 60 tractor trenches, sampling and drilling (6 diamond-drill holes, 60 rotary-drill holes for 3047 metres).

GEOLOGIC SETTING

The focus of economic interest on Blue Grouse Mountain is a sporadically mineralized shear zone which cuts through the mountain with an average dip of 13°. The trace of the shear is mapped as a thrust fault on Figure B-2-1. A peripheral road (not shown) intersects the shear zone in a number of places.

The shear zone includes a zone of graphitic phyllonite and altered remnants of feldspar porphyry. Underlying the shear zone are massive grey volcanic rocks (Unit 2a) to the south and greenish tuff agglomerates and lapilli tuffs (Units 3, 3a, 3b) to the north. Above the shear and exposed on the highest ground are grey bedded volcanic sediments and crystal tuffs (Units 2b, 2c).

Hyndman (1968) assigned the bedded volcanic sediments (Units 2b, 2c) to a lower member of the Triassic Slocan Group. The underlying massive grey volcanic rock (Unit 2a) were assigned to a stratigraphically higher member of the Slocan Group on the basis of regional mapping. The greenish pyroclastics (Units 3, 3a, 3b) were assigned to the Jurassic Rossland Group. In this interpretation the exposures on top of the hill constitute a klippe of Slocan sediments overlying younger Slocan volcanic rocks to the south and still younger Rossland pyroclastics to the north.

Read (1976) did not consider the zone to be a significant fault and suggested an angular unconformity may be present. He assigned the volcanic sediments to the Jurassic Archibald Formation and considered them to lie in normal stratigraphic sequence on Slocan volcanics. The greenish pyroclastic rocks to the north were also considered to be part of the Slocan Group.

Fieldwork in 1989 did not resolve the differing interpretations. Figure B-2-2 is a cross-section illustrating elements of the structure and stratigraphy. There is a lack

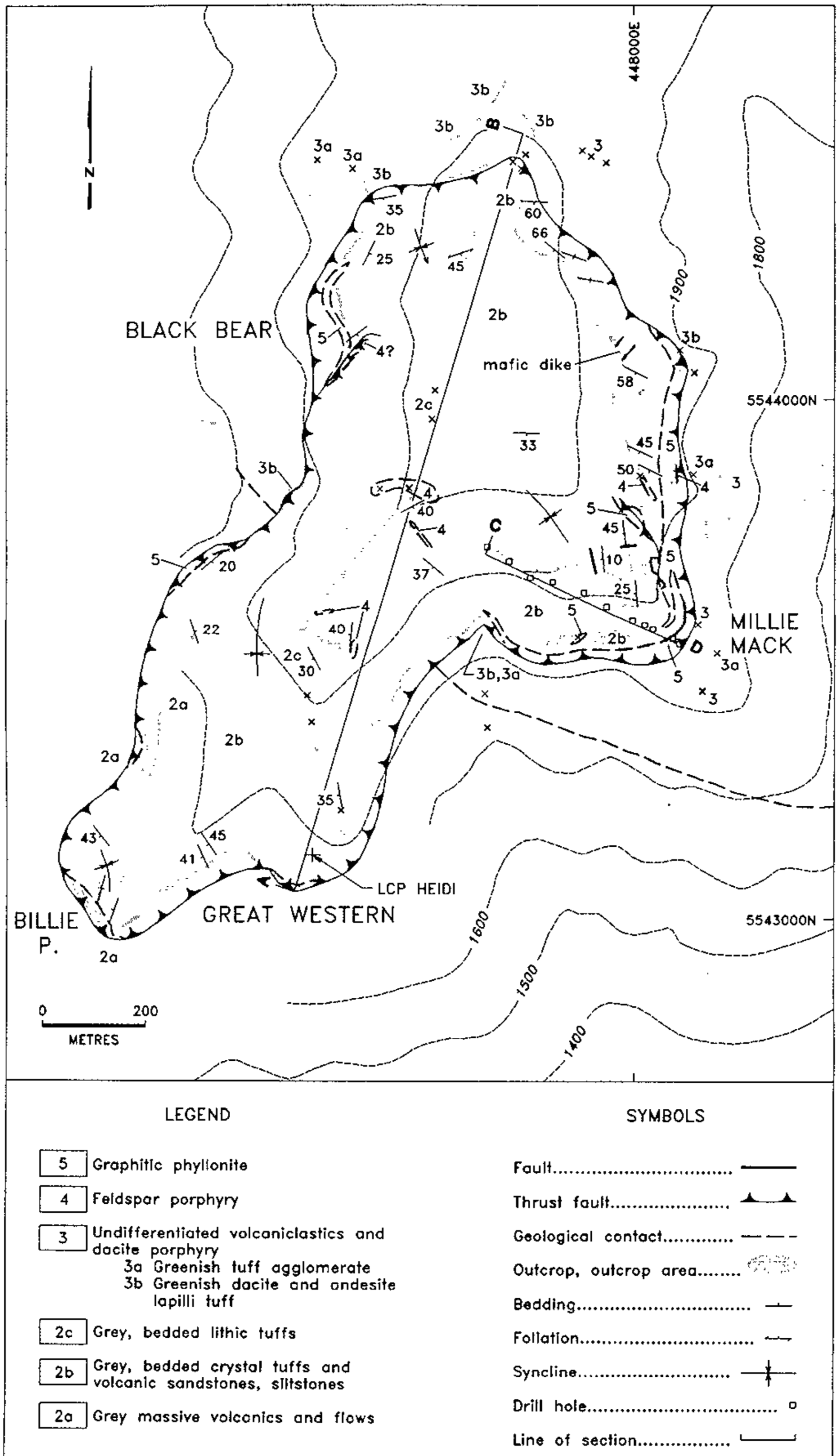

Figure B-2-1. Geology of the Millie Mack property.

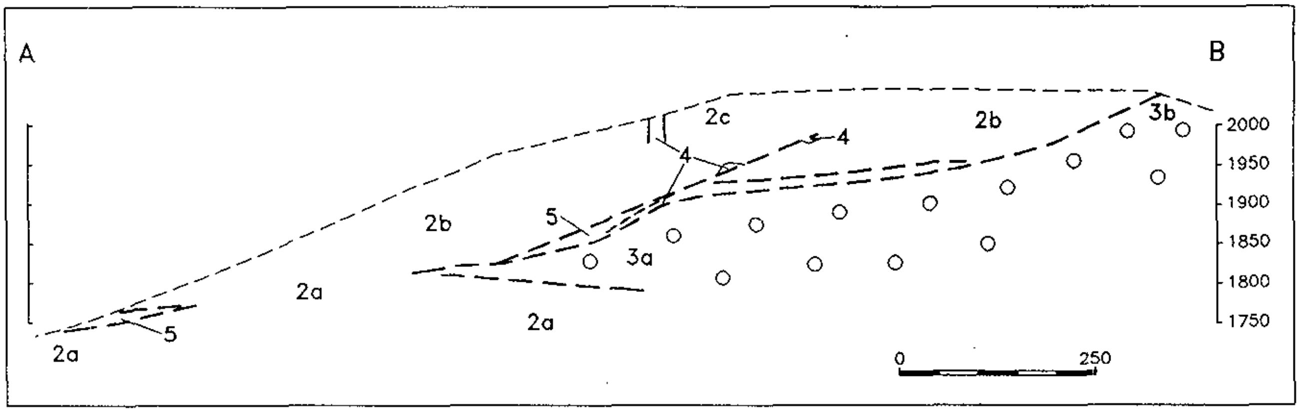

Figure B-2-2. Schematic cross-section showing relationship of the shear zone to geologic units. Legend as for Figure B-2-1.

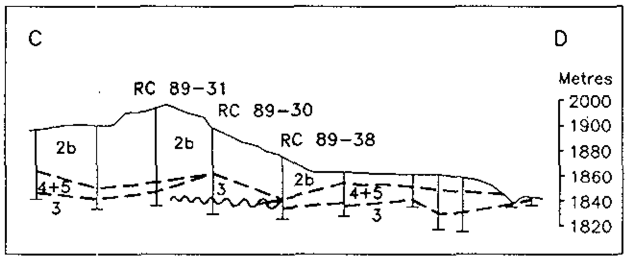

Figure B-2-3. Drill section through Millie Mack showing illustrating basement high, after Awmack (1190). Rock units as on Figure B-2-1.

of structural data for the massive volcanics underlying the shear zone. Regionally, the unit is mapped as dipping to the north, in contrast to the volcanic sediments above which dip southward. This indicates there is a structural discordance between the two units. However, the lithologic contrast between the sediments and massive volcanics diminishes southward. In one area massive volcanics appear to lie above the shear as well as below it. Awmack (1990) noted sediments on Dusty Ridge to the west appear to be on strike with massive volcanics on Blue Grouse Mountain. Further structural mapping and assessment of possible lateral facies changes needs to be done to clarify relationships.

DESCRIPTION OF UNITS

Unit 2a: Massive Grey Volcanics (Slocan Group)

The rocks underlying the southern half of Blue Grouse Mountain are comprised of massive grey volcanic rocks. Some minor argillite interbeds have been noted by Awmack.

These rocks are fine grained but include some with porphyritic textures. The rocks are well jointed and may superficially resemble massive siltstones of Unit 2b. In thin section they display flow lineation, protoclastic textures, and secondary fillings of microcavities. They are often dusted with carbon and have a sooty appearance. The porphyritic varieties consist of anhedral phenocrysts of sericitized plagioclase within an extensive microcrystalline to cryptocrystalline quartz-plagioclase mosaic (devitrified glass?). The groundmass also contains biotite, chlorite, muscovite and minor andalusite. Carbonatization is extensive.

Units 2b, 2c: Volcanic Sediments and Crystal Tuffs (Slocan Group or Archibald Formation?)

These stratified rocks are thinly laminated to moderately bedded. Rocks are fine to medium grained and variably calcareous. Grading is apparent in some beds. A few exposures at the very top of the Millie Mack property are coarser grained and have a pyroclastic texture.

In thin section these purplish grey rocks are seen to consist of angular to subrounded grains of andesine feldspar together with flakes of biotite and muscovite and minor fine-grained epidote. These grains are distinct against a microcrystalline matrix. Many of the crystals are broken and there is a complete size gradation between larger crystals and smaller angular fragments. The proportion of matrix varies and in some cases the grains are tightly packed. The alteration of feldspars is weak. Intergranular carbonatization is common.

The lack of alteration in the feldspars, the greater abundance of brown biotite and the density of crystal grains distinguishes these rocks from other units. The fine-grained varieties show evidence of weathering (rounded grain shapes) and sorting and contain detrital quartz and illite. The rocks are interpreted as lithic crystal tuffs to tuffaceous sandstones and carbonaceous siltstones.

Units 3, 3a, 3b: Greenish Pyroclastics (Agglomerate, Lapilli Tuff)

These rocks were ascribed to the Rossland Group by Hyndman (1968). They consist of greenish grey agglomerate with a tuffaceous to porphyritic matrix, lapilli tuff and dacitic(?) porphyry. Fragments up to 20 centimetres (usually < 1 cm.) in diameter are subrounded to subangular, commonly porphyritic and generally weather a lighter grey than the groundmass. Stretched and elongate fragments are evident in the pyroclastic rocks. At Blue Grouse Mountain lapilli tuff directly underlies most of the shear zone. The lapilli tuffs have thin interbeds of siltstone.

Original textures in these rocks are often obscured by alteration. Pervasive sericitization of fragments and lapilli of devitrified glass and feldspar phenocrysts are seen in thin section. Remnant feldspar phenocrysts are vaguely outlined and exhibit seive textures. Propylitic alteration is extensive and characterized by chlorite, epidote and muscovite; brown biotite is uncommon.

Unit 4: Feldspar Porphyry

These rocks consist of large rimmed feldspar phenocrysts in an aphanitic matrix with smaller mafic crystals in random fluidal arrangement. Intense propylitic alteration is apparent in thin section. The feldspars are characterized by replacements of clots or borders of fine to coarse sericite flakes. Where alteration is extensive, crystal margins are diffuse and intergrown sericite and calcite almost completely pseudomorph the feldspar. The matrix consists of a microcrystalline mosaic of quartz and plagioclase which is extensively sericitized and carbonatized. In one sample matrix micas are aligned and wrap around rounded feldspars, indicating deformation. No original mafic mineralogy is preserved. Pseudomorphs (after euhedral amphibole?) consist entirely of chlorite, carbonate, sericite and epidote. Sulphides include pyrite and marcasite.

Shear Zone and Unit 5: Graphitic Phyllonite

The shear zone varies in character from north to south. In the north it strikes roughly east-west and dips at about 23° to the south. There is some development of slaty cleavage at the margins as well as silicification of greenstone in the footwall. Graphitic material is thin to absent.

The dip flattens southward, as evidenced by the elevations of cuts into the shear, and the zone consists of graphitic phyllonite with both anchored and detached segments of footwall and hangingwall. The phyllonite averages 5 to 6 metres wide but locally exceeds 10 metres. The detached segments vary from thin tabular rafts to more equidimensional boudins and disrupted folded bodies within phyllonite.

A strongly altered sill-like body of feldspar porphyry occupies the shear zone discontinuously. The porphyry is occasionally exposed as polished and slickensided boudins within phyllonite (Billie P cut). It also occurs as deformed masses and is folded with the enclosing sediment (Millie Mack cut).

Faults dippings Southwest at 30 to 50° have been noted on the Great Western and Millie Mack claims in hangingwall rocks. Their strike is parallel to the main shear and the dip indicates they intersect the main zone. Graphitic phyllonite extends along these breaks. Minor thrust faults dipping to the northeast, and with obvious southwest movement of the hangingwall, have also been noted. The movement along these breaks is opposite to that presumed for the main shear.

The graphite zone is thickest at the Lower Millie Mack showing, averaging 14 metres wide, striking at 115° and resting on dark grey agglomerate. The bedded sediments immediately above the graphitic zone are strongly disrupted.

Drilling at the Millie Mack indicates that the footwall of the graphite zone undulates. Awmack (1990) reports that in the area of drill holes RC89-30, 31 and 38, a topographic high was intersected in the footwall volcanics. Little or no graphitic shear was present above it. However, the volcanics are cut by a weakly graphitic fault zone from 1 to 5 metres wide with up to 50 per cent quartz veining. (Figure B-2-3).

The graphitic phyllonite is often slickensided. The normal percentage of graphite is reported to be low (Bob McGowan, personal communication, 1990). Fine grained quartz, illite and graphite are recognized in thin section. Disseminated secondary sulphides, mostly pyrite, exceed 6 per cent.

On the outcrop scale, graphitic phyllonite is found in narrow wedges extending into blocks, suggesting plastic flow and injection. It may also be well locally isoclinally folded, crenulated and displaced by small thrusts.

Graphite may occur with quartz in tension veins in the hangingwall.

ECONOMIC GEOLOGY

Mineralization at the Millie Mack occurs in quartz augens within the graphitic phyllonite. Not all augens are mineralized and thicker zones of graphitic phyllonite host better grades of mineralization.

The augens comprise quartz, quartz-graphite, calcite, carbonaceous silicified tuffs and a varying assortment of sulphides. Their shapes are described as saucers, diamonds, nodules and boudins. Many augens are cut by late calcite veins and by microfaults that do not extend beyond the smooth and slickensided surface. Mineralogy is galena, sphalerite, arsenopyrite, pyrite with minor pyrrhotite, and chalcopyrite. Sulphides are found as granular fragments in the graphite, and as disseminations, thin bands and fracture-controlled veinlets within quartz. Some augens show alternating bands of quartz, graphite and sulphides. Awmack (1990) reports vuggy quartz boudins containing sulphides and low precious metal values.

Neither the footwall, the hangingwall nor the graphitic phyllonite itself is significantly mineralized. This was confirmed by sampling drillholes in very short intervals to separate the quartz-sulphide boulders from their graphitic host (Awmack, 1990) The values in the quartz sulphide lenses are an order of magnitude greater. Sampling by the author also demonstrated the graphitic phyllonite to be anomalous in metals but falls well short of economic grades (Table B-2-1).

TABLE B-2-1
GRAPHITE ZONE ANALYSIS

SAMPLE	CLAIM	Ag	Pb	Zn
040222	Billie P	4 ppm	110 ppm	433 ppm
040223	Millie	16 ppm	200 ppm	520 ppm
040224	G.Western	9ppm	432 ppm	1100 ppm

DISCUSSION

Early owners of the property (*e.g.* H.E. Forster in the 1920s) believed the mineralized quartz augens were part of a disrupted vein that could be found by tunneling through the mountain. No significant vein has ever been found although it is interesting that some quartz vein mineralization was intersected in drilling in the footwall of the shear.

As noted by Awmack (1990) the better-mineralized zones appear to lie in warps of the footwall. The major warp at the Millie Mack lies above the contact of the two lower volcanic units and suggests an anisotropic bedrock control. Zones of dilatancy apparently formed during deformation. Shearing affected a zone several tens of metres thick and involved displacements of footwall rocks into the zone of shear. Some hydrothermal activity occurred prior to shearing. This is suggested by the vein material passing into a shear zone within the basement high (Figure B-2-3). Hydrothermal activity continued during deformation and quartz-suphide mineralization formed in zones of dilatancy (strain shadows) within the shear. This syntectonic style of mineralization is suggested by the incorporation of graphitic bands within the banded quartz of the augens. As shearing and warping continued, the quartz-suphide lenses were broken apart, reannealed and sheared again to varying degrees. The evidence for this is the internal fracturing, calcite veining and microfaulting of graphite and quartz bands which does not extend beyond the slickensided surface of the augen. Over the period of mineralization the style of deformation apparently varied from ductile to brittle.

The porphyry predates the deformation as it is sheared and deformed within the graphite zone. It shows significant alteration but is not apparently mineralized. It may have been intruded late in the deformation, in the waning stages of mineralization.

The nature of the graphitic phyllonite is not well understood. It is spatially related to the mineralization. Awmack ascribes the phyllonite to a graphitic facies of the Slocan sediments. However, some features such as quartz-graphite veins, indicate the graphite has been mobile. The phyllonite occupying the shear zone is also essentially discordant with the overlying stratigraphy. On the other hand, the parental material appears to be a volcanic siltstone of Unit 2b.

In the Slocan camp, well to the east, graphitic shears cut and disrupt ore zones which occur as lenses, pods, shreds and breccias along obscure lode-fault structures (*e.g.* at the Silvana mine). The widespread graphitization is considered to be a post-mineralization event without economic significance. The Slocan slate belt has a mean value of 4.2 per cent total carbon (Logan and Sinclair 1988). The close spatial relationship between mineralization and graphitic phyllonite at the Millie Mack property suggests that further work needs to be done on the mobility and sources of carbon in the Slocan camp and the relationship of graphitization to mineralization.

ACKNOWLEDGMENTS

I am indebted to Mike Bapty of Bapty Research Ltd. and Bob McGowan of Dragoon Resources Ltd. for providing me with access to proprietary information.

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MINERAL POTENTIAL EVALUATION OF THE BILLYGOAT CREEK PROPOSED ADDITION TO GARIBALDI PROVINCIAL PARK NEW WESTMINSTER MINING DIVISION (92J/2E)

(Fig. B1, No. 3)

By Gregg Stewart and Rolf Schmitt

INTRODUCTION

In 1989 the Ministry of Parks proposed additions to Garibaldi Provincial Park to offset a reduction in park area resulting from the expansion of Blackcomb Ski Resort. The Billygoat Creek proposal, on the eastern edge of Garibaldi Park, was selected as one of these additions to protect important goat habitat.

This report summarizes the results of a mineral resource evaluation of the Billygoat proposal by the Ministry of Energy, Mines and Petroleum Resources. Field studies were conducted on September 10 and 11, 1990, and consisted of bedrock mapping at 1:20 000 scale, and collection of rock, soil and stream-sediment samples for geochemical analysis.

Mineral potential studies, such as this, are conducted in accordance with government policy for the purpose of making informed decisions with regard to land allocation in the province.

LOCATION AND ACCESS

The Billygoat Creek proposed addition is located in NTS map area 92J/2E. It lies west of the Lillooet River and north of Billygoat Creek and covers an area of approximately 175 hectares. Access is gained by a secondary gravel road on the west side of Little Lillooet Lake south from the Duffy Lake road or by helicopter from Whistler. The Billygoat Creek proposal contains a prominent east-trending ridge with elevations ranging from 240 metres at the eastern boundary to 1470 metres at the western boundary adjacent to Garibaldi Provincial Park (Plate B-3-1).

MINERAL TENURE

The Billygoat Creek proposal area was recently staked and covered by the BAPI mineral claim which expired on May 6, 1991. No work was recorded by the former registered owner, Stephen Schneiderman of Vancouver, British Columbia.

REGIONAL GEOLOGY

The study area lies in the southern Coast Belt of the Canadian Cordillera and contains a wide variety of rock types and structural elements as recently mapped and summarized by Journeay and Csontos (1989) (Figure B-3-1). These include: Middle Jurassic to Late Tertiary igneous rocks of the Coast plutonic complex. Late Triassic to Early Cretaceous volcanic complexes and related sedimentary rocks of the Nooksack and Cadwallader terranes; and deformed metamorphic and related sedimentary and plutonic rocks correlated to the Northwest Cascade system and the Cascade metamorphic core to the south (Brown, 1987).

Structurally, the region is dominated by three major fault systems: imbricate thrust faults of the Northwest Cascades System and adjacent Cascade metamorphic core; northwest-striking transcurrent faults of the Harrison Lake shear zone; and a series of Tertiary en-echelon, northeast-striking transcurrent and associated high-angle reverse faults.

LOCAL GEOLOGY

The mineral potential study included one day of traversing east along the main ridge from inside Garibaldi Provincial Park to Little Lillooet Lake and the valley bottom, and a second day prospecting and sampling a prominent shear zone on the south side of the ridge (Plate B-3-2).

The Billygoat Creek proposal is underlain almost entirely by the Middle Jurassic to Late Tertiary Pemberton diorite complex which is part of the Coast plutonic complex (Figure B-3-2, Unit Kdi). The Pemberton diorite complex here is fairly homogeneous and comprises medium to coarse-grained equigranular hornblende quartz diorite and hornblende granodiorite. Dioritic rocks typically contain plagioclase (40%), hornblende (30%), quartz (15%), biotite (5%) and accessory chlorite, apatite, minor magnetite, titanite and trace pyrite. The unit contains sparse xenoliths of hornblende-rich diorite up to 2 metres across and, less commonly, intermediate volcaniclastic rock.

The eastern part of the area is underlain by foliated diorite and granodiorite mapped as Unit Kdif (Figure B-3-2). This unit is similar in composition to Unit Kdi but is characterized by mylonitic and migmatitic textures, and local northeast-plunging isoclinal folds. The transition from massive to foliated diorite occurs over about 50 metres.

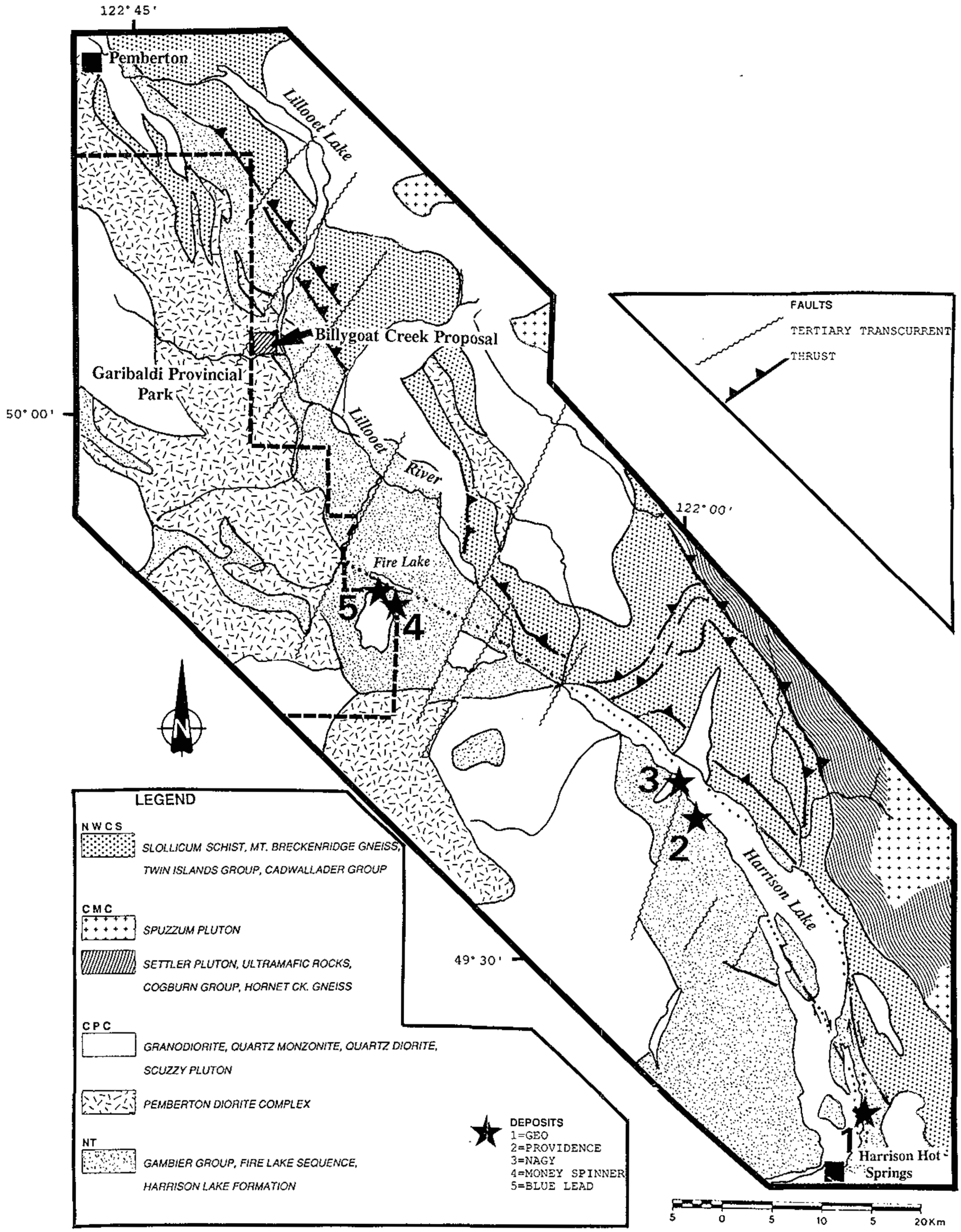

Figure B-3-1. Compilation of geology in the southern Coast Belt. Tectonic elements in this part of the Coast Belt include the Nootsack Terrane (NT), Cadwallader Terrane, Northwest Cascade system (NWCS), Cascade metamorphic core (CMC) and varied intrusive igneous suites of the Coast plutonic complex (CPC); modified from Journay and Csontos (1989).

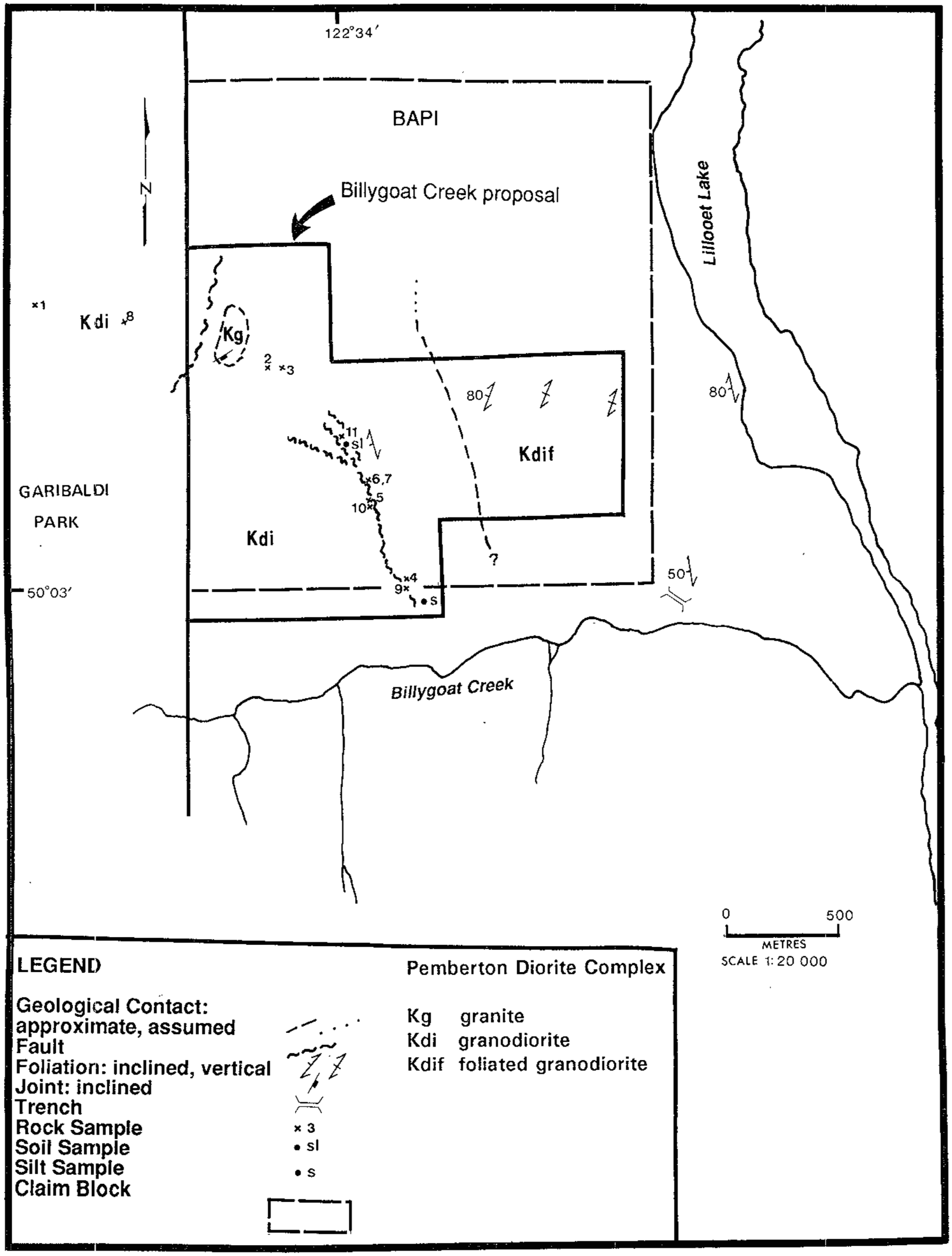

Figure B-3-2. Detailed geology of the Billygoat Creek Proposal.

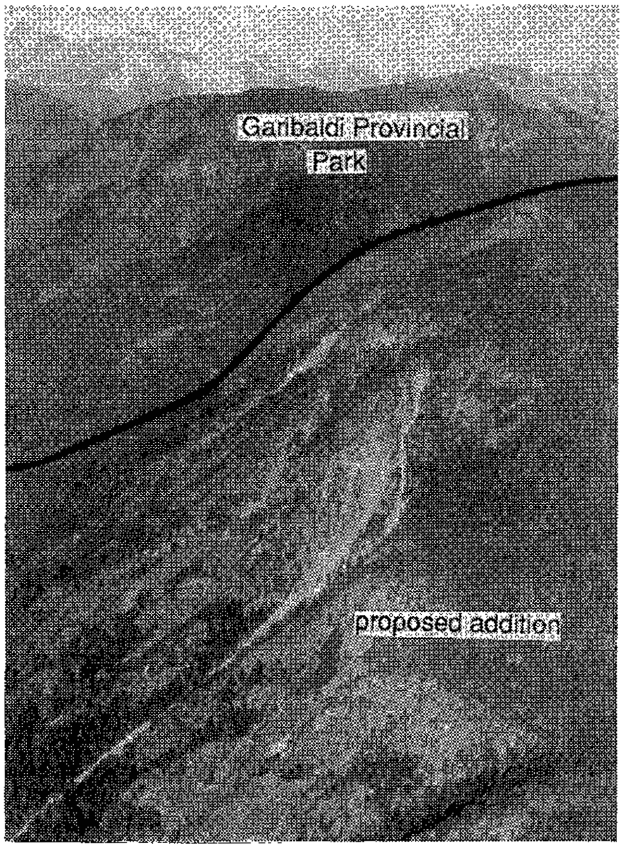

Plate B-3-1. Shear Zone and Garibaldi Park boundary looking west.

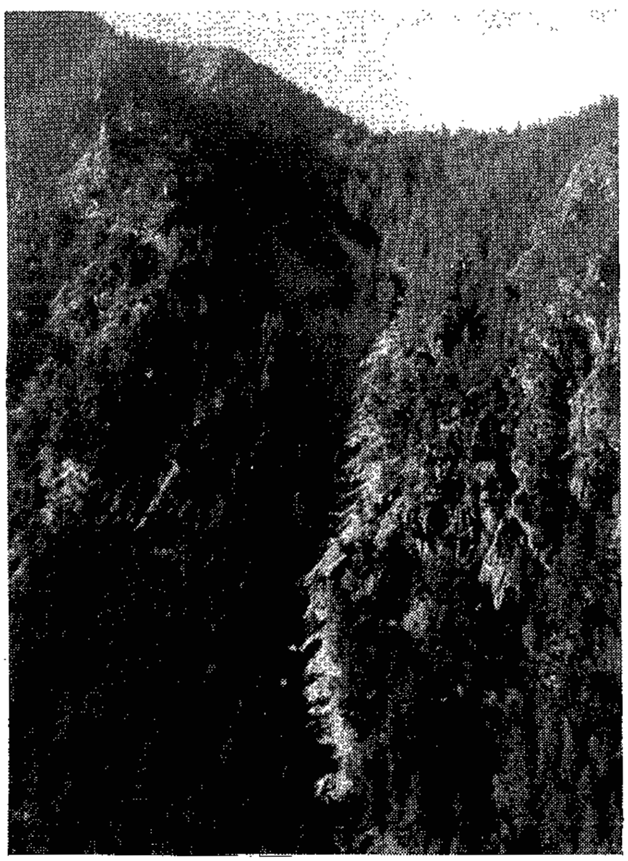

Plate B-3-2. Shear Zone gully (looking north).

A small muscovite granite plug (Unit Kg, Figure B-3-2), of possible Upper Cretaceous to Tertiary age, is exposed on the ridge in the northwest part of the proposed area. Contact relationships with the surrounding diorite were not observed.

A prominent northwest-trending shear zone is located in a large gully on the south side of the ridge. The shear may be related to regional Tertiary transcurrent faults east and north of the study area. The anastomosing shear zone is 2 to 3 metres wide and is continuous for over 500 metres along strike, over an elevation difference of about 300 metres. At the top of the gully, near the edge of the ridge, the shear zone splays into a few prominent horsetails. The shear zone and surrounding diorite at higher elevations are characterized by weak to moderate alteration and mineralization as discussed below. Minor dextral (west-side-up) movement along the shear is indicated by a faulted, narrow diabase dike at 1700 metres elevation.

MINERALIZATION

Mineral occurrences and mineral exploration are well documented throughout the region from Harrison Lake to Pemberton. The Harrison Lake shear zone (Ray *et al.*, 1984), as well as brittle fault systems along the western margin of this shear zone, and younger (Tertiary) northeast-striking transcurrent faults (Journeay and Csontos, 1989) are important regional controls for localizing Tertiary intrusions, hydrothermal activity and base or precious metal mineralization. Several of these regional structures are indicated on Figure B-3-1. Three deposit types are recognized on the basis of vein mineralogy and hostrock lithology:

- Gold-bearing quartz veins with variable precious metal and sulphide mineralization are genetically and temporally related to a 25-million year episode of regional diorite plutonism. These vein deposits are located near the Harrison Lake RN (Geo) mine (MINFILE 092HSW 092) and Nagy deposit (MINFILE 092HNW 071).

- Quartz veins with sporadic free gold and chalcopyrite occur in greenstones near Fire Lake, northwest of Harrison Lake. Examples include Money Spinner (MINFILE 092GNE 002) and Blue Lead (MINFILE 092GNE 004).

- Quartz-carbonate veins mineralized with galena, sphalerite, silver, and gold occur at the Providence mine (MINFILE 092HNW 030) located on the west side of Harrison Lake.

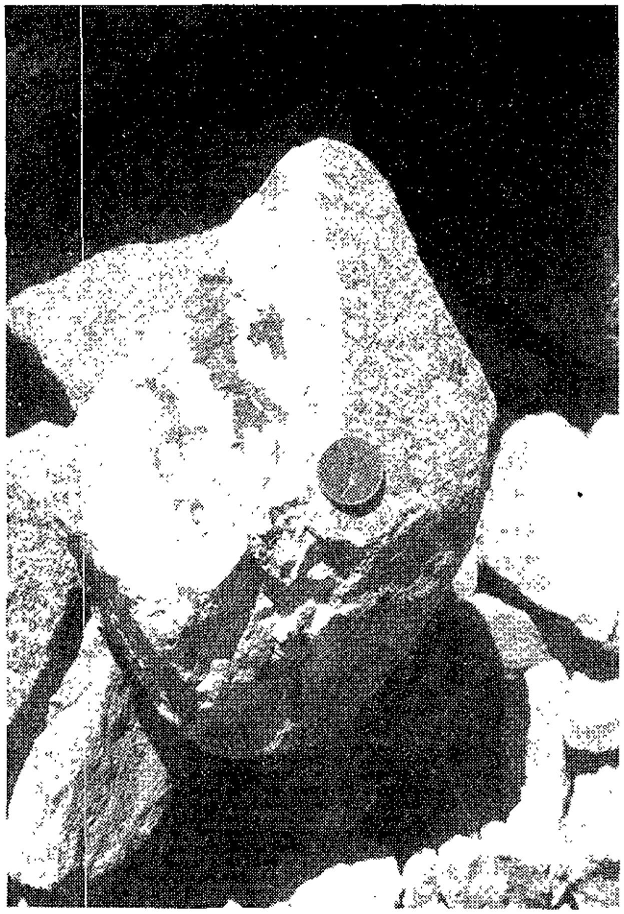

Plate B-3-3. Massive hornblende quartz diorite, weakly pyritic and magnetite bearing.

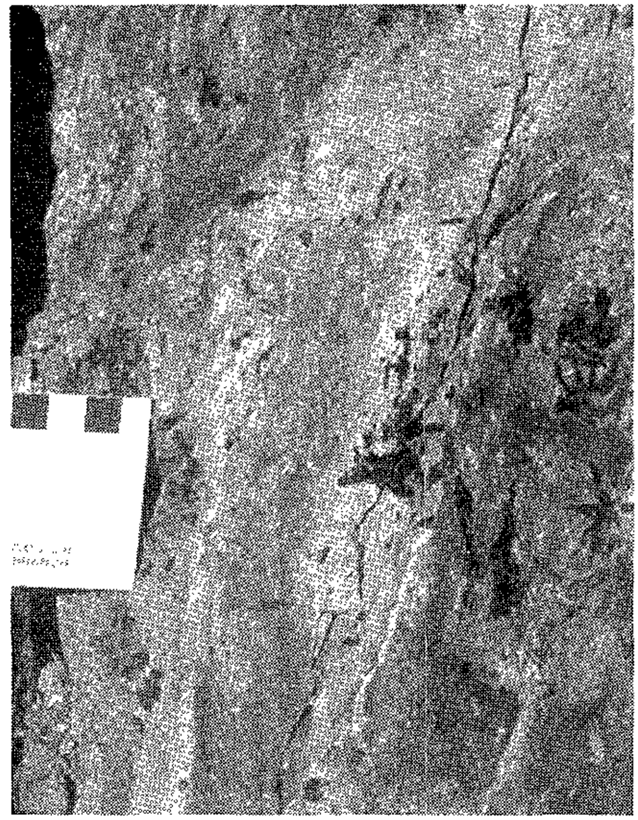

Plate B-3-4. Altered quartz-diorite, disseminated pyrite with prismatic tourmaline.

This survey resulted in the new discovery of mineralization in the prominent northeast-trending shear zone located in the Billygoat Creek proposal. Disseminated pyrite and minor magnetite in narrow, discontinuous brecciated quartz veins and hairline fractures in sheared and altered diorite (Plate B-3-3). Tourmaline occurs rarely as prismatic, radiating crystals up to 2.5 centimetres long in quartz-chlorite-pyrite veins (Plate B-3-4). Alteration minerals include silica, limonite, chlorite, sericite, and minor epidote. Rusty, oxidized pyritic diorite is prevalent in the gully over a strike length of at least 500 metres, and an elevation difference of 300 metres.

Eleven rock samples, one silt-sediment sample and one soil sample were collected. Samples were analyzed for gold and 34 other elements by instrumental neutron activation (INAA) by Activation Laboratories Ltd., and for silver, copper, lead and zinc by total digestion - atomic absorption spectrometry by the Ministry's analytical laboratory. Relevant geochemical analyses are listed in Table B-3-1.

Mineralized rocks from the shear zone contain sporadic elevated concentrations of copper up to 0.16 per cent and lead up to 1110 ppm. Several samples also contained weakly elevated concentrations of gold (24 ppb), antimony (23 ppm), and zinc (205 ppm). The soil and stream sediment samples did not contain anomalous concentrations of metals. The data indicate that hydrothermal activity associated with the shear zone resulted in local elevated concentrations of base metals, although economic concentrations were not detected.

A small trench has been recently dug southeast of the study area, at 250 metres elevation. A brief investigation revealed localized disseminations of pyrite in diorite. There is no documented exploration history or geochemical analyses for this excavation.

SUMMARY AND RECOMMENDATIONS

This report summarizes the results of a mineral potential study of a 175-hectare area proposed for addition to Garibaldi Provincial Park. The Billygoat Creek proposal is located west of Little Lillooet Lake in mountainous terrain of the southern Coast Belt.

The southern Coast Belt comprises a complex lithotectonic and structural setting that includes Late Triassic to Early Cretaceous sedimentary, volcanic, and deformed metamorphic rocks intruded by Middle Jurassic to Late Tertiary plutonic rocks. Recent regional mapping by the Geological Survey of Canada and B.C.

TABLE B-3-1
GEOCHEMICAL ANALYSES OF BILLYGOAT CREEK SAMPLES

Fig. 2	Field Sample Number	Description	Au ppb	Ag[1] ppm	As ppm	Ba ppm	Ca %	Co ppm	Cr ppm	Cu[1] ppm	Fe %	Na ppm	Ni ppm	Pb[1] ppm	Sb ppm	Zn[1] ppm
1	RS1-1B	hornblende quartz diorite	<5	<0.6	<2	390	8	41	52	103	8.04	16700	68	<3	<0.2	90
2	RS1-2B	pyritic hornblende diorite	10	<0.6	16	150	7	27	110	42	6.26	18500	<50	24	2.2	115
3	RS1-3B	pyritic volcanic xenolith	21	<0.6	18	110	6	48	170	15	6.10	12800	87	17	6.0	154
4	RS2-1B	pyritic diorite	<5	<0.6	4	200	5	39	<10	135	6.80	27800	<50	<3	0.7	98
5	RS2-3B	altered pyritic diorite	6	<0.6	5	890	1	30	<10	91	2.98	26500	<50	5	0.7	30
6	RS2-4A	quartz-tourmaline-pyrite vein	<5	0.6	20	930	6	69	52	16	6.95	10000	<50	6	23	27
7	RS2-4B	quartz-tourmaline-pyrite vein	12	<0.6	6	400	4	34	47	41	5.23	18600	<50	4	2.3	79
8	GS-01BG	quartz vein in diorite	<5	<0.6	<2	150	<1	49	<10	5	0.26	13000	<50	5	<0.2	10
9	GS-02BG	pyritic quartz diorite float	<5	<0.6	6	150	6	85	<10	0.16%	7.39	24400	120	<3	0.5	96
10	GS-03BG	brecciated pyritic quartz vein	24	<0.6	12	530	4	51	32	440	6.05	17400	<50	<12	1.3	65
11	GS-04BG	pyritic quartz diorite in shear	<5	1	13	380	7	33	12	74	6.97	14000	81	970	4.1	193
-	GS90-04BGDUP		9	2	16	210	7	32	14	70	6.79	13400	<50	1110	4.4	205
S1	90-2-1	oxidized soil over shear		1						113			117		130	
S	90-2-2S	silt at base of gully		0.8						66			27		129	

[1]Ag, Cu, Pb, Zn analyses by total extraction - AAS (B.C. MEMPR), all other analyses by INAA (Activation Laboratories).

Ministry of Energy, Mines and Petroleum Resources geologists has identified imbricate thrust faults, major transcurrent shear zones and related northeast-striking en-echelon transcurrent and high-angle reverse faults. The region contains favourable mineral potential for copper, zinc, lead, molybdenum, tungsten and gold deposits which are often related to these fault systems.

The Billygoat Creek proposal is mostly underlain by granodiorite and diorite of the Middle Jurassic to Late Tertiary Pemberton diorite complex. A northwest-trending shear zone cuts across the area and hosts the only known mineralization in the proposal. Pyritic, altered and sheared diorite contains sporadic elevated concentrations of copper and lead, as well as weak zinc, antimony and gold values. The data suggest that the prominent shear has some potential for disseminated copper and vein hosted mineralization worthy of further investigation.

Based on the new discovery of mineralization in the Billygoat Creek area, and its inferred relationship to the regional mineral potential, the Ministry has recommended that the Billygoat Creek proposal be designated as Recreation Area under the *Park Act*, subject to Section 19 of the *Mineral Tenure Act*. This designation allows claim staking and mineral exploration to occur subject to joint management by the Ministry of Energy, Mines and Petroleum Resources and Ministry of Lands and Parks. The publication of this report will commence a 10-year period providing for further mineral exploration by the private sector. At the end of the ten years (2001) government will decide the future status of the proposal based on improved subsurface data.

ACKNOWLEDGMENTS

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TALUS-FINES GEOCHEMISTRY OF THE PELLAIRE MESOTHERMAL GOLD VEIN PROSPECT (92O/4E)

(Fig. B1, No. 4)

By S.J. Sibbick and J.L. Gravel

INTRODUCTION

Mineral exploration in alpine regions of extreme relief is often difficult and dangerous due to the inaccessiblility of cliff faces or precipitous slopes. These areas are often characterized by thick aprons of post-glacial talus mantling the lower slopes and concealing the underlying bedrock. Stream sediments may prove to be inadequate for reconnaissance geochemical follow up as primary drainages in these areas are often short in length, fast flowing and lack fine-grained sediment. In this physiographic environment, exploration programs frequently rely upon exposures of gossans or alteration haloes as guides to ore. However, mineralization does not always produce visual clues to its presence; detection may result only through the use of geochemical methods. As a supplement to traditional geochemical techniques, Maranzana (1972) and Hoffman (1977) have recommended the sampling of talus fines (-177 micron fraction) as a prospecting technique in steep, mountainous areas. Talus fines represent weathered bedrock from an up-slope source. Unlike stream-sediment samples, they do not suffer dilution from barren material and are therefore a more effective method of detecting mineralization (Hoffman, 1977).

This study was undertaken to demonstrate the dispersion of talus fines originating from a known source of mineralization. A more detailed sampling program was employed than that used by Maranzana or Hoffman in order to document the style of dispersion and to further evaluate the effectiveness of talus-fines sampling as an exploration tool.

DESCRIPTION OF STUDY AREA

LOCATION AND PHYSIOGRAPHY

The Pellaire mesothermal (Au, Ag) vein prospect (MINFILE 92O 045) is located at latitude 51°05′48″ north, longitude 123°36′30″ west, approximately 150 kilometres southwest of Williams Lake and 2 kilometres north of Mount McLeod, at the southern end of Upper Taseko Lake. A road to the property, extending from the Hanceville-Nemaiah Valley provincial road is maintained by the property owners and only accessible while work is in progress at the property.

Located within the rugged Chilcotin Ranges of the Coast Mountains, the Pellaire propect lies above treeline at an elevation of approximately 2300 metres. Maximum elevations in the immediate vicinity range up to 2700 metres with relief exceeding 1300 metres. The deposit outcrops near the end of a bedrock spur marking the edge of a glacial cirque. Mine workings and the outcropping mineralization lie within the cirque.

Precipitation in the area ranges from 100 to 250 centimetres per year. Predominant soils of the area are brunisols, although soil development in the immediate vicinity of the deposit is almost nonexistent.

DEVELOPMENT HISTORY

Prospectors discovered gold-bearing quartz veins on the property in 1936. In the following year, five veins up to 2.4 metres wide and grading up to 400 grams per tonne gold and 1345 grams per tonne silver were reported (B.C. Minister of Mines Annual Report, 1937). Diamond drilling during the 1930s and 1940s established reserves of 31 000 tonnes grading 21 grams gold and 73 grams silver per tonne (Skerl, 1947). Recent work has included diamond drilling and additional drifting underground. Soil or talus-fines sampling has not played a significant role in the exploration of this prospect.

GEOLOGY AND MINERALIZATION

The region is underlain by Lower Jurassic to Upper Cretaceous volcanic and sedimentary rocks and Cretaceous granites and granodiorites of the Coast plutonic complex. Volcanic and sedimentary units represent rocks of the Tyaughton trough, a back-arc sequence marking the boundary suture between the Stikinia and Wrangelia terranes (McLaren, 1990). Numerous faults transect the region, including the Tchaiakazan fault, a northwest-trending structure with an estimated strike-slip displacement of 30 kilometres (Tipper, 1969).

Quartz veins at the Pellaire property are hosted by a lobe of Coast plutonic complex granodiorite which extends into the adjoining Cretaceous volcanic and sedimentary rocks. Volcanic rocks consist of pyroclastics and flows altered to pyritic hornfels (Holtby, 1987). Sedimentary rocks are similarly but less extensively hornfelsed (McLaren, 1990). Detailed work has been done on two groups of veins; the main workings, located up-slope from

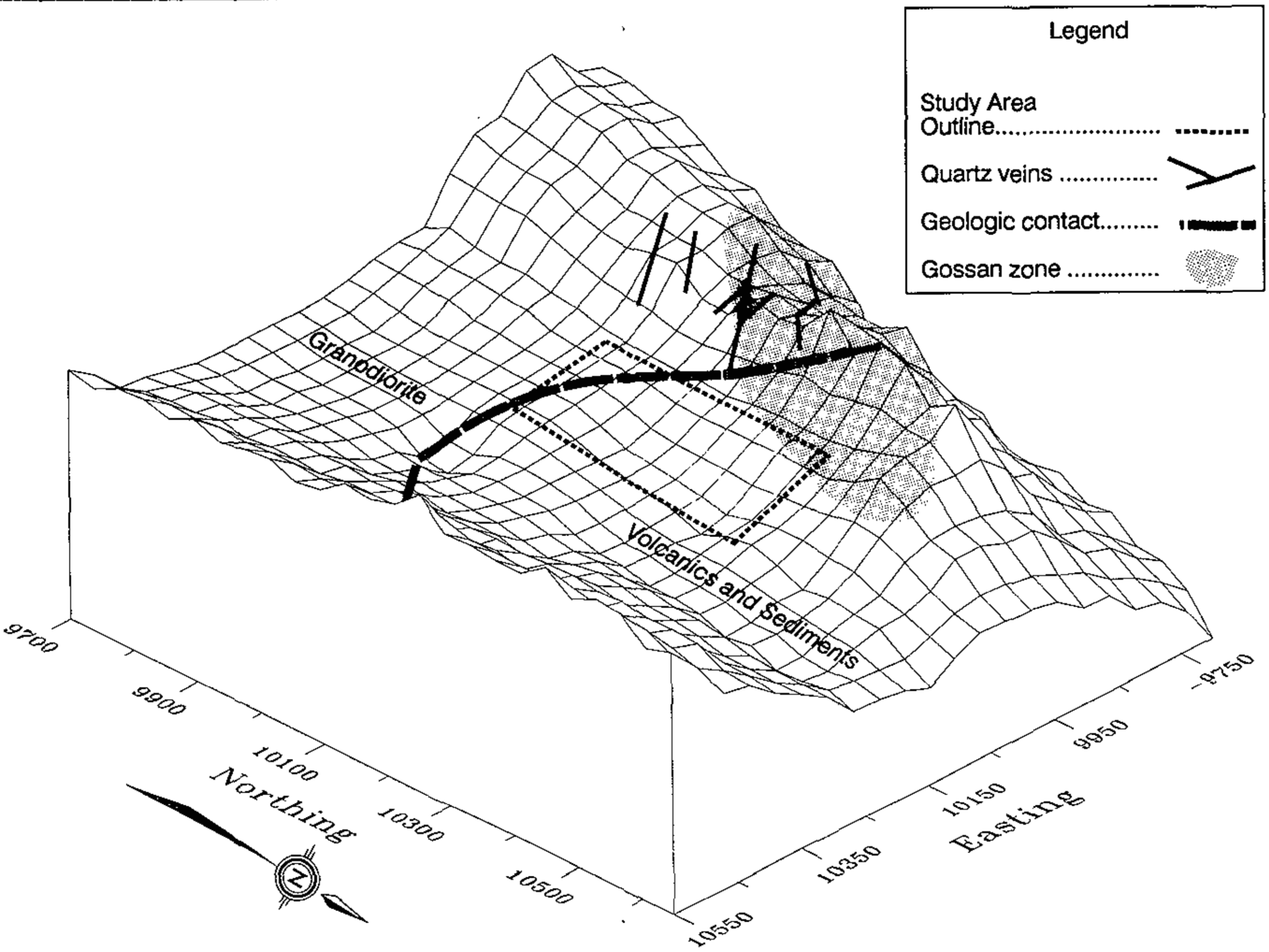

Figure B-4-1. Location of the study area in relation to the mineralized quartz veins, gossan zone and local topography. Axes scale in metres.

the midpoint of the study area, and two smaller veins at the southern limit of the survey (Figure B-4-1). Striking northeasterly, with dips of 30° to 60° to the north or northwest, the longest vein has a maximum surface exposure of 225 metres along strike with outcrop widths of the veins ranging from 0.3 to 7.5 metres. Zones of pervasive sericitization are associated with each vein; vein contacts are either sharp or contain clay gouge (Holtby, 1987). A large gossan (400 x 200 metres) is visible on surface, surrounding the main workings and covering the slopes and crest of the bedrock ridge. McLaren (1990) has classified Pellaire as a mesothermal vein deposit.

Sulphide minerals are present in limonite and malachite-stained friable quartz veins. Numerous casts from weathered pyrite and lesser chalcopyrite are common within the veins. Up to 10 per cent pyrite has been identified in drill core. Chalcopyrite, galena, rare visible gold, native antimony and hessite (a gold-bearing silver telluride) have been identified in the veins (Warren, 1947). Gold probably occurs as a telluride and possibly within pyrite (Holtby, 1987). Table B-4-1 lists the results of geochemical analyses rock-chip samples from the two groups of veins up-slope from the study area (McLaren, 1990).

Surficial Geology

Bedrock is exposed on the crest and upper slopes of the ridge cut by the quartz veins. A layer of blocky talus covers the lower two-thirds of the ridge, forming a thick blanket towards the bottom of the cirque. Individual fans within the talus are not visible. Rocks in the talus range up to 2 metres, but are commonly on the order of 30 centimetres in diameter. In general, the size of the talus blocks increases downslope. Space between the talus blocks is filled with coarse to fine sand-sized material, its abundance decreasing down-slope. The cirque floor is filled by a prominent moraine, its surface covered with an ablation till composed of large blocks of bedrock and talus from the surrounding slopes. A creek, draining from a small glacier at the head of the cirque, flows underneath the moraine until the break in slope at the mouth of the cirque. There are no other drainages within the cirque.

METHODS

Sample Collection

A 150 x 300-metre grid (base station 10000E 10000N) was established on the talus slope immediately below the mine workings. The long axis of the grid was oriented

TABLE B-4-1
RESULTS OF GEOCHEMICAL ANALYSES OF CHIP SAMPLES FROM MINERALIZED QUARTZ VEINS

Sample	Au ppb	Ag ppm	Cu ppm	Pb ppm	Zn ppm	Co ppm	Ni ppm	Mo ppm	Mn ppm	Fe %
Vein at 10000N 9950E										
RM 90	7200	55	800	42	114	82	<10	79	27	5.15
Vein at 10150N 10000E										
RM 91	251	2	16	<10	<5	144	<10	<10	22	0.66
RM 92	1400	1	13	24	58	41	9	<10	294	2.52
RB 31	70000	180	850	<10	5	71	<10	17	24	5.07

Data from McLaren (1990). Determination of Au by fire assay - atomic absorption spectometry. All other elements by total acid digestion with element determinations by atomic absorption analysis.

perpendicular to the slope in a north-south direction. Samples were collected every 25 metres on east-west lines (parallel to slope) 50 metres apart. Forty samples, weighing approximately 1 kilogram each, were collected from the finer grained talus (< 1mm) where available. Areas which appeared to be contaminated by the mine workings were not sampled. Duplicate samples were collected at three sites. Adits and outcropping quartz vein were noted at two locations near the grid, 10150N 10000E and 10000N 9950E.

Sample Preparation and Analysis

All samples were dried at 60°C and dry-sieved to -177 microns (-80 mesh). Six samples representing three duplicate sample pairs (samples 24, 25; 32, 33; 45 and 46) were sieved into three size fractions (-420+177 μm, -177+53μm and -53μm) to provide data on the size-fraction distribution of gold within talus fines.

One-half gram of each -177 micron subsample was digested with 3 millilitres of aqua regia (3 HCl: 1 HNO_3: $2H_2O$) at 95°C for 1 hour followed by dilution to 10 millilitres with water. This type of digestion results in near total dissolution of base metals and gold, partial dissolution of rock-forming elements and weak dissolution of refractory elements. Sample solutions were analysed by inductively coupled plasma (ICP) for thirty elements (Mo, Cu, Pb, Zn, Ag, Ni, Co, Mn, Fe, As, U, Au, Th, Sr, Cd, Sb, Bi, V, Ca, P, La, Cr, Mg, Ba, Ti, B, Al, Na, K and W). Gold analyses were performed by fire assay – inductively coupled plasma (FA-ICP) on 10 gram subsamples. Thirty-gram subsamples were analysed by FA-ICP for gold on samples selected for size-fraction analysis.

RESULTS

Multi-Element Data

Table B-4-2 lists the mean, standard deviation, coefficient of variation and the range in values (maximum/minimum) for each element. Elements which consistently returned analytical values at or below detection limit (U, Th, Sb, Bi, B and W) were excluded. Gold and silver display the widest distribution of values, expressed by large coefficients of variation, whereas elements such as vanadium, magnesium and aluminum have substantially smaller coefficients, reflecting a smaller range in concentration.

Inter-element relationships were determined using single linkage cluster analysis of Pearson correlation coefficients (Figure B-4-2). At a high (0.9995) level of confidence, two separate clusters are evident. The largest group represents the lithophile and siderophile elements (Ba, Co, Mn, La, Al, Sr, Na, P, Fe, Ti, Ni, Cr, Mg, V and K), a second group (Au, Ag, Mo, Pb, Zn, Cd and Cu), is composed of elements with a predominantly chalcophile association. Correlations for arsenic and calcium are poor, resulting in a failure to cluster with other elements.

Element Dispersion

The dispersion of several selected elements (Au, Pb, Cu, Fe, V and Ni) is shown in Figure B-4-3. These elements were chosen to represent the characteristic dispersion patterns for the lithophile-siderophile and chalcophile elements. In general, the highest concentrations of chalcophile elements occur immediately downslope from the two vein outcrops at 10150N 10000E and 10000N 9950E. Iron in the talus fines, however, has a contrasting pattern; concentrations increase toward the northwestern end of the grid. Similar patterns are noted for elements which show a high correlation to iron (Figure B-4-2), such as phosphorus, Al and Na.

SIZE FRACTION ANALYSES

Tables B-4-3 and 4 present the size-fraction weight, weight per cent and gold content for each size fraction. Fifty-three to eighty-eight per cent of each sample is contributed from the coarse (+420μm) fraction whereas the fine (-53μm) fraction contributes from 6.5 to less than

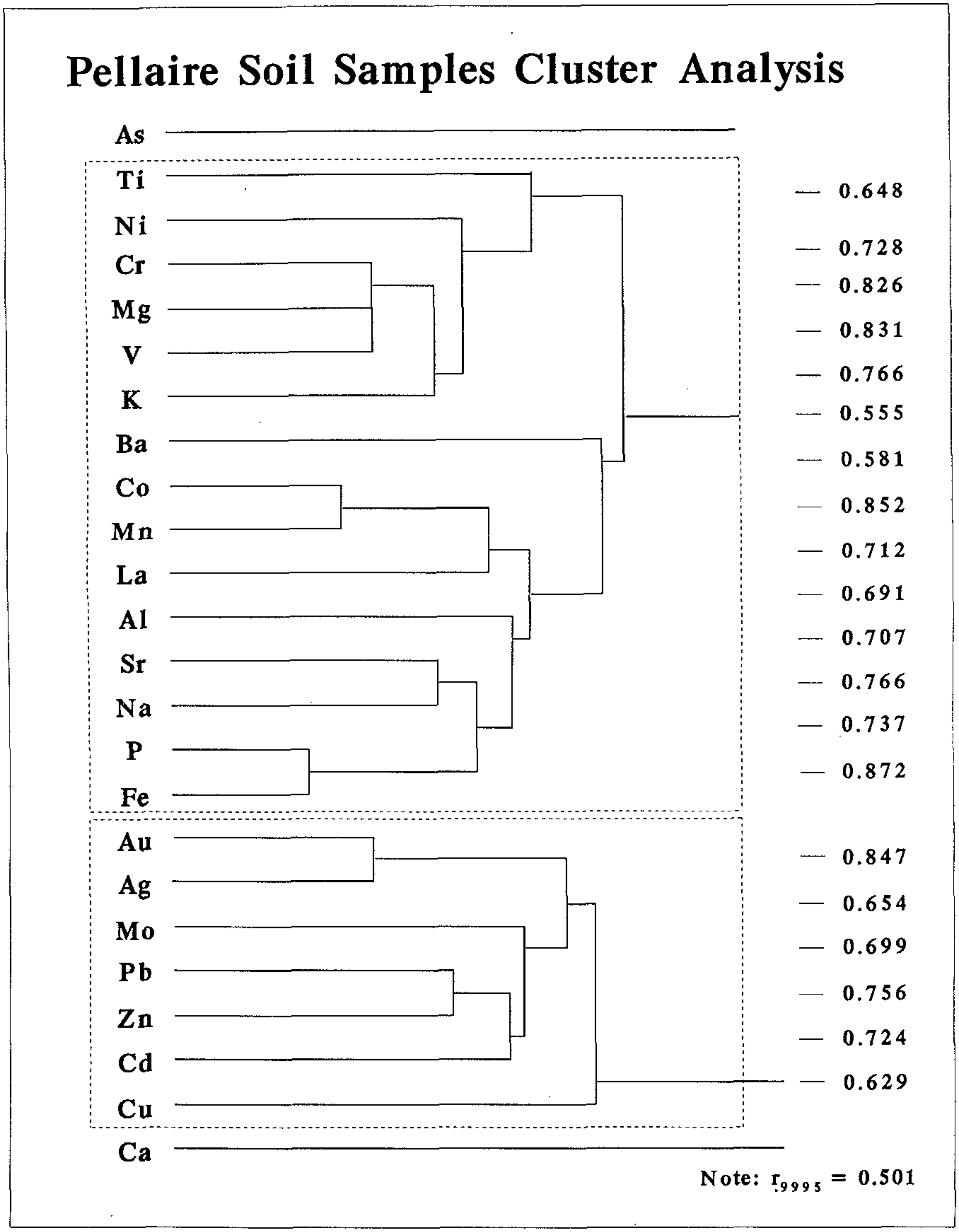

Figure B-4-2. Inter-element relationships determined using single linkage cluster analysis of Pearson correlation coefficients for n=40 samples.

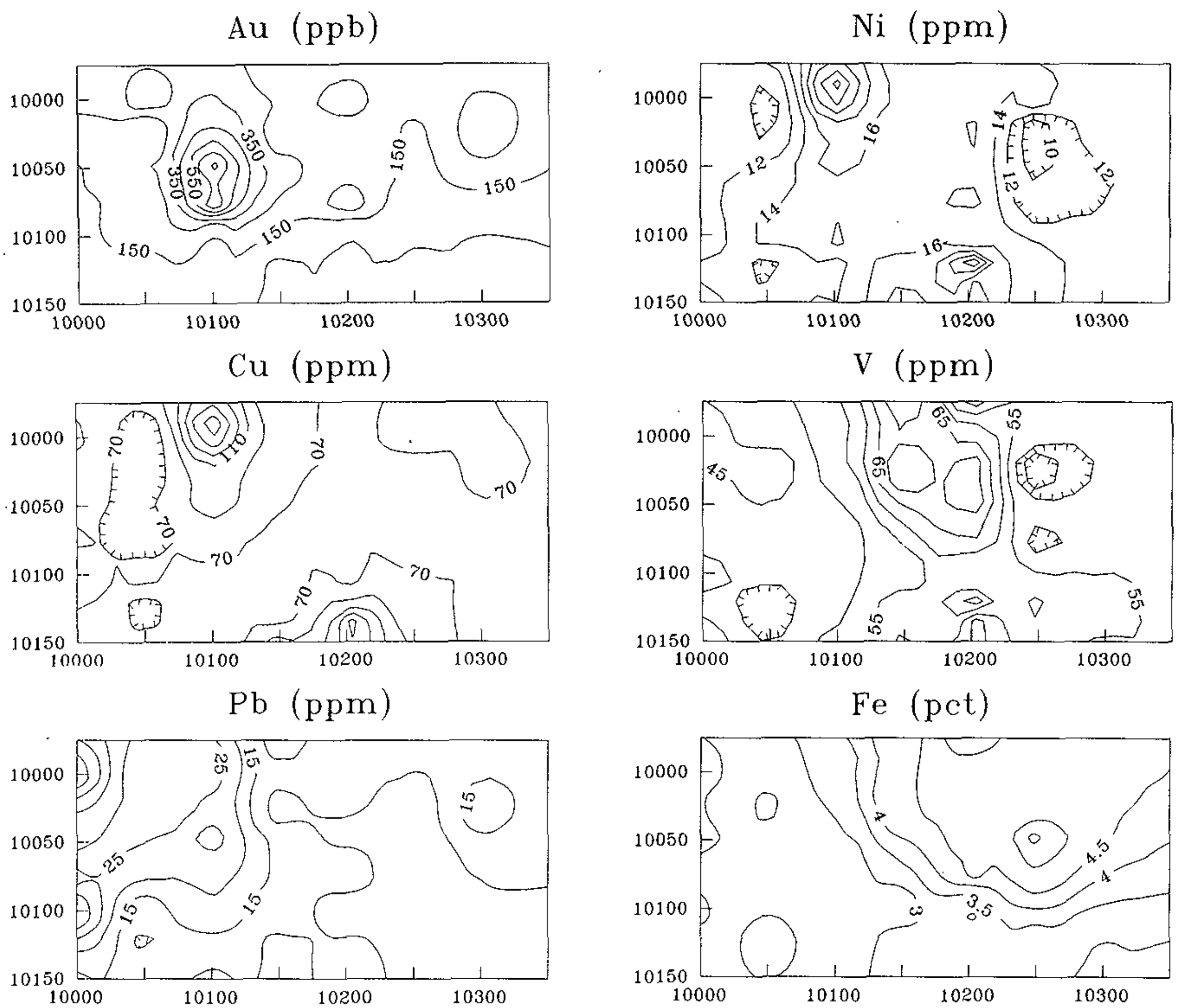

Figure B-4-3. Element dispersion patterns within the study area for Au, Cu, Pb, Fe, V and Ni. Down-slope direction in each diagram is from top to bottom.

1 per cent. Excellent reproducibility of gold values is observed between both duplicates and size fractions for sample pairs S-24/S-25 and S-45/S-46. Duplicate samples S-32/S-33 give the highest concentration and the greatest variability between duplicates and size fractions.

DISCUSSION

Clustering of the elements into lithophile-siderophile (Ba, Co, Mn, La, Al, Sr, Na, P, Fe, Ti, Ni, Cr, Mg, V and K) and chalcophile (Au, Ag, Mo, Pb, Zn, Cd and Cu) groups reflects partitioning between rock-forming elements (lithophile-siderophile group) and those elements associated with mineralization (chalcophile group). Anomalous levels of gold, silver, copper, lead, zinc and molybdenum have been detected (Table B-4-1) in chip samples from the veins up-slope from the grid area (McLaren, 1990).

Dispersion of gold, copper and lead in the talus fines is related to the outcrop of mineralized quartz vein on the slopes above the study area. The highest concentrations of elements associated with mineralization occur immediately down-slope from the mineralized outcrops and are restricted to a small area, likely confined within individual talus cones. The dispersion pattern for lead (Figure B-4-3) suggests a source area in the vicinity of the quartz vein at 10000N 9950E. Analysis of a rock-chip sample from this vein (Table B-4-1) returned a higher concentration of lead (42 ppm) than the veins at 10150N 10000E (<10ppm, <10ppm and 24 ppm). Although showing a similar spatial distribution, nickel and copper values correlate poorly. It is likely that the high nickel contents of the talus fines reflect alteration of the wall-rock surrounding the veins whereas copper values represent mineralization in the veins. High (>70 ppm) vanadium concentrations in the talus fines are not associated with either vein mineralization or alteration, but appear to be related to the contact between the granodiorite and the volcanic-sedimentary units.

TABLE B-4-2
ELEMENT STATISTICS FOR THE -177 MICRON (-80 MESH) FRACTION

Element	Mean	Std Dev	Max	Min	Coefficient of Variation
chalcophile					
Cu	74.6	29.4	188.0	37.0	39.4%
Zn	103.9	44.4	262.0	42.0	42.7%
Pb	17.2	12.6	58.0	5.0	73.4%
Cd	0.5	0.4	1.8	0.2	76.8%
Mo	2.3	1.9	8.0	1.0	84.2%
Ag	0.9	1.3	6.0	0.1	142.3%
Au (ppb)	243.3	472.4	2943.0	5.0	194.1%
lithophile-siderophile					
Mg (%)	0.93	0.19	1.36	0.59	20.7%
V	52.7	11.0	76.0	34.0	20.9%
Al (%)	2.7	0.6	4.0	1.63	21.9%
P (%)	0.07	0.03	0.12	0.05	26.3%
La	6.0	1.6	11.0	4.0	26.6%
Ba	125.5	34.6	206.0	71.0	27.6%
Ti	0.09	0.03	0.16	0.05	27.8%
Fe (%)	3.4	0.9	5.7	2.3	27.8%
Ni	13.9	3.9	26.0	7.0	28.0%
Cr	15.7	4.5	32.0	9.0	28.7%
Ca (%)	0.85	0.26	1.67	0.44	30.1%
K (%)	0.16	0.05	0.28	0.06	34.4%
Co	13.7	5.0	29.0	9.0	36.7%
Na (%)	0.03	0.01	0.05	0.01	40.5%
Sr	174.3	75.4	343.0	71.0	43.2%
Mn	865.9	452.3	2749.0	501.0	52.2%
As	3.4	2.4	12.0	2.0	72.7%

All values in ppm except where noted.
Statistics based on 40 samples.

TABLE B-4-4
GOLD CONTENT BY SIZE FRACTION

Sample	-420+177 μm (-40+80)	-177+53 μm (-80+270)	-53 μm (-270)
S-24	52	53	65
S-25	56	59	45
S-32	901	1741	1747
S-33	1924	2870	2451
S-45	245	640	359
S-46	233	312	332
Mean	569	946	833
Std. Dev	734	1133	1014

All values in ppb. ASTM mesh sizes in parentheses

TABLE B-4-3
SIZE-FRACTION WEIGHT DISTRIBUTION BY SAMPLE

Sample	+420 μm (+40)	-420+177 μm (-40+80)	-177+53 μm (-80+270)	-53 μm (-270)	Total (weight only)
S-24	309.6 (58.4)	93.8 (17.7)	101.6 (19.2)	25.0 (4.2)	530
S-25	247.2 (52.6)	92.1 (19.6)	103.5 (22.0)	27.2 (5.8)	470
S-32	1017.8 (87.7)	89.4 (7.7)	44.1 (3.8)	8.7 (0.8)	1160
S-33	967.5 (84.1)	110.3 (9.6)	58.2 (5.1)	14.0 (1.2)	1150
S-45	362.2 (67.1)	70.5 (13.1)	84.8 (15.7)	22.5 (4.2)	540
S-45	256.8 (54.6)	85.4 (18.2)	97.1 (20.7)	30.7 (6.5)	470
Mean	526.9 (67.0)	90.3 (14.0)	81.6 (14.0)	21.4 (4.0)	720
Std. Dev.	363.5 (15.0)	12.9 (5.0)	24.8 (8.0)	8.4 (2.0)	338

All sample weights in grams. Weight per cent of each subsample given in parentheses. Equivalent ASTM mesh sizes are listed beneath each micron size fraction.

The increase in iron content toward the northern, up-slope end of the grid correlates well with the gossanous cap overlying the pyritic hornfels zone. Although abundant weathering pyrite and limonite are associated with the quartz veins, iron correlates poorly with the chalcophile elements. The limited area of the quartz veins in relation to the gossan zone indicates that the weathering of barren pyrite in the hornfels has masked the iron signature associated with the quartz veins

Geochemical dispersion within the talus fines at Pellaire appears to be wholly post-glacial. Lateral displacement of anomalies by glacial transport is not evident, although it is likely that glacial moraine underlies the talus, especially near the cirque floor. Dispersion is controled by gravity, resulting in the transport of talus directly down-slope. The maximum anomalous dispersion distance is difficult to estimate; gold, copper and lead concentrations appear to diminish rapidly within 150 metres although a high concentration of copper (100 ppm) is encountered at the down-slope extremity of the sample grid. One hundred metres down-slope from the veins, near the base of the talus slope, talus fines containing locally anomalous concentrations of gold and lead occur over a width of 100 to 150 metres. This probably represents the lateral extent of the talus fines originating from the vicinity of the quartz veins. Hoffman (1977), using base-of-slope contour samples at 400-metre spacings, successfully identified bedrock copper sources in talus transported 400 to 1000 metres down-slope. Results presented here suggest that a reconnaissance talus-fines sampling program could successfully use a base-of-slope contour sample spacing approximately equivalent to the length of the talus slope as a cost-effective geochemical exploration technique. However, it must be emphasized that variations in geology and physiography will control the occurrence of talus and may significantly alter sampling-density.

Size-fraction analysis indicates that coarse (> 420μm material constitutes the majority of each talus-fines sample, whereas fine (-53μm material is a very small fraction, a reflection of the recent derivation of the talus from bedrock and possibly the removal of fines due to rainfall. High reproducibility of gold values for a majority of the subsamples implies the presence of uniformly disseminated, fine-grained gold in the talus. More erratic gold values, most notably in subsamples of S-32 and S-33, indicate the presence of larger gold grains.

CONCLUSIONS

Use of talus-fines sampling as a geochemical exploration tool in mountainous terrain is effective as a follow-up technique for large-scale stream sediment surveys. Due to the lack of primary drainages in this environment, base-of-slope sampling of talus is a more efficient method than detailed stream-sediment sampling. Talus-fines sampling also provides a quick method of evaluating gossans identified from the air. Identification of anomalous elements in talus fines would be followed by detailed sampling and prospecting up-slope of the sample site. Conclusions based on this study are:

- Geochemical anomalies in talus fines have a restricted source area; the source of the anomaly lies either directly or at a slight angle up-slope from the sample site.
- Talus-fines sampling effectively detects mineralized and gossanous bedrock. Use of cluster analysis can differentiate between rock-forming elements and those associated with mineralization.
- Base-of-slope sample spacing should be approximately equivalent to the length of the talus slope. However, variations in local geology and physiography should be strongly considered when selecting sampling densities and sample locations.

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AN INVESTIGATION OF THE GOLD CONTENT OF PLACER TAILINGS IN THE LIKELY-WELLS AREA (93H/4; 93B/12, 13, 16; 93G/1)

(Fig. B1, No. 5)

By Stephen J. Day and Tim Giles

INTRODUCTION

Gold recovery at placer mines is generally thought to be very poor, perhaps for the following reasons:

- the gold particles are physically too small for hydraulic gravity concentration to be effective and;
- the processing equipment may not be efficient below a certain grain size. This grain size will be much greater than the size limit for hydraulic recovery, is unlikely to be constant, and may depend on a number of factors including the type and design of the equipment, the texture of the gravels being worked, and the rate of throughput.

Gold which is not recovered in sluice boxes and jigs is swept into the placer tailings pond. If the paydirt contains fine gold, the tailings may contain sufficient gold that reworking by hydraulic or other means may be economically viable. There are reports of placer tailings containing in excess of 30 grams per tonne at a placer mine in the Cariboo (V. McKeown, personal communication, 1990), however systematic studies of gold in placer mine tailings have not been conducted.

The current study was initiated in September 1990 with the objective of obtaining an estimate of typical recoverable gold concentrations in placer tailings at four mines in the Cariboo. This was achieved by collecting statistically representative samples of placer tailings, determining the gold content of several size fractions, and investigating the possibility of recovering gold from tailings by physical or chemical reprocessing.

STUDY AREA AND DESCRIPTION OF MINES

Four placer mines in the Cariboo region (Figure B-5-1) were selected for sampling, based on the presence of intact tailings and the willingness of operators to participate in the study. An attempt was made to select mines with different sizes and shapes of gold particles and different gravel-processing circuits (*e.g.* hourly throughput, initial screening, final concentration equipment).

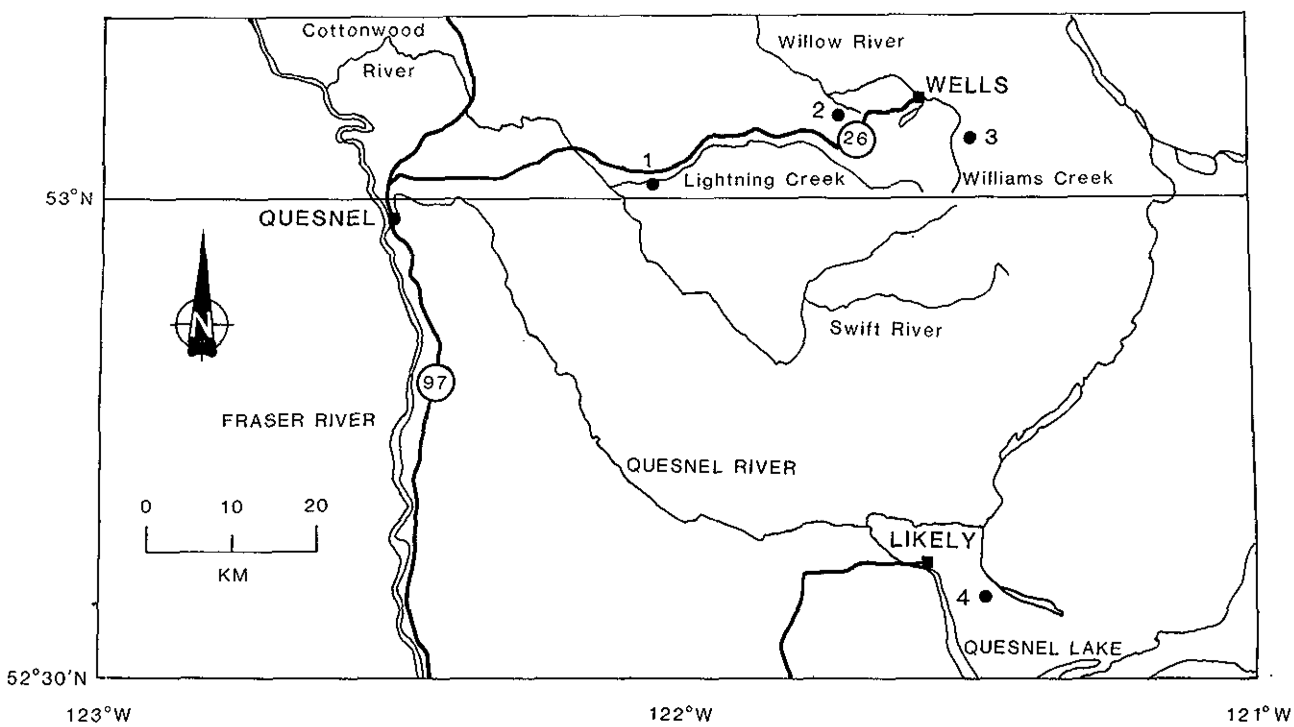

Figure B-5-1. Location of placer mines sampled in this study. 1=Gallery Gold; 2=Nelson Creek; 3=Ballarat mine; 4=McKeown mine, Spanish Mountain.

Gallery Gold (samples designated GG) mine is located along Lightning Creek, south of Highway 26, approximately 35 kilometres east of Quesnel. Deep gravels underneath alluvial terraces are being mined. Gravels are processed at a rate of up to 1800 cubic yards per day (Jan Schutze, personal communication, 1989). Gold is generally finer than 3 millimetres and flakey. The gravels are screened to 0.5 inch (1.3 cm) and heavy minerals are concentrated by five jigs. Coarse tailings (coarser than medium sand) are deposited from a single fixed point within several metres of the plant and must be frequently bulldozed. Fine tailings and water are channelled through a ditch 400 metres long to a series of settling ponds. Water is recycled to the processing plant.

Nelson Creek (samples designated NC) mine is a small operation located north of Highway 26, approximately 10 kilometres west of Wells. Colluviated tills and gravels are mined and processed by trommel, 0.5-inch (1.3 cm) grizzly and four sluices in parallel. Coarse tailings are deposited at the downstream end of the sluice box and are removed by backhoe. Fine tailings and water are carried down a steep channel to a 2000 square metre tailings pond. Water is clarified by a series of ponds and is then recycled to the processing plant. At the time of sampling, the operation was experiencing problems with obtaining adequately clean water, as a result of drought conditions.

At Ballarat Mine (samples designated BA) near the Wells airstrip, a well-defined 5000 square metre abandoned tailings area, bounded on three sides by retaining dikes was sampled. The tailings, which are finer than 0.5 inch (1.3 cm), were produced by a plant containing a trommel and sluices. Both fine and coarse tailings were carried along a 150-metre pipe and deposited. Coarse tailings were deposited over about two-thirds of the pond, and fine tailings were deposited over the remaining area.

The operation at McKeown mine at Spanish Mountain (designated SM), near Likely, works placer deposits below till. Gravels are screened to less than 1.5 inch (3.8 cm), and coarse and nugget gold is concentrated in two jigs. A scavenger sluice box is used as a final trap prior to releasing tails to a small (less than 1000 m^2) tailings area. Coarse tailings are deposited in a fan-like deposit downslope from the scavenger sluice box. Fine tailings are deposited in two settling ponds.

SAMPLING DESIGN

Field Program

Each tailings pond contains two distinct types of sediments. Proximal tailings, deposited within a few metres of the point of discharge, are very coarse, being composed primarily of pebble gravel less than 1.3 centimetres in diameter at all sites except McKeown mine where it was less than 3.8 centimetres. Medium to fine sand, with a very high moisture content is deposited beyond the proximal deposit. The proximal tailings are probably far greater in volume than the distal tailings, however the distal deposits are generally more contiguous as they do not require removal by backhoe or bulldozer during operation. The proximal tailings are frequently bulldozed away from the discharge point to maintain an open channel to the settling ponds. Except at the Ballarat mine, the proximal tailings are piled at several locations around the gravel processing plant.

Bearing in mind the problems of obtaining representative samples for gold analysis due to the nugget effect, it was recognized that large volumes of material were required and that some duplicate analysis was essential. In addition, field screening of proximal tailings was needed to reduce the quantity of sample for laboratory processing.

For each sample, enough sediment was wet-screened to obtain about 60 to 70 kilograms (wet) of material finer than 1 millimetre. This size of sample has previously been found to provide an adequate characterization of the gold content of auriferous gravels (Day, 1988). The field-screening apparatus consisted of a Nalgene screen which fits snugly over the top of a 5-gallon (18.9 L) plastic pail. During sieving the pail was placed in a plastic tub to recover any fine sediment that overflowed the pail. Inevitably some loss of silt and clay particles did occur but these amounts are probably insignificant. The total volume of tailings processed was estimated from the number of sieve volumes.

Two samples, each consisting of two pails of sediment finer than 1 millimetre, were collected for both proximal and distal tailings. For each tailings type, the two samples were taken from different parts of the pond to provide some indication of spatial variability. The two pails for each sample were numbered separately to allow processing as separate subsamples (Table B-5-1).

Laboratory Processing and Analysis

The samples were dry-screened to yield five fractions (-1000+425 μm, -425+180 μm, -180+105 μm, -105+53 μm, and -53 μm). Wide sieve intervals were selected to yield large samples for gold analysis, and a number of samples which could be analyzed within the constraints of the program. It was initially proposed that heavy mineral separates be prepared for each sample by floating the low density minerals using a heavy liquid. This approach was rejected in favour of an inexpensive direct gold extraction using cyanide.

A commercially available cyanidation method was selected for estimation of the gold content of the tailings. A 500-gram sample is rolled for 6 hours in 100 millilitres of 0.25 per cent NaCN solution. Gold in the leachate is subsequently concentrated into 10 millilitres of 2, 6-dimethyl-4-heptanone (DIBK) and determined by graph-

TABLE B-5-1
DISTRIBUTION OF SEDIMENT SIZE BY WEIGHT PER CENT

SAMPLE[1]	SEDIMENT SIZES (μm) +1000 %	-1000+425 %	-425+180 %	-180+105 %	-105+53 %	-53 %	TOTAL SAMPLE WEIGHT kg
Proximal Tailings							
BA 011	89.00	7.76	2.57	0.27	0.32	0.08	280.9
BA 012	88.40	8.19	2.60	0.31	0.40	0.09	283.2
GG 021	0.00	3.58	60.16	20.12	14.20	1.93	26.3
GG 022	0.00	6.84	61.85	21.31	8.52	1.47	27.7
NC 011	88.23	7.02	3.34	0.94	0.43	0.04	272.0
NC 012	87.90	7.66	2.94	1.07	0.39	0.04	272.4
SM 011	90.41	6.55	2.40	0.22	0.31	0.11	339.9
SM 012	90.21	7.47	1.82	0.13	0.29	0.09	340.4
SM 021	92.86	4.15	2.35	0.21	0.35	0.08	438.8
SM 022	92.55	4.76	2.01	0.24	0.36	0.08	437.4
Distal Tailings							
BA 031	0.00	2.02	32.58	35.49	24.55	5.36	23.6
BA 032	0.00	7.39	29.32	37.88	22.81	2.61	25.4
GG 041	0.00	1.94	31.70	49.91	15.42	1.03	24.0
GG 042	0.00	2.08	35.54	44.03	17.20	1.15	22.7
NC 031	0.00	14.14	40.53	38.00	6.74	0.58	26.3
NC 032	0.00	16.62	35.96	37.80	8.29	1.33	22.7
SM 031	0.00	6.45	33.93	22.92	30.20	6.50	28.6
SM 032	0.00	6.53	43.17	30.58	16.55	3.17	28.1
SM 041	0.00	3.63	19.23	34.46	37.06	5.61	25.4
SM 042	0.00	1.82	10.86	38.83	42.25	6.24	25.4

1 Sample notation: 011 indicates first subsample (pail) of sample 01, 012 is second subsample of sample 01. BA = Ballarat mine, GG = Gallery Gold mine, NC = Nelson Creek mine, SM = McKeown mine (Spanish Mountain).

ite-furnace atomic absorption. The detection limit is 5 ppb gold. There may be problems with this method if the sample is exceptionally fine or organic-rich. However, Sibbick and Fletcher (1991) found that the method provided acceptable recovery of free gold (total gold was determined by fire assay fusion) in the -53 micron soil fractions, provided that the organic content was low. The distal placer tailings are as fine as this soil but are not organic-rich, therefore cyanidation would produce reliable results. The laboratory which analyzed the tailings samples indicated that gold recoveries of at least 90 per cent should be possible for this type of material.

One sample of -53 μm material obtained in this study was digested by both fire assay (15 g sample) and cyanide leach. The result for fire assay (856 ppb Au) was comparable to the result using the cyanide method (1015 ppb).

A further advantage of the cyanide digestion is that it estimates gold which might be recovered if the tailings are reprocessed in a cyanide leach operation.

Only a limited number of samples could be processed and analyzed as part of this project. All samples from McKeown mine were analyzed but for the remaining mines, one sample of both proximal and distal tailings was processed. Both pails of each sample were processed to estimate reproducibility of results. The analytical subsample was 500 grams if sufficient sample was available. The quantity of -53 micron sediment analyzed varied from 50 to 500 grams (Table B-5-2).

RESULTS AND DISCUSSION

SIZE-FRACTION ANALYSES

Reproducibility of the size-fraction analyses for both distal and proximal tailings was excellent for the individual subsamples and texture did not vary significantly in the samples collected at different points in the tailings (Table B-5-1). Size distributions were quite similar for the different mines (Figure B-5-2), except for the proximal sample from Gallery Gold (Figure B-5-2a) which was not collected immediately below the discharge point and appears similar to the distal samples (Figure B-5-2b).

The quantity of coarse silt and finer sediment (-53-μm fraction) was very small (less than 7% for distal tailings, less than 2% for the proximal tailings) for all mines. The modal size of the sieved fractions for proximal samples was in the 425 to 1000 micron size range (coarse

TABLE B-5-2
GOLD CONCENTRATIONS IN SIZE FRACTIONS OF PLACER TAILINGS

SAMPLE[1]	SIZE FRACTION (μm) -1000+425	-425+180	-180+105	-105+53	-53	Mass of -53 μm analyzed[2]	Average mass-weighted
	ppb	ppb	ppb	ppb	ppb	g	ppb
Proximal Tailings							
BA 011	15	20	55	145	310	150	16.1
BA 012	15	80	75	135	310	150	23.1
GG 021	15	15	15	20	35	400	12.6
GG 022	15	15	5	10	25	300	16.1
NC 011	5	145	135	75	115	50	58.0
NC 012	5	80	110	80	125	50	35.3
SM 011	40	145	575	730	1015	310	111.5
SM 012	40	225	940	1135	NA	250	NA
SM 021	20	60	85	310	775	310	58.2
SM 022	15	15	65	265	NA	320	NA
Distal Tailings							
BA 031	15	20	20	20	20	500	19.9
BA 032	15	15	15	15	15	500	15.0
GG 041	10	10	10	10	15	150	10.1
GG 042	10	10	5	10	10	180	7.8
NC 031	5	5	5	5	5	80	5.0
NC 032	5	5	5	5	5	200	5.0
SM 031	35	30	35	50	135	500	29.5
SM 032	20	25	40	75	NA	500	NA
SM 041	35	30	30	25	50	500	44.3
SM0 42	10	35	30	25	NA	500	NA

1 Sample notation: 011 indicates first subsample (pail) of sample 01, 012 is second sub-sample of sample 01. BA = Ballarat mine, GG = Gallery Gold mine, NC = Nelson Creek mine, SM = McKeown mine (Spanish Mountain).

2 500 g of all fractions were analyzed.

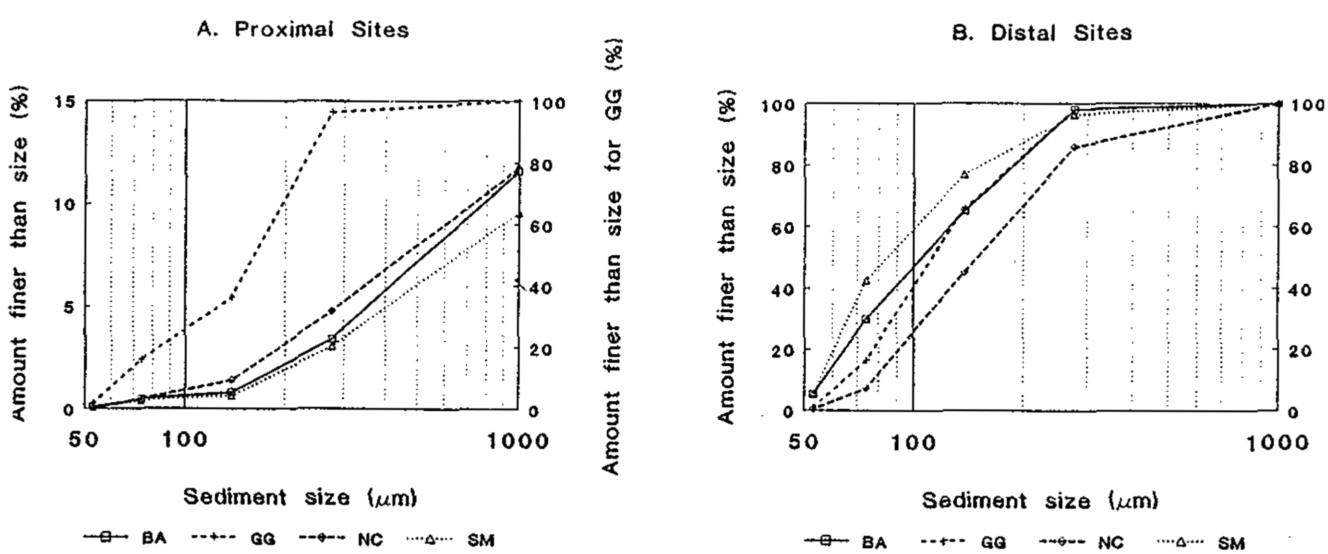

Figure B-5-2. Cumulative size distributions for proximal and distal placer tailings. BA = Ballarat mine, GG = Gallery Gold mine, NC = Nelson Creek mine, SM = McKeown Mine (Spanish Mountain).

TABLE B-5-3
ESTIMATED NUMBER[1] OF GOLD PARTICLES IN SIZE FRACTION

SAMPLE[2]	SIZE FRACTION (m)				
	-1000+425 Number	-425+180 Number	-180+105 Number	-105+53 Number	-53 Number
Proximal Tailings					
BA 011	0.01	0.05	1.1	18.3	33.1
BA 012	0.01	0.20	1.5	17.0	33.1
GG 021	0.01	0.04	0.3	2.5	10.0
GG 022	0.01	0.04	0.1	1.3	5.3
NC 011	0.00	0.36	2.7	9.4	4.1
NC 012	0.00	0.20	2.2	10.1	4.5
SM 011	0.03	0.36	11.6	92.0	224.2
SM 012	0.03	0.56	18.9	143.0	NA
SM 021	0.01	0.15	1.7	39.1	176.7
SM 022	0.01	0.04	1.3	33.4	NA
Distal Tailings					
BA 031	0.01	0.05	0.4	2.5	7.1
BA 032	0.01	0.04	0.3	1.9	5.3
GG 041	0.01	0.03	0.2	1.3	1.6
GG 042	0.01	0.03	0.1	1.3	1.3
NC 031	0.00	0.01	0.1	0.6	0.3
NC 032	0.00	0.01	0.1	0.6	0.7
SM 031	0.02	0.08	0.7	6.3	48.1
SM 032	0.01	0.06	0.8	9.4	NA
SM 041	0.02	0.08	0.6	3.1	17.8
SM 042	0.01	0.09	0.6	3.1	NA

1 The number of gold particles was estimated assuming spherical free gold, diameter of geometric midpoint of the sieves, and density of 18 g/cm^3.

2 Sample notation: 011 indicates first subsample (pail) of sample 01, 012 is second subsample of sample 01. BA = Ballarat mine, GG = Gallery Gold mine, NC = Nelson Creek mine, SM = McKeown mine (Spanish Mountain).

sand), except for Gallery Gold which was as fine as the coarsest distal sample (Figure B-5-2b, Table B-5-1). The modal size of the distal samples was in the 105 to 180-micron (fine sand) range except for Nelson Creek samples which were in the 180 to 425-micron range.

The distal tailings are not homogeneous but show interbedded coarse and fine strata. No distinct layers were seen in the proximal tailings because they are deposited rapidly and in most cases are bulldozed every few hours during operation.

Gold Analyses

Results of gold analyses are summarized in Table B-5-2 and Figure B-5-3. Reproducibility of the gold results was surprisingly good (2%) for individual fractions, considering the probable presence of gold particles which cause nugget effects. To assess this source of sampling variability, the number of gold particles in each sample was estimated (Table B-5-3) assuming that the gold occurs as spherical grains with a density of 18 grams per cubic centimetre and size at the geometric midpoint of the size fraction. In the case of the very low gold concentrations in the coarsest fractions, it is probable that there were no coarse gold particles in the analytical subsample, therefore the gold present represents fine sand-sized and finer gold adhering to larger sediment particles. Gold results for Ballarat mine, Gallery Gold and Nelson Creek are generally well reproduced, based on the Poisson sampling distribution, for the expected size of the gold particles and the low gold concentrations. For example, the expected range in number of gold particles for the -105+53-micron fraction of the Ballarat samples should be 11 to 23 (lower and upper 95% confidence limits on the Poisson distribution) for the gold concentration determined, rather than 17.0 to 18.3 (Table B-5-3).

It is probable that the gold in all but the finest fractions from Ballarat mine, Nelson Creek and Gallery Gold partly reflects both actual particulate gold of that size, and incompletely screened fine sand, silt and clay-sized gold particles. The high gold concentrations in samples from McKeown mine may be indicative of relatively coarse particulate gold in fractions finer than 180-microns.

In general, the proximal samples contained the highest gold concentrations, except for the Gallery Gold samples which were texturally similar to the distal samples. Gold was barely detectable in all distal samples fractions except the -53-micron fraction of the samples from McKeown mine. Gold concentrations for all mines

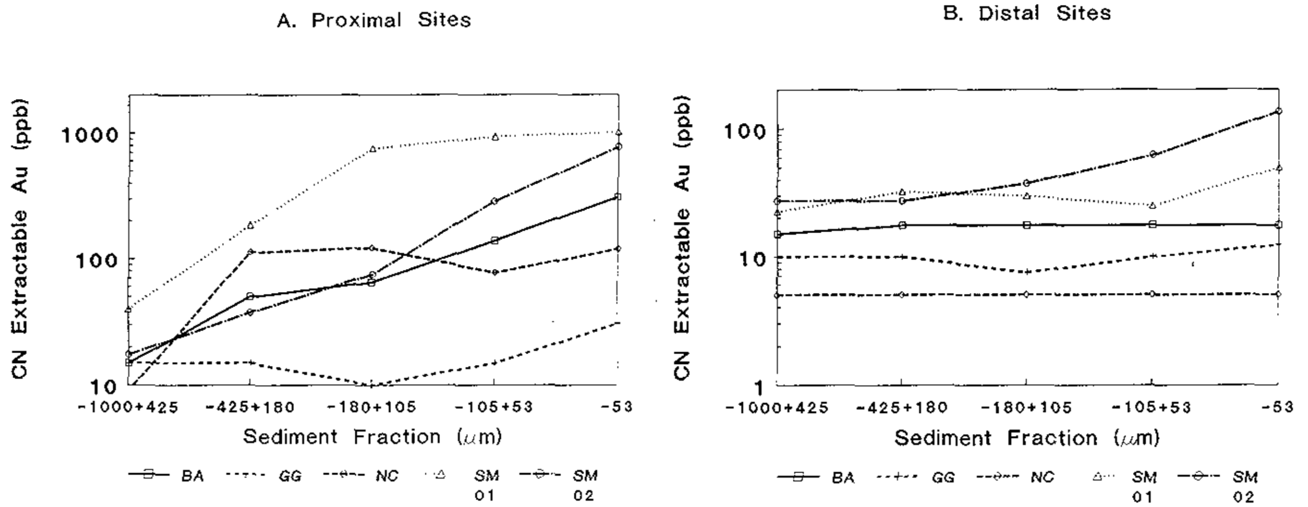

Figure B-5-3. Cyanide-extractable gold concentrations in placer tailings sediment fractions. BA = Ballarat mine, GG = Gallery Gold mine, NC = Nelson Creek mine, SM = McKeown mine (Spanish Mountain).

tended to be greatest in the finer sediment sizes but this may reflect lack of gold particles in the coarse fractions, inadequate sample sizes for the coarse fractions, and incomplete screening of fine sand, silt and clay, as described above.

INTERPRETATION

Expected Gold Grade in Placer Mine Tailings

An estimate of the minimum gold grade of the placer tailings can be obtained by weighting the gold concentration of each fraction by the mass of the fraction (Table B-5-2, last column). This calculation probably underestimates the actual gold concentration because there is a low statistically probability of finding gold in the two coarsest fractions, and it is not known how much gold is present in the field coarse-reject (gravel coarser than 1 mm). Ideally, most gold coarser than 1 millimetre should have been recovered when the gravel was originally processed.

Average gold concentrations for true proximal tailings (not including Gallery Gold samples) range from 23 ppb for Ballarat mine to 112 ppb for McKeown mine. The majority of the total gold mass is in the two coarsest fractions of the proximal tailings. At 100 per cent recovery and US$365/ounce of gold, the proximal tailings at McKeown mine have a minimum value of about C$2/cubic yard (C$2.7/m^3) to C$4/cubic yard (C$5.3/m^3). In comparison, gold concentrations in distal tailings (which are likely to be fairly representative due to the fineness of the sediment) vary from 5 ppb (Nelson Creek) to 44 ppb (McKeown). The dollar value of these tailings is very low.

Although it appears that no coarse gold particles were found in the analytical subsamples of the 1000 + 425-micron fractions (proximal tailings), another estimate of overall gold concentration was calculated by assuming that there is some coarse gold in this fraction. Because no gold particles were found in six samples (Table B-5-3), the gold grade was arbitrarily calculated for a tenth of a spherical gold particle (425μm in diameter) in a 500-gram sample (or one particle in every 5000 grams). For this case, gold grades for proximal tailings range from 110 ppb to 180 ppb, and values from C$3/cubic yard (C$4.7/m^3) to C$6/cubic yard (C$8.7/m^3). Clearly, these grades are speculative, but they indicate the importance of obtaining a better estimate of gold concentrations in the coarse fraction by taking larger samples. These estimates may be most realistic for McKeown mine where the fine fractions indicate that gold may be present in the coarser fractions.

In conclusion, highest gold grades were found at McKeown mine, and indicate that tailings at this mine may be suitable for reprocessing or improvements to current processing. Gold grades of 30 grams per tonne were previously reported for tailings at this mine. Ballarat Mine has the largest well-defined tailings mass, however the estimated gold content is the lowest of the three true proximal tailings deposits.

Deposition of Gold in Placer Tailings Ponds

Placer tailings are deposited in the ponds by processes comparable to natural sediment-sorting in gravel-bed rivers. Close to the point of discharge the tailings are deposited as a steeply sloping fan, which is extremely mobile during deposition as sheets of sediment are deposited and eroded by shifting channels. At the base of the fan, sediment in suspension is deposited in a low energy pool. The distribution of gold between proximal and distal tailings is comparable to that reported by Day and Fletcher (1989, 1991) for gravels and sands in a gravel bed stream. The proximal tailings environment acts as an efficient trap for gold of all sizes. A significant difference from these earlier studies is the lack of gold finer than 53 microns in the distal tailings, perhaps reflecting the difference in hydraulic conditions for placer tailings ponds and natural gravel-bed streams.

POTENTIAL FOR ECONOMIC EXTRACTION OF GOLD FROM PLACER TAILINGS

Cyanidation in a heap-leach operation would be the most appropriate means of extracting gold from the proximal tailings. The distal tailings are too fine for direct leaching and would require agglomeration. In any case, this material is effectively barren of gold.

The quantities of proximal tailings at individual mines are too small to justify construction of heap-leach pads and metal recovery plants. A centrally located facility would be required to extract gold from several mines. In addition to this factor, the low overall gold concentrations and relatively small quantities of tailings dictate that extraction of gold from tailings would not be profitable at this time. There are currently no heap leach operations using rock with gold grades as low as those in the tailings (McQuiston and Shoemaker, 1981; van Zyl *et al.*, 1988).

Although chemical leaching is not likely to be profitable, means for improving the recovery of fine sand-size gold during gravel processing should be investigated at mines where gold of this size is being lost.

CONCLUSIONS

The conclusions are drawn from this study:

1. Placer tailings are composed of two distinct facies. Proximal tailings are coarse gravelly material deposited in a fan close to the discharge point. Sandy, distal tailings are deposited from suspended material, usually in a settling pond. The proximal tailings are frequently bulldozed at most mines and are therefore not preserved as a connected mass.
2. Proximal tailings from most mines contain varying concentrations of gold. McKeown mine at Spanish Mountain yielded the highest overall gold concentrations with up to 1135 ppb in the fine-sand fraction. Typical concentrations of gold in this fraction at other mines are close to 100 ppb. Significant gold concentrations were not measured in the very coarse sand fraction, however, there is a low statistical probability of finding gold in this fraction. Problems were encountered with effectively dry-sieving the tailings.
3. Distal tailings contain very low gold concentrations (less than 20 ppb) at most mines. Slightly higher gold concentrations were detected in the fine fraction of distal tailings from McKeown mine.
4. Commercial reprocessing of placer tailings is very unlikely to be profitable due to low overall gold concentrations and small quantities of tailings. However, where gold is present in the sand fraction, recovery may be possible by refining the current processing plant.
5. Future testing of tailings should involve analysis of a larger volume of the coarser fractions and more thorough sieving to improve separation of fine material from the coarser fractions.

ACKNOWLEDGMENTS

We are grateful to Jan Schutze (Gallery Gold), Bill McCullaugh (Nelson Creek), Bert Ball (Ballarat mine) and Virginia McKeown (McKeown mine) for permission to collect samples at their operations. Provision of clean running water for sample processing was much appreciated.

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GEOCHEMICAL DISPERSION IN COMPLEX GLACIAL DRIFT AT THE MOUNT MILLIGAN COPPER-GOLD PORPHYRY DEPOSIT (93N/1E, 93O/4W)

(Fig. B1, No. 6)

By J. L. Gravel and S. J. Sibbick

INTRODUCTION

Mining camps in glaciated areas evolve from initial discoveries of outcropping or subcropping mineral deposits and progress until all deposits detectable by surface or near surface exploration methods are located. Standard geological, geophysical and geochemical exploration techniques are often ineffective in regions of thick, complex glacial drift. However, depletion of known ore reserves and the extrapolation of favourable geology beneath drift-covered regions forces mineral exploration into these areas. Its success often depends on the utilization of drift-exploration methodologies which can interpret the three dimensional relationships between underlying bedrock, transported surficial deposits and soils formed during post-glacial weathering. Mineral exploration programs in eastern and central Canada, where areas of high mineral potential are blanketed by thick surficial deposits, have evolved a comparatively advanced drift-prospecting capability. Application of these techniques, devised for shield areas which underwent continental glaciation, may be inappropriate for exploration in British Columbia which has experienced predominantly alpine glaciation.

An integrated geochemistry and surficial geology program has been undertaken by the British Columbia Geological Survey Branch to develop drift-prospecting strategies appropriate for the province. This program will involve a number of case studies which will examine glacial and post-glacial processes which influence geochemical dispersion patterns.

The Mount Milligan alkaline copper-gold porphyry deposit was chosen for the inaugural study on the basis of several attributes. Intense exploration for this style of deposit is concentrated within the Quesnel trough, a region of extensive glacial drift cover. Also, the Mount Milligan deposits are concealed by complex surficial deposits comprising colluvial, morainal and glaciofluvial sediments of variable thickness.

During 1990, several features of geochemical dispersion at Mount Milligan were examined:

- Copper and gold concentrations outwash and till.
- Dispersion of copper and gold soils developed in outwash and till.
- Lateral and vertical dispersion of anomalous copper and gold in glaciofluvial sediments.
- Dispersion of gold in colluvial soils.

The term surficial deposit refers to oxidized or unoxidized colluvium, till and glaciofluvial outwash, whereas the terms soil and soil horizon refer to the upper layers of these surficial deposits which have undergone post-depositional weathering and soil formation.

This study has shown the importance of distinguishing surficial deposits and the recognition of weathering effects in the interpretation of geochemical trends. Mean background concentrations of copper and gold are predominantly influenced by the type of surficial deposit and soil horizon. Misidentification of sample media may mask true anomalies and highlight false anomalies.

PROPERTY OVERVIEW

LOCATION AND ACCESS

Mount Milligan is located at latitude 55°08'N, longitude 124°02'W (NTS map sheet 93N/01), approximately 150 kilometres northwest of Prince George in north-central British Columbia (Figure B-6-1). The property can be reached by truck along a series of active logging roads leading west from Windy Point on Highway 97.

LOCAL GEOLOGY AND MINERALIZATION

The Mount Milligan property is dominantly underlain by upper Triassic alkalic flows, pyroclastics and related sediments (Figure B-6-2). Recent regional mapping by Nelson *et al.* (1991) in the Mount Milligan area identifies the assemblage as the Witch Lake Formation within the Takla Group. Units comprise augite (±plagioclase) porphyry agglomerate, trachyte breccias and flows and bedded epiclastic sediments. Locally intruding this sequence are several monzonite bodies of early Jurassic age. Loci of mineralization at Mount Milligan are the MBX and Southern Star stocks composed of crowded plagioclase-porphyritic monzonite. The stratigraphy strikes northwest and dips at 30° to 60° to the northeast. The porphyry systems are spatially related to long-lived faults which controlled intrusive activity (Nelson *et al.*, 1991). The Great Eastern fault, immediately east of the

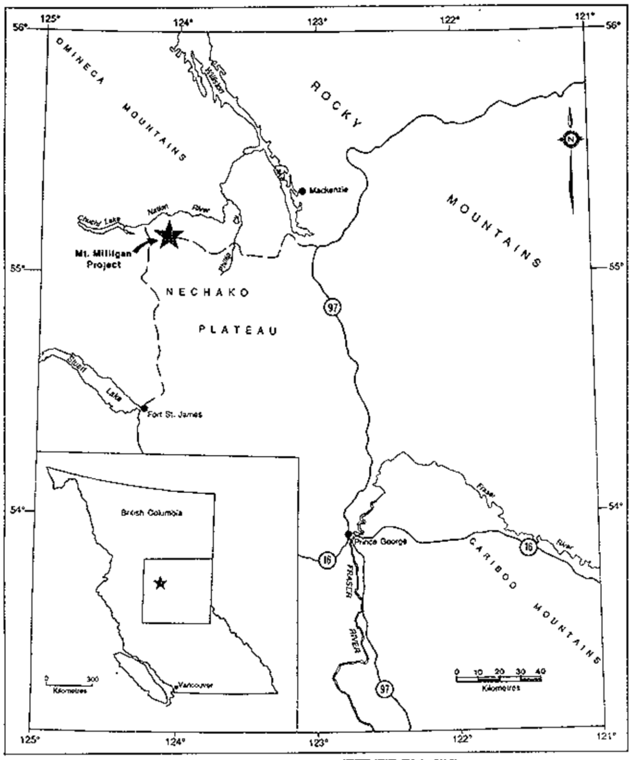


Figure B-6-1. Location of the Mount Milligan deposit.

porphyries, juxtaposes Takla Group rocks with Eocene continental sediments within an extensional basin.

Mineralization is centred on the porphyry intrusions and consists of disseminated and stockwork sulphides. Delong *et al.* used cluster analysis to demonstrate the significant association between mineralization (copper, gold; chalcopyrite, bornite and magnetite) and potassic alteration (biotite, K-feldspar) enveloping the stocks. Nelson *et al.*, postulated that much of the latite and trachyte units mapped in drill core are potassically altered andesite flows and derived sediments. Delong *et al.* statistically identified the assemblage of calcite, albite, epidote and pyrite associated with propylitic alteration which has developed peripheral to the potassic zone. A pyrite alteration halo measuring 3.0 kilometres by 4.5 kilometres, elongate about an east-west axis extends outwards from the deposits. Combined geological reserves of the two deposits are 400 million tonnes grading 0.48 gram per tonne gold and 0.20 per cent copper. Lesser deposits include high-grade gold-copper (arsenic, silver, lead, zinc and molybdenum) quartz veins in the Esker and Creek zones and an oxidized supergene cap of less than 10 million tonnes (D. Forster, personal communication, 1990) overlying the MBX stock. Within the supergene

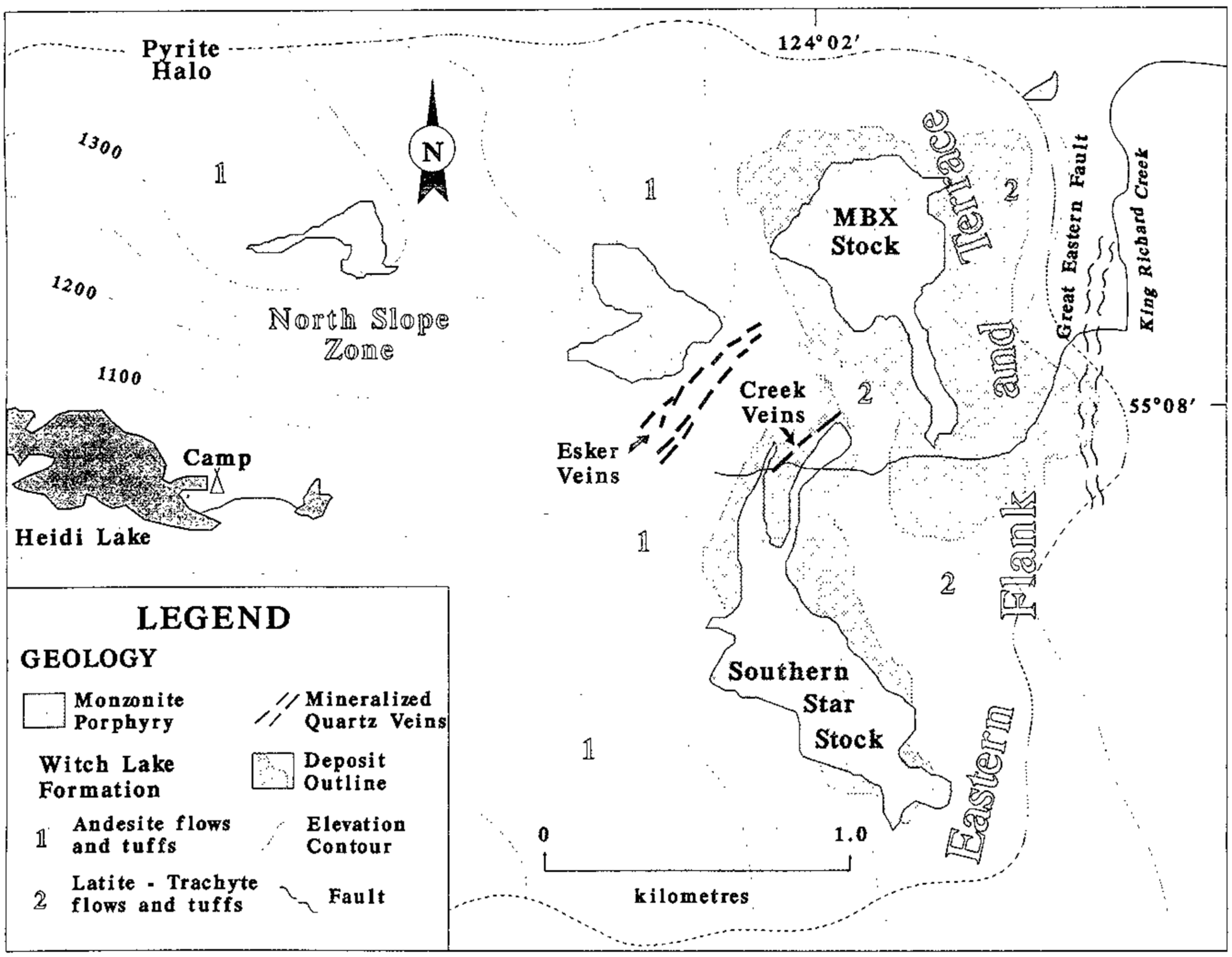


Figure B-6-2. Geology of the Mount Milligan area.

zone chalcopyrite, the dominant copper-bearing mineral, has been altered to chalcocite, djurleite, covellite, malachite, cuprite and native copper.

Surficial Geology

The Mount Milligan area was glaciated during the last glacial episode. All glacial features observed in the study area are associated with this event. Ice-flow indicators such as drumlinoids and striae suggest a southwest to northeast direction of ice advance across the area. The surficial deposits, which may attain tens of metres in thickness, consist mainly of matrix-supported diamictons in the form of a till blanket, as well as glaciofluvial deposits of sand and gravel. The latter generally exhibit a southwest trend as defined by sinuous esker ridges; the dominant meltwater paleocurrent direction obtained from outwash sediments is to the northeast. Till veneer and colluvium deposits frequently mantle the steeper slopes of hills, whereas glaciofluvial sediments define broad gently rolling terraces. Isolated deposits of fine glaciolacustrine sand, silt and clay are found within several topographic depressions. Thickness of surficial deposits varies considerably, from less than 1 metre to in excess of 90 metres. Test pits and cut faces expose a complex stratigraphic sequence. A more complete discussion of Quaternary geology in the Mount Milligan area is given by Kerr and Bobrowsky (1991, this volume).

Physiography and Climate

The Mount Milligan property lies in the Nechako Plateau, a region of flat to gently rolling terrain. Local relief is provided by a northwest-trending ridge which rises 300 to 500 metres above the local plateau elevation of 1000 metres. Mount Milligan, with a summit elevation of 1508 metres lies at the northwestern end of the ridge. Drainage along the ridge is dendritic, becoming glacially disturbed on the surrounding plateaus where short meandering stream courses connect pothole lakes, ponds and swamps. The MBX and Southern Star stocks underlie a terrace on the eastern flank of the ridge. At this location the ridge and terrace are dissected by an east-west oriented valley occupied by Heidi Lake which drains to the west and King Richard Creek which drains to the east.

The region has a sub-boreal climate. Winters are long and cold, average daily temperature in January is -15 to -20°C. Summers are short and cool, July average daily temperature is less than 16°C. The area is moderately wet receiving between 500 to 1000 millimetres of precipitation annually. Predominant soil type of the region is a humoferric podzol (soil and horizon nomenclature based on the Canadian System of Soil Classification, *Agriculture Canada*, Queen's Printer, Canada) based which is characterized by a moderately thin (10-20 cm) organic-rich Ah horizon, a thin to absent leached Ae horizon, a moderately thick (20-40 cm) iron-enriched Bf horizon, a thin to moderately thick (10-30 cm) olive-brown Bm horizon, an oxidized C1 horizon in which pre-soil development textures and glacial structures are preserved and an unoxidized C2 horizon typically found at a depth greater than 2 metres (Epp and Kenk, 1983). Forest cover comprises hybrid Engelmann – white spruce and subalpine fir on hills whereas extensive areas of lodgepole pine cover plateaus.

Exploration History

Initially explored in the 1970s as a porphyry copper prospect and subsequently dropped, the Mount Milligan property was acquired in the early 1980s as an alkaline copper-gold porphyry target based on the QR deposit model. Release of British Columbia regional geochemical survey data (BC RGS 11 - NTS 93N, Manson River) in 1984, confirmed the property's anomalous nature. King Richard Creek, draining the Mount Milligan property, recorded the second highest copper value (493 ppm) in the RGS 11 survey. Geochemical soil surveys from 1984 to 1986 defined broad copper-gold soil anomalies in colluvium on the North and South Slope zones east of Heidi Lake and small, linear copper-gold soil anomalies in moraine and glaciofluvial sediments on the eastern flank and terrace.

By 1990, follow-up geophysical surveys and extensive diamond drilling had defined the mineralized systems associated with the MBX and Southern Star stocks underlying the anomalies on the eastern flank and terrace. The association between soil anomalies developed in the complex, often thick surficial deposits and underlying mineralization was unclear. In addition, a bedrock source for the North Slope colluvium anomalies had not been defined.

METHODS

Sample Collection

SURFICIAL DEPOSIT AND SOIL HORIZON COMPARISONS

One-kilogram B and C-horizon soil samples were collected from 26 test pits ranging from 2 to 5 metres in depth, in the area underlain by the MBX and Southern Star stocks (Figure B-6-3). Mean depth for B-horizon soil samples was 30 centimetres, individual depths ranged from 20 to 60 centimetres, C horizon soil samples varied from 50 to 210 centimetres and averaged 115 centimetres in depth. Field duplicate samples were collected at six of the sites. Samples of mineralized float and bedrock were collected where available. Site observations were recorded regarding: soil type and horizon, depth of sampling, texture of sample, type of overburden, site physiography, nature and abundance of float, nature and abundance of barren and mineralized float and any abnormalities within the overburden such as ferromanga-

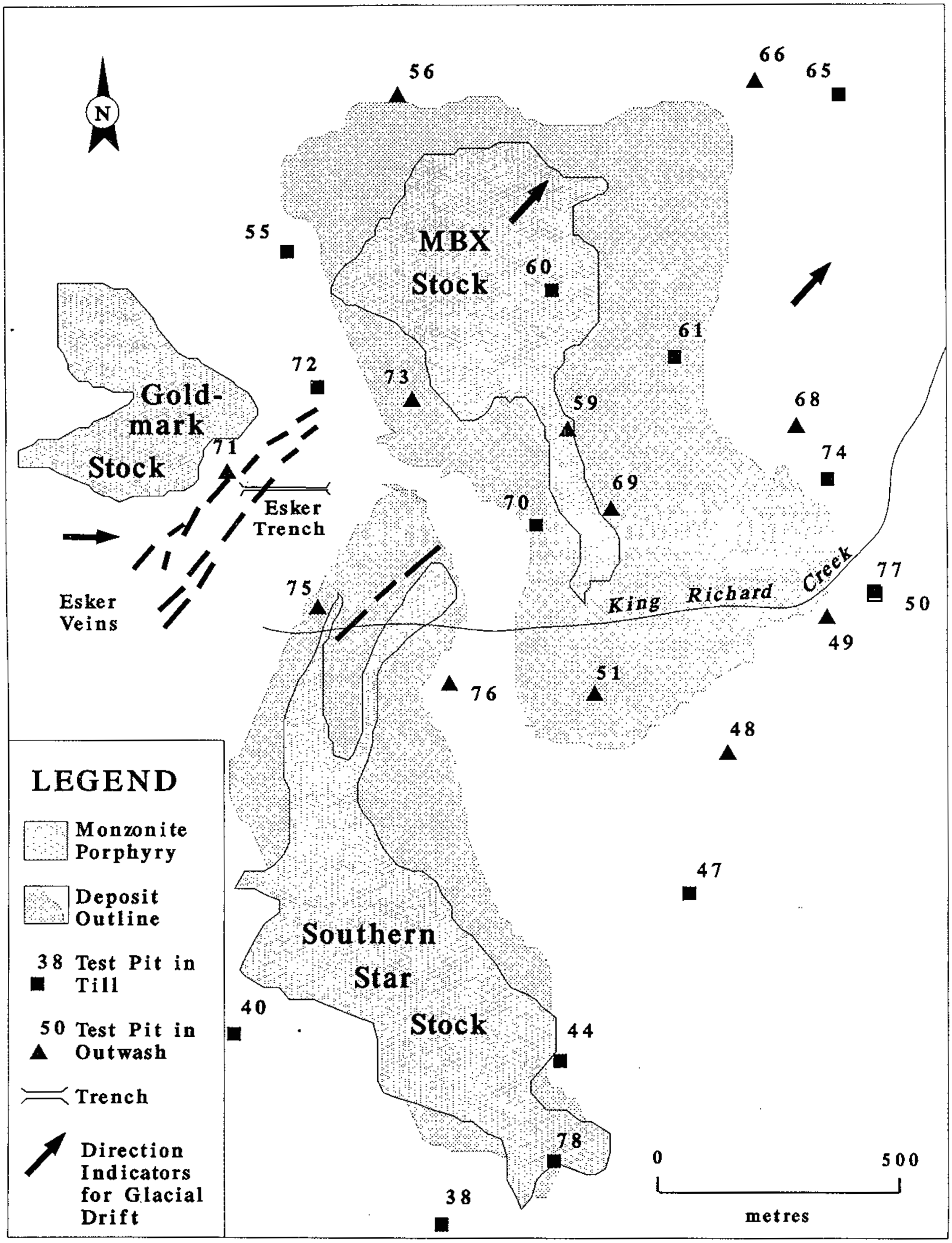


Figure B-6-3. Location of test pits and the Esker zone trench in relation to mineralization.

neous concretions. Photographs and sketches were made of sampled profiles.

DISPERSION IN GLACIOFLUVIAL SEDIMENTS

Profile sampling was conducted along a 160-metre trench intersecting mineralized veins in the Esker zone. Bulk 10-kilogram B-horizon soil samples and routine 1-kilogram C-horizon soil samples were collected at 50-centimetre intervals down profile. Eight profiles spaced 10 to 20 metres apart were sampled with each profile yielding from two to six samples. Rock-chip samples (1 kilogram) of underlying bedrock were collected where possible. Photographs, sketches and site observations were recorded for each profile.

DISPERSION IN COLLUVIAL SOILS

Seven sites were sampled for bulk B-horizon soil, C-horizon soil and bedrock-chip samples (were possible). Research centred on grid location 115+00N, 93+50E where a 19000 ppb (0.55 oz/t) gold anomaly was reported by the original soil sampling program conducted by the property owners. A pair of field duplicate samples, spaced 5 metres apart, was collected at this site.

SAMPLE PROCESSING

All samples were sent to ACME Analytical in Vancouver for processing and analysis. B and C-horizon soil samples were dry sieved to -80 mesh ASTM (-177 μm). In addition, C-horizon soils were dry sieved to -40+80 mesh (-420+177 μm). Chip samples of float and bedrock were crushed and pulverized to -100 mesh (-150 μm).

B-horizon bulk samples were divided into two splits, one split from each sample was dry sieved to coarse (-40+80 mesh) and fine (-80 mesh) size fractions. Magnetic and nonmagnetic heavy liquid concentrates were produced from the -80 mesh fraction of the remaining split using bromoform (specific gravity = 2.96 g/cm^3). Pan concentrates were produced from coarse reject material.

SAMPLE ANALYSIS

Subsamples (0.5 gram) of all size fractions of soil and pulverized rock were subjected to aqua regia digestion (3 millilitres of 3-1-2 $HCl:HNO_3:H_2O$ at 95°C for 1 hour then diluted to 10 millilitres with water). Sample solutions were then analysed by inductively coupled plasma emission spectrometry (ICP-ES) for determination of a suite of 29 elements (Al, Sb, As, Ba, Bi, B, Cd, Ca, Cr, Co, Cu, Fe, La, Pb, Mg, Mn, Mo, Ni, P, K, Ag, Na, Sr, Th, Ti, W, U, V and Zn). Results are quantitative for base metals and silver (0.1 to 2 ppm detection limits), semi-quantitative for siderophile and lithophile elements (1 ppm to 100 ppm detection limits) and qualitative for refractory elements such as boron, chromium and tungsten (1 ppm detection limits). Gold content was measured using 10-gram soil subsamples (-80 mesh) and 30-gram rock-chip subsamples (-100 mesh) by fire assay flux digestion followed by ICP-ES determination. Reported detection limit by this method is 1 ppb.

Some pan and heavy liquid concentrates from bulk B-horizon samples were examined under a binocular microscope to recover gold grains for examination and photography using the scanning electron microscope (SEM) at The University of British Columbia in Vancouver. Samples were selected based on gold content determined by fire assay ICP-ES.

RESULTS

GEOCHEMICAL COMPARISON OF SURFICIAL DEPOSITS

Locations of the 26 test pits for this comparison are presented in Figure B-6-3. Thirteen of the profiles are in glaciofluvial outwash, the remaining sites are in till. Most of the Southern Star deposit is blanketed by matrix supported till which increases in thickness towards King Richard Creek. Conversely, the MBX deposit is covered primarily by outwash of variable thickness which contains isolated exposures of the underlying till and bedrock. Outwash texture ranges from coarse cobbles in a sandy matrix to well-sorted, stratified sands. Soil profiles developed in both parent materials are dominantly humo-ferric podzols. Angular fragments of local mineralized bedrock were evident in varying amounts in both the till and outwash units. Ferro-manganous concretions were noted within the C horizon in several pits close to the MBX stock, generally in close association with abundant mineralized float.

Table B-6-1 lists the pH, copper content and gold content by soil horizon and overburden type within the test pits. Mean copper concentrations of B and C-horizon samples in till-derived soil exceed two times the average concentration found in the corresponding horizons for soil derived from outwash. F-tests indicate a significant (95% confidence limit) difference in mean copper concentrations in soils developed over till, relative to soils formed in outwash (Table B-6-2a).

Mean gold concentrations demonstrate a similar geochemical distinction between surficial deposit types. B horizons in till-derived soils have mean gold contents 2.7 times higher than outwash-derived B-horizon soils. After excluding test pit 71 (C horizon concentration of 733 ppb) which significantly biases statistical calculations, C-horizon gold concentrations in till-derived soils average 2.3 times higher then C-horizon concentrations in outwash-derived soils.

GEOCHEMICAL COMPARISON OF SOIL HORIZONS

Overall, soil pH values are slightly acidic, ranging from a pH of 4.9 to 6.4. Mean B-horizon pH levels are lower than C-horizon pH levels for both till and outwash-

TABLE B-6-1
pH, COPPER AND GOLD CONCENTRATIONS IN SOIL PROFILES OVERLYING THE MBX AND SOUTHERN STAR ZONES

Outwash								Till							
Test Pit	Samp #	Soil Hor.	Depth (m)	Zone	pH	Cu (ppm)	Au (ppb)	Test Pit	Samp #	Soil Hor.	Depth (m)	Zone	pH	Cu (ppm)	Au (ppb)
71	905001	Bf	0.30	MBX	5.1	75	19	72	905004	Bf	0.30	MBX	5.5	71	29
71	905002	C	0.70	MBX	5.6	495	733	72	905005	C	1.20	MBX	5.7	715	85
56	905011	Bf	0.20	MBX	5.0	42	39	55	905008	Bf	0.20	MBX	5.3	165	40
56	905012	C	0.60	MBX	5.8	114	52	55	905009	C	1.20	MBX	5.2	99	37
66	905017	Bf	0.35	MBX	5.6	55	46	65	905014	Bf	0.30	MBX	5.4	137	507
66	905018	C	1.00	MBX	5.8	143	57	65	905015	C	0.70	MBX	5.7	511	134
59	905024	Bf	0.25	MBX	5.3	61	77	61	905021	Bf	0.30	MBX	5.4	129	12
59	905026	C	0.90	MBX	5.7	228	78	61	905022	C	0.50	MBX	5.6	172	19
73	905032	Bf	0.30	MBX	5.5	59	55	60	905030	Bf	0.50	MBX	5.1	258	41
73	905034	C	0.70	MBX	5.7	161	20	60	905031	C	0.95	MBX	5.9	1094	90
69	905042	Bf	0.30	MBX	5.0	93	16	70	905040	Bf	0.35	MBX	5.3	332	103
69	905043	C	1.50	MBX	5.4	241	23	70	905041	C	0.60	MBX	5.5	1229	73
68	905046	Bf	0.25	MBX	4.9	57	205	74	905049	Bf	0.30	MBX	5.0	31	28
68	905047	C	1.00	MBX	5.5	126	14	74	905050	C	2.00	MBX	5.4	58	8
75	905052	Bf	0.40	S.S	5.0	152	12	77	905072	Bm	0.30	S.S	5.7	123	285
75	905054	C	1.20	S.S	5.7	93	23	77	905074	C	2.00	S.S	6.3	327	57
76	905058	Bm	0.30	S.S	5.2	66	10	47	905079	Bm	0.60	S.S	5.8	168	69
76	905059	C	1.60	S.S	5.5	140	22	47	905080	C	1.20	S.S	5.9	183	65
51	905062	Bf	0.40	S.S	5.2	42	5	44	905081	Bh	0.50	S.S	5.8	193	115
51	905063	C	0.80	S.S	5.4	79	13	44	905085	C	1.00	S.S	5.2	386	109
49	905066	Bf	0.25	S.S	5.0	26	18	78	905087	Bm	0.30	S.S	6.4	60	47
49	905067	C	2.10	S.S	5.5	46	35	78	905088	C	0.60	S.S	5.9	95	114
50	905069	Bf	0.30	S.S	5.1	37	4	38	905091	Bm	0.45	S.S	5.7	67	55
50	905070	C	0.70	S.S	5.6	64	11	38	905092	C	1.60	S.S	6.1	147	27
48	905076	Bf	0.30	S.S	5.1	47	4	40	905093	Bf	0.30	S.S	5.8	70	17
48	905077	C	1.90	S.S	5.9	76	15	40	905095	C	1.80	S.S	5.9	380	50
Mean - B horizon:					5.2	62	39	Mean - B horizon:					5.6	139	104
Std dev - B horizon:					0.2	32	55	Std dev - B horizon:					0.4	86	141
Mean - C horizon:					5.6	154	84	Mean - C horizon:					5.7	415	67
Std dev - C horizon:					0.2	118	196	Std dev - C horizon:					0.3	382	39

derived soils. Mean copper concentrations show a strong difference between the B and C soil horizons in both types of overburden. Mean copper concentrations in the C horizon average 2.5 to 3.0 times higher relative to the B horizon for soils derived from outwash and tills respectively. At test pit 72 which demonstrates the greatest contrast, copper increases by an order of magnitude between the B (71 ppm) and C (715 ppm) horizons. Results of F-tests (Table B-6-2a) clearly indicate that B and C soil horizons contain significantly different copper concentrations at the 95 per cent confidence level in both till and outwash.

An analysis of variance (Table B-6-2b) which examines within-site variability (B versus C horizon) relative to between-site variability (B horizon at site 1 versus B horizon at site 2) was conducted using copper concentrations. F-ratios for both till and outwash-derived soils exceed the critical F-value at the 95 per cent confidence limit, indicating that differences between soil horizons are greater than differences between sites.

A comparison of gold concentrations between soil horizons demonstrates an erratic pattern. Significant differences, measured by a 100 per cent difference in concentration between horizons, are noted at 10 of 19 anomalous sites (average gold concentration between horizons is >25 ppb). These ten sites are evenly split with five reporting higher B-horizon gold concentrations and five having higher concentrations in the C horizon.

DISPERSION OF COPPER AND GOLD IN GLACIOFLUVIAL SEDIMENTS

A series of high-grade copper-gold (arsenic, silver, lead, zinc, molybdenum) quartz veins hosted by Witch Lake Formation volcanics comprise the Esker zone. The veins, which trend 050° and dip 70° northwest, lie approximately 500 metres southeast of the MBX stock. Profile sampling was conducted along a previously excavated 160-metre trench which intersects the Esker zone. The trench lies 20 metres south of line 91N and extends from 122+30E to 123+90E. Mineralized bedrock is exposed sporadically from 122+50E to 123+15E.

Surficial cover, shown schematically in Figure B-6-4, comprises outwash varying in depth from 0.5 to 2.5 metres (maximum depth of trenching). Orientation of the trench parallels the local paleocurrent direction of 090°. Sediment textures vary from clast-supported coarse cobbles in a sandy matrix to well-sorted stratified sands. B-horizon development in the dominantly humo-ferric podzols ranges from 30 to 70 centimetres in depth and is underlain by an oxidized C horizon (C1). Unoxidized C horizons (C2) were noted in the bottom of three pits at an average depth exceeding 2.0 metres and as a perched layer at a depth of 1.0 to 1.5 metres in test pit 95.

Copper and gold concentrations in mineralized bedrock samples range from 97 to 1471 ppm and 41 to 107 ppb respectively. Large, angular, mineralized clasts were noted in all profiles. Abundance of mineralized clasts varies from 50 per cent near bedrock to 5 per cent in distal profiles. Iron and manganese cementation of the outwash is found close (<5 metres) to bedrock and is conformable to bedding within the drift.

Table B-6-3 presents the results of reduced major axis regression analysis comparing -40+80 mesh and -80 mesh fractions of B and C soil horizon samples from the Esker trench. Concentrations of most elements are significantly higher (95% confidence limit) in the -80 mesh fraction. Significant (95% confidence limit) correlations are noted between the two size fractions for all elements except gold.

Table B-6-4 compares concentrations for copper, iron, manangese, gold and pH between horizons and size fractions. Considerable increases in concentration with depth are noted for these elements, with the effect generally greater in the -80 mesh fraction.

This trend is most pronounced for copper (Figure B-6-5). Excluding test pit 91, which contains subcroping mineralized bedrock, mean concentration of copper in the Bf horizon (sampled at an average depth of 25 cm) is 57 ppm (standard deviation of 13 ppm). In the upper C1-horizon samples (collected at an average depth of 55 cm), copper increases to an average concentration of 179 ppm (standard deviation of 97 ppm). Greatest variability occurs in profiles close to bedrock (test pits 90 to 95) where copper concentrations generally increase four-fold between the B and upper C horizon and attain maximum concentrations at the base of the pits.

Laterally, copper concentrations diminish with distance. Test pit 98, located 55 metres down paleocurrent from mineralized bedrock, has a maximum concentration of 134 ppm. Background for glaciofluvial sediments, based on test pits 48 to 51, is 66 ppm (standard deviation of 15 ppm). Contouring sample concentrations (Figure B-6-5), using arbitrarily chosen levels of 100 and 300 ppm, defines two lobes of moderately enriched copper in sediment extending down paleocurrent from mineralized bedrock. The upper-most lobe is not evident in surface (B horizon) samples.

Figure B-6-6 presents vertical and lateral variability for gold concentrations in soils. Moderately enhanced concentrations (>15 ppb) are noted near bedrock with good correlation between bedrock and surrounding overburden concentrations. A plume of gold-enriched material (>100 ppb) is seen extending towards the surface and down paleocurrent from test pit 95 to test pit 98. Background for glaciofluvial sediments, as determined from test pits 48 to 51, is 7.8 ppb (standard deviation of 6.5 ppb). The anomalous plume is present within the B-horizon. Heavy mineral concentration of the B horizon bulk soil sample from test pit 90 produced several coarse (>50 microns) gold grains. One equant gold grain recovered

TABLE B-6-2a
RESULTS OF F-TESTS ON CU CONCENTRATIONS OF B AND C HORIZON SOILS

Outwash

B horizon variance:	1022.7	Degrees of Freedom: 12
C horizon variance:	13947.6	Degrees of Freedom: 12

Till

B horizon variance:	7389.1	Degrees of Freedom: 12
C horizon variance:	145618.6	Degrees of Freedom: 12

F-ratios

($F_{crit(0.05,12,12)}$: 2.69)

	B Horizon	C horizon
Till vs. Outwash	7.22	10.44
	Till	**Outwash**
B Horizon vs. C Horizon	19.71	13.64

TABLE B-6-2b
ANALYSIS OF VARIANCE ON B AND C HORIZON CU CONTENTS

Outwash

Source	Sum of Squares	DF	Mean-Square	F-ratio	$F_{crit(0.05,12,12)}$
Between	1022.8	12	85.2	23.3	2.69
Within	23852.8	12	1987.7		

Till

Source	Sum of Squares	DF	Mean-Square	F-ratio	$F_{crit(0.05,12,12)}$
Between	7389.1	12	615.8	14.2	2.69
Within	105133.4	12	8761.1		

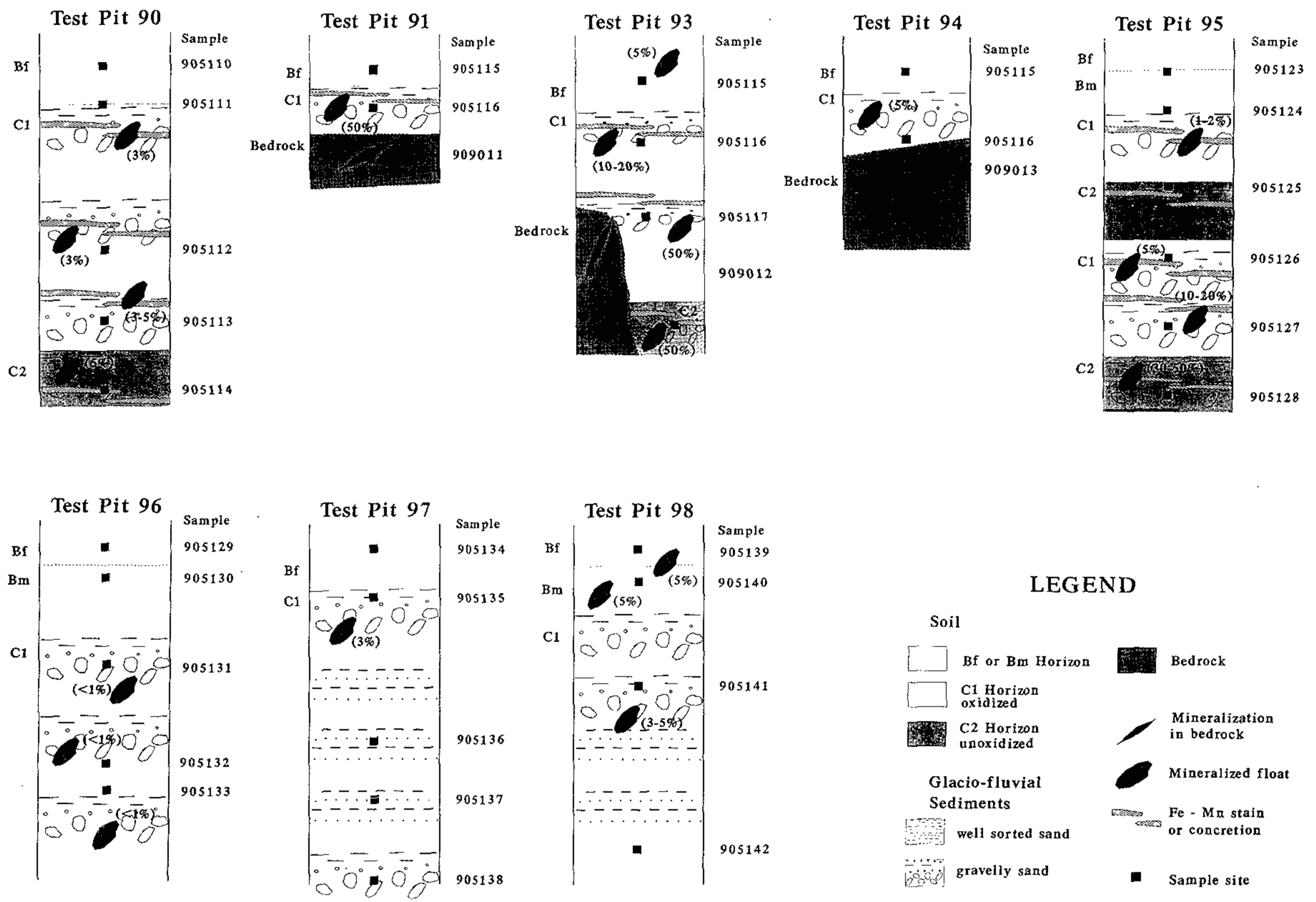


Figure B-6-4. Schematic representation of overburden profiles at the Esker zone trench.

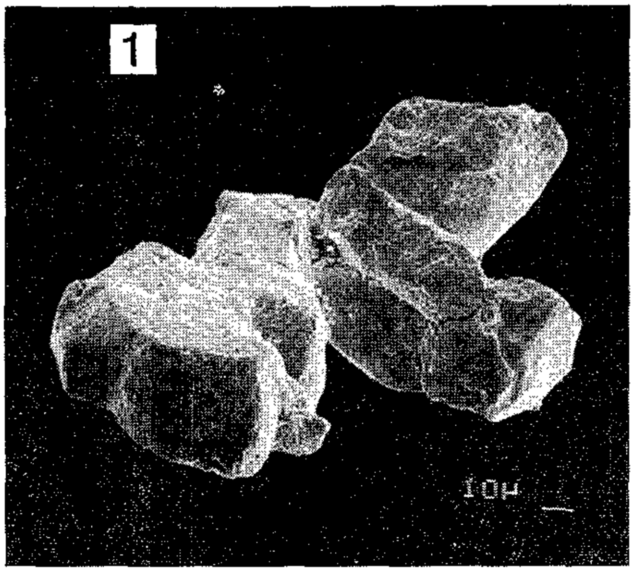
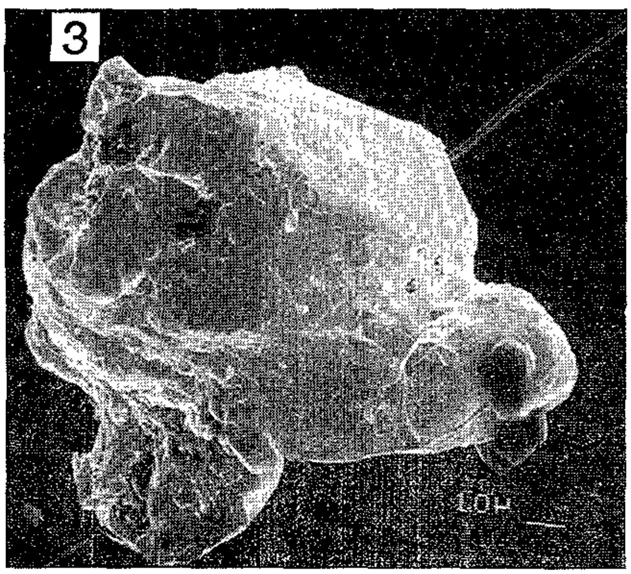
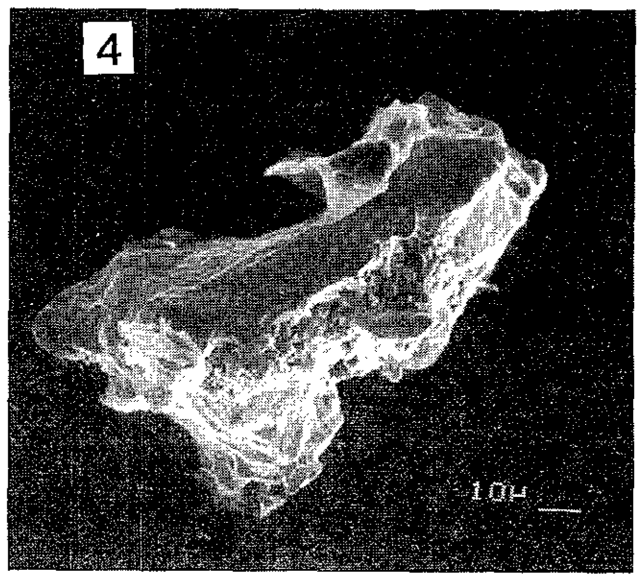
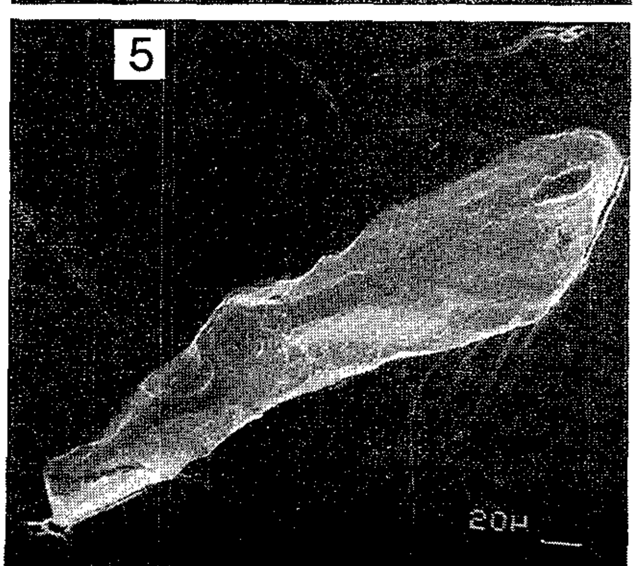


Plate B-6-1. Equant gold grain recovered from the Esker zone trench.







Plates B-6-3, B-6-4, B-6-5. Gold grains recovered from the North Slope site.

Plate B-6-2. Site of 19 000 ppb (0.54 oz/ton) gold soil anomaly on North Slope. Note the veneer (15-30 cm) of colluvium overlying bedrock. Cursory field panning of duplicate samples produced numerous visible grains.

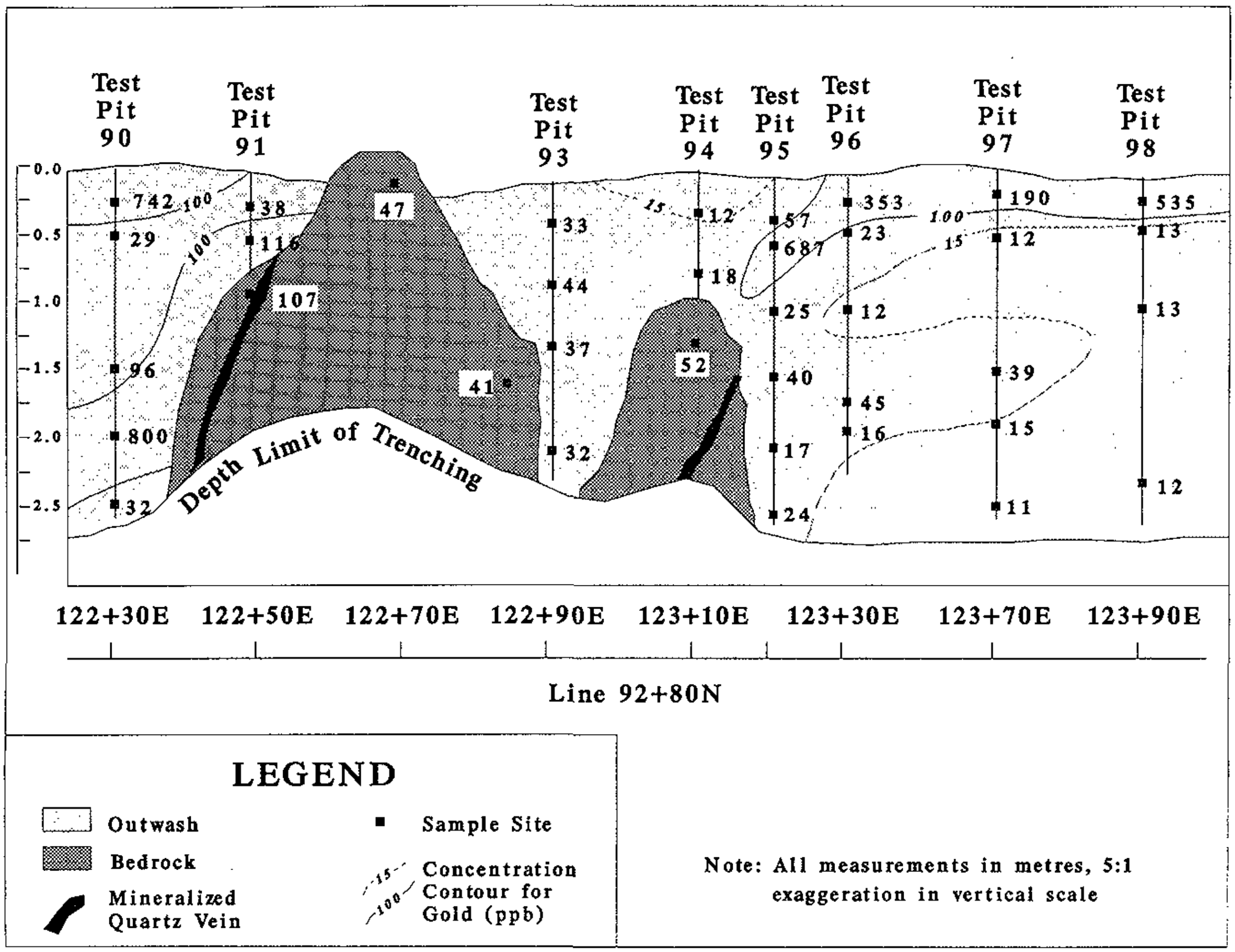


Figure B-6-5. Vertical and horizontal variations in copper concentration along the Esker zone trench.

(Plate B-6-1) has well-defined crystal faces which have been pitted.

Dispersion of Gold in Colluvium

A broad, coherent region of elevated gold (> 30 ppb) and copper (> 100 ppm) concentrations in complex overburden covering the north wall of the Heidi Lake valley, approximately 1300 metres west of the MBX intrusion, is locally known as the North Slope zone (Plate B-6-2). Underlying lithology consists of andesite flows intruded by minor dikes and plugs of monzonite porphyry. Surficial deposits vary from a colluvium veneer (< 1.0 metre thick) on the steep (> 30°) middle slopes to a morainal blanket (> 1.0 metre thick) on the gentle uppermost slopes. Site 93N, 115 + 50E, in the original soil survey, contained strongly anomalous gold (19 000 ppb) in thin colluvium (Plate B-6-2). Subsequent bedrock sampling by the owners could not locate a conclusive source.

Sampling of the overburden and nearby bedrock at site 93N, 115 + 50E (Table B-6-5 and Figure B-6-7) essentially reproduced original results, although absolute concentrations of gold are considerably lower. Colluvium at this site is strongly anomalous, containing 3074 ppb gold as detected in the -80 mesh fraction of a 1-kilogram sample. Bedrock immediately down-slope (93N, 115 + 44E) gave only moderately enhanced levels (66 ppb mean concentration). Analysis of various size and density fractions from a 10-kilogram bulk B horizon sample collected at the strongly anomalous site gave remarkably consistent gold contents of 2860 ppb (-80 mesh size fraction), 3736 ppb (-270 mesh size fraction) and 2128 ppb (+ 270 mesh size fraction, < 2.96 g/cm^3 density fraction). The coarse size fraction (+ 80 mesh) contained less gold (875 ppb).

Samples from surrounding sites gave lower concentrations, although all samples exceeded 100 ppb gold and 175 ppm copper. Nearly identical values for copper and highly consistent values for gold are noted in coarse to fine size fraction comparisons at these sites. Profile samples from sites 93 + 50N, 114 + 50E and 93N, 115 + 55E show increasing copper concentration with depth.

Binocular microscope scanning of heavy mineral (magnetic and nonmagnetic) and pan concentrates produced surprisingly few gold grains. A maximum of four

TABLE B-6-3
REDUCED MAJOR AXIS REGRESSION ANALYSIS COMPARING FINE AND COARSE FRACTION CONCENTRATIONS FOR VARIOUS ELEMENTS

Slope of Element	Intercept of Regression	Correlation Regression	95% Confidence Coefficient	95% Confidence Limits on Slope Lower	Upper	Limits on Intercept Lower	Upper
Copper	0.857	0.176	0.9767	0.822	0.884	0.098	0.255
Zinc	0.859	-0.050	0.9828	0.833	0.884	-1.394	1.293
Manganese	0.771	40.868	0.9714	0.741	0.800	25.692	56.054
Iron	0.795	-0.004	0.9306	0.746	0.844	-0.225	0.217
Arsenic	0.666	-0.156	0.7757	0.580	0.752	-1.486	1.173
Vanadium	0.900	0.690	0.8614	0.816	0.984	-8.569	9.949
Calcium	0.962	0.111	0.9086	0.892	1.032	0.080	0.143
Aluminium	0.759	0.038	0.9548	0.722	0.796	-0.039	0.115
Gold	-0.726	2.969	-0.2057	nil		nil	

Notes: Regression equations are of the form $Y = sX + i$; where Y is the Y axis value (element concentration in +80 mesh fraction subsample) and X is the X axis value (element concentration in -80 mesh subsample), i is the Intercept of Regression and s is the Slope of Regression. A Slope of Regression value < 1.0 indicates higher concentrations in the -80 mesh fraction. Critical Correlation Cofficient (r) for 43 paired samples at the .95 confidence limit is 0.264.

gold grains larger than 50 microns were recovered per bulk sample. Ubiquitous limonitic coatings and numerous relict pyrite grains were noted. SEM examination of gold grains revealed pristine crystals (classification after DiLabio, 1990) having smooth surfaces and no evidence of curled thin edges (Plates B-6-3 to B-6-5).

DISCUSSION

Variations in Copper and Gold Concentrations Related to Surficial Deposits

The significantly higher mean copper and gold concentrations of till-derived soils relative to outwash-derived soils probably reflects the genesis of the two forms of drift. Outwash, in general, originates from a larger source area than till and will contain a greater proportion of sediment derived from nonlocal, barren sources. Till units overlying the property have a more local origin and contain a higher proportion of local, anomalous bedrock. However, observations of abundant mineralized float in the trench on the Esker zone and other test pits indicate that anomalous outwash can develop by incorporating local mineralized bedrock or by reworking mineralized drift of local derivation.

Variations in Copper Concentrations Related To Weathering

Significantly higher copper concentrations within the C horizon relative to the B horizon appear to be the result of weathering and soil-forming processes acting upon sulphides ubiquitous to the various types of glacial drift. Depleted copper concentrations in till, outwash and colluvium B-horizon soil samples at Mount Milligan indicates a common process affecting the surficial materials during soil formation. Evidence for sulphide weathering and hydromorphic remobilization is suggested by:

(a) an extensive pyrite halo in bedrock which encompasses the study area,
(b) relict pyrite grains in panned bulk samples,
(c) limonitic coatings on all mineral grains,
(d) low pH levels in most soils which increase in value with depth,
(e) uniformly lower copper contents in upper B soil horizons,
(f) the development of iron-manganese concretions close to mineralized bedrock and float.

Features c, d, e and f are readily explained by the oxidation of sulphides, particularity pyrite and chalcopyrite, in the upper soil horizons. In a simplified reaction (Levinson, 1974):

$$4FeS_2 + 15O_2 + 10H_2O \text{ -> } 4FeO(OH) + 8H_2SO_4.$$

Pyrite in the presence of oxygen and water decomposes to form limonite and sulphuric acid. With sufficient decomposition of pyrite and other sulphides, together with naturally occurring humic and carbonic acids, the buffering capacity of the soil (if any) is exceeded such that soil pH drops below the point of hydrolysis of Fe^{+2} (5.5), promoting the mobility of iron as free ions in surface

TABLE B-6-4
ELEMENT CONCENTRATIONS IN VARIOUS SOIL HORIZONS AND SIZE FRACTIONS - ESKER ZONE TRENCH

Test Pit	Sample #	Soil Hor.	Depth (m)	pH	Copper -80	Copper +80	Iron -80	Iron +80	Manganese -80	Manganese +80	Gold -80	Gold +80
90	905110	Bf	0.25	5.4	52	61	3.83	4.02	271	357	742	12
	905111	C1	0.50	5.6	165	106	6.02	5.16	467	411	29	-
	905112	C1	1.50	5.6	274	144	5.37	5.19	642	466	96	-
	905113	C1	2.00	5.7	593	352	4.78	5.04	711	628	800	-
	905114	C2	2.50	5.8	1185	817	4.81	4.64	1666	1283	32	-
91	905115	Bf	0.25	6.1	1172	841	5.65	5.04	590	574	38	15
	905116	C1	0.50	5.7	1401	679	6.95	5.18	669	582	116	-
93	905117	Bf	0.30	5.6	87	93	4.13	4.18	213	306	33	13
	905118	C1	0.75	5.7	306	169	6.33	4.52	508	450	44	-
	905119	C1	1.20	5.6	625	310	5.94	5.51	624	465	37	-
	905120	C2	2.00	5.7	513	392	4.47	4.37	667	643	32	-
94	905121	Bf	0.30	5.5	65	62	3.99	3.96	224	325	12	7
	905122	C1	0.75	5.3	323	219	6.22	4.01	341	333	18	-
95	905123	Bf	0.30	5.6	55	54	3.90	3.52	232	314	57	24
	905124	C1	0.50	5.5	84	53	4.94	3.04	437	377	687	-
	905125	C1	1.00	5.5	191	102	5.12	4.13	578	411	25	-
	905126	C2	1.50	5.5	184	114	5.59	3.82	524	417	40	-
	905127	C1	2.00	5.6	544	281	5.01	4.23	740	543	17	-
	905128	C2	2.50	5.7	623	457	4.06	3.56	841	677	24	-
96	905129	Bf	0.20	5.6	48	47	3.94	3.50	213	313	353	15
	905130	Bm	0.40	5.5	104	95	4.00	3.17	287	285	23	-
	905131	C1	1.00	5.4	145	86	4.43	4.34	514	418	12	-
	905132	C1	1.70	5.7	74	57	4.66	3.05	527	401	45	-
	905133	C1	1.90	5.8	208	117	5.08	3.66	654	476	16	-
97	905134	Bf	0.20	6.0	48	53	4.62	3.22	235	303	190	155
	905135	C1	0.50	5.4	96	75	4.47	3.63	305	321	12	-
	905136	C1	1.50	5.7	62	53	6.18	2.84	428	360	39	-
	905137	C1	1.90	6.0	74	64	6.35	3.52	560	467	15	-
	905138	C1	2.50	7.5	122	63	5.15	3.69	753	481	11	-
98	905139	Bf	0.20	6.1	49	44	5.05	3.26	313	315	535	16
	905140	C1	0.40	5.7	104	80	4.47	4.28	342	362	13	-
	905141	C1	1.00	5.6	134	87	4.10	3.50	445	398	13	-
	905142	C1	2.30	6.1	72	63	5.12	3.27	533	436	12	-

Notes: *-80 = -80 mesh size fraction; +80 = -40 to +80 mesh size fraction*

TABLE B-6-5
ANALYTICAL RESULTS FOR COPPER AND GOLD FROM NORTH SLOPE ZONE SAMPLES

Grid Location	Soil Hor.	pH	Depth (m)	Routine 1-kg Soil Sample Cu+80	Cu-80	Au-80
92+50N 115+00E	Bf	5.4	0.30	418	400	107
	C1	6.0	1.20	838	1023	158
93N 115+00E	Bf	5.8	0.30	267	257	741
93N 115+44E	Bf	5.1	0.25	434	423	679
	Rock 1				281	72
	Rock 2				456	30
	Rock 3				442	96
93N 115+50E	Bf	5.1	0.25	504	430	3074
93N 115+55E	Bf	5.0	0.25	381	344	140
	C1	5.4	1.80	880	854	100

Grid Location	Soil Hor.	pH	Depth (m)	Bulk 10-kg Soil Sample Cu+80	Cu-80	Au+80	Au-80	Au-270	Au+270
93N 115+50E	Bf	5.1	0.25	882	741	895	2860	3736	2128
93N 115+47E	Bf		0.25	470	417	161	277		
93N 115+55E	Bf	5.0	0.25	488	480	94	131		
93N 115+02E	Bf		0.50	177	184	226	290		

Notes: Rock 1 = sample of altered andesite; Rock 2 = fault gouge material; Rock 3 = fresh andesite; +80 = -40 to +80 mesh size fraction; -80 = -80 mesh size fraction; -270 = -270 mesh size fraction; +270 = +270 mesh size fraction, low-density fraction following methylene iodide heavy mineral separation; All copper values in ppm; all gold values in ppb;

water. Upon interaction with the groundwater table at a lower depth, iron-enriched surface water is buffered to a higher pH, resulting in the precipitation of iron as ferruginous cement. In a similar manner, copper as chalcopyrite or related sulphides, is released and mobilized as the Cu^{+2} ion. Precipitation occurs upon encountering a soil pH exceeding 5.3.

Lateral Variations of Copper and Gold in Glaciofluvial Sediments

The source of elevated gold and copper concentrations within the glaciofluvial outwash exposed in the Esker zone is the underlying mineralized bedrock. Evidence to this effect is seen in the close relationship between mineralized bedrock and abundant mineralized float and ferro-manganous concretions in the surrounding fluvioglacial sediment.

Near-surface plumes of copper and gold-enriched sediment can be traced down paleocurrent from mineralized bedrock in test pit 95 to test pit 98, giving a minimum anomalous dispersion length of 50 metres. The plumes likely extend further; lack of a backhoe to extend the trench prevented further sampling. Concentrations of copper and gold in test pit 98 are still significantly above (95^{th} percentile) background. The juxtaposition of the copper plume at a lower depth relative to gold is due to

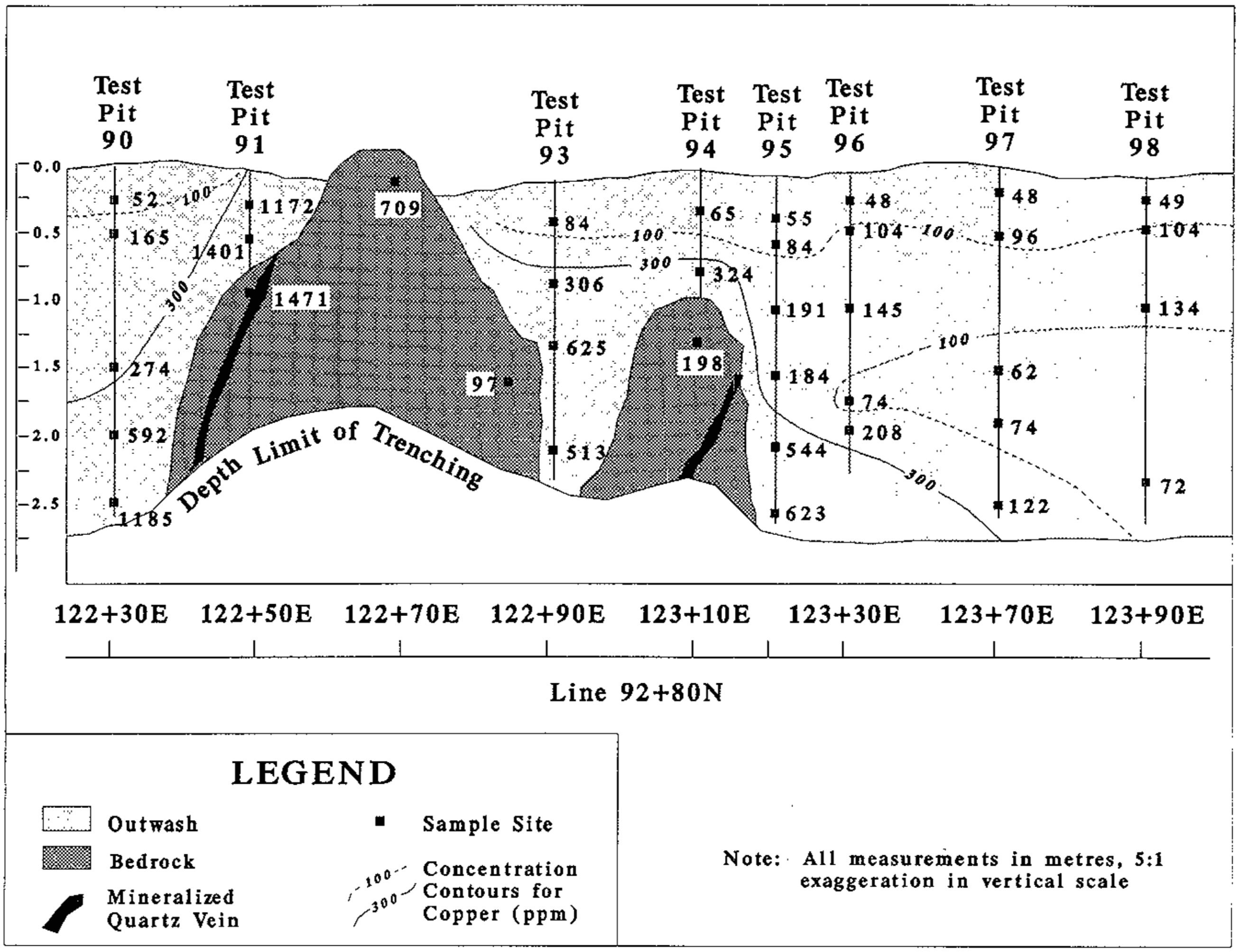


Figure B-6-6. Vertical and horizontal variations in gold concentration along the Esker zone trench.

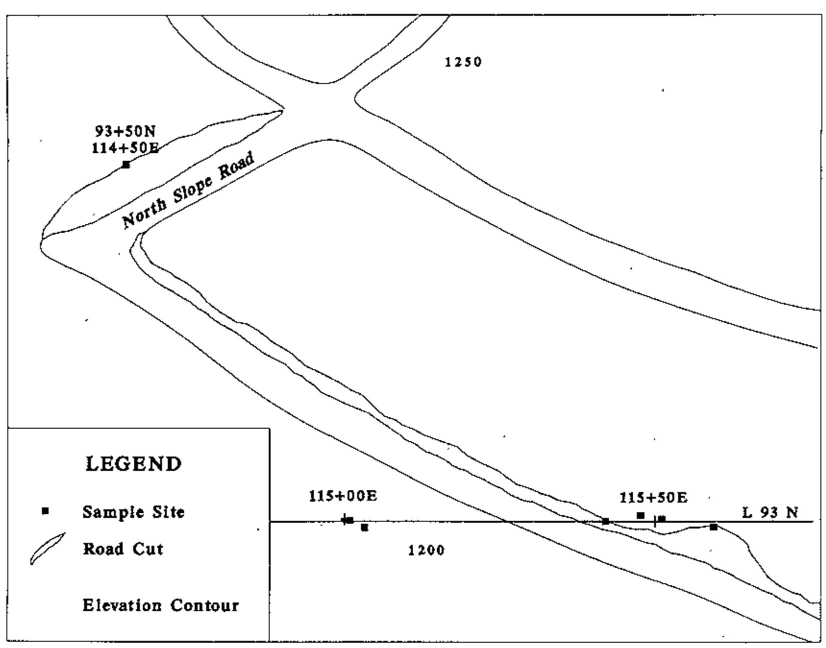


Figure B-6-7. Sample locations at the North Slope site.

post-glacial weathering of near-surface sediment with downward hydromorphic movement of copper. Gold distribution reflects mechanical dispersion developed during initial deposition of the sediment.

Geochemical Behavior of Colluvium

Local (immediately up-slope) point sources of mineralization containing fine-grained gold are thought to underlie the North Slope zone. Gold concentrations in site duplicates and subsamples are reproducible (Table B-6-5) suggesting sufficient grains are available to limit the nugget effect (Ingamells, 1981). Comparable values in coarse and fine fraction subsamples suggest a uniform distribution of fine grains in a lithic or mineral matrix. Additional evidence for fine-grained gold is seen in the apparent lack of coarse (>50 micron) grains recovered in the heavy mineral and panned concentrates as well as the high content of gold in the light-density separate from site 93N, 115+50E.

Abrupt lateral concentration gradients for gold in thin, bedrock-derived colluvium surrounding site 93N, 115+50E suggests a local source with minimum lateral mixing during colluvial processes. Studies by Averill (1978), Averill and Zimmerman (1983), Sauerbrei *et al.* (1987) and DiLabio (1990) document abrasion of gold grains in morainal deposits. Abundance of gold grains and their morphology can be used as a qualitative guide to distance of travel. Insufficient gold grains were recovered from the North Slope samples to qualitatively determine distance of travel, however pristine features on the few grains recovered seem to indicate a local source.

CONCLUSIONS

The following conclusions are made concerning some aspects of the geochemical patterns observed in the complex drift at Mount Milligan.

Significant differences in mean copper and gold concentrations exist in soils derived from till versus soils derived from outwash. The source of this difference is related to the origin of the surficial deposits, specifically the relative proportions of local mineralized material to nonlocal barren material incorporated in the two types of drift. Failure to correctly classify surficial deposit types will complicate interpretation of soil geochemistry and may mask true anomalies and create false anomalies.

Hydromorphic remobilization of copper resulting from oxidation and acid leaching in the near surface environment produces steep vertical concentration gradients within soil. B-horizon samples over mineralization may be so depleted in copper as to be indistguishable from background. Indiscriminant sampling of the B and C soil horizons could generate false anomalies.

Highest copper concentrations are noted in the fine (-80 mesh / -177 micron) fraction, probably due to remobilized copper precipitating as a surface coating on grains.

In the Esker zone trench, a mineralized dispersion train within the glaciofluvial outwash can be traced for a minimum of 50 metres down paleocurrent from a bedrock source and probably extends beyond this distance. Grid soil sampling employing 50 metre spacings would detect the anomalous drift.

Small mineralized subcrops are thought to lie immediately up-slope from the North Slope study site, as suggested by the thin bedrock-derived colluvium and by gold concentrations which exhibit abrupt lateral gradients and good within-site reproducibility.

In summary, anomalous dispersion patterns of gold and copper in surficial materials at Mount Milligan are influenced by the type of surficial deposit and post glacial remobilization due to weathering. Successful application of geochemical techniques in drift prospecting requires a solid understanding of glacial and post-glacial processes. Preliminary mapping of surficial deposits will significantly aid the design and subsequent interpretation of geochemical soil surveys. Orientation surveys, involving detailed sampling of soil profiles in various surficial materials, can delineate influences due to mechanical or weathering effects on dispersion patterns.

ACKNOWLEDGMENTS

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QUATERNARY GEOLOGY AND DRIFT EXPLORATION AT MOUNT MILLIGAN (93N/1E, 93O/4W) AND JOHNNY MOUNTAIN (104B/6E, 7W, 10W, 11E), BRITISH COLUMBIA

(Fig. B1, No. 7)

By D.E. Kerr and P.T. Bobrowsky

INTRODUCTION

An integrated research program in Quaternary mapping and drift prospecting in areas of high mineral potential was initiated in 1990 by the Geological Survey Branch. The long-term objective of the program is to illustrate the utility of surficial geological methods and techniques of analysis applied to the detection of mineral deposits in drift covered areas. Interpretive drift-exploration models applicable to British Columbia will be produced based on types of landforms, sediments and depositional environments.

All areas of British Columbia have been subjected to one or more glaciations. Local topography, style of glacial erosion and deposition and the geologic history of postglacial events influence the type of sediment present, the thickness of the deposits over bedrock and the stratigraphy of an area. Collectively, these factors affect the nature of the surface expression (geochemical anomalies) of the underlying mineral occurrences. In many areas of the province, mineral exploration is hindered and often unsuccessful in dealing with complex and thick Quaternary successions of tills, debris-flow deposits, outwash sand and gravel, lake deposits and colluvium. Quaternary geology can be used as an aid to mineral exploration through the application of drift-prospecting techniques. Proper interpretation of surface geochemical results requires a clear understanding of the Quaternary geology to ensure success in the identification of hidden mineral deposits.

Drift prospecting has proven to be an invaluable tool for mineral exploration in many regions of Canada (Shilts, 1975, 1984), and we believe it can be successfully applied to broad areas of drift-covered or mountainous terrain in British Columbia. Drift-prospecting research was undertaken in two areas of the province during the summer of 1990 (Figure B-7-1):

- the Mount Milligan property north of Prince George, a copper-gold alkali porphyry deposit in the Quesnel trough, and
- the Johnny Mountain property in the northwest, a mesothermal gold-silver vein deposit in the Golden Triangle region.

The approach entailed air-photo interpretation and ground follow-up to produce 1:50 000-scale surficial geology maps for each study area. Detailed maps (1:10 000 and 1:14 000), illustrating the local Quaternary geological features, further assisted in the interpretation of geological and geochemical data. Stratigraphic studies of natural and man-made exposures, as well as overburden drill-hole logs, provided important information as to the composition and nature of the surficial deposits. Pebble-fabric measurements and other paleocurrent determinations were obtained in a variety of sediments to assist in the interpretation of sediment genesis and paleoflow. Pebble counts (lithologic determination) of clasts within sediments helped to confirm ice-flow patterns in relation to mineralized sources. Geochemical soil-profile sampling of pits and trenches at Mount Milligan (Gravel and Sibbick, 1991, this volume) was carried out to illustrate trends in the distribution and concentration of economic elements in different types of surficial materials. Geochemical data previously collected by Continental Gold and Skyline Gold Corporations were reinterpreted using the geological data resulting from this study.

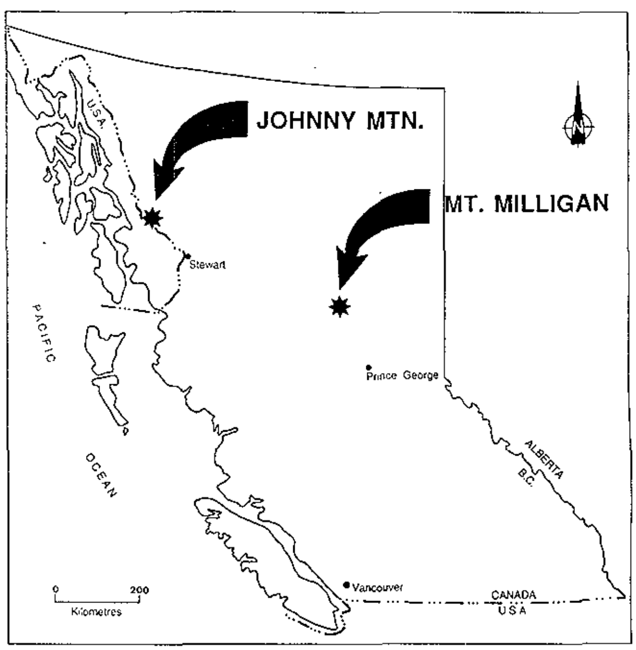


Figure B-7-1. Location map of drift prospecting studies. Mount Milligan in north-central and Johnny Mountain in northwestern British Columbia.

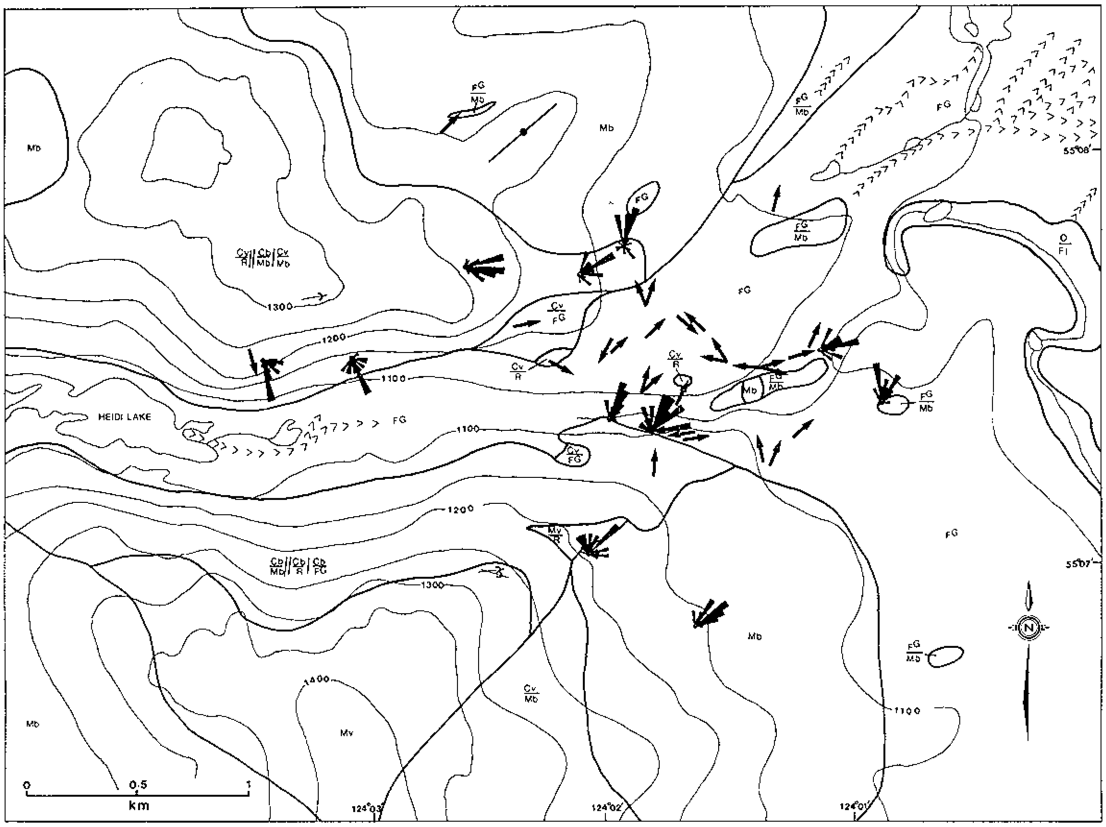


Figure B-7-2a. Detailed surficial geology map of the Mount Milligan property area. Paleocurrent symbols include rose histograms for pebble fabrics, arrows for sand/gravel crossbedding, open-checks for eskers and the standard crossed-line symbol for striations. Map units include Cv (colluvial veneer), F^G (glaciofluvial), Mb (morainal blanket), Mv (morainal veneer), O (organics) and R (bedrock).

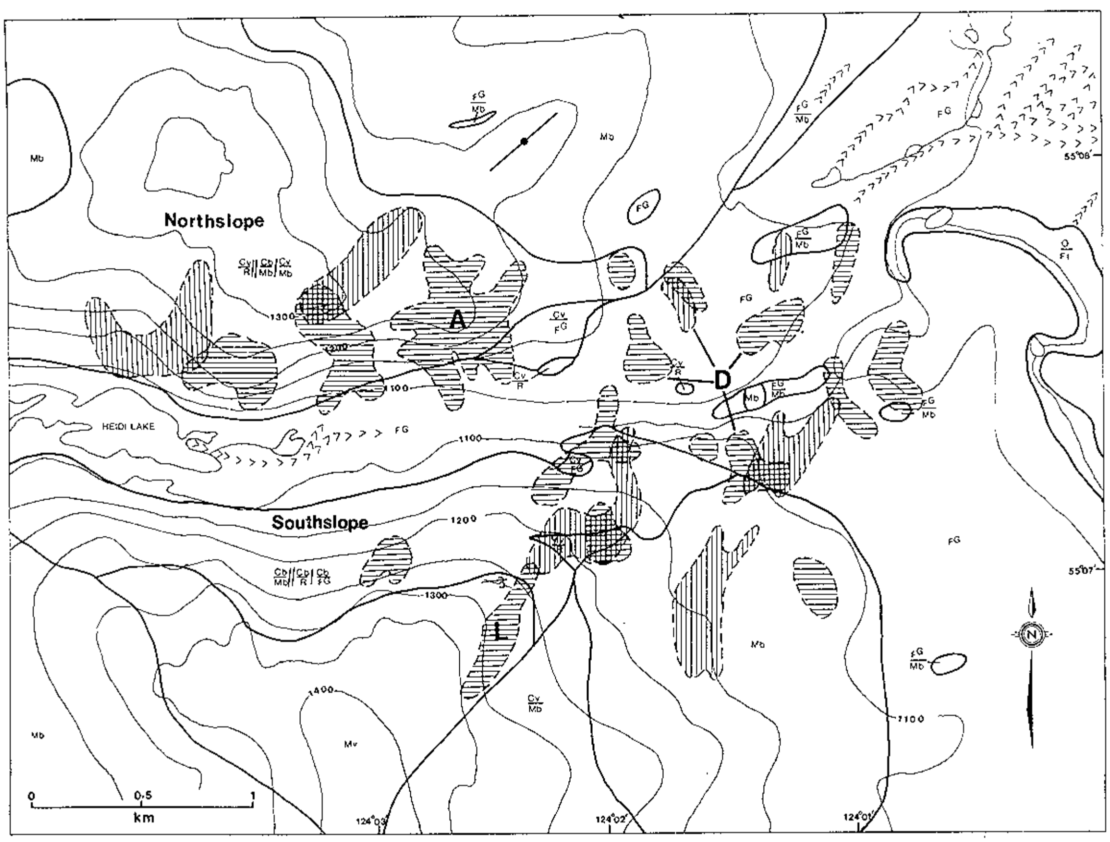


Figure B-7-2b. Illustrated soil anomalies consist of Cu at 150 ppm (vertical lines) and Au at 80 ppb (horizontal lines). Modified from unpublished Continental Gold data. Map units same as in Figure 2a. See text for explanation of letters A, L and D.

RESULTS

MOUNT MILLIGAN

The Mount Milligan property lies approximately 160 kilometres north of Prince George. Situated within the early Mesozoic Quesnel trough, this copper-gold alkali porphyry deposit comprises a series of biotite quartz monzonite, monzonite porphyry and diorite stocks which intrude augite plagioclase porphyries, bedded tuffs and porphyritic agglomerates. The geology of Mount Milligan and surrounding area has been described by Armstrong (1949), DeLong *et al.* (1991), Faulkner (1986, 1988), Faulkner *et al.* (1990), Nelson *et al.* (1991a, 1991b), Rebagliati (1990), Tipper *et al.* (1979), as well as in a number of unpublished assessment reports.

SURFICIAL GEOLOGY

The last glacial episode in the Mount Milligan region probably occurred some 20 000 to 10 000 years ago during the Late Wisconsinan (Fraser Glaciation). Regional ice movement during this final event was primarily to the northeast, as interpreted from ice-flow indicators such as well-developed striae scoured into bedrock and drumlinoid features developed in and on unconsolidated sediments (Kerr, 1991a). This observation of regional flow is in accordance with earlier studies by Armstrong (1949) to the north, west and south of the Milligan area, as well as those of Plouffe (1991) in the Stuart – Fraser Lakes area to the southwest. Southeast of the study area, in the McLeod Lake region, Struik and Fuller (1988) mapped the extent of glacial lake deposits and noted the presence of mineralized clasts in morainal deposits. Previous glacial episodes also affected the study area, but the conditions surrounding these older events can only be interpreted from deeply buried deposits preserved in bedrock depressions.

Surficial sediments identified in the Mount Milligan study map area include diamicton (till and debris-flow deposits), glaciofluvial and fluvial sand and gravel, glaciolacustrine sand, silt and clay, colluvium and organic materials (Kerr, 1991a and Plate B-7-1). Hummocky and drumlinized till deposits are widespread throughout the area, occurring primarily as a blanket along the east half of the map sheet from south of Philip Lakes north to the Nation River. Drift cover is highly variable, ranging from 1 to more than 90 metres in thickness. Drill-hole data show that significant thicknesses of unconsolidated sediments in excess of 100 metres are common directly west of Mount Milligan, and in excess of 200 metres in the Nation Lakes area farther west (Ronning, 1989). For most areas, the till is compact, very poorly sorted and consists of angular to well-rounded pebbles to boulders in a sand-silt-clay matrix (Plate B-7-2).

Drumlinized features, often occurring in "drumlin fields", are restricted to till plains and are best developed in the northern and southeastern parts of the map area. The shape and size of the flutings are variable, and some are more evident on air photos than at ground level. Although the dominant trend of these landforms is to the northeast, easterly oriented features paralleling the Nation River are present in the northeast part of the map area.

A northeast-trending belt of glaciofluvial sediments occurs in the western part of the map area along Fort St. James Highway #27. A second belt, trending east, borders the Nation River to the north, and a third concentration of glaciofluvial sand and gravel dominates the central part of the map directly east of the Mount Milligan property. These sand and gravel deposits consist of sinuous esker ridges, kame deposits with some kettle lakes, and broad overlapping outwash fans (Plate B-7-3). They attain 30 kilometres or more in length and 6 to 8 kilometres in width. Several smaller glaciofluvial corridors occupy the narrow east-west oriented valleys between highpoints south of Mount Milligan.

Stratified glaciolacustrine sediments consisting of interbedded rhythmites of sand, silt and clay occur as isolated deposits (Plate B-7-4). The most extensive deposits (>20 m thick) are exposed in sections along the Nation River (elevation of 850 m) and appear to be confined to the river valley. Elsewhere, such as along tributaries of Rainbow Creek, thin (2-5 m thick) planar and cross-stratified sand and silty clay, glaciolacustrine sediments are evident (elevation of 1025 m). There does not appear to be any spatial relationship between these deposits and the more extensive glacial lake sediments in the Fort St. James basin to the south (Armstrong, 1949).

Holocene postglacial drainage is responsible for the braided and meandering river deposits occurring along the major water courses and tributary streams. Many low-lying and poorly drained areas are now occupied by organic accumulations in bogs, most commonly associated with glaciofluvial and morainal deposits. Colluvium deposits frequently mantle the steeper slopes of hills and valleys and mainly occur directly north and south of Heidi Lake.

A detailed surficial geology map (1:10 000 scale) of the Mount Milligan property was compiled from various data obtained during this investigation, as an aid to reinterpretation of geochemical data (Figures B-7-2a, b). The surficial deposits consist predominantly of diamictons in the form of a till blanket which varies in thickness from 0.5 metre to over 30 metres. A belt of glaciofluvial sand and gravel is confined to the Heidi Lake valley in the west, but fans out to the east over the MBX stock and beyond. Colluvium derived from till and bedrock weathering dominates the hills north and south of Heidi Lake. An approximation of the stratigraphy in the area of the MBX stock

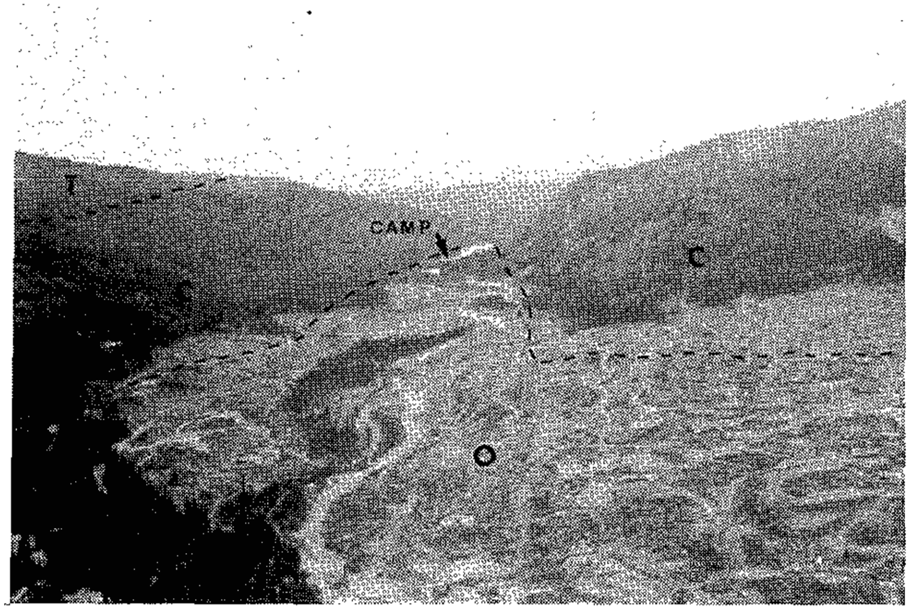


Plate B-7-1. View to west of Mount Milligan property. Symbols include T (till), C (colluvium) and O (outwash). Camp in background is near Heidi Lake.

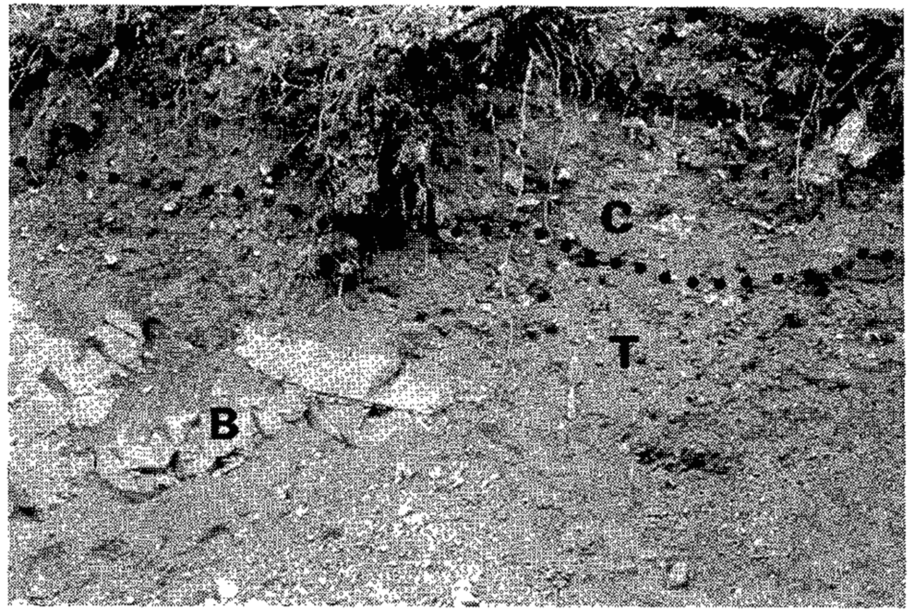


Plate B-7-2. View of colluvium (C) and till (T) over bedrock (B) at Mount Milligan. Dotted line marks approximate transition between the two diamictons. Note trowel near letter T for scale.

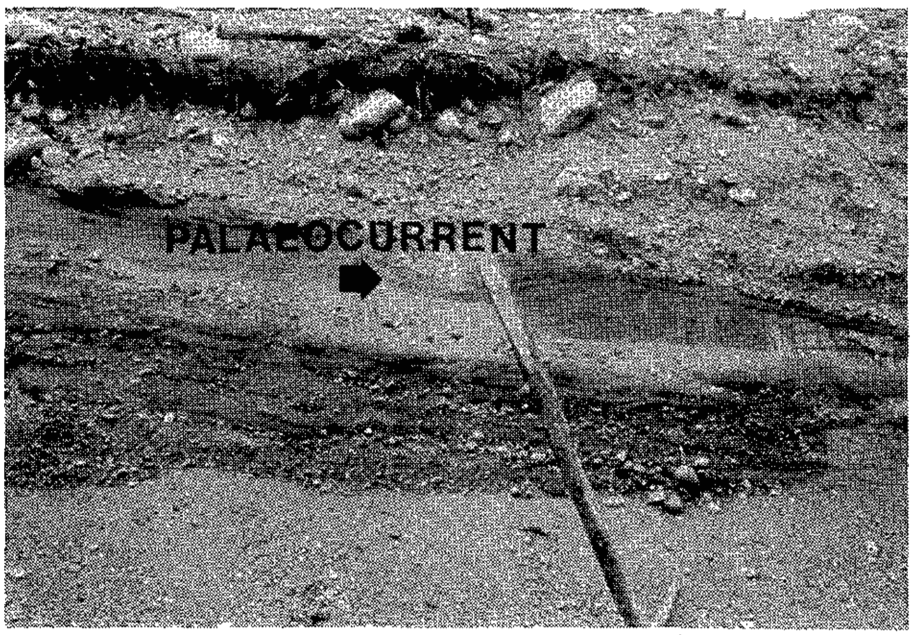


Plate B-7-3. Example of stratified sand and gravel comprising the outwash plain at Mount Milligan. Paleocurrent illustrated.

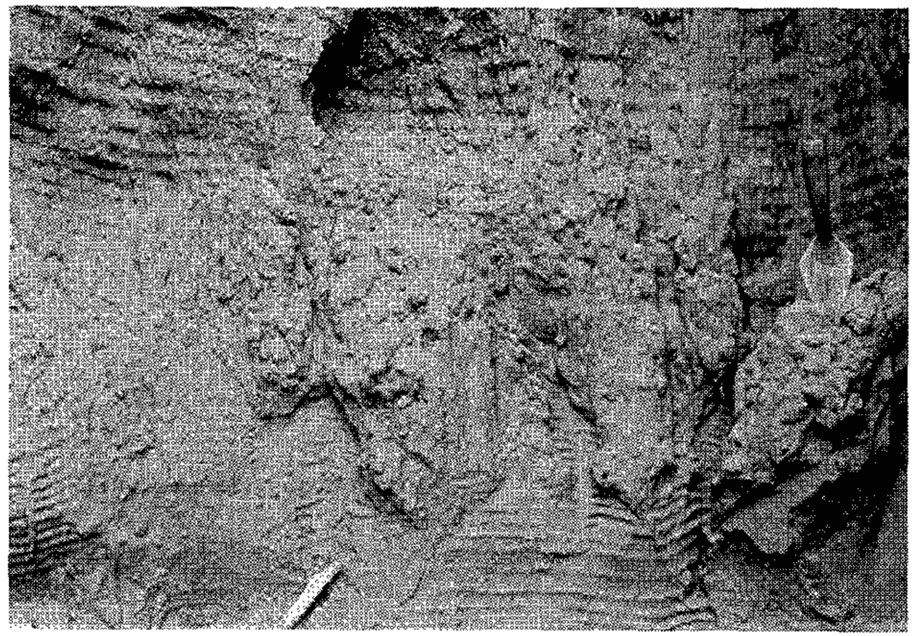


Plate B-7-4. View of deformed sand, silt and clay glaciolacustrine rhythmites directly east of Mount Milligan property.

was interpreted from the drill-hole logs (Figure B-7-3). Although generalized, this interpretation illustrates the stratigraphic complexity of the unconsolidated sediments over very short distances. Noteworthy is the high paleotopographic relief of the underlying bedrock surface.

Striated bedrock and pebble fabrics determined from till indicate that during the last glaciation, ice was deflected locally by hills and funnelled through the small valley now occupied by Heidi Lake. Fabrics indicate initial southeasterly, easterly and northeasterly ice-flow directions in the early stages of ice advance (Figure B-7-2a). This was followed by a predominant northeasterly flow during full glacial conditions as indicated by striae on hill tops and by drumlins (Figure B-7-4). Pebble counts (Figure B-7-5) in till reflect local lithologies (porphyries, monzonite, tuff). These data suggest basal transport in the ice, as well as a proximal origin for the source materials of the till. In only one locality at the northern extremity of the Southern Star stock, a few clasts of rock types outcropping about 30 kilometres to the west were observed, suggesting that a very small fraction of exotic material has been incorporated with the locally derived drift. Deglaciation took place by down-wasting and ice stagnation, and was accompanied by intense glaciofluvial meltwater activity. This is evidenced by extensive well-stratified sand and gravel deposits. Paleocurrent measurements derived from crossbedding and ripple marks exhibit variable flow directions (Figure B-7-2a) which is typical of deglacial outwash sediments. However, the general trend is towards the northeast as indicated by esker ridges and other large-scale sedimentary structures.

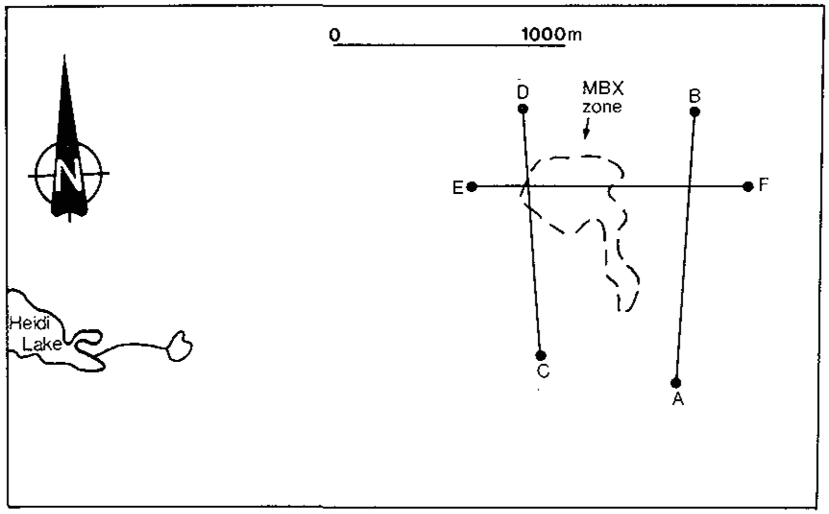
DISCUSSION

The Mount Milligan property provides an excellent example of the importance of surficial geology in drift prospecting surveys because of its known geological setting, the size of the mineralized zones, variable drift thickness and abundance of geochemical data. The complexity of the stratigraphic record for surficial deposits is illustrated in a series of cross-sections (Figure B-7-3). Drill-hole information indicates that the unconsolidated cover of sediment in the Mount Milligan area consists of alternating beds of clay, sand, gravel, boulders and till. Considerable vertical and lateral variation in texture and character of the deposits exists over the entire area. This variability, together with significant changes in drift thickness over short distances (Section E-F), makes correlation of units difficult. It remains unclear if more than one glaciation is recorded in these deposits, as no datable organic material was observed in sections. However, a diamicton interpreted as a second till was encountered east of the property during drilling operations. This till was overlain by a basalt bed and may represent a pre-Late Wisconsinan glacial event.

In areas of relatively thin drift cover, an evaluation of new and existing soil geochemical data was undertaken to study the development of mineralized dispersal trains within various types of surficial sediments (Gravel *et al.*, 1991; Gravel and Sibbick, 1991). Soil geochemistry for copper and gold, as well as other pertinent surficial geology features are summarized in the detailed surficial map.

In the Mount Milligan area, soil geochemical anomaly patterns can be classified into three which in turn, can be related to overburden type as seen in Figure B-7-2b: amorphous-shaped (A), linear or ribbon-shaped (L) and discontinuous or fan-shaped (D). Copper (>150 ppm) and gold (>80 ppb) soil anomalies occur as broad amorphous zones covering 100 000 square metres downslope from source areas in thin colluvium and till veneers over the North Slope and South Slope mineralizations. Linear dispersal trains, some approaching 1 kilometre in length, are associated with till in the Southern Star area. Linear anomalies in till parallel the dominant ice-flow direction to the northeast. Shorter, dispersed anomalies occur in glaciofluvial sand and gravel. Although the latter anomalies trend in the paleocurrent directions of the outwash deposits, their form is discontinuous.

Determining the direction and source of till provenance, as well as the direction of transport of outwash sediments helped to resolve the mineralized source location of anomalies. A local mineralized bedrock source is inferred for the colluvium anomalies as this material appears to be locally derived. Soil anomalies in till are likely associated with the Southern Star stock (SS in Figure B-7-6), although smaller anomalies up-ice (south) of the Southern Star deposit suggest that there may be additional mineralization as yet undiscovered in this area. The discontinuous anomalies in glaciofluvial deposits are a result of a combination of meltwater erosion of mineralized bedrock in the Esker Zone (EZ) and Creek Zone (CZ), and reworking of locally derived till from the MBX and Southern Star stocks. This relationship has been established using boulder tracing. Mapping of mineralized float lithologies and relative abundance approximations was conducted using test pits over the MBX and Southern Star deposits (Figure B-7-6). The resulting patterns may then be used for determining transport directions and distances. At a local scale, abundant float of easily comminuted, oxidized supergene ore was encountered at a depth of less than 2 metres. The underlying till exceeds 25 metres in thickness. The nearest subcrop of supergene material lies approximately 90 metres up-ice, indicating that some surficial deposits overlying the mineralized zones are proximally derived. On a more regional scale (Figure B-7-6), a greater concentration of mineralized clasts was observed in areas of thin overburden and closer to various mineralized sources. Further proven-



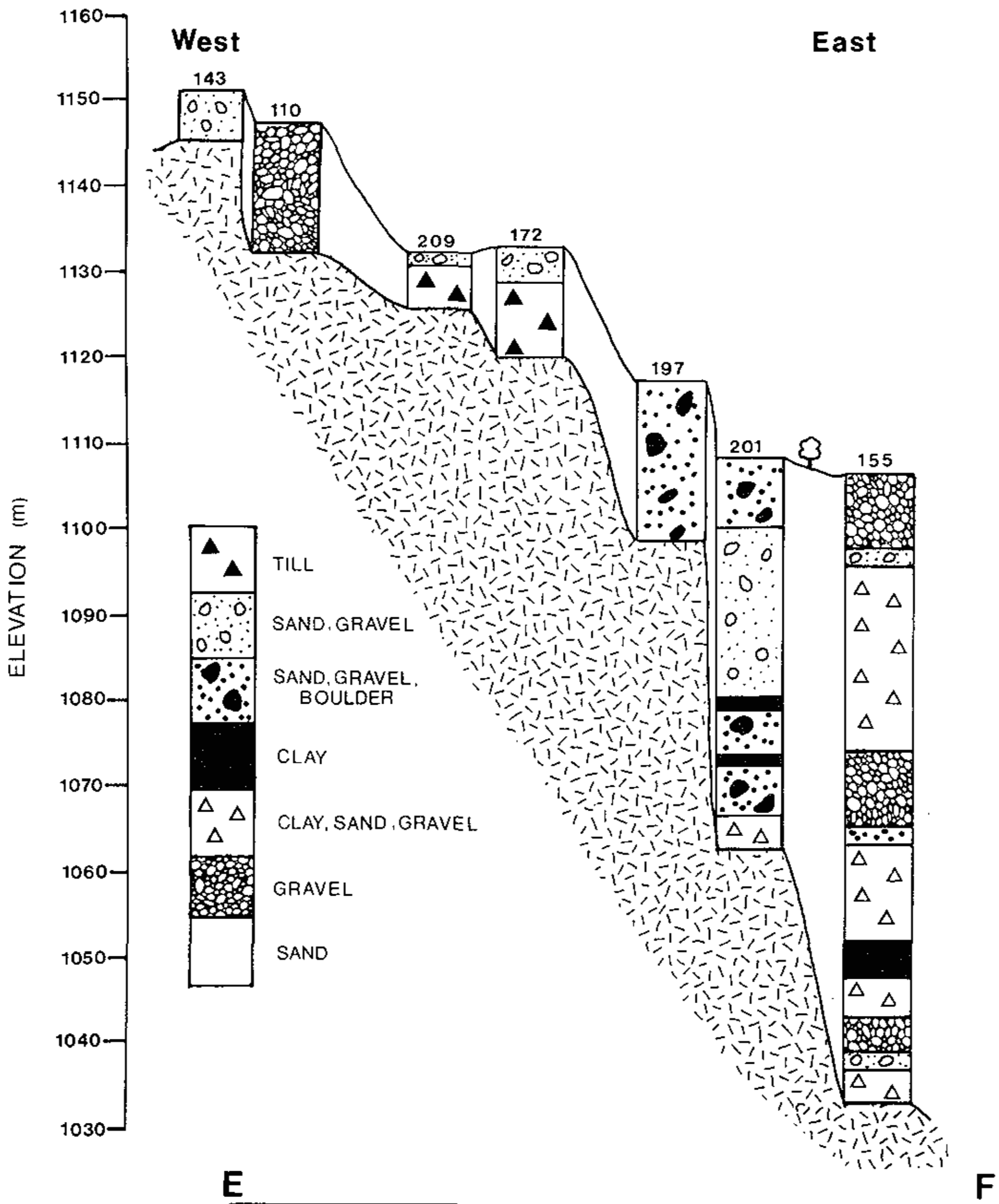
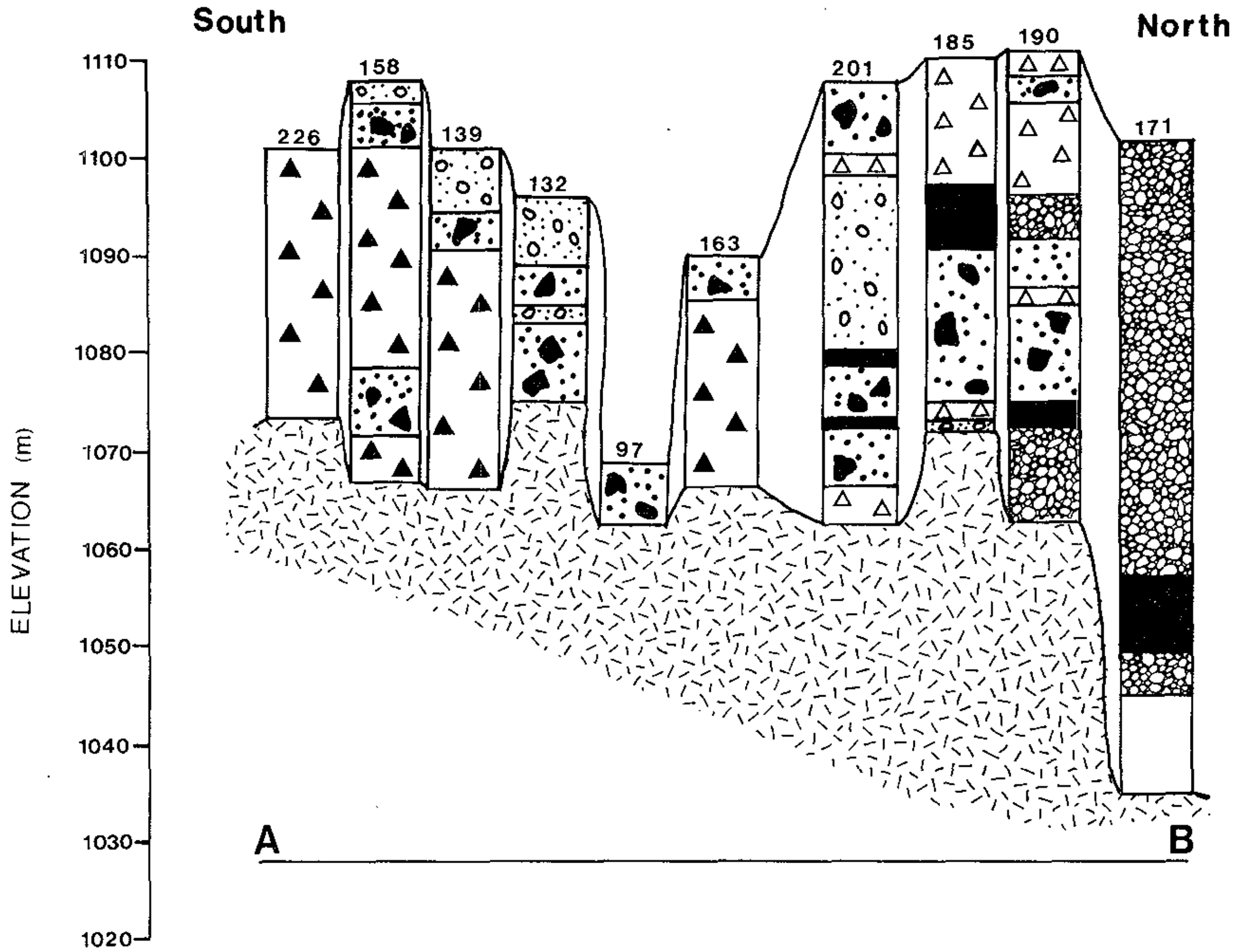
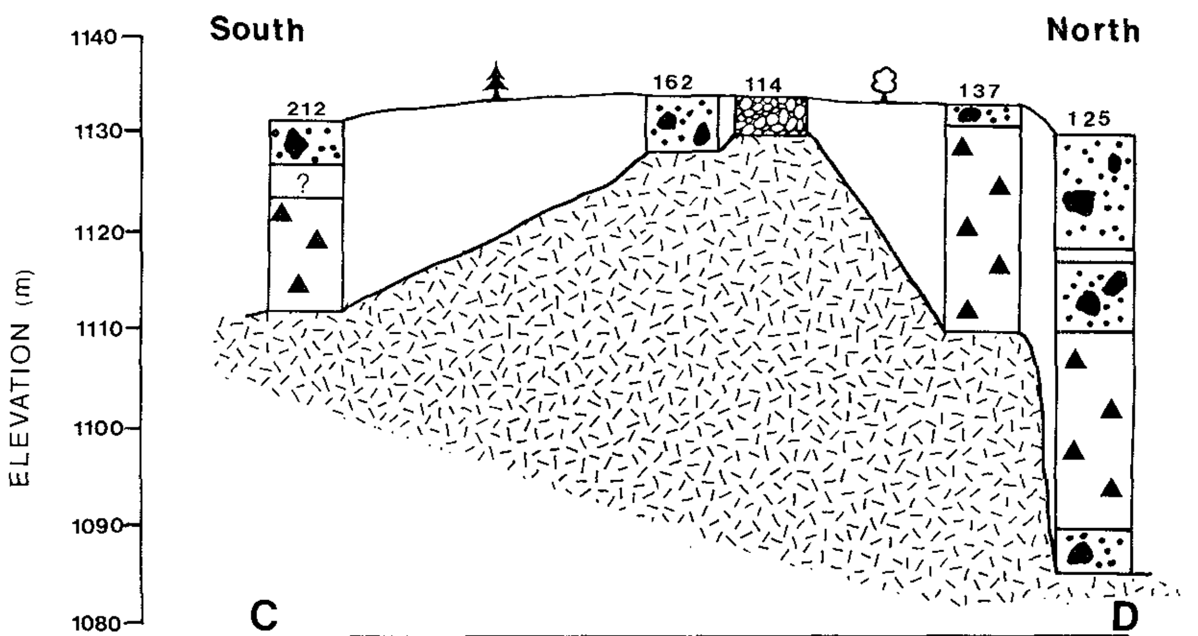


Figure B-7-3. Location map and Stratigraphic cross-sections of the surficial geology over the Mount Milligan deposit. Sections are based on drill hole data; (continued on facing page).


South
North
ELEVATION (m)
1110
1100
1090
1080
1070
1060
1050
1040
1030
1020
226
158
139
132
97
163
201
185
190
171
A
B


South
North
ELEVATION (m)
1140
1130
1120
1110
1100
1090
1080
212
?
162
114
137
125
C
D

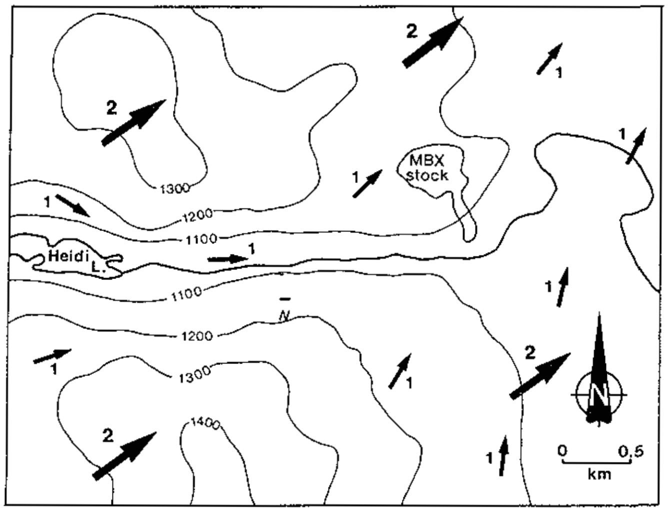


Figure B-7-4. Generalized glacial-flow history for the Mount Milligan area. Small arrows (1) illustrate first phase of local ice flow which was topographically controlled and larger arrows (2) illustrate a later stage of regional ice-sheet flow.

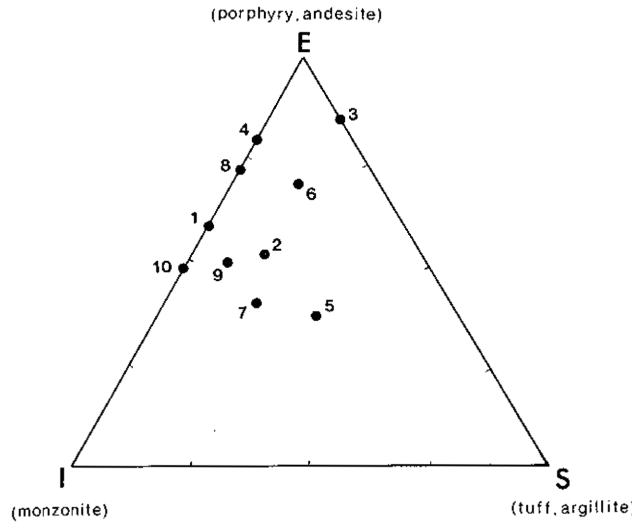


Figure B-7-5. Ternary plot of pebble lithologies for the Mount Milligan area. S-sedimentary, I-intrusive and E-extrusive rocks. Numbers refer to separate sample locations.

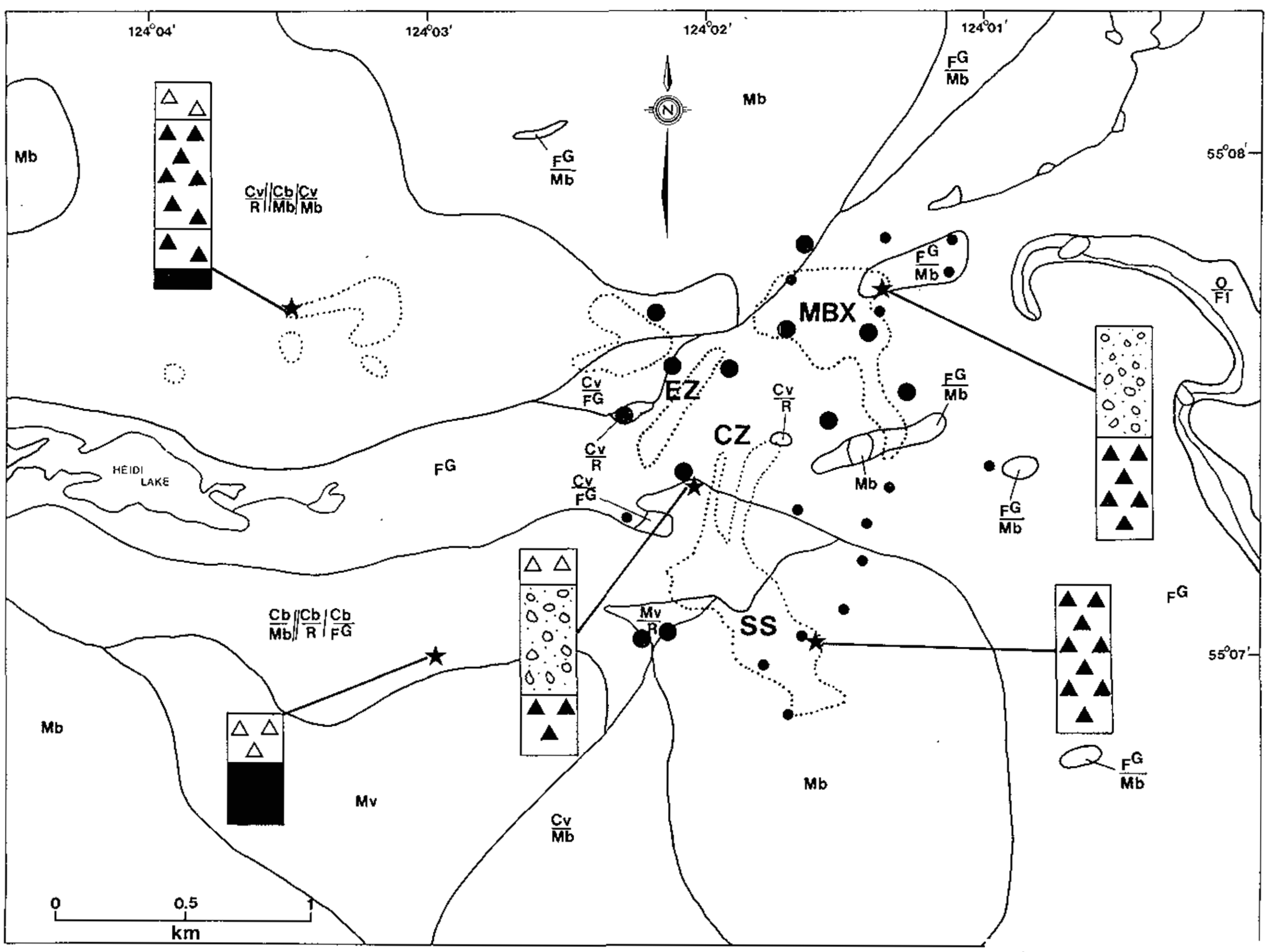


Figure B-7-6. Distribution of sulphide bearing clasts in test pits over the MBX zone, Southern Star (SS) zone, Esker Zone (EZ), Creek Zone (CZ) and other mineralized zones (shaded): large dots represents 5% mineralized clasts, small dots %; Generalized overburden stratigraphy throughout the study area is also presented: black=bedrock (R), black triangles=till (Mb, Mv), open triangles=colluvium (Cb, Cv), stippling=glaciofluvial deposits (F^G).

ance studies over a broader area down-ice would be needed to determine if boulder concentration increases in an up-ice direction, that is close to the mineralized stocks.

CONCLUSION

An understanding of the regional and local surficial geology of the Mount Milligan area is the major controlling factor in successful application of drift-exploration techniques. A conceptualized flow chart clarifies the relationship between anomaly form and surficial sediment type in the study area (Figure B-7-7. During glaciation, mineralized bedrock may be eroded and incorporated into glacier ice. The sediment in the ice is eventually deposited in a variety of forms such as till, outwash sand and gravel, or debris-flow deposits. The characteristics of the mineralized bedrock, as expressed by the geochemical anomalies differ depending on the depositional history of the elements. Linear-shaped geochemical anomaly patterns represent minimally altered proximal mineral indicators and occur most commonly in deposits such as till. Amorphous or discontinuous patterns represent moderately altered distal indicators and are generally observed in outwash deposits. Subsequent modification of these two types of sediments through colluviation further complicates the geochemical anomalies resulting in discontinuous patterns. However, if the colluvium is a product of weathered bedrock, the resulting anomaly pattern is amorphous and represents a proximal indicator.

Morainal deposits (till) over the Southern Star are predominantly locally derived, as evidenced by pebble lithologies and boulder trains. Till deposits in this area are characterized by linear geochemical anomalies which primarily reflect the underlying mineralization. However, some of the anomalies near Southern Star cannot be associated directly to known mineralization. Glaciofluvial deposits over the MBX stock exhibit discontinuous anomalies parallel to paleocurrent directions. The anomalies result from erosion of local bedrock, reworking of underlying till and melting of sediment-laden glacier ice. The broad amorphous anomalies in colluvium over the North Slope suggest local point-sources of mineralization and not a second stage of resedimentation of pre-existing till or outwash.

Elsewhere in the area, where the sediment cover is thicker, greater attention must be given to documenting the types of surficial deposits present. The complexity of the stratigraphic record and the large variations in drift thickness (<1 m to >30 m) over lateral distances of tens of metres directly influences the application and interpretation of geochemical exploration programs. A greater effort to describe overburden encountered during drilling facilitates subsequent interpretation and represents a cost-effective exploratory technique. An understanding of the nature and origin of stratigraphic units is essential in the interpretation stages; soil sampling should be directed toward particular materials which, in order of sampling priority, are bedrock-derived colluvium, till, outwash, and other colluviated surficial deposits.

JOHNNY MOUNTAIN

The Johnny Mountain gold mine lies approximately 100 kilometres northwest of Stewart, within the Boundary Ranges of the Coast Mountains physiographic belt (Figure B-7-1). This mesothermal vein deposit, in British Columbia's Golden Triangle, is part of a volcanic package consisting of interbedded andesite and dacite volcaniclastics and volcanic sediments ranging from mudstones to conglomerates. The geology of the Johnny Mountain deposit and the Snippaker Creek map area is described in Alldrick *et al.* (1989, 1990), Anderson (1989), Britton *et al.* (1990), Fletcher and Hiebert (1990), Kerr (1948), Lefebure and Gunning (1989), Read *et al.* (1989) and Souther *et al.* (1979).

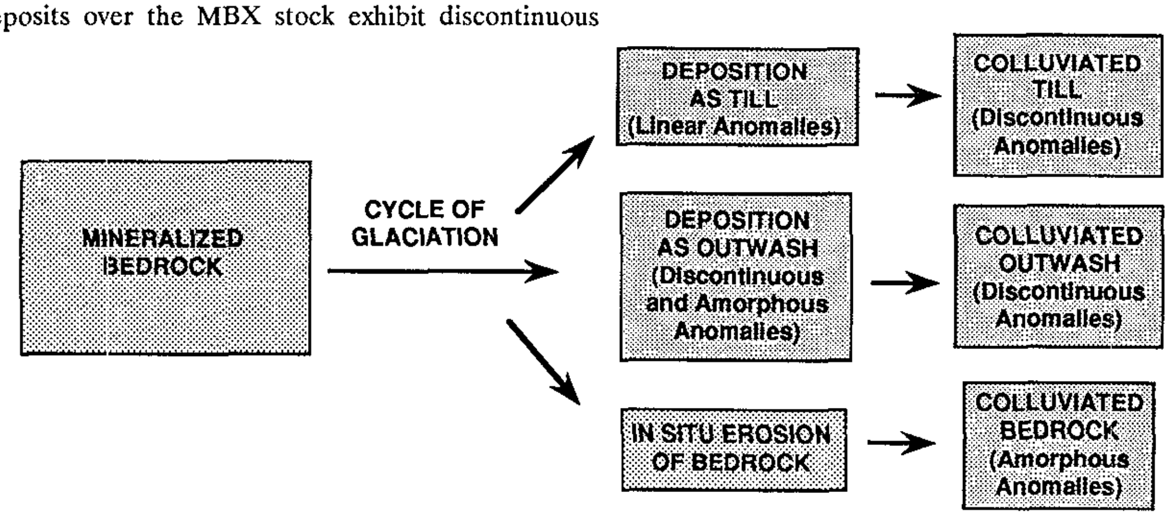


Figure B-7-7. Mount Milligan flow chart illustrating relationship of geochemical anomaly patterns to types of surficial sediments.

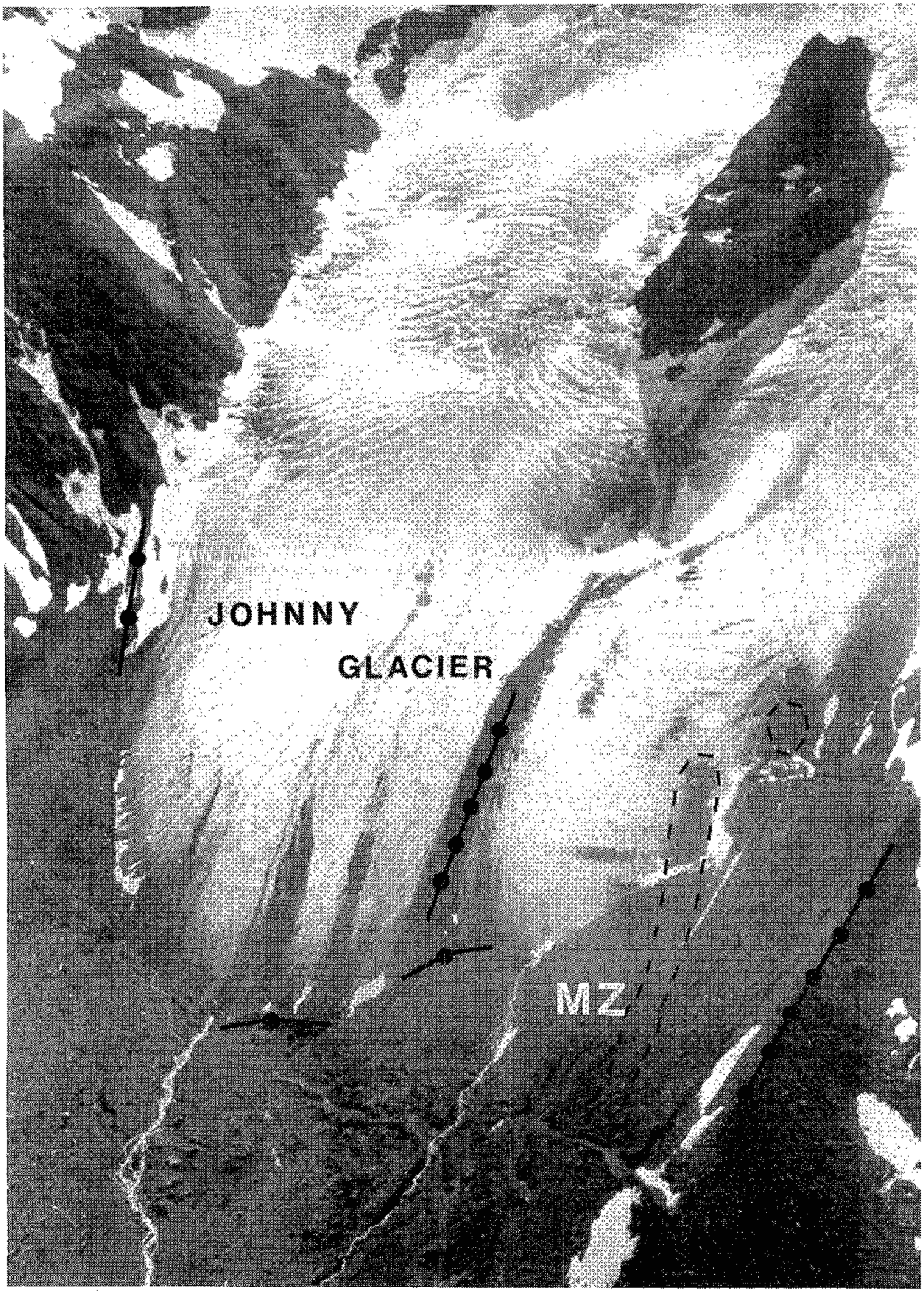


Plate B-7-5. Oblique view of Johnny Glacier. Dotted line illustrates predominant morainal debris, and dashed line shows position of the McFadden Zone.

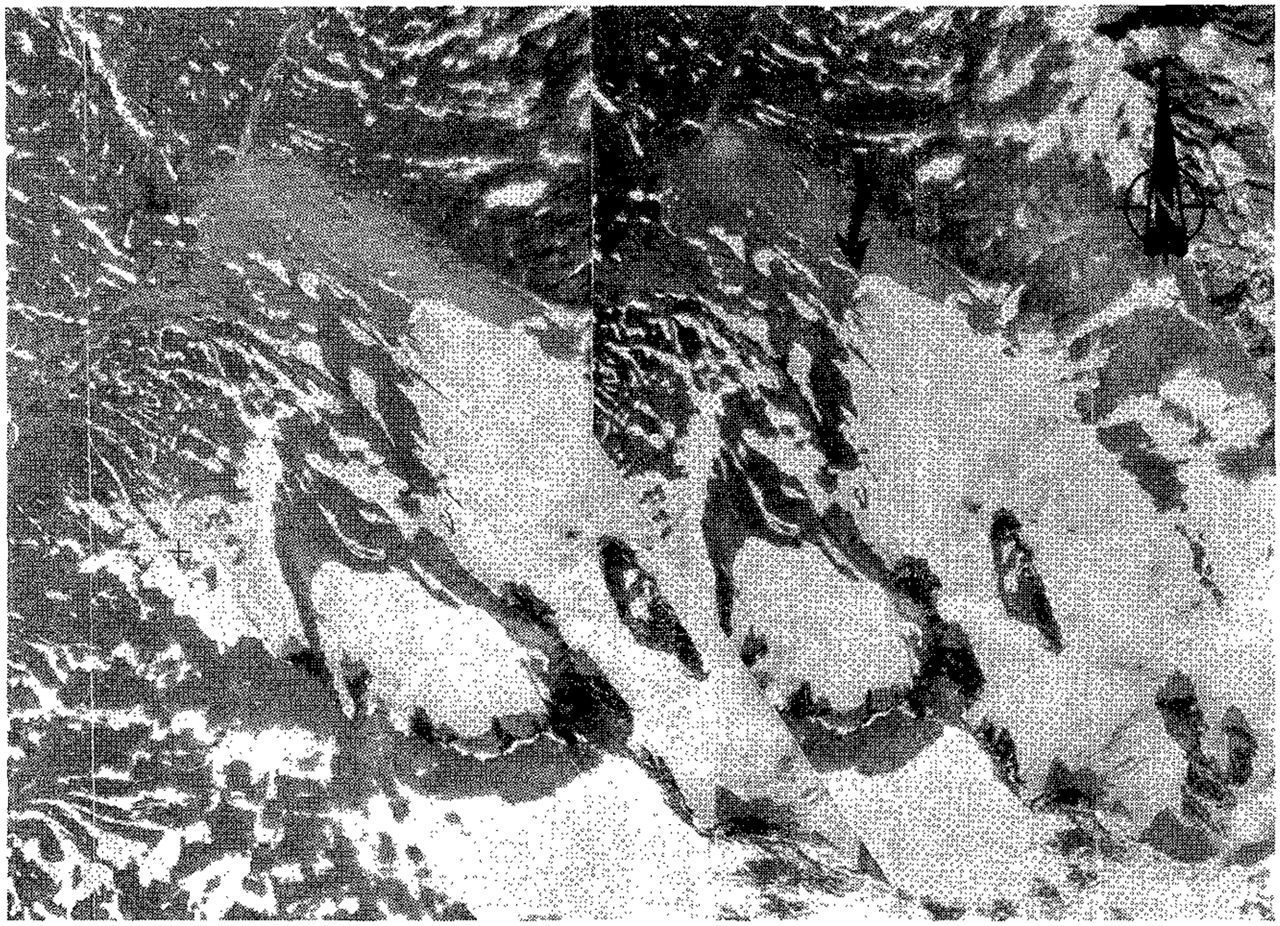


Plate B-7-6. Stereo photograph of the Johnny Glacier showing position of ice front (arrow) on August 19, 1949 (British Columbia A12226-138 and 139).

SURFICIAL GEOLOGY

The Snippaker Creek map area was last glaciated extensively during the Late Wisconsinan. Since the "Cordilleran ice Complex" owes its origin to the Coast Mountains, this area was likely one of the first and last regions to be glaciated during the Pleistocene. During this glaciation many glaciers, remnants of which exist today, advanced and coalesced to occupy all major and minor valleys including the Iskut, Jekill, Snippaker and Bronson. Ice thickness at this time would have been on the order of 2000 metres in the valleys. Subsequent Holocene glacier expansion may have occurred about 4000 years ago as documented for some parts of the northern Cordillera and southeastern Alaska (Ryder, 1987). West and north of the map area, glaciers were considerably more extensive 500 to 600 years ago than they are at present. The Stikine-Iskut region also experienced two late Neoglacial maxima consisting of an early advance 300 to 350 years B.P., and a later advance culminating about 100 years B.P. Glacier recession in the last century has been rapid with glaciers being currently smaller than at any other period during the last 4000 years (Ryder, 1987).

Pleistocene basaltic lava flows east of the map area have been dated to 70 000 years B.P. (Grove, 1986). During the Holocene, lava damming of local drainage took place between about 8730 and 3660 years B.P.; fluvial and lacustrine deposits associated with lava-dammed lakes have yielded ages of 3930, 3540 and 2610 years B.P. (Read *et al.*, 1989). In the southern map area, lava flows are responsible for the formation of Lava Lakes (Alldrick *et al.*, 1990) by the damming of Lava Fork Creek. The lower flows date to about 130 years B.P. (Grove, 1986).

The Snippaker Creek map area consists of rugged, mountainous terrain of which approximately one third is presently covered by icefields and glaciers (Kerr, 1991b). Glaciers emanate in all directions from central ice-fields often forming radial patterns. The glaciers are commonly 1 to 2 kilometres in length, although some attain 5 kilometres or more. Most permanent ice is surrounded by bedrock with little or no surficial cover. Morainal veneers occur near glaciers in areas which have recently been deglaciated. Lateral moraines are frequently associated with this surficial unit and range from 100 to 3000 metres in length. Colluvial veneer is the dominant surficial deposit, mantling many of the steep-sided valleys. It is the result of a combination of mass movement processes

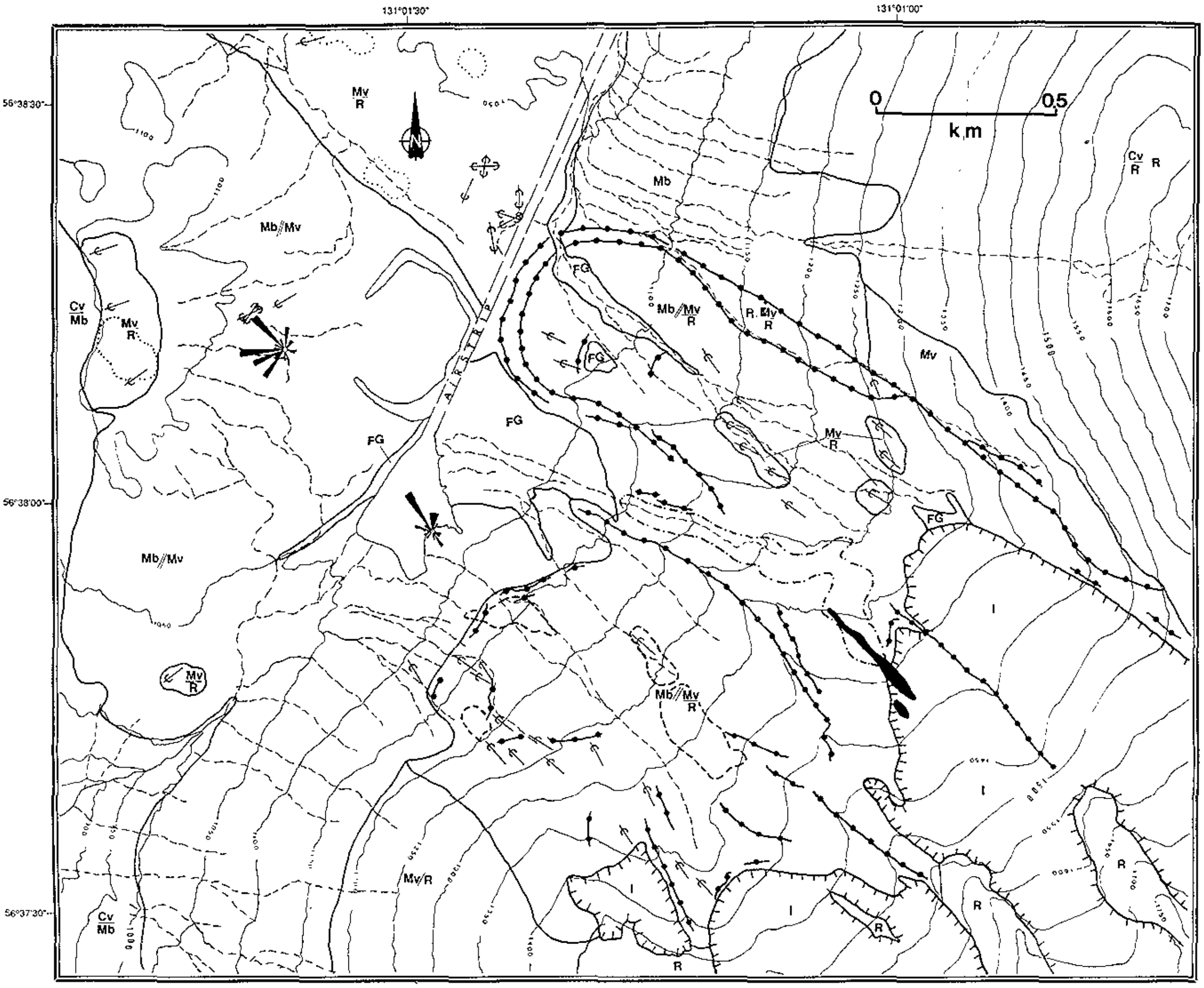


Figure B-7-8. Detailed surficial geology map of the Johnny Mountain property area. Paleocurrent symbols include fabrics and striations. Map units are in Figure B-7-2 but also include I (ice). Solid linear feature southeast of centre is the McFadden Zone. Illustrated soil anomalies consist of Ag at 5-25 ppm (dotted lines), Au at 100-300 ppb (dashed lines) and Au at 900 ppb (dot/dash lines).

(landslides, rockfalls, debris flows) which over time have modified till and other unconsolidated Quaternary sediments. Fluvial deposits occur along valleys occupied by floodplains and braided streams.

A detailed surficial geology map of the Johnny Mountain property illustrates the dominant glacial features (Figure B-7-8 and Plate B-7-5). The area locally called the "flats" west of the airstrip is characterized by morainal blanket and veneer deposits. Striae and fabric data suggest that ice flow originating from Johnny Mountain glacier did not override this area or if it did, the evidence has long since been eroded. A more likely interpretation of the glaciation on the flats would target a source of ice originating from the northeast. However, recent morainal deposits southeast of the airstrip are related to the advance and retreat of the Johnny glacier. Figure B-7-9, a longitudinal section of Johnny glacier near its terminus, illustrates the extent and thickness of the morainal deposits which extend beneath. A series of lateral and recessional moraines define the limits of the last ice advance. Although most moraines are small, they are relatively continuous and have sharply defined ridges. Local ice-flow history is summarized for the area on the basis of a "striation stratigraphy" (Figure B-7-10). The Late Wisconsinan glaciation is represented by the initial advance of Johnny and Camp glaciers toward the northwest, which was later followed by ice-sheet glaciers flowing from the northeast over the flats. Limited Neoglacial activity is reflected in a another set of striae which are imprinted over the original ice movement of the Johnny and Camp glaciers.

The presence of distinctive terminal and recessional moraines suggests a slow and/or irregular initial ice retreat, followed by more rapid and/or continuous retreat

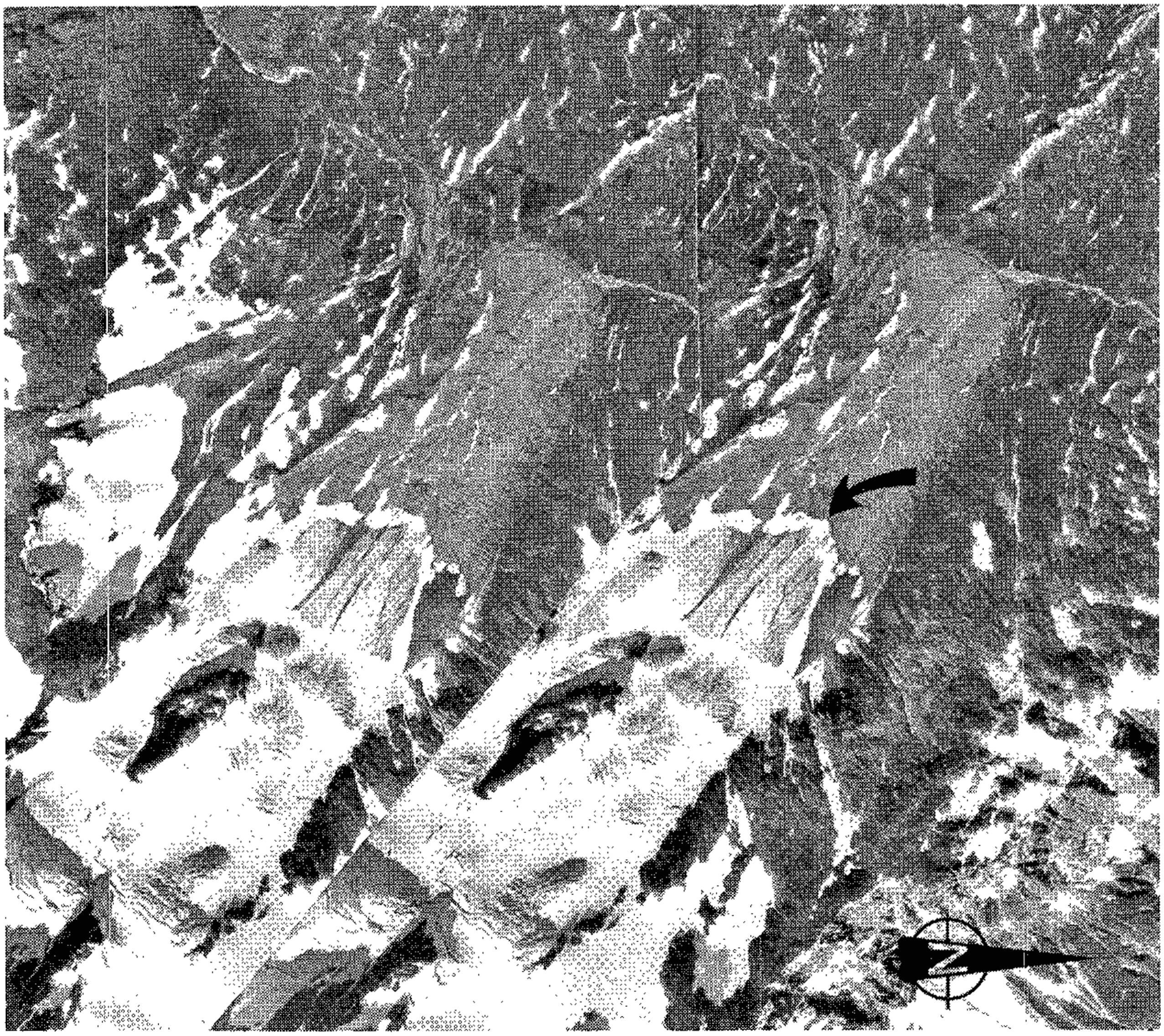


Plate B-7-7. Stereo photograph of the Johnny Glacier showing position of ice front (arrow) on August 5, 1965 (British Columbia BC5157-014 and 015). N (Neoglacial moraine).

during which moraines were not preserved. The different ice-front positions which have been identified from air photos taken in 1949 and 1965, and ice conditions in 1990 for Johnny Glacier, provide a means of estimating retreat rates (Figure B-7-11 and Plates B-7-6 and 7). The rate of ice retreat for the glacier terminus for the period of 1949-1965 is approximately 17 metres per year, compared to about 4 metres per year for the 1965-1990 period. Using an average retreat rate of 10 metres per year, it is probable that the Johnny Glacier end moraine represents the late Neoglacial advance limit attained some 100 years ago. Indeed, a local account of an early prospector working this area in the 1920s reports the presence of ice near the flats at that time. The Holocene glacial history inferred for this area is in general agreement with conclusions made by Ryder (1987), that at least in some areas, a late Neoglacial advance culminated in the late nineteenth and early twentieth centuries, and that most terminal moraines date to that period.

Additional glaciological data for the local area are also obtainable from neighboring glaciers. For instance, Bronson Glacier, 2 kilometres east of Johnny Glacier, has been maintaining an internal ice flow velocity of about 23 metres per year from 1949 to 1965, and 20 metres per year from 1965 to 1982. These rates are significantly higher to those of the Athabasca Glacier in Jasper National Park, where ice velocity near the toe of the glacier is 15 metres per year (Inland Waters Directorate, 1980). Like other glaciers in the area, the Bronson Glacier has been receding since at least 1949. Unfortunately, it is not possible to determine the rate of retreat as the terminus is heavily covered by supraglacial debris which obscures the exact position of the ice front.

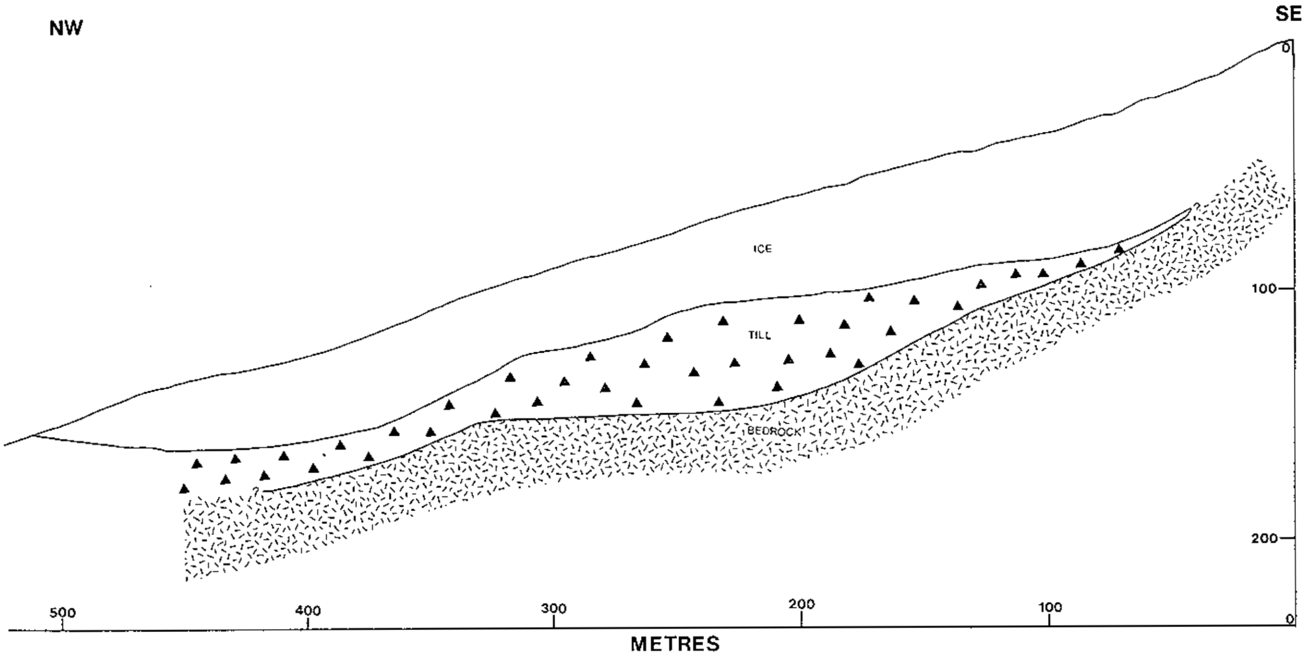


Figure B-7-9. Longitudinal section through Johnny glacier near its terminus, based on drill-hole data. Modified from Burlington *et al.*, (1985).

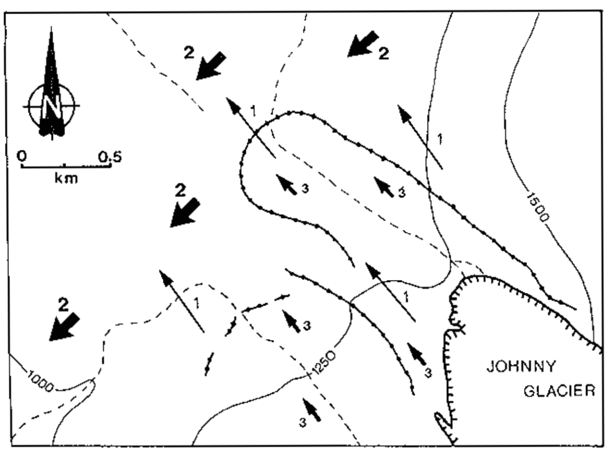


Figure B-7-10. Generalized glacial-flow history for the Johnny Mountain area. Long, thin arrows (1) illustrate early stage of cirque-glacier flow, thick arrows (2) indicate late stage of ice-sheet flow; both episodes presumed to have occurred during the Late Wisconsinan. Intermediate size arrows (3) indicate Neoglacial ice-flow of Johnny Glacier.

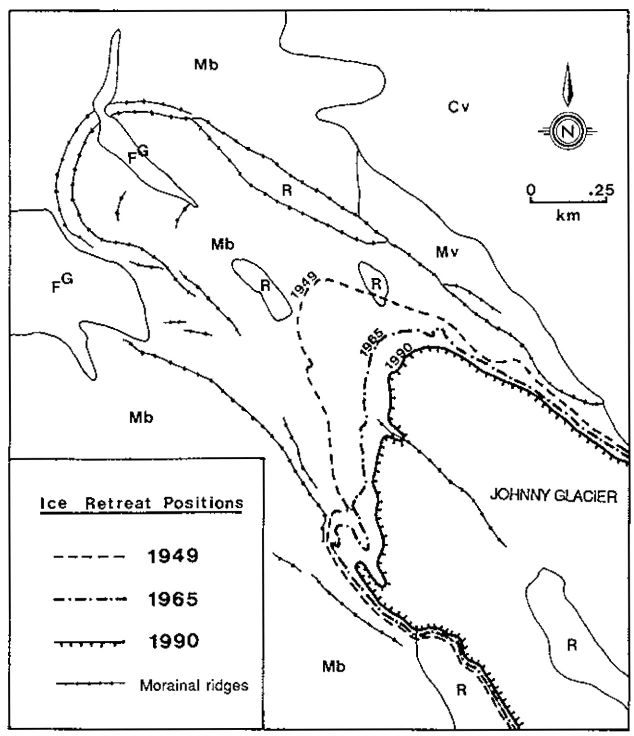


Figure B-7-11. Ice-retreat positions of Johnny Glacier at three time intervals as determined from air-photographs. Rates of ice-retreat given in text.

DISCUSSION

The Johnny Mountain property is an ideal location for provenance investigations in areas of active alpine glaciation. Although mineral exploration in the mountainous terrain of British Columbia has increased in recent years, little has been written on geochemical exploration in alpine glaciated areas (Evenson *et al.*, 1979; Stephens *et al.*, 1983, 1990). Recent approaches involve the integration of lithological, mineralogical and geochemical data obtained from medial moraines, as well as soil and stream surveys. In the present study, previous geochemical soil surveys, boulder tracing and trenching in the ice were employed.

Two types of geochemical soil anomaly dispersal patterns are present at this property. Well-defined linear -gold (100-300 ppb and >900 grams/tonne or ~27 oz/ton) dispersal trains, one almost 1 kilometre in length, are associated with the morainal deposits of Johnny and

Camp glaciers. These anomalies strongly parallel ice-flow directions to the northwest and fall within the areas glaciated during the late Neoglacial period. The most prominent dispersal train consists of a significant portion of mineralized, strongly altered (limonitic) angular clasts containing gold. Locally called the McFadden float zone, this train is about 350 metres long and 30 metres wide and extends from the toe of Johnny Glacier onto the ice-marginal sediments flanking the snout. This latter half forms part of the larger, linear gold geochemical anomaly trending northwest. Minor amounts of comparable float material are also found south of the head of the McFadden float zone (Figure B-7-8). Discontinuous soil anomalies (Ag, 5-25 ppm) are also present in the area. These patterns are developed in till veneers and blankets in the "flats" directly west of the air-strip (Figure B-7-8). The irregular shaped anomalies may result from in-situ weathering of mineralized outcrops, hydromorphic dispersion processes in topographic depressions or a history of crosscutting glacial flow patterns. They are, however, unrelated to the mineralization associated with the Johnny Mountain gold mine.

Two ice-trenches were excavated in Johnny glacier during the fall of 1990 in an attempt to determine the distribution of mineralized clasts within the ice; a lower trench along the McFadden Zone at the ice margin, and an upper trench south of the head of McFadden zone (Figure B-7-8). The lower ice trench is 7 metres deep and is underlain by poorly sorted glaciofluvial outwash and/or washed till composed of angular to subrounded clasts less than 0.5 metre in diameter. Foliation planes 1 to 30 centimetres thick occur within the ice as alternating opaque and clear bands. On the southwest wall, foliation planes are nearly horizontal, whereas on the southeast and northeast sides, they curve upwards away from the centre of the glacier, at angles of 15° to 30°. Occasionally, debris is found concentrated along these planes. Mineralized clasts which characterize the McFadden zone are found below, within and on top of the ice. They make up about 1 per cent of the drift under the ice and occur as rare isolated clasts scattered throughout the ice, most notably on the southwest wall. The highest concentration of mineralized clasts occurs on the surface of the glacier.

The upper trench is about 6 metres deep and exposes three large ice bands which become progressively darker and sediment-rich towards the base of the glacier. The uppermost band is a clear blue ice with little or no debris and has well-defined foliation planes. The lower contact with the middle zone is defined by a debris-rich foliation plane about 10 centimetres thick. This, as well as the other planes in the upper and middle bands, curve upward towards the western margin of the glacier at angles of 20° to 45°. The middle band represents light to medium gray ice with only a few scattered clasts 1 to 2 millimetres in size. The middle band is separated from the lowermost band by a foliation plane 15 centimetres thick containing a greater amount of sediment and small clasts than the surrounding ice. The lowest band has a slightly higher concentration of debris trapped within medium dark to dark grey ice. The basal zone is characterized by debris-rich ice where debris comprises approximately 50 per cent by volume. No mineralized clasts were noted either on or within the ice. Also, few foliation planes were observed in this unit.

Based on the local distribution of mineralized clasts, the source for the McFadden zone is probably mineralized bedrock beneath the glacier, up-ice from the head of this dispersal train. The presence of mineralized clasts as subglacial, englacial and supraglacial material indicates that material is being eroded, incorporated into the ice and transported to the surface of the glacier along foliation planes (Figure B-7-12). Given the limited supraglacial expression of the mineralized train, the source outcrop is most likely of limited extent and is possibly trending northwest. The argument for limited outcrop size is further supported by the negative results of dia-

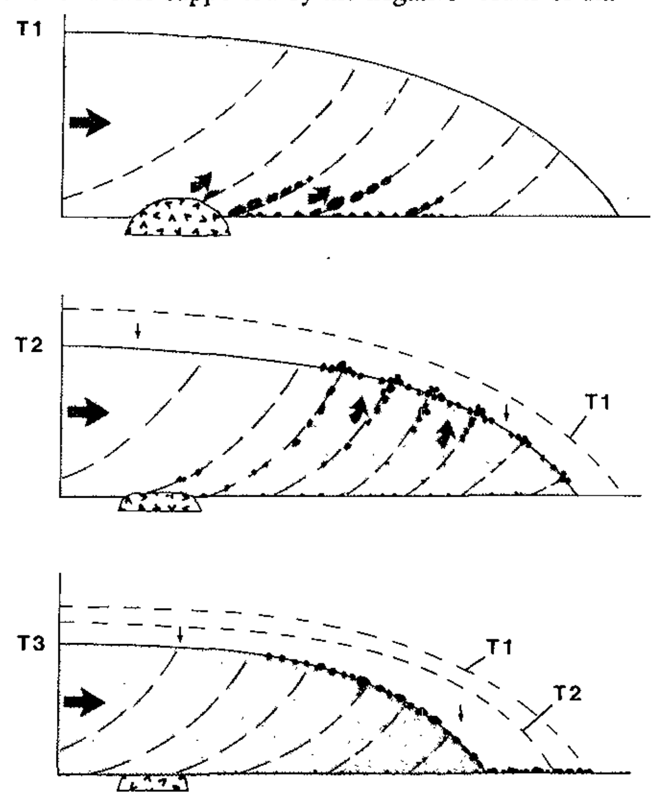


Figure B-7-12. Schematic longitudinal cross-section through terminus of Johnny Glacier illustrating probable creation of the McFadden zone. T1 to T3 indicate relative time lines. Dashed lines in ice represent foliation planes. At T1 subglacial erosion has incoporated mineralized boulders into the shear planes of the ablation zone. At T2 continued flow and subequent net ablation results in a surface accumulation of the mineralized debris. At T3 most mineralized boulders have formed a linear deposit in front of the glacier as well as a supraglacial lag on the ice as Johnny Glacier continues to retreat.

mond drilling which failed to encounter mineralized material up-ice of the float. If the mineralized bedrock has not already been completely eroded, a conservative estimate of its location would be the area between the McFadden zone and the nunatak of Johnny Glacier.

CONCLUSION

The retreat of Johnny Glacier over the last 100 years or so has led to the exposure of a well-defined mineralized boulder train over 350 metres long. A strongly developed linear soil geochemical anomaly 0.9 kilometre long associated with the boulder train, together with smaller soil anomalies related to the Camp Glacier, are evident in till deposited by these glaciers. The orientation of the geochemical anomalies found within the glaciated basins is parallel to the direction of local ice flow (NW) as determined by a survey of glacial striae and geomorphic ice-flow indicators. The linear distribution of mineralized clasts on the glacier surface and beyond the ice front, as well as their distribution within the ice as defined by ice trenching, suggest a local origin for the float. Glacier mechanics and the presence of debris bands and shear planes in areas where float was observed also point to local erosion of mineralized bedrock as a probable source. On the flats, away from the glacier terminus, regional ice-flow indicates movement to the southwest. Here geochemical anomaly patterns are discontinuous, not because of the type of surficial materials, but rather as a result of a complex history of multiple ice-flow directions. Patterns observed in this area can be a composite feature representing overprinting (flow to SW) on top of a previous distribution pattern which originated from the Johnny and Camp glaciers (flow to the NW).

SUMMARY AND IMPLICATIONS

Drift exploration in the mountainous terrain of British Columbia is often hampered by the complex relationship between local and regional glaciers and the effects of multiple glaciations on the character of the surficial deposits. Successful exploration strategies require an accurate interpretation and understanding of types, genesis and distribution of surficial materials, frequency and patterns of glaciation, and the morphology of soil geochemical anomalies. Some implications for mineral exploration programs in glaciated terrain are listed below.

- In areas of active alpine glaciers, geochemical sampling of moraines and boulder tracing can significantly reduce a large exploration area to a more specific region within a glacial catchment basin. Supraglacial and englacial mineralized anomalies can be detected by boulder tracing and traced up-ice, based on their trajectories which depend upon the nature of glacial erosion processes.

- In deglaciated areas, an understanding of the sequence of ice flow and the tills corresponding to these ice flows, is necessary to successfully interpret geochemical data. Linear to fan-shaped dispersal patterns generally reflect a single unidirectional ice-flow direction. More complex, irregular shapes in till may reflect the effects of multiple ice-flow phases within a single or several glaciations.

- Soil anomaly patterns which relate to the major mineralized zones at Mount Milligan, are longest and narrowest in till, and their detection requires the highest sampling density. Glaciofluvial sediments can also be sampled in order to detect dispersal patterns which parallel paleoflow directions, though these trains may not be as well developed as those associated with till.

- Bedrock-derived colluvial deposits, by their nature, are ideal for geochemical sampling because they can produce wide dispersal patterns. At Mount Milligan, anomalies found in colluvium of locally derived material occur in broad zones which suggest a local source of mineralization.

- A thorough understanding of the nature of glacier movement and depositional processes will greatly improve the chances for success in exploration of glaciated alpine environments. Furthermore, the application of geophysical surveys should also be considered, in addition to geochemical and surficial geology techniques, as part of the approach to detailed drift-provenance investigations.

ACKNOWLEDGMENTS

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GEOLOGY AND POTENTIAL COAL AND COALBED-METHANE RESOURCES OF THE SEATON COAL BASIN (93M/3, 7)

(Fig B1, No. 8)

By Barry Ryan

INTRODUCTION

Between 1890 and 1915 prospective rail routes were being surveyed through much of British Columbia. Railway companies acquired land for its timber values and potential coal resources, both essential to build and operate railways. The railways required thermal coal to operate but also provided a means of transporting coke, a bulk commodity that in the 1900s was often made at the colliery in banks of beehive ovens. The activity stimulated tremendous interest in coal exploration and many showings, favourably located with respect to possible rail lines, were found. Often shafts and adits were driven into the coal and preliminary sampling and analyses performed.

By the 1920s, the railway construction boom and the economic spin-off of World War I were over and coal exploration waned. It was not until the late 1960s, when large companies started exporting metallurgical coal for coke making, that coal exploration resumed.

The Grand Trunk British Columbia rail line (now the CN line) was built through the Bulkley Valley in 1910. This stimulated much coal exploration and a number of small coal basins, including the Seaton coal basin, were found. Only the Telkwa coal basin sustained commercial mining and by 1930 most of the other basins, including Seaton, had been abandoned. Exploration activity briefly resumed in the Seaton Basin in 1986 to 1988.

This report summarizes pre-1986 data, compiles some of the data generated in the 1986 to 1988 period and describes additional mapping and sampling undertaken by the author in 1990.

The Seaton coal basin is in the Bulkley River valley, 42 kilometres north of Smithers (Figure B-8-1). The Bulkley River, flows west and north past the towns of Telkwa and Smithers, joining the Skeena River at Hazelton. North of Smithers, the Bulkley Valley, which is flat and generally filled with alluvium, is about 5 kilometres wide; surrounding mountains rise 1000 to 1500 metres above the valley and are comprized of Cretaceous rocks of the Skeena Group and Jurassic rocks of the Bowser Lake Group. The valley-fill alluvium is interspersed with scattered outcrops as young as Paleocene (Figure B-8-2). In the vicinity of the Seaton coal basin the valley is a graben; faults trending north or northwest have throws of over 1000 metres.

PREVIOUS WORK

The first reference to coal in the Seaton basin was by Dawson (1881). Dowling (1915) summarized work in the area up to 1915; much of the information was from Leach (1911). Activity was in three areas which cannot be accurately located. A 3.4-metre section of carbonaceous shale and coal was trenched and tunnelled near Boulder Creek (Figure B-8-3). North of Boulder Creek, eleven thin coal seams were found in a 150-metre section (north samples Table B-8-1). Ash contents were high but the coal was reported to produce a firm coke. In an area south of the 150-metre section where beds strike and dip at 140°/30° northeast, six seams varying in thickness up to 1 metre were described. Three analyses (south samples Table B-8-1) indicate that the seams are medium volatile bituminous with moderate ash contents. Based on the strike and dip, this area is probably south of Sharpe Creek (Figure B-8-3).

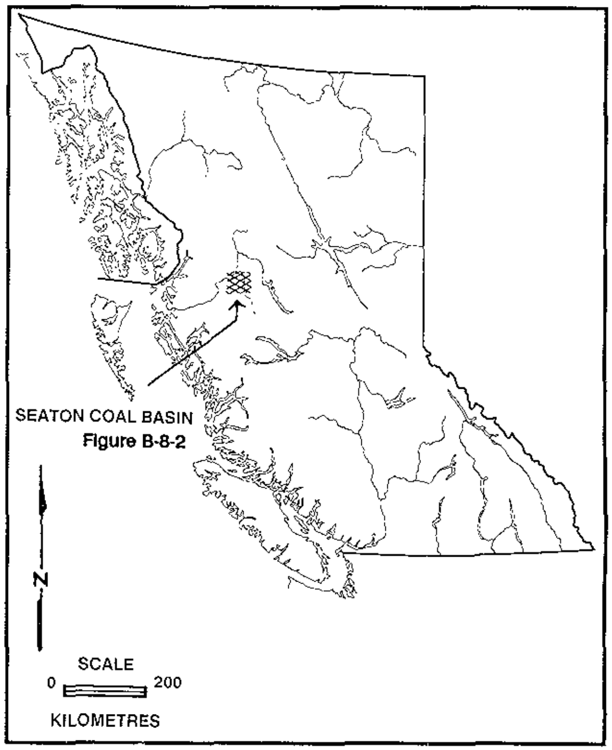

Figure B-8-1. Location map; Seaton coal basin, British Columbia.

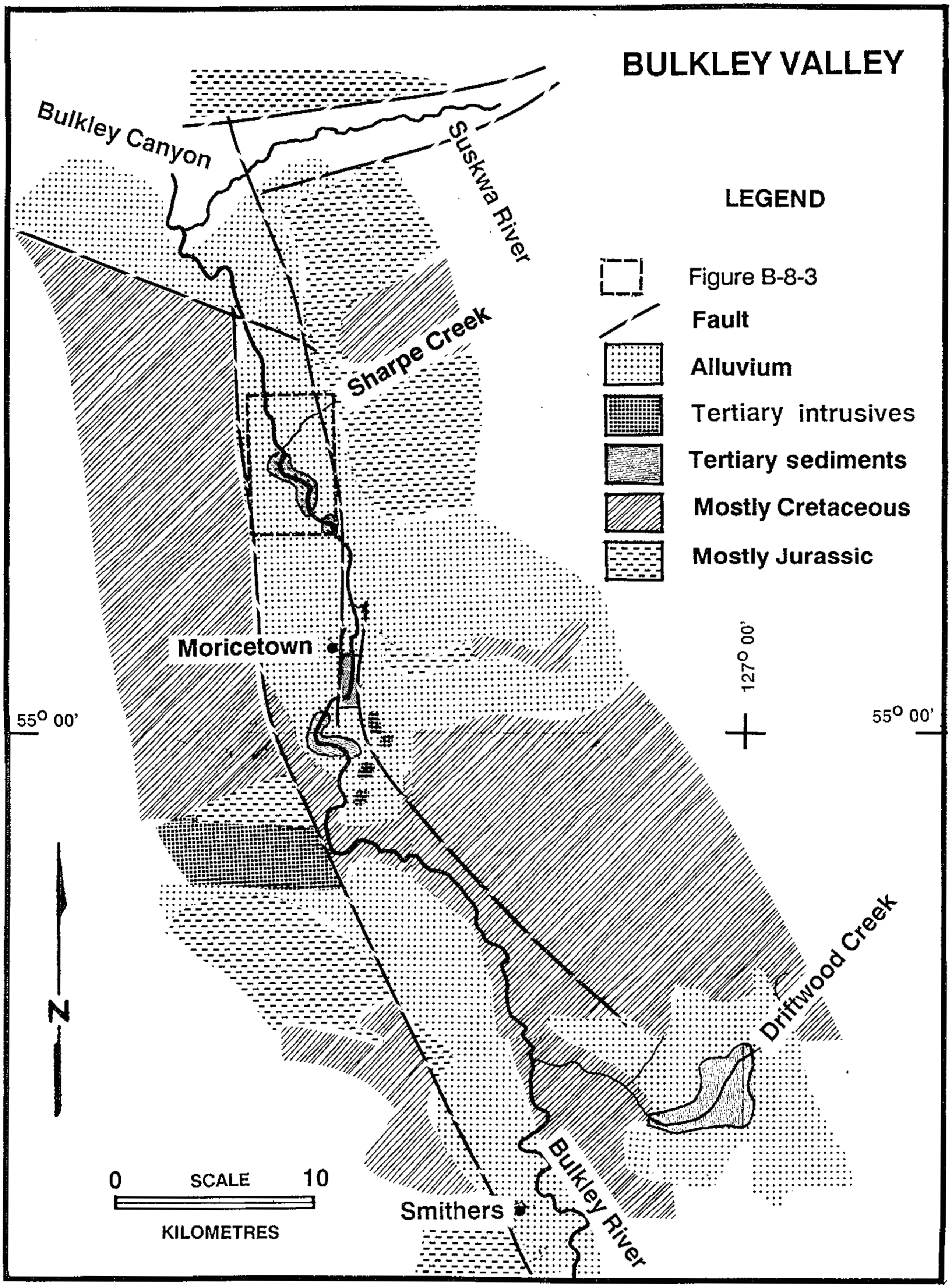

Figure B-8-2. Bulkley Valley; Distribution of Pre-Tertiary and Tertiary rocks.

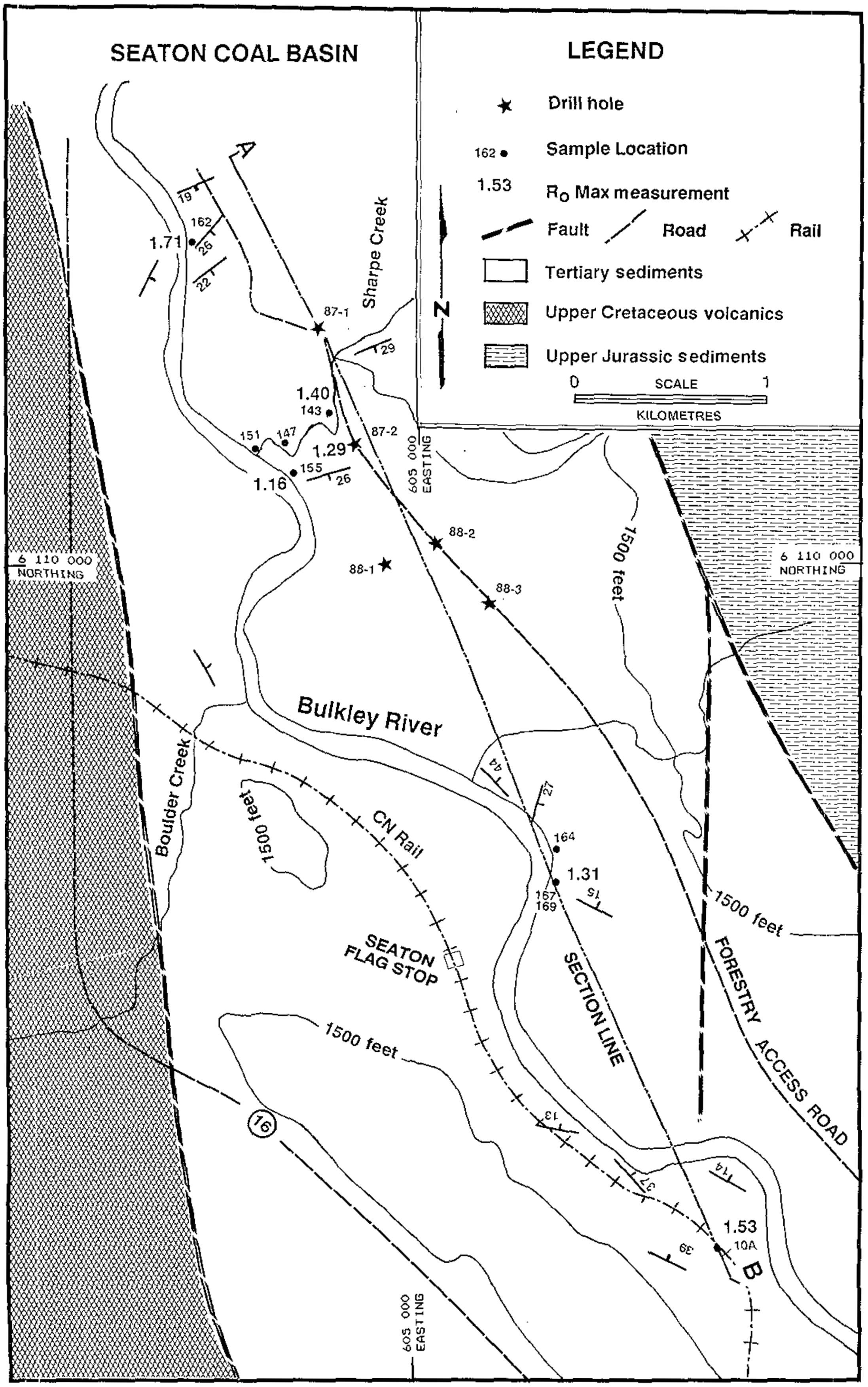

Figure B-8-3. Simplified geology of the Seaton coal basin.

TABLE B-8-1
SEATON COAL BASIN
RAW COAL QUALITY

DESCRPTION	T/T	ADM%	ASH%	VOLS%	FC%	S%	CV
1990 Analysed							
10 A	0.45	0.85	36.81	17.87	44.5	2.46	-1
143	0.60	1.06	20.51	22.42	56.0	1.18	-1
147	0.60	0.75	15.75	23.37	60.1	-1	-1
151	0.55	0.91	10.54	24.13	64.4	-1	-1
155	0.50	0.85	57.17	14.78	27.2	-1	-1
162	0.65	0.94	35.84	12.61	50.6	0.58	-1
164	0.35	1.43	19.75	23.47	5.4	-1	-1
167	0.40	1.20	36.12	18.50	44.1	-1	-1
169	0.60	1.09	38.33	18.07	42.5	-1	-1
1986 to 1988[1] Atna Analyses							
PS191	0.65	1.58	19.67	24.04	54.7	1.0	6681
CH1	0.65	1.65	26.75	24.50	47.1	0.95	6047
CH3	1.60	1.82	54.19	26.03	18.0	0.95	3062
CH5	0.60	1.54	28.87	23.52	46.1	1.99	5879
1916-1927 Seaton flag stop[2]							
STN SM1	1.37	1.80	43.80	17.70	36.7	-1	-1
STN SM2	0.43	3.00	16.00	21.20	59.0	-1	-1
STN SM3	0.91	1.40	35.70	19.50	43.4	-1	-1
Not Located[2]							
TUNNEL	-1	1.20	46.70	17.20	34.9	-1	-1
TUNNEL	-1	0.90	34.80	18.70	45.6	-1	-1
TUNNEL	-1	0.90	37.00	18.20	43.9	-1	-1
Pre-1915 exploration activity[2]							
Gravel Trunk B.C. Coal Company							
NORTH SM1	0.38	1.02	20.32	25.70	53.0	-1	-1
NORTH SM2	0.46	1.39	22.99	25.56	50.1	-1	-1
SOUTH SM1	0.51	1.12	23.46	23.70	51.7	-1	-1
SOUTH SM2	0.97	2.15	32.16	22.03	43.7	-1	-1
SOUTH SM3	0.51	1.36	18.05	25.18	55.4	-1	-1

T/T *True thickness in metres*
ADM *Air dried moisture*
CV *Calorific value in calories /gram*
FC *Fixed carbon*
VOLS *Volatile matter*
1 *From Perry (1786)*
2 *From Dowling (1915)*

An area on the west bank of the Bulkley River near the Seaton CN flag-stop was explored in 1916 and 1927 (Kindle, 1940). Three sample analyses identified as STN in Table B-8-1 are from this area. The "No. 1 seam", which is 1.4 metres thick and about 400 metres south of Seaton, was explored by an 84-metre drift from river level and an inclined shaft. Analyses reported by Kindle indicate a high ash bituminous coal. Four hundred metres down river towards Sharpe Creek the "No. 2 seam" was explored; is 0.43 metre thick and has a moderate ash content. Other seams, including "No. 3 seam" (1.0 metre thick) are mentioned but locations are not specified and all are described as thin. A 20-ton trial shipment was mined from the No. 3 seam in 1927 (Lay, 1928); the quality indicates a medium volatile coal, no other information is available.

No coal exploration occurred in the period 1927 to 1985. In 1986 Atna Resources Limited acquired four licences. Two NQ diamond core holes were drilled in 1987 and three holes in 1988 for a total length of 794 metres. A geological report (Perry, 1986) was prepared for the company and a single petrographic analysis was made (Pearson, 1987). Dr. T. Richards provided the Atna Resources Limited drill and quality data and the two consultants

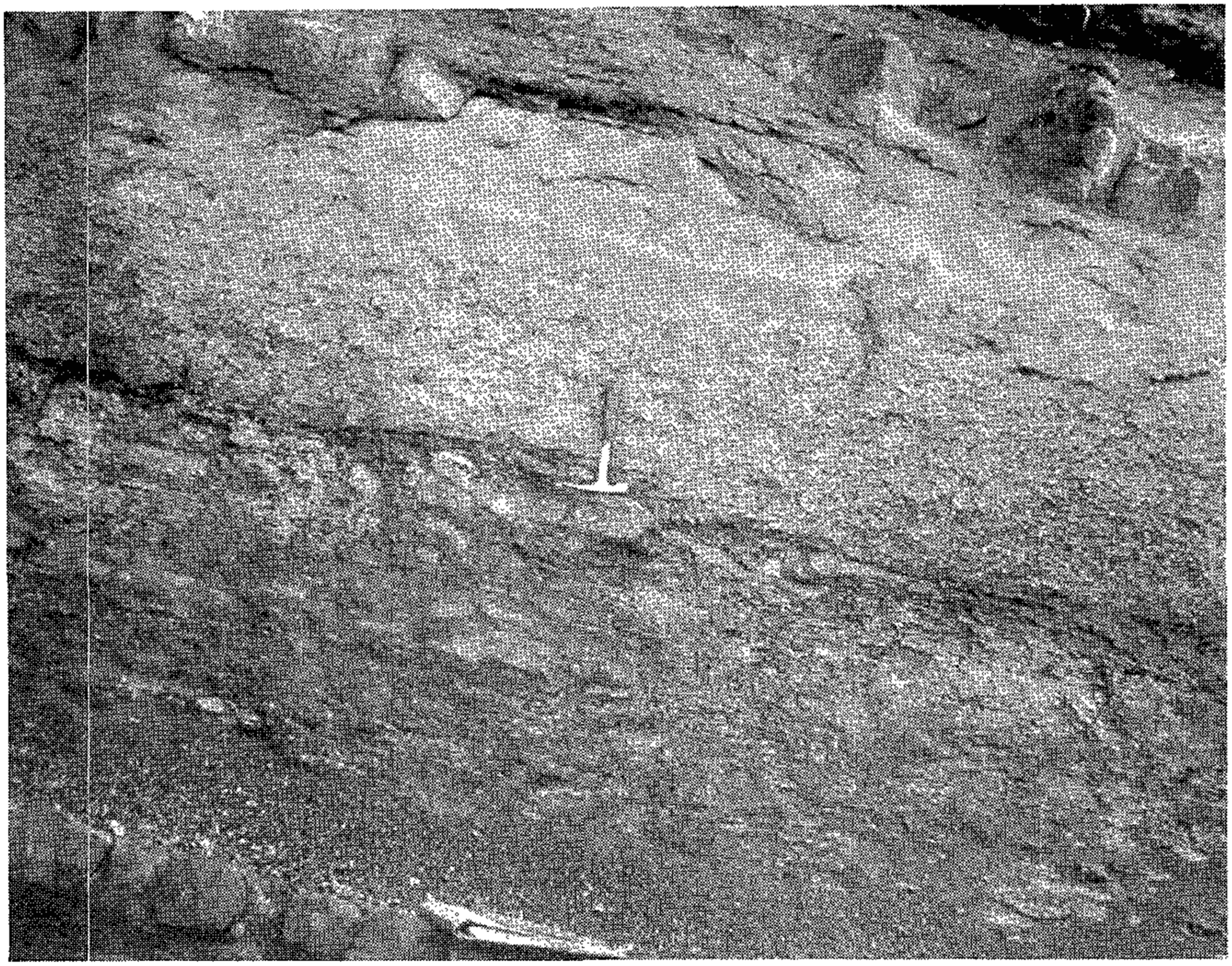

Plate B-8-1. Erosional contact and graded bedding in the lower part of a depositional cycle.

TABLE B-8-2
SEATON COAL BASIN
NQ DIAMOND-DRILL HOLE LOCATIONS

HOLE	DEPTH	OB	EASTING	NORTHING	ELEVATION	GEOPHYSICAL LOGS
87-1	145.1	54.9	604 464	6 111 290	396	NONE
87-2	147.1	48.8	604 667	6 110 652	396	G D N
88-1	192.0	24.4	604 812	6 110 029	373	G D R
88-2	186.0	39.6	605 102	6 110 130	398	G D R
88-3	123.6	48.8	605 377	6 109 739	400	G D R

Note *All measurements in metres*
Note *locations are approximate, not surveyed*
OB *Overburden*
G *Gamma log*
D *Density log*
N *Neutron log*
R *Resistivity log*

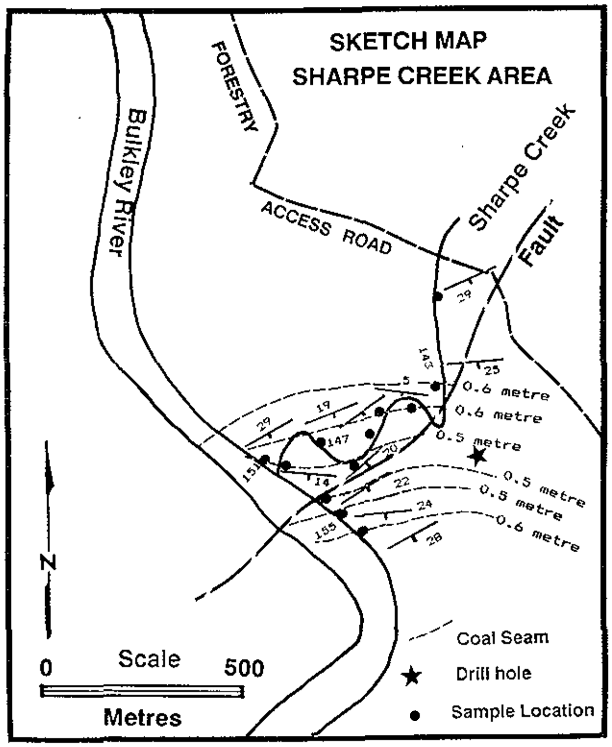

Figure B-8-4. Coal-seam distribution in the Sharpe Creek area.

reports to the author in 1990, making the preparation of this report possible.

The author mapped and sampled in the area for 4 days in 1990.

STRATIGRAPHY

The regional geology is covered by the maps of Sutherland Brown (1960), Tipper and Richards (1976) and Richards (1981). No detailed map of the Seaton coal basin exists. Outcrop in the area is scarce and is found mostly along the banks of the Bulkley River.

The eastern and western edges of the coal basin are defined by faults which trend along the break in slope (Figure B-8-3). The northern and southern limits of the basin are not as well defined. It probably extends at least 4 kilometres north of Sharpe Creek, but not beyond the Suskwa River where an east-trending fault is bounded on the north by Jurassic rocks.

The southern limit of the basin is obscured by alluvium, but it is possible that it extends to the village of Moricetown, 15 kilometres south of Sharpe Creek. Tertiary sandstones outcrop on the east bank of the Bulkley River south of Moricetown. Poorly consolidated arkosic sandstones and volcanics of Tertiary age outcrop 3 kilometres north of the village, at Causqua Creek. Beds are folded into an anticline plunging 210°/5°.

In the Seaton coal basin exposures of Tertiary rocks are restricted to the banks of the Bulkley River, Sharpe Creek and rail cuts near Seaton flag stop (Figure B-8-3). The five drill holes provide additional information. There are two areas of outcrop on the east bank of the Bulkley River in the vicinity of sample locations 169 and 162 (Figure B-8-3) where sections were mapped. There is also sufficient outcrop scattered along Sharpe Creek to prepare a simple geological sketch map.

North of Sharpe Creek, in the vicinity of sample location 162, outcrop extends for about 500 metres along the east bank of the Bulkley River. Average strike and dip in the area is 060°/25° to the southeast and approximately 165 metres of section is exposed. The base of the section is a massive conglomerate. Two coal seams 0.35 and 0.65 metre thick were found in the section. Sediments form a number of fining-upward cycles from 5 to 30 metres thick. Cycles start with chert-pebble conglomerate, grit or coarse sandstone deposited on an erosional surface and overlain in succession by sandstone, siltstone, mudstone and sometimes carbonaceous mudstone with coal. The coarse units are often graded (Plate B-8-1).

Two kilometres south of Sharpe Creek, at least 600 metres of sediments are exposed along the east bank of the Bulkley River near sample location 169. Sediments are predominantly coarse grained, poorly consolidated orange sandstones with minor amounts of mudstone and coal. The average strike and dip is 160°/35° to the northeast. Sediments were deposited in fining-upward cycles varying in thickness from 2 to 10 metres. Two river-bank sections were measured, the first of 26 metres true thickness, contains five cycles and is composed of 20 metres of sandstone, 5 metres of mudstone and 0.85 metre of coal distributed through six seams. The second section, 32 metres contains 5 cycles and is composed of 18.7 metres of sandstone, 11.5 metres mudstone and 1.8 metres of coal distributed through five coal seams.

Sharpe Creek (Figure B-8-3), a small creek that flows through thick second-growth brush and deadfall, exposes a number of coal outcrops over a length of about 600 metres (Figure B-8-4). Average strike and dip of the beds is 065°/20° to the southeast. Outcrop also extends south from the mouth of Sharpe Creek along the east bank of the Bulkley River for 200 metres. The area represents a section with a true thickness about 150 to 200 metres. Sediments form fining-upward cycles 5 to 10 metres thick, similar in composition to the cycles described above. Coal seams are up to 0.60 metre thick. A fossil trunk was observed in one location; one piece was still rooted in-place and a second piece was loose on the river bank (Figure B-8-6). Eight coal outcrops were located in the area; they probably represent 6 seams ranging in thickness from 0.50 to 0.60 metre (Plate B-8-2).

Simplified lithologic sections for the five NQ diamond-drill holes are presented in Figure B-8-5. Holes are projected along strike onto the section line A-B in Figure B-8-3, consequently Figure B-8-5 represents a simplified

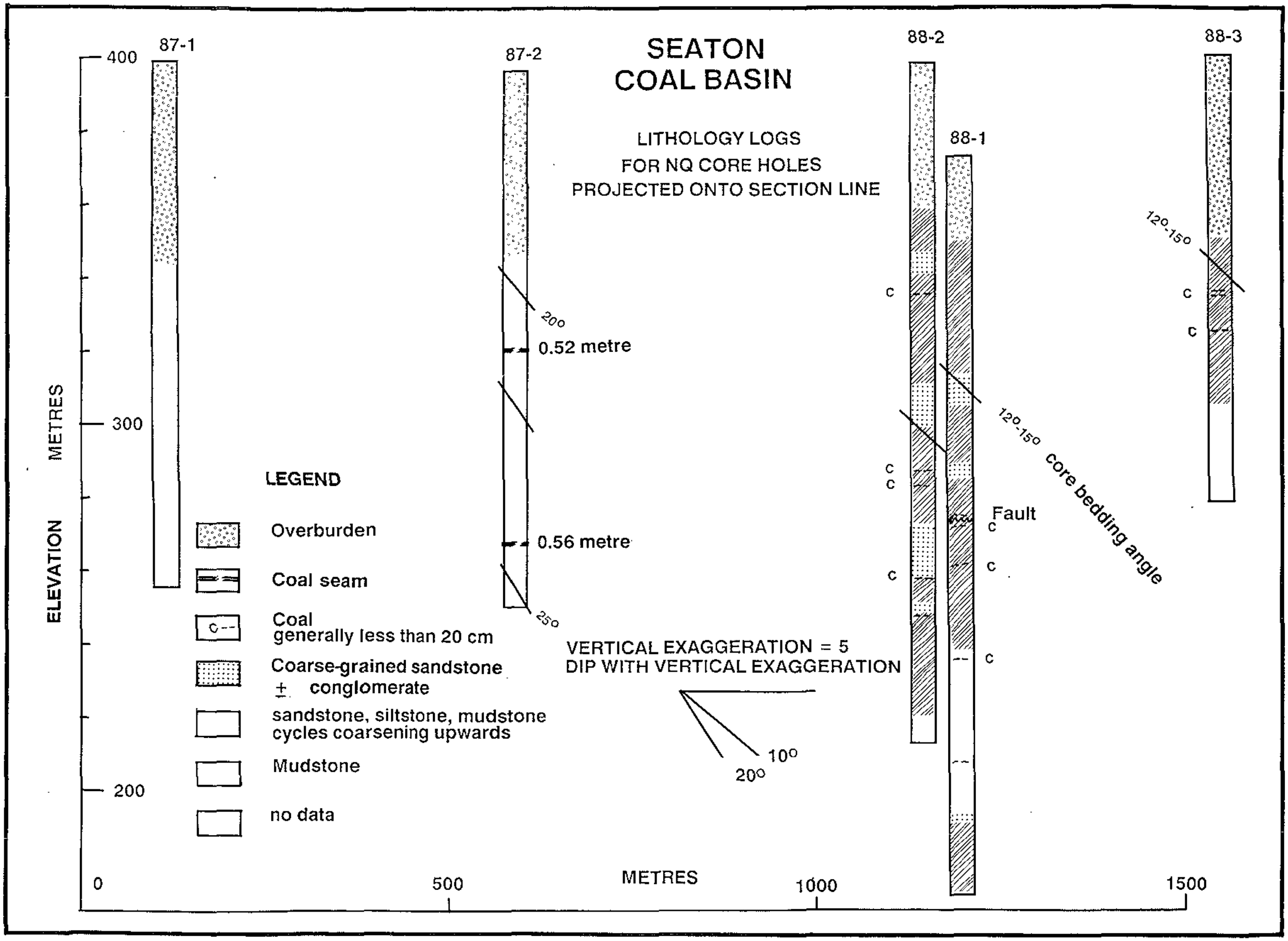

Figure B-8-5. Lithology logs projected onto section line A-B; Figure B-8-3.

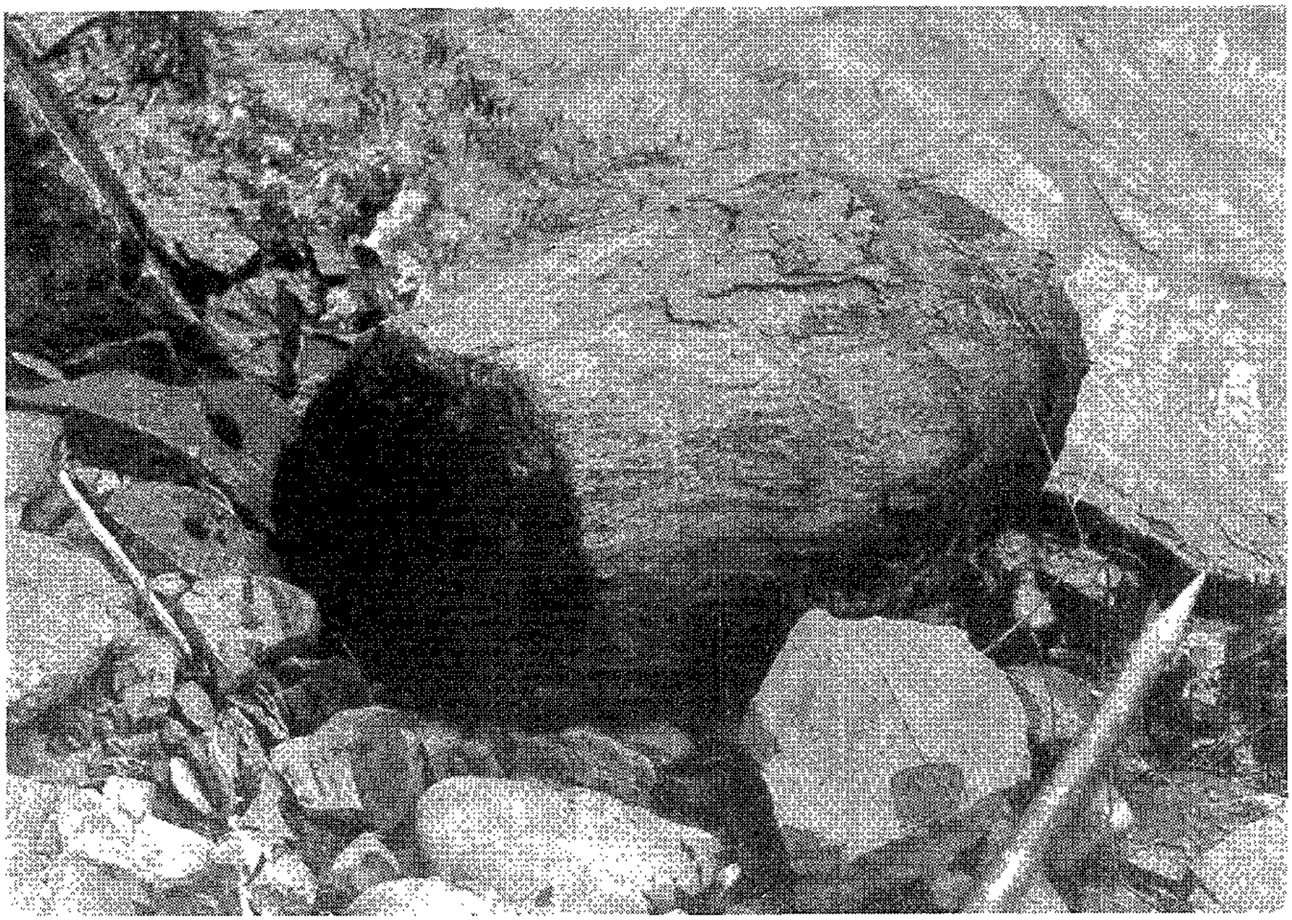

Plate B-8-2. Photograph of fossilized tree trunk; scale in bottom right is part of an ice axe.

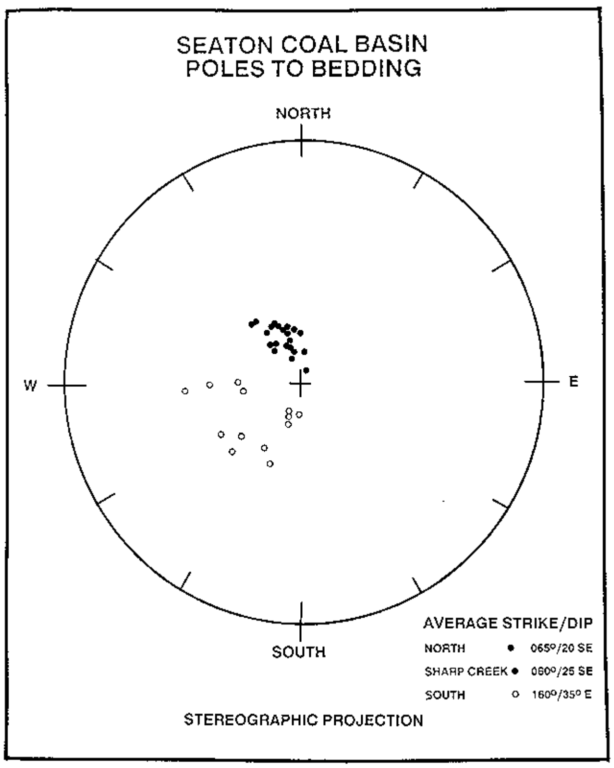

Figure B-8-6. Steriographic projection of poles to bedding; Seaton coal basin.

vertical section with a five times vertical exaggeration. The 5 drill holes penetrated overburden ranging in thickness from 24 to 55 metres (Table B-8-2) and bedrock composed of cycles of sandstone to mudstone interspersed with some units of conglomerate or coarse-grained sandstone. The lithology is generally similar to the outcrop sections. Holes 88-1 and 88-3 also intersected a grey to brown mudstone which does not outcrop. Hole 87-2 intersected two coal seams 0.52 and 0.56 metre thick; other holes intersected traces of coal but no seams over 0.20 metre thick. No hole-to-hole stratigraphic correlations can be made; obviously changes in lithology occur over short distances. The drilling tested about 200 metres true thickness of the middle of the stratigraphy with outcrops north of Sharpe Creek being lower in the section and outcrops south of Sharpe Creek higher.

Outcrops on the rail line south of Seaton flag stop (Figure B-8-3) provide a short section. A single coal seam 0.45 metre thick was located. No attempt was made to find the 1916 to 1927 workings on the old No. 1, No. 2 and No. 3 seams.

In general, the section north of Sharpe Creek, which is stratigraphically the lowest, contains more conglomerate and less coal than the Sharpe Creek and southern sections. In all areas cycles are variable in thickness and

TABLE B-8-3
SEATON COAL BASIN
AVERAGE RAW COAL QUALITY

NAME	CNT	AV VAL	WT AV VAL	SD	H VAL	L VAL
ADM %	24	1.33	1.44	0.51	3.0	0.75
ASH %	24	30.47	35.67	12.3	57.17	10.54
VOLS %	24	21.17	20.95	3.73	26.03	12.61
FC %	24	47.00	41.92	10.5	64.42	17.96
SULP %	7	1.30	1.18	0.67	2.46	0.58
CV	4	5417	4594	1607	6681	3062

CNT *Sample count*
AV VAL *Numerical average*
WT AV VAL *Mass weighted average value*
SD *Standard deviation*
H VAL *High value*
L VAL *Low value*
ADM *Air-dried moisture*

composition but always contain over 50 per cent sandstone or sandstone and conglomerate. No crossbedding was observed though some graded bedding is present in the coarse sandstone and conglomerate. The presence of erosional bases to the cycles indicates a fluvial rather than lacustrine environment.

Old references to the Seaton coal basin date rocks variously as Jurassic, Cretaceous or Tertiary. Eight mudstone samples were collected in 1990 for palynology. Results indicate a late Eocene to early Oligocene age for the sediments along the Bulkley River (Sweet; personal communication, 1991). The unexpectedly high coal rank of the samples made extraction of spores and pollen difficult. Some of the samples appear to contain material reworked from a source of Campanian age.

STRUCTURE

Beds in the Seaton coal basin strike 060° in the north and 125° in the south dips are towards the southeast or northeast (Figure B-8-6). The change in orientation could indicate a southeast plunging syncline. A single minor fold, located in the south, has a similar orientation. In one outcrop folding of beds is interpreted as deflection of beds against a fault. The fold axis trends 030°/20°. This trend could be caused by a vertical 030°-striking fault downdropping beds to the west. Bedding in most outcrops dips gently and there is little evidence of folding. The basin may be extensively faulted; the absence of marker beds and limited outcrop make it difficult to detect.

COAL QUALITY AND COAL UTILIZATION POTENTIAL

Data for coal samples analyzed prior to 1915 are summarized in Dowling (1915). The report by Perry (1986) for Atna Resources Limited provides four new analyses. In conjunction with the Atna Resources' exploration in the period 1986 to 1988, Pearson (1987) performed a single petrographic analysis on a sample from drill hole 87-2. In 1990 the author collected a number of samples for coal quality analysis. Nine samples were analyzed for ash, moisture, fixed carbon and volatile matter contents; a number of additional tests were also performed. Table B-8-1 provides all the raw quality data located; data sources are indicated in the table.

All samples, with the exception of those collected from the Seaton flag stop were collected from surface trenches and were therefore probably oxidized. Oxidation decreases free swelling index and heat value and increases equilibrium moisture and volatile content. The average as-received moisture for the nine 1990 samples is 3.64 per cent which is not much higher than the expected equilibrium moisture content for fresh bituminous coals. The average calorific value and ash content for three samples are respectively 6202 calories per gram (2597 MJ/kg) and 25.1 per cent ash; based on the rank as indicated by mean maximum reflectance measurements in the area, it appears that oxidation has degraded the heating value of the coal by about 2.0 per cent.

All raw analytical data are in Table B-8-3. Data are averaged numerically and by using the weight represented by each sample (WT. AV. VAL. Table B-8-3).

Two samples (143 and 162, Table B-8-4) were washed at 1.5 specific gravity (S.G.) to provide information on the upgrading potential for Seaton coal. The bituminous rank and high vitrinite content of the coal ensures that it will be amenable to agglomeration. It is therefore important to know how easy it will be to remove ash and sulphur and what wash-plant recovery can be expected. The wash ash contents for Samples 143 and 162 are 12.9 and 14.2 per cent. An S.G. of 1.5 corresponds to 27 per cent ash;

TABLE B-8-4
SEATON COAL BASIN
ASH CHEMISTRY AND WASH COAL DATA

No.	TYPE	REC%	ADM%	ASH%	VOLS%	FC%	SULPHUR%
143	RAW	100.0	1.06	20.51	22.42	56.01	1.18
143	WASH	80.01	1.16	12.90	23.75	62.19	1.02
162	RAW	100.0	0.94	35.84	12.61	50.63	0.58
162	WASH	36.48	0.94	14.22	15.73	69.11	0.71

NOTE: Samples washed at 1.5 S.G

SULPHUR FORMS

No.	TOTAL%	SULPHATE%	PYRITE%	ORGANIC%
143 WASH	1.02	0.17	0.17	0.68

ASH OXIDE ANALYSIS IN PER CENT

No.	Si_2O_3	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	Na_2O	K_2O	P_2O_5	SO_3	??
143	58.5	23.6	.93	7.95	1.47	1.47	.92	2.0	.77	.61	1.76

ELEMENTAL CONCENTRATIONS IN PER CENT

No.	Si	Al	Ti	Fe	Ca	Mg	Na	K	P	S
143	*3.58*	*1.64*	*0.07*	*0.73*	*0.14*	*0.12*	*0.09*	*0.22*	*0.04*	*0.61*

CSR CALCULATION

using
(1) estimated fluidity = 2000 ddpm
(2) R_o Max = 1.4%
(3) log fluidity = .994 + .0635 * (C+D) -.00012 * (C+D)^2 (*)
(4) CSR = 56.9 + .0826 * (C+D) - 6.86 * (MBI)^2 + 11.47 * R_o Max (*)

predicts
CSR = 20
C+D = Total dilitation
MBI = Modified basicity index

Equations (*) from Price and Gransden (1987)

ASH PROPERTIES

Ash type =	Bituminous
Silica ratio =	84.3
Slagging factor =	0.17
T250 poise =	1325 C

ASH MINERALOGY

MINERAL	PER CENT
Quartz	26
Kaolinite	31
Illite	16
Pyrite	6
Feldspar+chlorite	14
Other	7

depending on the degree of physical liberation, the wash coal can have an ash content ranging from 0.0 to 27.0 per cent. Bituminous coals generally wash to less than 10 per cent ash at 1.5 S.G. It is apparent that Seaton coal has a high content of ash. A more sophisticated method of estimating washability from small samples is used to calculate "predicted optimum washability numbers" (Ryan, 1989). The predicted optimum washability numbers for Samples 143 and 162 are 38 and 4. These numbers are characteristic of coal that is difficult to wash and which will have a low plant recovery.

The sulphur contents of Samples 143 and 162 were measured on a raw and 1.5 S.G. wash basis (Table B-8-4). The sulphur content in Sample 143 decreased from 1.18 to 1.02 per cent on an air-dried basis after washing. This indicates that the coal has a moderate background of difficult-to-remove sulphur. The sulphur content of Sample 162 increased from 0.58 per cent to 0.71 per cent after washing, indicating that the sulphur content of the coal is higher than that of the rock. A sulphur form analysis on Sample 143 (1.5 S.G. wash) indicates that 66.0 per cent of the sulphur is organic, 17.0 per cent sulfate and 17.0 per cent pyritic. It appears that Seaton coal has variable amounts of pyrite ranging up to about 2 per cent, most of which is easily removed, and a background level of organic sulphur of about 0.6 per cent. The sulphur content of the surrounding rock appears to be low.

Sales contracts for metallurgical coal generally specify less than 1.0 per cent sulphur and often less than 0.6 per cent. Seaton coal will probably wash to less than 1.0 per cent sulphur, making it a moderately high-sulphur metallurgical coal. Sulphur in thermal coal is a major environment pollutant. Present limits in the United States are usually 2.5 pounds per million BTU or less, by the year 2000 the limit will be 1.2 pounds (Corcoran 1991). Seaton coal will release about 5 pounds of sulphur dioxide per million BTU if all the sulphur is converted to SO_2, but usually only pyritic sulphur is converted when the coal is burnt, in which case Seaton coal is in borderline compliance coal with today's standards.

The petrographic analysis of a coal sample from drill hole 87-2 (0.56 metre seam at 129 metres); (Pearson, 1987) indicates that the sample is over 97 per cent vitrinite on a mineral-matter-free basis. The mean maximum reflectance is 1.29 per cent, indicating a medium volatile bituminous rank. The free swelling index (FSI) estimated from petrography (Pearson, 1987) is 9, calculated stability index is 62 and fluidity is high, probably over 2000 dial divisions per minute (ddpm). The bituminous rank and high vitrinite content of the coal probably mean that it also has a wide fluid-temperature range which would make it an excellent "bridging coal". Bridging coals remain fluid in the coke oven over an extended temperature range and help coke mixtures of blended coals with fluid tempera-

TABLE B-8-5
SEATON COAL BASIN
MEAN MAXIMUM REFLECTANCE DATA

LOCATIONS

SAMPLE	LOCATION	EASTING	NORTHING	ELEVATION
143	Sharpe Creek	604 522	6 110 812	381
155	Bulkley River	604 348	6 110 493	357
162	Bulkley River	603 797	6 111 739	351
169	Bulkley River	605 739	6 108 260	366
10 A	Seaton flag stop	606 623	6 106 290	394
87-2	Sharpe Creek	604 667	6 110 652	206
90-9	Moricetown	607 000	6 097 000	381
90-1	Driftwood Cr.	626 700	6 076 900	762

REFLECTANCE DATA

SAMPLE	TYPE	T/T METRES	R_o MAX%	MEAN RANDOM%
143	1.5 S.G.	0.6	1.40	1.32
155	Raw	0.5	1.16	1.09
162	1.5 S.G.	0.65	1.71	1.65
169	Raw	0.6	1.31	1.24
10 A	Raw	0.45	1.53	1.42
87-2	Raw	0.56	1.29	ND
90-9	Raw	Coalspar	1.71	1.64
90-1	Raw	0.15	0.65	0.64

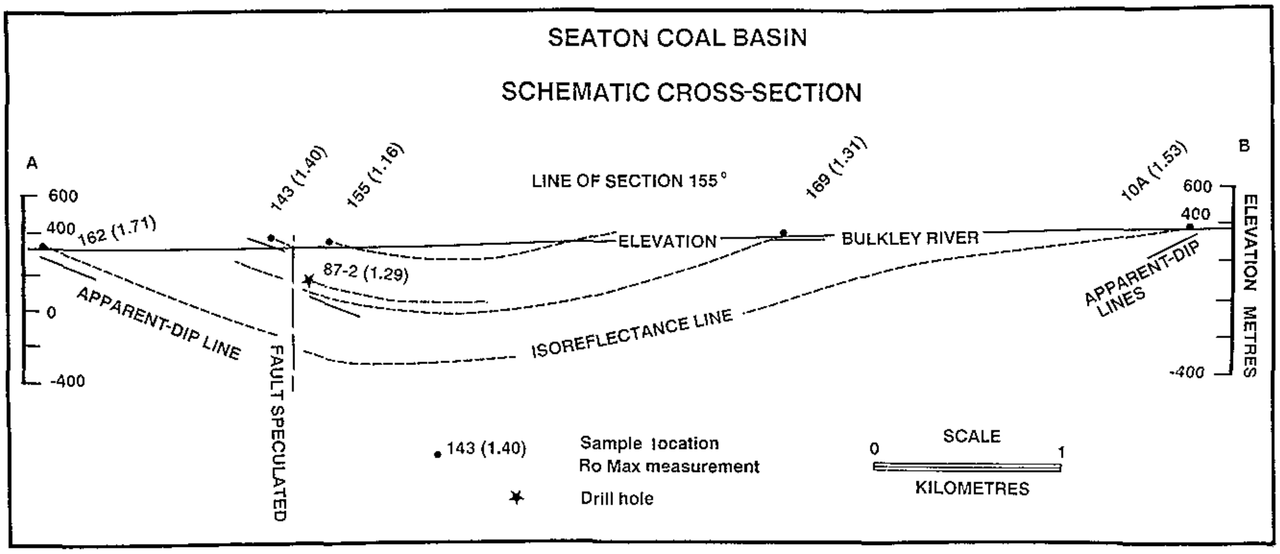

Figure B-8-7. Schematic cross-section of the Seaton coal basin showing reflectance data and apparent dip lines.

ture ranges that do not overlap. A stability index (calculated value) of 62 is excellent, but in this case may be an overestimate of the stability factor (measured value) because of the unusual composition of the coal.

Ash chemistry influences the behavior of metallurgical and thermal coal almost as much as do properties of the pure coal. The ash chemistry of Sample 143 (1.5 S.G. wash) was analyzed and a number of parameters calculated (Table B-8-4).

For metallurgical coals, an important parameter influenced by ash chemistry is "coke strength after reaction" (CSR; Yasuschi *et al.* 1983). This parameter can be calculated from rheology, rank and ash-chemistry data with reasonable success (Price and Gransden, 1987). The CSR value of 20 calculated for Sample 143 (1.5 S.G. wash) indicates that, on its own, Seaton coal may not have an acceptable CSR value but this does not detract from its value as fairly unique blend coal. The phosphorous content expressed as elemental concentration in coal, is 0.04 per cent. This is moderate to low and would not be a problem in the blast furnace where phosphorous can contaminate the hot metal.

A number of parameters calculated from ash chemistry are important for evaluating a thermal coal. Some of these parameters are:

base acid ratio (B/A), the sum of base oxides divided by: the sum of acid oxides;

silica ratio (SI ratio), a prediction of the amount of free quartz in the ash;

slag factor, an estimate of the tendency of the ash to melt in the boiler;

T250° C, an estimate of the temperature at which the molten ash has a viscosity of 250 poise.

These parameters are calculated in Table B-8-4. The B/A ratio of 0.166 is moderate to low. The silica ratio is high. The ash type is bituminous with a low slag factor. A T250° C temperature of 1325°C indicates a low to moderate slagging propensity.

Coal ash originates from a limited suite of silicate and carbonate minerals. The actual mix of minerals present depends on depositional factors and can be predicted with only moderate accuracy using a normative calculation approach. A computer program written by the author uses the ash oxide analysis and a combination of normative calculations, assumptions based on experience and iteration to estimate the minerals present. Results indicate trends but not accurate percentages. The results in Table B-8-4 indicate a mineralogy rich in kaolinite, quartz and illite with minor amounts of feldspar, chlorite and siderite. The low base/acid ratio and high kaolinite plus quartz contents indicate a nonmarine origin for the ash; but high organic sulphur and vitrinite contents are often associated with marine-influenced coal seams. A marine influence is unlikely in the Tertiary basins of northwest British Columbia. The high vitrinite and organic sulphur contents are more likely the result of rapid submergence into anaerobic brackish water.

REFLECTANCE DATA

To date six measurements of mean maximum reflectance (R_O Max) exist for the Seaton coal basin. One originates from the exploration activity in 1987 (Pearson, 1987), the other five were made in 1991 by the Geological Survey Branch. The results are tabulated in Table B-8-5 and plotted in Figures B-8-3 and 7. Figure B-8-7 is a regional section along the line A-B (Figure B-8-3); it shows projected R_O Max per cent sample data, apparent dip form-lines and speculative isoreflectance lines.

It is apparent from Figure B-8-7 that isoreflectance lines are in reasonable agreement with the apparent dip

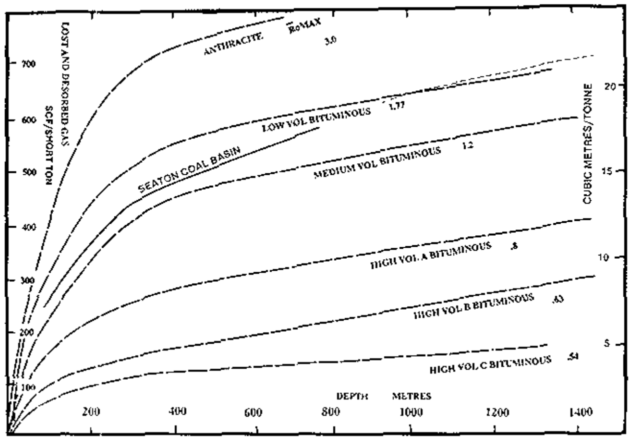

Figure B-8-8. Coalbed-methane retention track as a function of depth and rank for the Seaton coal basin.

form-lines. Reflectance values indicate that a rank of medium to low volatile bituminous extends for 6 kilometres along the Bulkley River through the Seaton coal basin and possibly an additional 11 kilometres south to Moricetown where an R_o Max value of 1.71 per cent was measured (Table B-8-5). This represents a large area of unusually high rank for Tertiary coal. It could result from a high geothermal gradient operating over the whole area or from numerous unconnected local heat sources associated with Tertiary intrusions and dikes. No intrusive rocks were found in outcrop or intersected by the drilling, consequently it is proposed that the pattern of reflectance values results from a high geothermal gradient that operated over at least 17 kilometres. This proposal is developed to see if it is at least one of many possible explanations for the preliminary data.

The reflectance data can be explained using a regional pretectonic geothermal gradient disrupted by a single fault. The fault is postulated to explain the disruption of isoreflectance lines near Drill Hole 87-2 (Figure B-8-3). Outcrop data neither confirm nor disprove the existence of the fault. If it exists, it trends northwest along Boulder and Sharpe creeks near the Bulkley River and has a throw of between 300 and 400 metres.

The R_o Max gradient indicated by the iso-reflectance lines is about 0.06 per cent per 100 metres calculated using the R_o Max values 1.71 per cent (Sample 162) and 1.16 per cent (Sample 155) and an estimated 900 metres of separation. This R_o Max gradient is in the range of values found in southeast British Columbia. (Table B-8-3, Hacquebard and Cameron, 1989). England and Bustin (1986) use equations of the type:

$$\text{Depth} = Ax(\log[R_o \text{ Max} \times 100]) - B\mu \quad (1)$$

to describe the relationship between depth and reflectance data from drill holes in the Western Canadian sedimentary basin. Using the two reflectance values above and the 900 metre separation. Equation 1 can be solved for the log gradient expressed as (log [R_o Max %])/km (*i.e.* the reciprocal of A x 1000 in Equation 1). A value of 0.187 is calculated for Seaton. A gradient value of 0.187 is bracketed by two values in Table 4 of England and Bustin (1986). The corresponding equations predict depths of 3285 and 2905 metres at an R_o Max value of 1.16 per cent (Location 155). Apparently approximately 3000 metres of missing cover is indicated for the basin.

The depth of burial of the basin can also be estimated from geothermal-gradient data. Figure 80 of Bustin *et al.* (1983) depicts the relationship between temperature, depth, R_o Max per cent and time. If the rocks were maintained at close to their maximum temperature for 50 million years, then a geothermal gradient of 39°C per kilometre is predicted using the R_o Max values of 1.16 and 1.71 per cent and 900 metres. This corresponds to a temperature of 115°C at the location of sample 155 (R_o Max = 1.16 %). Using a surface temperature of 10°C and the gradient of 39°C, a cover of 2700 metres is indicated above Sample 155. If the calculation is repeated using Figure 80 and a heating time of 10 million years then a gradient of 50°C per kilometre is predicted with a temperature of 185° at the location of Sample 155 and a cover of 3500 metres. The actual heating time must be less than 50 million years (the sediments are Eocene to Oligocene age) and probably longer than 10 million years, consequently a cover of approximately 3000 metres is indicated.

It should be emphasized that the above discussion is based on limited data and is only one of many possible explanations. If it is at least partially true, then the Seaton coal basin was subjected to a high geothermal gradient for a long time and probably at one time had considerable cover which has since been eroded.

A single R_o Max per cent measurement was made on coal from Driftwood Creek (Figure B-8-2). The value of 0.65 per cent indicates a rank of high volatile bituminous B, considerably lower than the rank at Seaton and similar to the rank in other Tertiary coal basins.

COALBED METHANE

Coalbed methane is extracted from coal seams in the United States on an ongoing commercial basis and in Western Canada a number of companies have pilot projects. There are many publications discussing the theory, resource and extraction of coal gas including a general reference by Rightmire *et al.* (1984). Ryan (1991) provides an example of a methane resource assessment for a coal basin in British Columbia. In the near future only large coal fields close to existing gas pipelines will be exploited for coal gas, however, small coal basins might provide low-cost energy to nearby communities.

A single house requires the desorbed gas from up to 400 tonnes of coal a year to meet its energy requirements. A small basin with a few million tonnes of coal can provide useful volumes of gas to augment gas, oil or electricity transported into the area.

The speculative coal resource in the Seaton coal basin is 56 million tonnes, estimated using 1.5 metres of coal over an area of 5.0 x 5.0 kilometres. Coal is distributed through the section in thin seams with some indication that thicker seams might be low in the section, below the levels intersected by drilling. The sediments accompanying the coal are at least 50 per cent sandstones and conglomerates with good permeability and porosity.

No attempt is made to evaluate the coalbed methane resource. Curves derived from Eddy *et al.* (1982) (Figure B-8-8) illustrate the amount of gas that can be recovered from coal of different ranks and depths of burial if pressure is reduced from *in situ* to atmospheric pressure. Isorank curves are drawn on Figure B-8-8; in fact, as depth increases, so usually does rank. At Seaton, the increase in rank can be approximated by a linear gradient of 0.06 per cent per kilometre. An equation derived by the author (Ryan, 1991) models the desoption curves. Using the equation and the reflectance gradient, it is possible to calculate the desorption versus depth track for coal in the Seaton section (Figure B-8-8). Because of the steep reflectance and geothermal gradients any coal deep in the Tertiary section could be very gassy, especially considering its high vitrinite content, and therefore could have a high hydrogen content.

COAL RESOURCE

Drilling and surface mapping have failed to locate any seams thicker than 1.40 metres. Most of the work was on the east side of the Bulkley River, probably in the middle or upper part of the section. Exploration in 1916 and 1927 was on the west side of the river and south of Seaton flag stop, and in most cases appeared to have located seams less than 1 metre thick. Thick coal-seam formation is probably not favoured by the generally coarse nature of sediments and evidence of short-term cyclical deposition. Thicker seams may exist in the basin, much of which remains untested, especially the stratigraphically lower part south and west of Seaton flag stop.

The topography and thick alluvium make it difficult to envisage a moderate strip ratio for surface mining. The coal quality is unique for Tertiary coals and it has interesting metallurgical coal properties. The location of the coal basin next to a rail line already transporting coal to a coal terminal would reduce development and operating costs. Before any further exploration of the basin for conventional mining can be expected there will have to be indications of the presence of thicker coal seams and an improvement in coal markets.

The Seaton coal basin is probably a better coalbed methane resource than a conventional coal resource. The rank, coal composition and interburden rock types are favourable. The disadvantage of thin seams might be offset by the advantage of good lateral permeability within each sedimentary cycle.

CONCLUSIONS

All the data available to the author are summarized in this report. Not all outcrops of Tertiary sediments were visited and it is planned to conduct more mapping in the basin.

The coal and coalbed-methane resources of the Seaton coal basin appear to be limited. There are untested areas, however, and this should not be considered as the final assessment. Seaton coal has unique properties that make it interesting as a coalbed methane and metallurgical coal resource.

The discussion of possible geothermal gradients and cover thicknesses is speculative and based on limited data. Coal samples will be obtained from the drill core for reflectance measurements. Data will establish a well-controlled R_0 Max gradient over about 200 metres.

ACKNOWLEDGMENTS

Thanks are extended to Dr. Richards who made the Atna Resources Limited data available and in so doing, allowed me to make use of the work of Collin Harival and Ashton Mullen. The reflectance measurements were performed at short notice by JoAnne Schwemler. Field assistance was provided by Jack Whittles and the manuscript was cheerfully typed under tight time constraints by Marylin Demarchi.

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RECONNAISSANCE LITHOGEOCHEMISTRY, OWEEGEE AND KINSKUCH AREAS, NORTHWESTERN BRITISH COLUMBIA (104A/11, 12; 103P/11)

(Fig. B1, No. 9)

By C.J. Greig

INTRODUCTION

Thirty-eight lithogeochemical samples were collected in the 1990 field season from previously undocumented mineral occurrences or alteration zones in the Kinskuch Lake area and Oweegee Range of northwestern British Columbia (Figure B-9-1). Samples were collected during the course of 1:50 000-scale mapping which is part of a study with the primary intent of describing the regional stratigraphy and structure along the west-central margin of the Bowser Basin. The regional work forms the basis the author's ongoing doctoral dissertation at the University of Arizona. Fieldwork for the study is funded primarily by the Frontier Geoscience Program, as part of the Geological Survey of Canada's Bowser Basin project, which is under the direction of C.A. Evenchick. A grant was obtained from the British Columbia Ministry of Energy, Mines and Petroleum Resources, Geological Survey Branch, to help defray the costs of sample collection and analysis for the lithogeochemical portion of the study.

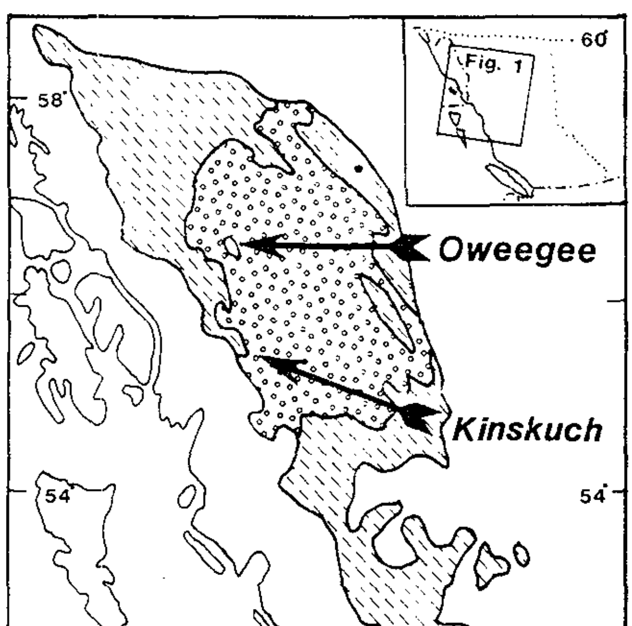

Figure B-9-1. Location map of Oweegee and Kinskuch areas, north-central British Columbia. Stippled pattern represents Bowser Lake Group strata; hachured pattern represents Middle Jurassic and older basement rocks of the Stikine Terrane.

The impetus for lithogeochemical sampling in the Oweegee and Kinskuch areas comes primarily from the economic promise of "basement" rocks which underlie the Middle Jurassic to Early or middle Cretaceous Bowser Lake Group (Anderson and Thorkelson, 1990; Lefebure and Malott, 1990). Lower and Middle Jurassic rocks, in particular those of the Hazelton Group, have a well-deserved reputation as the host for economically significant vein and volcanogenic massive sulphide deposits. In addition, Paleozoic and lower to middle Mesozoic rocks of the Stikine Terrane in northwestern British Columbia host significant porphyry copper-gold reserves. Also, a number of Eocene porphyry molybdenum deposits with significant reserves occur in the vicinity of the Kinskuch area (Carter, 1981).

In the northern Oweegee Range, at the north end of the "Oweegee dome", recognition of a thick sequence of flows and pyroclastic rocks of the Early to Middle Jurassic Hazelton Group suggests that preservation of Stikine Terrane stratigraphy is relatively complete. Details of the geology are given in Greig (1991), and a geologic sketch map is used as a location map in Figure B-9-2. Previous work in the area has consisted of reconnaissance mapping (Koch, 1973; Monger, 1977), and no mineral occurrences are recorded in MINFILE (104A) for the area.

In contrast, the Kinskuch area (Figure B-9-3) preserves a much less complete stratigraphic succession [Lower Jurassic(?) and younger], but has been the focus for much more mineral exploration (MINFILE 103O&P) and geologic mapping (Hanson, 1935; Grove, 1986; Alldrick *et al.*, 1986; Dawson and Alldrick, 1986; Greig, 1991).

SAMPLE COLLECTION, ANALYSIS AND RESULTS

Most samples weighed approximately one kilogram and were taken from the most heavily mineralized or intensely altered sections of outcrops of potential economic interest. In the Kinskuch Lake area, an attempt was made to sample only mineral showings undocumented in MINFILE.

Results of analyses for a suite of seven elements (Au, Ag, As, Hg, Sb, Cu, Pb, Zn and Ba) are presented in Table B-9-1, together with a brief sample description and UTM

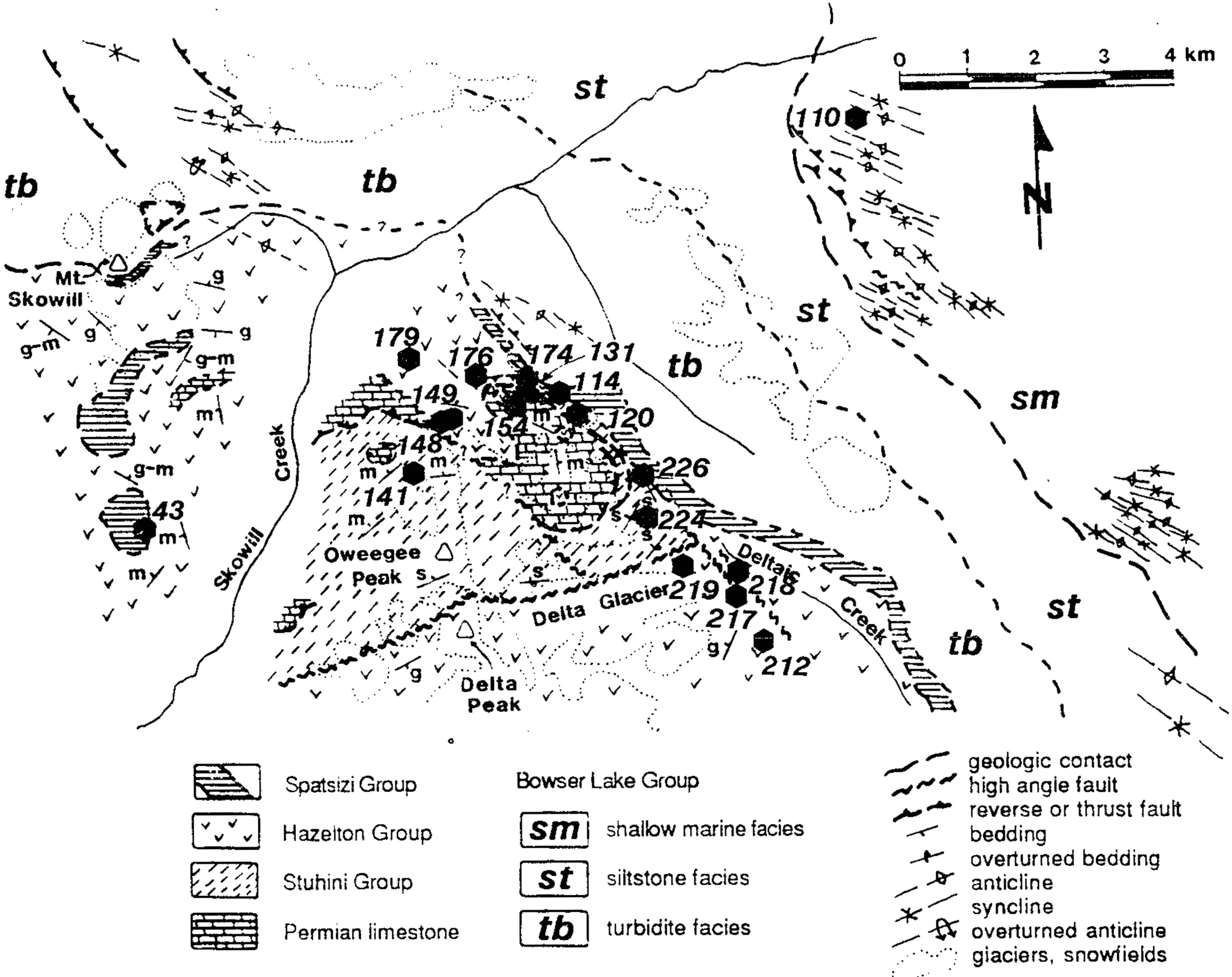

Figure B-9-2. Sample location (filled hexagons) map and generalized geology, Oweegee area.

TABLE B-9-1. Lithogeochemical results, Oweegee and Kinskuch areas. Abbreviations: qz=quartz, py=pyrite, fs=feldspar, Fe cb=iron carbonate, sus=sulphides, vfg=very fine grained, sil.=silicification, altn=alteration, dissem.=disseminated.

SAMPLE NUMBER	UTM EASTING	UTM NORTHING	SAMPLE DESCRIPTION	Au ppb	Ag ppm	As ppm	Hg ppb	Sb ppm	Cu ppm	Pb ppm	Zn ppm	Ba ppm
43	460670	6280130	laminated, siliceous argillite	3	0.3	15	390	1.0	78	12	110	740
110	471290	6285970	limonitic felsic dike; 5% dissem. py, <1m	3	<0.2	9	50	<0.2	250	2	112	320
114	466440	6282200	clay-altered tuffaceous(?) mudstone, <10cm	3	<0.2	13	150	0.6	16	10	110	1340
120	466860	6281480	Fe cb veins (cm-scale); siliceous argillite	2	0.2	3	50	<0.2	60	<1	44	320
131a	466250	6281940	Fe cb and qz veins, sil., <1m zone	3	0.3	6	80	<0.2	20	2	150	160
131b	466250	6281940	Fe cb and qz veins, sil., <1m zone	<1	<0.2	4	30	<0.2	16	<1	30	120
131c	466250	6281940	Fe cb and qz veins, sil., <1m zone	3	0.2	8	120	0.2	82	<1	104	220
141	464490	6280890	siliceous tuffaceous(?) siltstone; semi-msv py; float	26	0.7	6	130	1.8	52	20	60	230
148	464930	6281620	siliceous, semi-msv py; m-scale irregular zone	6	1.0	300	910	11.4	220	70	255	820
149	465040	6281650	qz-sericite-py altn; grab-chip from m-scale irregular zone	71	1.2	176	1900	3.2	70	10	56	1300
154	465970	6281970	pyritic chert and boxwork limonite in limestone host	6	0.2	2320	650	11.6	52	88	330	3600
174a	466130	6282200	pyritic fault gouge	8	0.2	2370	2900	6.2	14	10	110	180
174b	466130	6282200	pyritic fault gouge	12	0.2	2800	3300	14.6	26	20	255	160
176	465410	6282300	Fe cb vein and altn zone; average width 20cm	<1	<0.2	110	170	0.6	62	4	110	200
179	464440	6282450	pyritic porphyritic felsic dike, qz micro-veinlets	2	<0.2	40	90	0.2	32	4	106	4500
212a	469080	6278530	limonite cb breccia with qz veins, dissem. py; angular float	<1	<0.2	8	50	<0.2	20	<1	50	120
212b	469080	6278530	limonite cb breccia with qz veins, dissem. py; angular float	1	0.2	12	60	<0.2	38	<1	100	140
217a	468870	6279110	cm-scale, discont. cb and qz veins across 2m; local vfg sus	<1	<0.2	5	30	<0.2	56	<1	56	180
217b	468870	6279110	cm-scale, discont. cb and qz veins across 2m; local vfg sus	<1	0.2	3	40	<0.2	28	<1	58	130
218	468930	6279170	sil., felsic diking(?); 2m brittle fault zone	52	4.0	62	130	20.0	20	82	180	1520
219a	468280	6279340	sil. +/- semi-msv py; irregular m-scale zones	3	<0.2	5	60	<0.2	140	<1	66	280
219b	468280	6279340	sil. +/- semi-msv py; irregular m-scale zones	3	<0.2	15	180	<0.2	34	8	14	1200
219c	468280	6279340	sil. +/- semi-msv py; irregular m-scale zones	6	<0.2	9	70	<0.2	98	6	58	200
224	467530	6280180	5% dissem. py; silty shale	7	<0.2	10	100	<0.2	64	10	26	380
226	467840	6280550	semi-msv py, qz veins and sil.; moraine boulder	19	2.6	36	780	10.6	52	6	184	100
257	484760	6166280	Fe cb, limonite breccia, 2mx10m, in felsic volcanic host	1	<0.2	26	180	<0.2	18	2	220	2500
259	484670	6166540	pyritic (<10%), felsic/silicified tuff-breccia	<1	<0.2	24	110	1.6	8	4	100	1000
260	484720	6166580	pyritic qz, cb fracture-filling; <20cm	<1	<0.2	40	120	9.6	12	4	64	3200
261	484780	6166490	siliceous argillite; <10% dissem. py, rare py veinlets	23	0.2	2150	140	5.6	10	16	40	1400
286	471350	6170720	cb-cemented brecciated argillite	4	0.8	82	350	7.4	24	16	86	1000
302	474300	6172490	semi-msv py; siliceous felsic intrusion/silicified zone(?)	1	0.2	22	80	1.4	20	2	86	4200
303	474300	6172780	semi-msv py; siliceous felsic intrusion/silicified zone(?)	4	<0.2	23	290	1.8	150	10	20	1560
326a	470340	6174850	Fe-cb veins, sil., dissem. vfg sulfides; <3m fracture zone	3	<0.2	6	50	<0.2	86	8	20	300
326b	470340	6174850	Fe-cb veins, sil., dissem. vfg sulfides; <3m fracture zone	10	<0.2	142	80	12.6	94	4	76	460
328	469900	6175100	dissem. py (10%), semi-msv py; m-scale clay-altered zone	<1	<0.2	136	80	8.6	88	2	76	520
329	469880	6175120	fs porphyry; dissem. py, clay alteration, sil.(?)	101	1.3	46	400	24.0	54	16	22	900
359	484420	6167480	calcareous silty mudstone; <5% dissem. py	6	0.3	36	210	9.6	136	20	330	1800
365	484230	6169190	calcareous siltstone-possible hydrozincite(?)	3	<0.2	40	180	14.0	40	12	68	1300

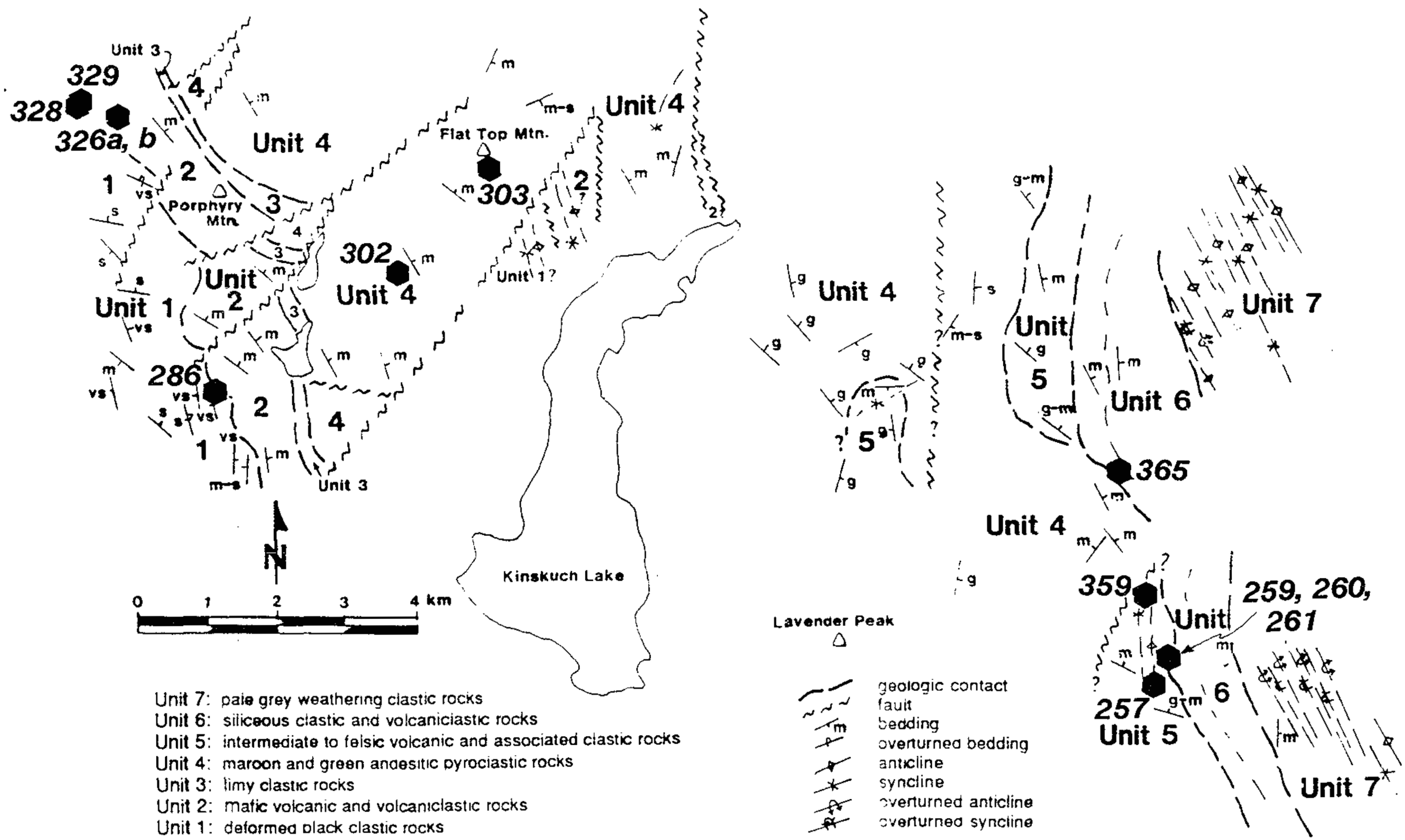

Figure B-9-3. Sample location (filled hexagons) map and generalized geology, Kinskuch area.

grid coordinates taken from 1:50 000 topographic maps. Sample locations are shown on the geologic sketch maps in Figures B-9-2 and 3. Samples were also analyzed for tin and tungsten, but all results were at or below the 2 ppm detection limit and are therefore not shown in Table B-9-1. Analyses were performed by Chemex Labs Ltd.

Several results of this study warrant discussion. In both Oweegee and Kinskuch areas, the thick sequence of marine clastic rocks comprising the Bowser Lake Group appears to have little metallic mineral potential. Despite a complex structural history, many traverses showed that the Bowser Lake Group has experienced minimal igneous or hydrothermal overprinting and it is no surprise that there is a dearth of mineral occurrences recorded in MINFILE for areas underlain by these rocks.

In the Oweegee area, there is a common association of northwest-striking faults and pyritic, typically siliceous mineralization containing elevated values of arsenic, mercury and antimony, and a suggestion of enrichment in precious metals (Figure B-9-2, Table B-9-1). Locally, such as along the margins of Oweegee and Delta glaciers, mineralization close to the faults is highlighted by conspicuous orange limonite zones, but in general, the structures are poorly exposed. In light of this and considering that much of the southern Oweegee dome appears to be underlain by rocks of the metals-rich Hazelton Group, further work is merited to evaluate the mineral potential of the faults and possible related structures.

Of the samples collected in the Kinskuch area, perhaps the most economically interesting are those from the western study of the map-area, northwest of Porphyry Mountain (Figure B-9-3, Table B-9-1, samples 326-329). Although not yielding outstanding base or precious metal values, the scattered, intensely altered outcrops of mafic(?) volcanic rock from which the samples were collected indicate that this area was affected by an extensive hydrothermal system.

SUMMARY

Mapping and lithogeochemistry in the Kinskuch River area and Oweegee Range has identified significant potential for mineral exploration. In the Oweegee Range, the previously undocumented presence of Lower Jurassic rocks correlative with the metallogenically significant Hazelton Group represents a significant target for "grass roots" exploration. Faults near the eastern margin of the Oweegee dome may have localized pyrite-rich mineralization with elevated arsenic, mercury, and antimony values. Further work is suggested to evaluate the potential of these systems for localizing precious metals. In the Kinskuch area, an extensive zone of hydrothermal alteration northwest of Porphyry Mountain also merits further attention. In both the Kinskuch and Oweegee areas, the Bowser Lake Group exhibits little metallic mineral potential.

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

(Fig. B1, No. 10)

T.E. Kalnins and A.F. Wilcox

SUMMARY OF ASSESSMENT WORK, 1990

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

The value of work declared in Assessment Reports represents approximately 40 per cent of the estimated $143 million total exploration expenditures in the province. About one half of the assessment work costs is credited to tenure extension of mineral claims. Submission of extra information in Assessment Reports is encouraged by the Portable Assessment Credit (P.A.C.) system introduced in 1977 (Table B-10-2).

The number of Assessment Reports submitted and approved in 1990 totalled 1199 with a declared value of $58 421 502, a small decrease from 1989 (Table B-10-1, Figure B-10-4).

Most of the reported exploration occurred in northwestern B.C. (NTS 104/114, "Golden Triangle" area, Figure B-10-1, 2), followed by continued activity in southern B.C. (NTS 82 and 92) and central B.C. (NTS 93, Cariboo district). Drilling accounted for about 40 per cent of the expenditures, geochemistry 28 per cent, and other surveys 32 per cent (Figure B-10-3).

Average exploration project unit costs by work type are shown in Tables B-10-3 and 4. These values are based on clearly apportioned cost statements declared in 627 selected Assessment Reports, including labour, consult-

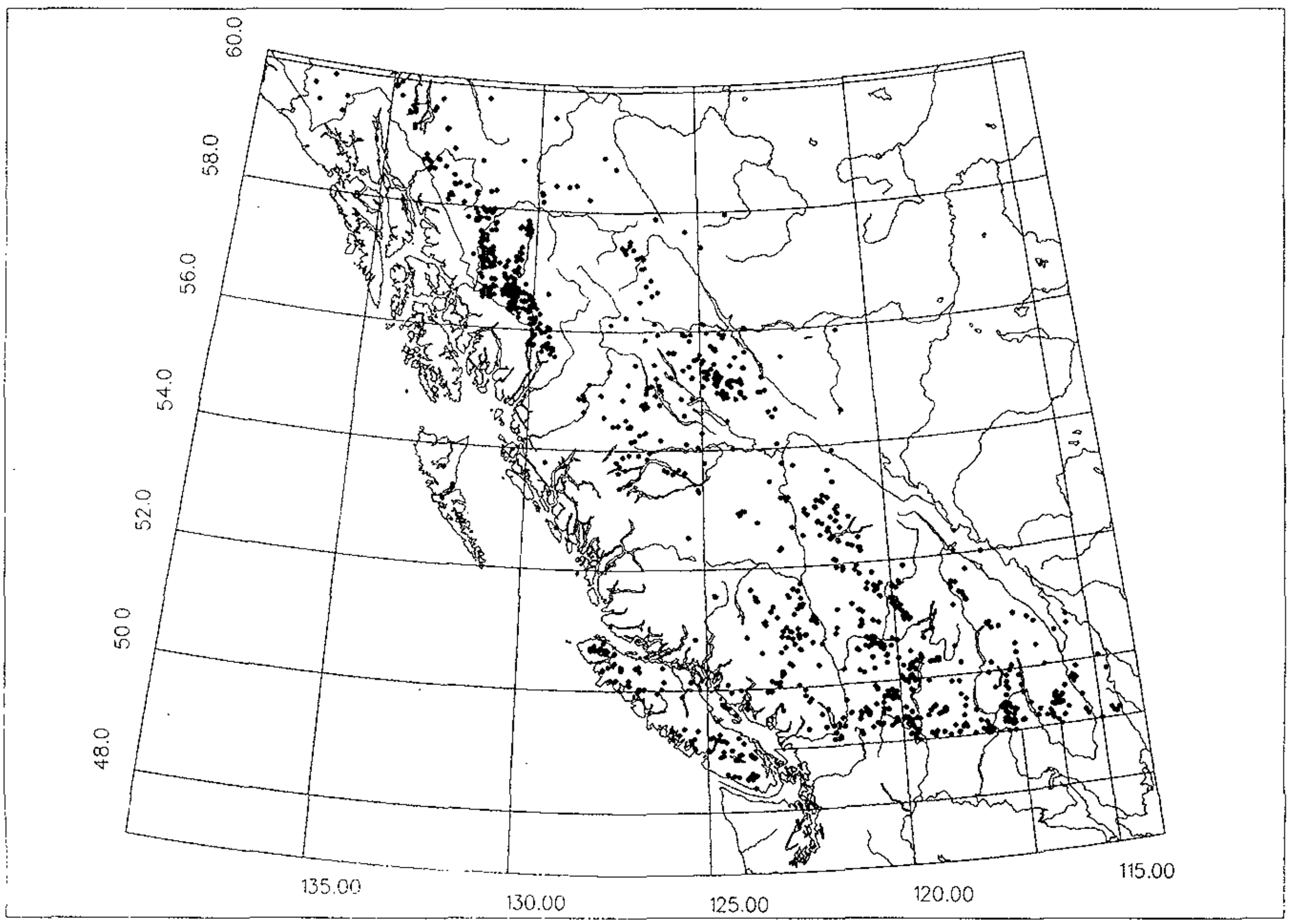

Figure B-10-1. Distribution of Assessment Reports, 1990.

TABLE B-10-1
SUMMARY OF ASSESSMENT WORK, 1990

NTS	No. of A.R.	Value $	Geological (ha)	Geophysical Airborne (km)	Geophysical Ground (km)	Geochem. No. of samples	Drilling Core (m)	Non-Core (m)	Prosp. (ha)	Trench-ing (m)	Access Roads (km)	Line/ Grid (km)	Tunnel (m)
82/83	273	10 976 646	88 163	6787	3337	63 573	46 232	5 374	13 752	9519	429	1138	--
91/102	272	9 847 434	73 174	2460	2333	69 240	39 486	10 658	13 114	13 441	39	1209	--
93	230	10 274 534	63 878	19 846	2570	87 216	34 113	5106	11 460	10 074	48	1519	--
94	36	2 308 792	19 578	-	757	12 038	9 043	-	2 060	363	-	486	--
103	47	4 476 271	33 813	191	979	16 164	19 846	-	1 225	747	1	123	--
104/114	341	20 537 825	63 958	7566	1044	66 275	36 399	1221	85 663	5 353	20	685	765
TOTALS													
1990	1199	58 421 502	342 564	36 850	11 020	314 506	185 119	22 359	127 274	39 497	537	5160	765
1989	1233	60 856 206	264 373	36 756	10 451	363 152	207 511	34 139	124 516	42 025	222	5921	3961
1988	1403	79 018 639	322 187	20 174	15 294	481 245	344 262	52 524	61 076	67 782	425	9285	4723

TABLE B-10-2
PORTABLE ASSESSMENT CREDIT (PAC)
TO END OF 1990

YEAR	NO. CO.[1] INDIV.	DEBITS	CREDITS	WORK DEBITS	DEBITS CATEGORIES TITLE EXTENS.	NO. CO.	FEE[2] REFUNDS	NO. CO.
1978	95	545 758	2 647 638	97 658	10 000	2	438 100	4
1979	110	941 592	2 516 306	123 492	-	-	818 100	9
1980	200	1 359 276	7 317 374	216 876	87 600	5	1 054 800	7
1981	300	4 714 766	18 120 394	670 366	170 800	6	3 873 600	16
1982	240	5 305 102	15 061 571	563 702	181 600	5	4 559 800	14
1983	225	4 287 576	14 141 138	501 376	181 400	6	3 604 800	20
1984	468	5 668 026	8 612 085	956 626	35 100	5	4 676 300	19
1985	264	2 226 853	9 464 256	529 553	71 000	3	1 626 300	20
1986	441	3 006 531	14 948 056	1 219 431	119 600	6	1 667 500	24
1987	372	2 050 501	14 746 216	682 001	223 800	5	1 144 700	20
1988	422	2 426 221	35 285 633	492 921	174 000	4	1 759 300	21
1989	401	1 132 300	27 832 446	661 300	471 000	1	Discontinued	-
1990	267	541 998	17 064 932	453 998	88 000	9	-	-
TOTALS		34 206 500	187 758 045	7 169 300	1 813 900		25 223 300	
BALANCE			153 555 885					

[1] *The PAC ledger contains 878 active accounts and 1009 inactive accounts (no entries in last four years).*
[2] *A debit of $100.00 is made for every $5.00 recording fee refunded.*

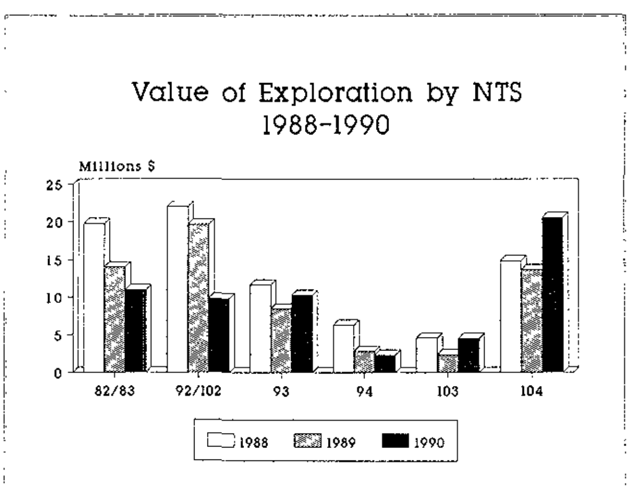

Figure B-10-2

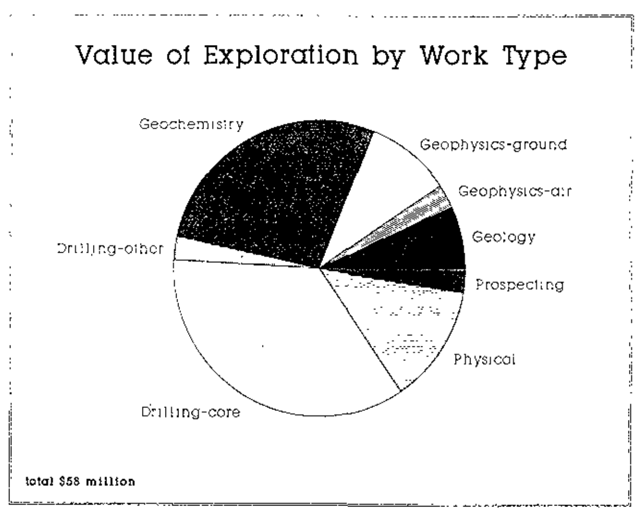

Figure B-10-3

TABLE B-10-3
EXPLORATION PROJECT COSTS, 1990

TYPE OF WORK	AMOUNT	UNITS	VALUES $	AVERAGE COST $		NO. OF SURVEYS
Geological mapping	296 206	ha	3 154 567	11	per ha	165
Photo interpretation	14 800	ha	15 964	1	per ha	4
Petrography	177	samples	15 787	89	per sample	18
Magnetic, airborne	16 697	km	643 601	39	per km	43
Electromagnetic, air	14 336	km	594 929	41	per km	39
Magnetic, ground	3 681	km	627 396	170	per km	103
Electromagnetic, ground	2 441	km	695 031	285	per km	100
Induced polarization	727	km	966 537	1329	per km	38
Resistivity (alone)	67	km	72 100	1078	per km	6
Seismic	10	km	38 894	3969	per km	3
Self potential	12	km	3 451	281	per km	3
Soil sampling	99 288	samples	3 219 716	32	per sample	208
Stream sediment	2 531	samples	292 092	115	per sample	53
Rock chip	11 315	samples	889 895	79	per sample	147
Heavy minerals	267	samples	39 349	147	per sample	13
Sampling-assaying	43 299	samples	1 173 281	27	per sample	91
Metallurgy	7	samples	13 478	1925	per sample	3
Diamond drilling	80 449	metres	8 763 278	109	per metre	70
Percussion drilling	3 204	metres	143 410	45	per metre	7
Rotary drilling	8 351	metres	588 199	70	per metre	4
Prospecting	92 328	ha	782 378	8	per ha	160
Line cutting, grid	3 166	km	1 254 243	396	per km	125
Road work	81	km	309 891	3831	per km	17
Trenching	12 295	metres	375 224	31	per km	32

TABLE B-10-4
EXPLORATION PROJECT COSTS, 1988 - 1990
($ PER UNIT OF WORK)

TYPE OF WORK	1988	1989	1990
Geological mapping	15/ha	12/ha	11/ha
Magnetic, ground	225/km	242/km	170/km
Electromagnetic, ground	321/km	302/km	285/km
Mag./E.M., airborne	94/km	90/km	80/km
Induced polarization	1720/km	1986/km	1329/km
Seismic	-	8978/km	3969/km
Soil sampling	25/sample	23/sample	32/sample
Silt sampling	71/sample	86/sample	115/sample
Rock sampling	49/sample	46/sample	79/sample
Drilling, core	111/m	99/m	109/m
Drilling, non-core	71/m	80/m	70/m
Prospecting	10/ha	7/ha	8/ha
Line/grid estab.	244/km	290/km	396/km

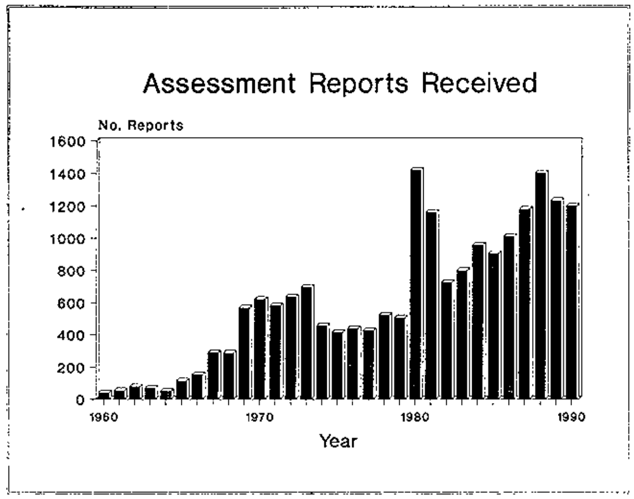

Figure B-10-4

ing, food, accommodation, transport, equipment rentals and supplies, laboratory analyses, report preparation, and direct administration - management of the project.

Most exploration was directed toward polymetallic base metals and precious metals deposits. Industrial minerals accounted for about 2 per cent of the assessment work costs.

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 over 21 000 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 on 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 COMFICHE.

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A complete library of original Assessment Reports is located at the Branch's headquarters in Victoria. Partial libraries are located at the District Geologists' offices in Smithers, Prince George, Kamloops, Nelson and Victoria. Complete libraries of microfiche Assessment Reports are available in all District Geologists' offices and Vancouver. Partial libraries are maintained in nineteen Gold Commissioners' offices throughout British Columbia. For further information contact:

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