885726

MOUNT MILLIGAN (93N 194)

(Fig. B1, No. 12)

By E.L. Faulkner, V.A. Preto, C.M. Rebagliati and T.G. Schroeter

LOCATION:	Lat. 55°08′00″ Long. 124°04′00″ (93N/1E) OMINECA MINING DIVISION. The property is located on the southeast flank of Mount Milligan, approximately 95 kilometres north of Fort St. James.
CLAIMS:	PHIL 1, 8-12, 21-26, 29 HEIDI 1-4 and one fractional claim (275 units).
ACCESS:	Approximately 145 kilometres northwest of Prince George via Highway 97, Windy, Philips Mainline and Rainbow Creek logging roads.
OWNER/OPERATOR:	Joint Venture between CONTINENTAL GOLD CORP. (69.8%) and BP RESOURCES CANADA LIMITED (30.2%). Continental Gold Corp. is the operator.
COMMODITIES:	Gold, copper.

INTRODUCTION

This report is an update of previous reports by Faulkner (1986, 1988). A major exploration program, with year-round drilling by as many as seven machines since late 1988, has outlined two large-tonnage low-grade open pittable gold-copper deposits, the Mount Milligan and Southern Star. The total mineral inventory currently exceeds 400 million tonnes, with grades ranging from 0.15 to 0.7 per cent copper and 0.17 to 2.75 grams per tonne gold.

A Prospectus has been filed with the British-Columbia Mine Development Review Committee, with a production decision expected late in 1990.

HISTORY

The earliest record of exploration activity in the area is by prospector George Snell, who found gold-bearing float on the western flank of Mount Milligan in 1937. In 1945 Mr. Snell returned to the area and staked 10 two-post claims west of Mitzi Lake. Five pyritic andesite float samples returned assays ranging from trace to 148.8 grams per tonne gold. The source of the float was not found and no other gold-bearing mineralization was found in place.

In 1972 Pechiney Development Ltd. staked 10 two-post claims on the western flank of Mount Milligan and the following year drilled five holes to test induced polarization and copper soil geochemical targets for porphyry copper mineralization. The claims were subsequently allowed to lapse.

In 1982 and 1983, Selco Inc. (now BP Resources Canada Inc.) staked the Phil claims, encompassing the former Pechiney claims, as an alkali-porphyry copper-gold prospect.

In April 1984, Richard Haslinger staked the Heidi claims, tying on to the eastern side of the Selco/BP claim block to cover a copper-gold prospect he had discovered in 1983. BP optioned the Heidi claims from Richard Haslinger in August 1984 and staked additional claims.

In 1984-85, BP undertook extensive geological, soil geochemical, magnetic and induced polarization surveys, identifying large, high-contrast coincident anomalies. A modest backhoe-trenching program identified two medium-grade auriferous, polymetallic, multiple vein systems and low-grade porphyry gold-copper mineralization.

In early 1986, the Mount Milligan property became inactive when BP discontinued exploration for bulk tonnage porphyry gold-copper deposits in British Columbia.

In April, 1986, Lincoln Resources Inc. entered into an exploration agreement with BP and work resumed on the property. On September 25, 1987, Lincoln Resources drilled discovery hole 87-12 into the Mount Milligan gold-copper deposit. Additional drilling, in early 1988, substantiated the discovery of a major porphyry gold-copper deposit. By early 1988 BP's interest had been diluted to 30.16 per cent but since late 1988 it has participated in funding on-going exploration to maintain its interest at this level.

In July, 1988, Lincoln Resources reorganized to become United Lincoln Resources Inc. and continued drilling to expand the deposit. In August 1988 Continental Gold Corp. acquired 64 per cent of the outstanding shares of United Lincoln Resources Inc., and the two companies subsequently merged.

Delineation drilling on the Mount Milligan deposit continued and on July 12, 1989, Hole 89-200 discovered the Southern Star deposit.

WORK DONE

To December 31, 1989, after coring 96 390 metres in 406 diamond-drill holes, drilling had delineated in excess of 400 million tonnes of gold-copper mineralization in the Mount Milligan and Southern Star deposits. Expenditures on the property to December 31, 1989 were approximately $11.35 million.

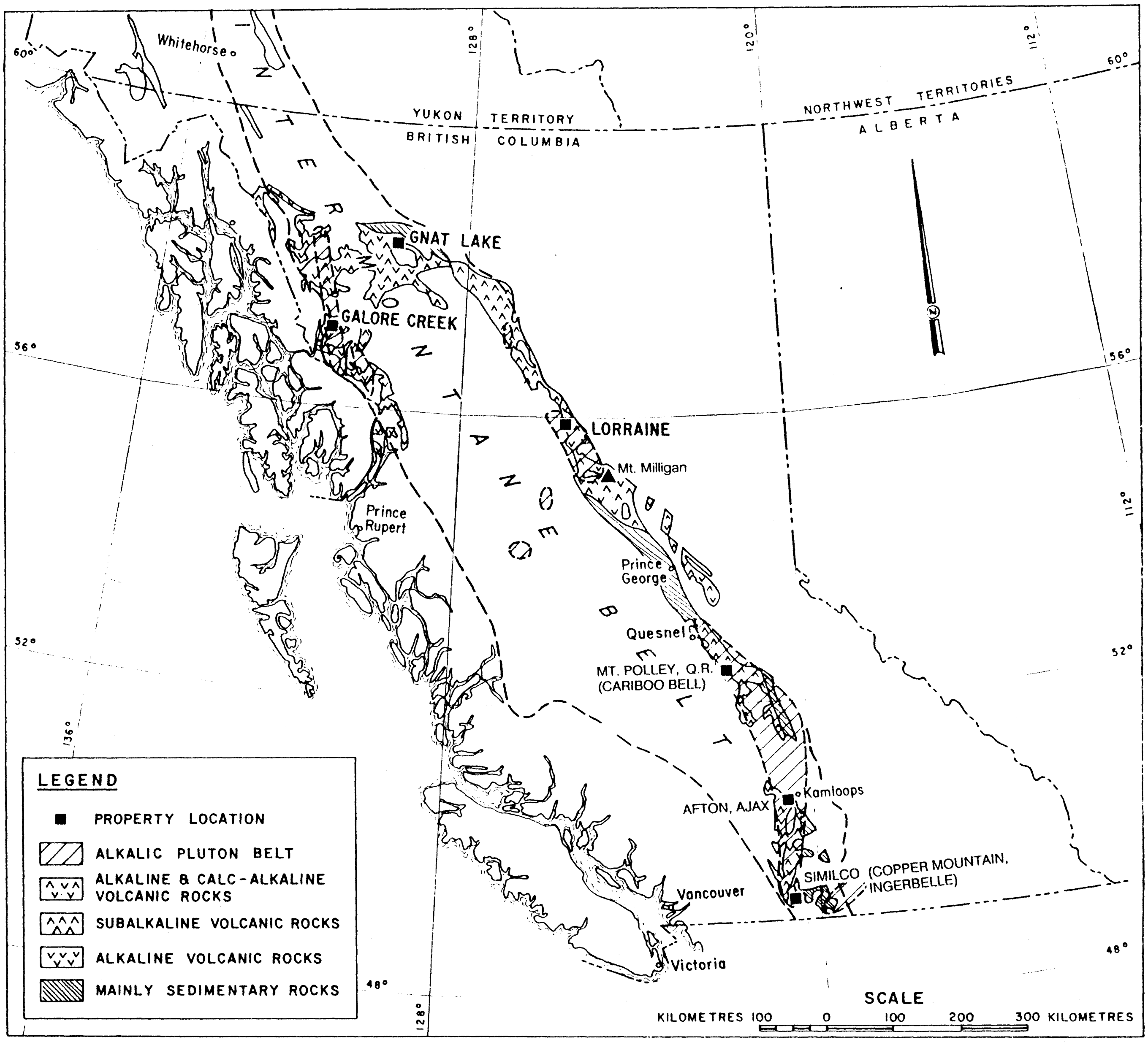


Figure B-12-1. Upper Triassic and Lower Jurassic volcanic rocks, significant copper deposits and associated alkalic plutons in the Canadian Cordillera.

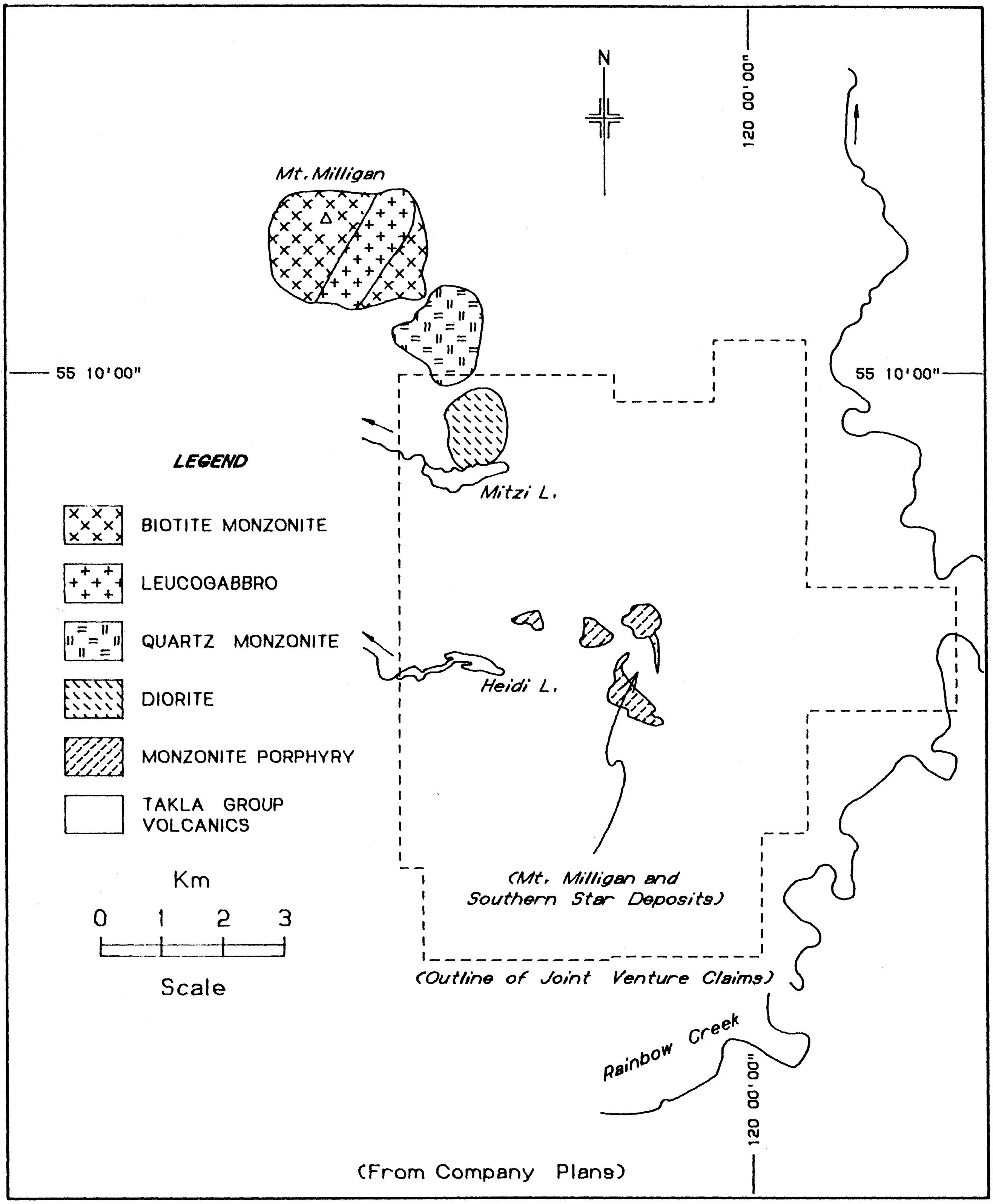


Figure B-12-2. Mount Milligan intrusive complex.

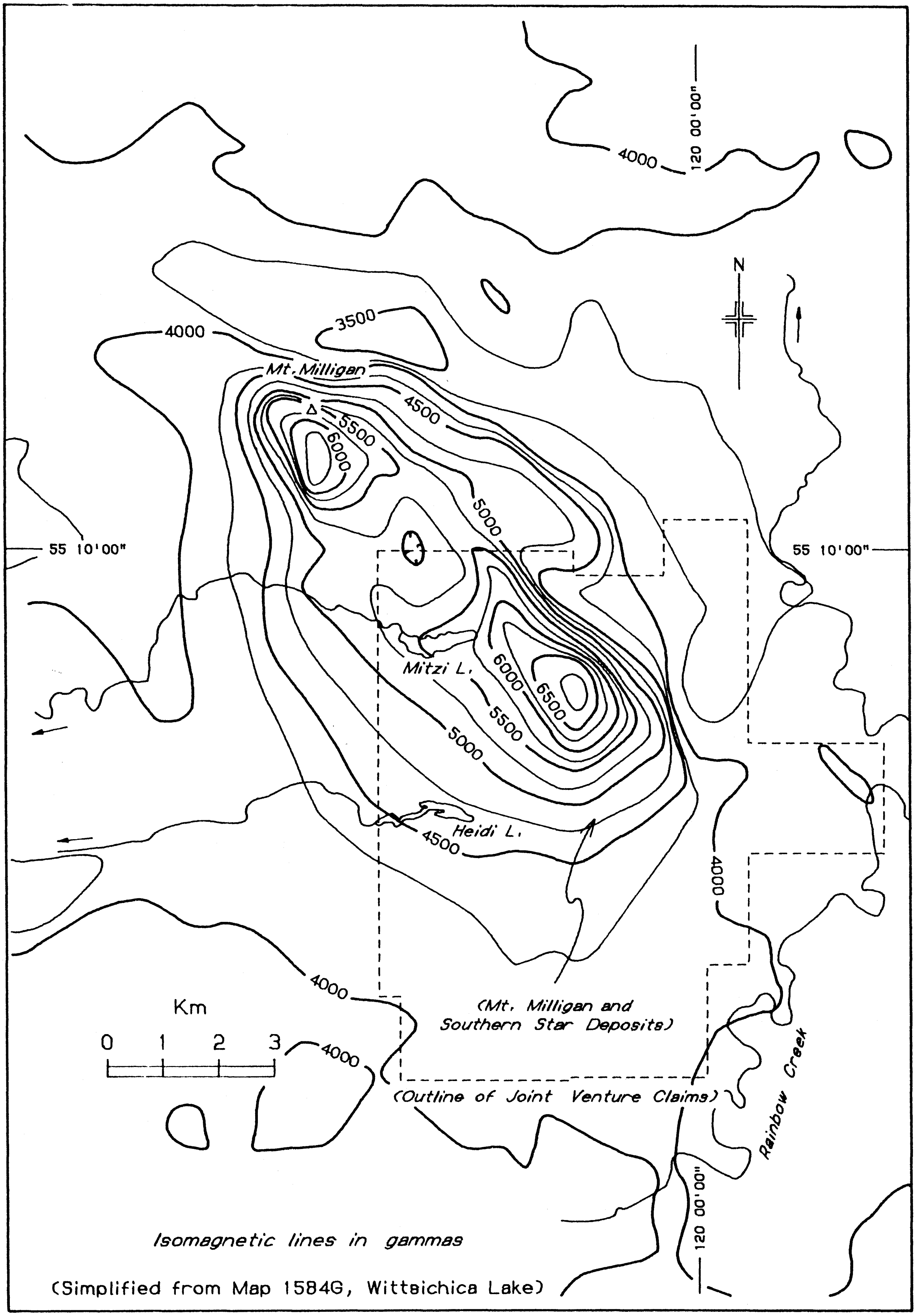


Figure B-12-3. Mount Milligan aeromagnetic map.

GEOLOGY

REGIONAL GEOLOGICAL SETTING

The Mount Milligan property lies within the regionally extensive early Mesozoic Quesnel belt. This belt extends northwesterly for 1200 kilometres and includes equivalent rocks of the Upper Triassic to Lower Jurassic, Takla, Nicola and Stuhini groups (Mortimer, 1986) (Figure B-12-1).

To the west, deformed uplifted Permian Cache Creek Group rocks are separated from the Quesnel belt by the Pinchi fault zone. To the east, the Manson fault zone separates this belt from the uplifted Proterozoic/early-Paleozoic Wolverine metamorphic complex and the Mississippian-Permian Slide Mountain Group (Garnett, 1978).

The volcanic centres are intruded by generally coeval alkaline stocks of monzonite, syenite and diorite. In the southern part of the Quesnel trough, many of these stocks have a northwest linear alignment, suggesting a strong fault control of intrusions and associated volcanic rocks. In the northern Quesnel trough however, the intrusions appear to be more scattered. Throughout the trough, several of these intrusions are the sites of significant alkali-porphyry copper-gold mineralization.

In the Mount Milligan area, the Takla Group is dominated by a thick sequence of subaqueous augite porphyry and hornblende porphyry flows and related pyroclastics of intermediate composition. These form a homoclinal succession which strikes northwest with steep to moderate easterly dips. Regional metamorphism is of greenschist grade, with some local skarn-like assemblages that are probably the result of hydrothermal alteration.

The Mount Milligan intrusions comprise biotite monzonite, quartz monzonite, monzonite porphyry, diorite and leucogabbro phases (Figure B-12-2) and have a pronounced magnetic signature (Figure B-12-3). Discrete magnetic highs reflect the composite nature of the intrusions. The contact of the leucrogabbro with the biotite monzonite (Figure B-12-2), where observed, is strongly sheeted. Other contacts have not been observed.

The quartz monzonite is medium to very coarsely porphyritic, fresh and unaltered, and appears to be of later, possibly Cretaceous age.

PROPERTY GEOLOGY

Figure B-12-4 shows the property geology. There is little outcrop in the area of current exploration, and none in the area of the Mount Milligan deposit. The geology has been inferred largely from drill-hole information, and the degree of geological detail therefore largely reflects the density of drilling. Consequently the Mount Milligan deposit is defined in some detail, the Southern Star deposit is less well defined, and other areas are poorly defined. Areas between drill targets are largely unexplored.

Figure B-12-5 shows the geology of the Mount Milligan deposit inferred at the 1050 metre elevation. Figures B-12-6, and B-12-7 are east-west cross-sections of this deposit.

The hostrocks are a thick east-dipping sequence of massive, pale to dark greenish-grey pyroxene porphyries of andesite and latite composition, with lesser heterolithic agglomerates, some discontinuous, pale, bedded tuffs and rare tuffaceous argillites. This sequence has been intruded by a number of small stocks and dikes of porphyritic monzonite and lesser syenite. Similar rocks have been intersected at depth in several drill holes, and it is probable that many of these plutons are continuous below the level of current drilling, rather than separate intrusions or discrete phases of a single intrusive event.

The porphyritic monzonite is typically fine to medium grained, and consists of approximately 20 per cent plagioclase laths in an aphanitic groundmass of potash feldspar, with minor mafic minerals. The MBX stock has a steep-sided funnel shape (Figure B-12-7). A prominent porphyritic dike, the Rainbow dike, 10 to 45 metres thick, trends south from the MBX stock and several smaller dikes have been intersected. Porphyritic monzonite with scattered volcanic fragments, fractured to brecciated monzonite and monzonite intrusion breccia occur around the margin of the MBX stock and throughout the Southern Star stock.

Some diorite and trachyte dikes are unaltered contain only traces of pyrite, and appear to be the youngest rocks in the area of exploration.

STRUCTURE

The Mount Milligan area is dominated by strong northwest and lesser northeast structural trends. The area of the Mount Milligan and Southern Star deposits appears to be a zone of extension characterized by northwest and northeast-striking fault and fracture systems.

The plutons of the Mount Milligan suite are aligned in a northwesterly direction (Figure B-12-2) as are the main body of the Southern Star stock, dike-like offshoots of the MBX stock, both orebodies, and a number of steeply dipping faults such as the Harris fault which separates the deposits (Figure B-12-4). A number of pre and post-mineral dikes also trend in a northwesterly direction. Two intersected low-angle faults, the east dipping Rainbow and west dipping Franzen faults, trend northerly to northwesterly and appear to have controlled the emplacement of dike-like offshoots of the MBX stock. Recent drilling east of this stock has indicated the presence of a north or northwesterly trending graben filled with younger sediments and basaltic flows.

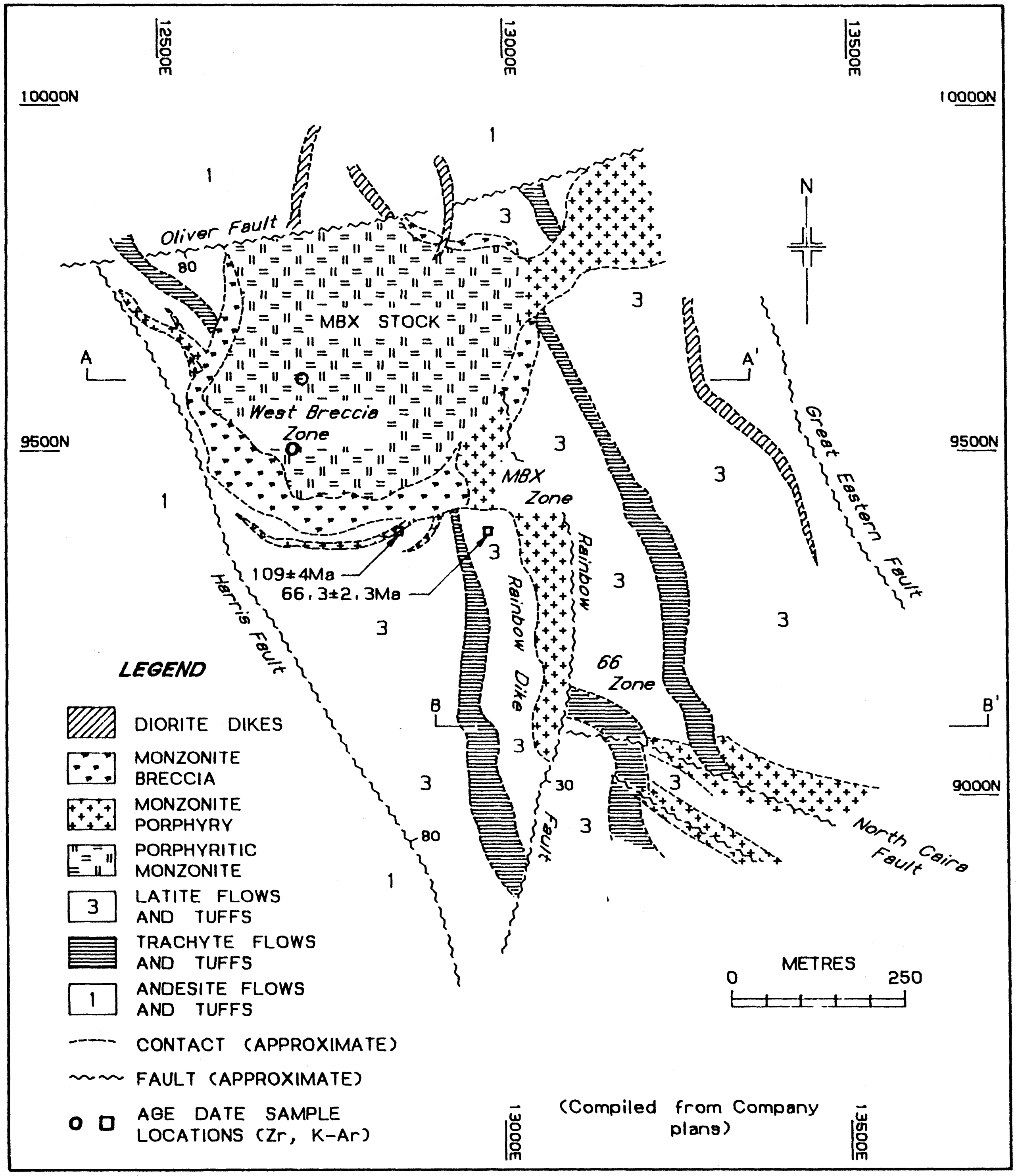


Figure B-12-5. Geology of Mount Miligan deposit inferred at 1050 m elevation.

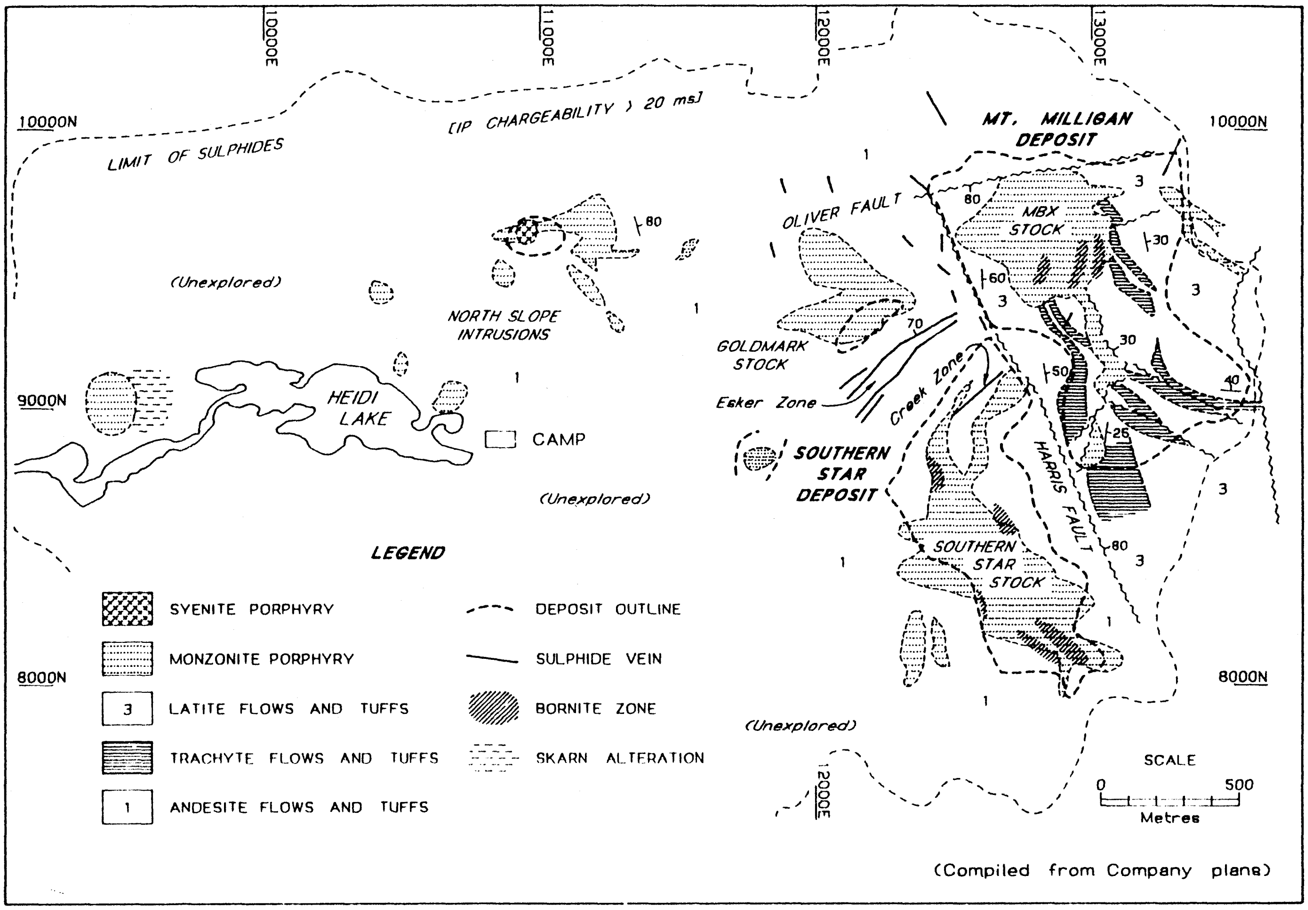


Figure B-12-4. Geology of Mount Milligan property.

The northeasterly trend is marked by dike-like offshoots of the Southern Star stock and by prominent polymetallic sulphide veins, the Esker and Creek zones north of this stock (Figure B-12-4). The northeast-trending Oliver fault truncates part of the MBX stock to the north and approximates the northern boundary of the Mount Milligan orebody.

ALTERATION

Alteration is widespread and generally pervasive, with subordinate fracture-control. Weak pervasive propylitic alteration characterized by epidote, pyrite and carbonates, extends outward from the MBX and Southern Star stocks up to 2500 metres. The propylitic alteration is overprinted by strong potassium silicate alteration localized around the periphery of the MBX stock, the Rainbow dike, and the Southern Star stock. In the volcanic rocks the potassic alteration assemblage comprises from 10 to 35 per cent early, fine-grained biotite and from 1 to 10 per cent (locally to 50 per cent) later, grey potassium feldspar. Pyroxene phenocrysts, where present, are replaced by actinolite and calcite. In the stocks, pink potassium feldspar is common, becoming pervasive in the marginal zones, and the mafic minerals are partially replaced by sericite. Clusters of radiating crystals of black tourmaline are found occasionally on fractures and some late magnetite-chalcopyrite veinlets are also present. Two zones of albite alteration also occur in the MBX and 66 zones. Gold values are low in the centres of these zones of albitization, with higher values in the outer parts.

MINERALIZATION

Economic mineralization occurs in both intrusive and volcanic rocks and is of two types - disseminated and vein. Widespread disseminated sulphide mineralization accompanied by lesser veinlet and fracture-filling mineralization occurs in two deposits - the Mount Milligan and Southern Star - and in a number of smaller zones. Disseminated grains and grain aggregates of pyrite and chalcopyrite are the most common form of sulphides. Pyrite and chalcopyrite veinlet and fracture-filling mineralization is less common but locally important, and sulphides associated with quartz veining are rare. Bornite is present in minor amounts, generally confined to a number of small zones within the disseminated mineralization; these zones contain little or no pyrite.

Native gold is associated with bornite, pyrite and chalcopyrite, typically as small particles up to 100 micrometres in diameter, located along sulphide grain boundaries and microfractures in pyrite. Some gold is also associated with magnetite (D. Harris, Geological Survey of Canada, personal communication). Silver is uniformly distributed throughout the mineralized zones in small amounts, typically of the order of 1.5 grams per tonne.

The Mount Milligan deposit consists of three gradational zones; the West Breccia zone (WBX), the Magnetite Breccia zone (MBX) and the 66 zone (*see* Figure B-12-5). Approximately 70 per cent of the ore is in volcanics and 30 per cent in porphyritic monzonite. The pyrite content increases from 1 to 2 per cent in the MBX zone to 5 to 10 per cent along the south and east margins of the deposit. The sulphides are irregularly zoned, with pyrite to chalcopyrite ratios varying from 1:1 north of the MBX zone, increasing to the west and south to 20:1. There is a relative enrichment of gold with increasing pyrite to chalcopyrite ratio. This enrichment reaches a maximum at the potassic alteration front, where the gold content locally approaches 2.75 grams per tonne. As a consequence of this irregular zoning, the 66 zone is gold-rich, and the WBX and northern part of the MBX zones are copper-rich. The northwestern corner of the deposit is cut by a gold-copper-bearing quartz vein stockwork.

The Mt. Milligan deposit is bounded on the north and west by the steeply dipping Oliver and Harris faults, and is cut by the pre and postmineralization Rainbow and Franzen faults. Two steep 115° striking faults termed the Caira faults appear to post date the gold mineralization in this area. Mineralization is open both to the east and southeast, below economic mining depths.

The Southern Star deposit is dominated by crackle stockwork and intrusion breccia yet is qualitatively similar to the Mount Milligan deposit, but to date grades appear to be lower. This may be because predominant volcanic hostrocks in the Southern Star deposit are andesites, compared to latites and trachytes in the Mount Milligan deposit which may be more favorable hosts. Approximately 70 per cent of the ore in the Southern Star deposit is in brecciated monzonite and only about 30 per cent in volcanic rocks.

Polymetallic sulphide vein mineralization occurs within the zone of propylitic alteration north and west of the two deposits, mostly within 500 metres of the main stocks (Figure B-12-4). At least seven zones have been identified that appear to radiate outward from the MBX stock. The best developed of these, the Creek and Esker zones, strike northeast and dip steeply northwest. Each of these zones consists of three to five subparallel veins of semimassive to massive pyrite and chalcopyrite 0.3 to 3.0 metres thick within a 60 to 90-metre zone width. Individual veins within a zone assay from 3 to 100 grams per tonne gold and 0.2 to 10 per cent copper and contain 1 to 3 per cent sphalerite and traces of arsenopyrite and galena. The hostrocks within and adjacent to these zones are propylitically altered and contain anomalous gold and silver concentrations.

ECONOMIC POTENTIAL

The total mineral inventory of the Mount Milligan and Southern Star deposits currently exceeds 400 million tonnes. Current preliminary calculations by Continental Gold Corp. indicate that 265.5 million tonnes of probable ore grading 0.19 per cent copper and 0.56 gram per tonne gold are contained in the Mount Milligan deposit, and 145.8 million tonnes of possible ore grading 0.23 per cent copper and 0.34 gram per tonne gold are contained in the Southern Star deposit. To date there has been insufficient exploration to develop mineable reserves in any of the vein zones.

Preliminary mine planning has been based on a milling rate of 50 000 tonnes per day, with production coming initially from a starter pit in the southern part of the MBX zone, where higher grade ore is available at a low stripping ratio. Stripping ratios are expected to be between 1.1:1 and 1.3:1 and recoveries, based on preliminary metallurgical testing, are approximately 80 per cent for gold and 88 per cent for copper.

SHOSHONITIC ASSOCIATION

Spence (1985) has discussed the chemical compositions of volcanic rocks from the Quesnel trough in some detail and has demonstrated the shoshonitic nature of the alkaline potassic suites of the trough. Whole rock analyses were made of 12 drill-core samples from the area of current exploration. Table B-12-1 gives details of the samples and the analytical results. Figure B-12-8 shows these results plotted on various oxide ratio diagrams, with the fields obtained by Spence for the majority of the samples in her study.

The samples chosen had low sulphide contents, but were all altered to some extent, as can be seen from the generally high losses on ignition. However, both intrusive and extrusive samples, with the exception of the postore dikes in some plots, generally fall within the shoshonite fields. Similarities include SiO_2 range of 49.7 to 56.8 per cent, high K_2O:Na_2O ratios (average = 1.94 per cent), low TiO_2 (average = 0.59 per cent) and high Al_2O_3 (average = 14.65 per cent). The most notable differences are that the samples are not as high in CaO and MgO as most of the samples reported by Spence, and the total iron relative to SiO_2 is lower. It is probable that during mineraliza-

TABLE B-12-1
WHOLE-ROCK ANALYSES - MT. MILLIGAN
(all analyses expressed as %)

FIELD NAME	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	L.O.I.	SUM
1) diorite porphyry	63.51	0.40	15.10	4.56	0.06	1.45	3.54	2.24	3.53	0.19	5.24	99.82
2) monzonite, MBX	48.62	0.60	12.42	8.20	0.11	9.09	7.27	2.71	3.86	0.42	6.09	99.39
3) latite lapilli tuff	50.62	0.90	12.48	9.88	0.12	7.61	6.49	3.36	3.26	0.30	4.19	99.21
4) andesite flow breccia	49.73	0.96	12.60	10.88	0.25	8.50	7.97	3.00	1.92	0.33	3.33	99.47
5) trachyte	50.65	0.64	15.75	6.45	0.15	1.64	5.16	2.15	8.96	0.56	7.00	99.11
6) monzonite	56.79	0.49	17.83	5.47	0.04	2.87	3.35	5.16	3.50	0.36	3.49	99.35
7) syenite orthoclase porphyry	55.34	0.41	19.09	4.59	0.05	1.69	2.03	1.66	10.02	0.22	4.72	99.82
8) diorite, MBX	60.30	0.46	15.27	4.99	0.13	1.93	4.05	1.64	3.94	0.22	6.95	99.88
9) trachyte dike	53.07	0.41	16.03	5.81	0.15	3.09	4.55	4.74	4.71	0.22	6.54	99.32
10) monzonite	50.98	0.77	16.66	9.46	0.18	4.37	5.27	3.25	4.61	0.44	3.22	99.21
11) andesite lapilli tuff	51.32	0.69	11.98	8.66	0.12	10.19	7.36	2.19	2.19	0.26	4.38	99.34
12) diorite porphyry dike	55.40	0.31	10.60	11.36	0.50	1.72	7.91	0.08	3.85	0.16	7.20	99.09

XRF Analyses by EMPR Laboratory

tion calcium was remobilized into the alteration zones and some of the iron formed sulphides.

DATING

Two samples were submitted to the University of British Columbia in early 1989 by two of the authors (C.M.R. and T.G.S.) for whole-rock K-Ar dating. One sample was from a dike of porphyritic monzonite intruding latitic pyroclastics and the other was from altered latitic pyroclastic rocks. Both were from drill core from two separate holes drilled along the southern contact of the MBX stock (Figure B-12-5). Results from these two samples were highly discordant and inconclusive with the altered latitic pyroclastic rock giving an Albian age of 109±4 Ma and the monzonite giving a Late Cretaceous to early Tertiary age of 66.3±2.3 Ma. As a result, two additional samples of monzonite from near the core of the MBX stock were collected and submitted to T. Krogh at the Royal Ontario Museum in Toronto for further dating, utilizing either zircons or titanium-bearing minerals. Results from these samples are not yet available.

DISCUSSION

The Mount Milligan property is clearly part of the alkaline-suite porphyry deposits which occur in the Intermontane Belt from the Stikine region to the International Boundary (Figure B-12-1) and are associated with the Upper Triassic to Lower Jurassic Nicola-Takla-Stuhini volcanic assemblages and comagmatic alkaline plutons. As such it displays many features common to other deposits of this type, but also some significant differences.

Alkaline-suite deposits are subvolcanic porphyry systems that are localized along fault, fracture or rift zones of regional extent and are invariably associated with small complex alkaline plutons that are coeval and comagmatic with the surrounding volcanic rocks (Barr *et al.*, 1976, page 359). The deposits are generally low-sulphur copper systems with abundant magnetite in which molybdenite is rare but gold and silver are usually present in sufficient quantities to constitute a significant credit. In some deposits, such as Q.R., gold is the only economically recoverable product.

Hydrothermal alteration in alkaline-suite deposits is dominated by extensive biotite, potassium feldspar and albite closer to the mineralizing stocks, with a broad fringe of propylitic alteration. Quartz veining is very rare or absent. Some deposits, such as Ingerbelle, exhibit considerable scapolite veining and occasional garnets indicating the tendency of these high-level systems to grade towards skarn assemblages. In some deposits, including Mount Milligan (Figure B-12-4), skarn alteration fringes the porphyry system. Massive to semimassive sulphide veins, usually containing some lead and zinc mineralization and radiating outward from the mineralizing stocks, are another common feature of alkaline-suite porphyry systems, as well as of calcalkaline porphyries.

The mineralizing porphyry stocks are generally of monzonite to diorite composition, with phases or offshoots grading to syenite. They are invariably related to larger, deeper seated diorite and gabbro intrusions in which the earlier or border phases may contain considerable amounts of hybridized country rock. Field, chemical, petrogenetic and structural relationships are such that productive alkaline-suite porphyry systems invariably appear to have been emplaced in active structural zones and to have evolved in an active structural regime progressing

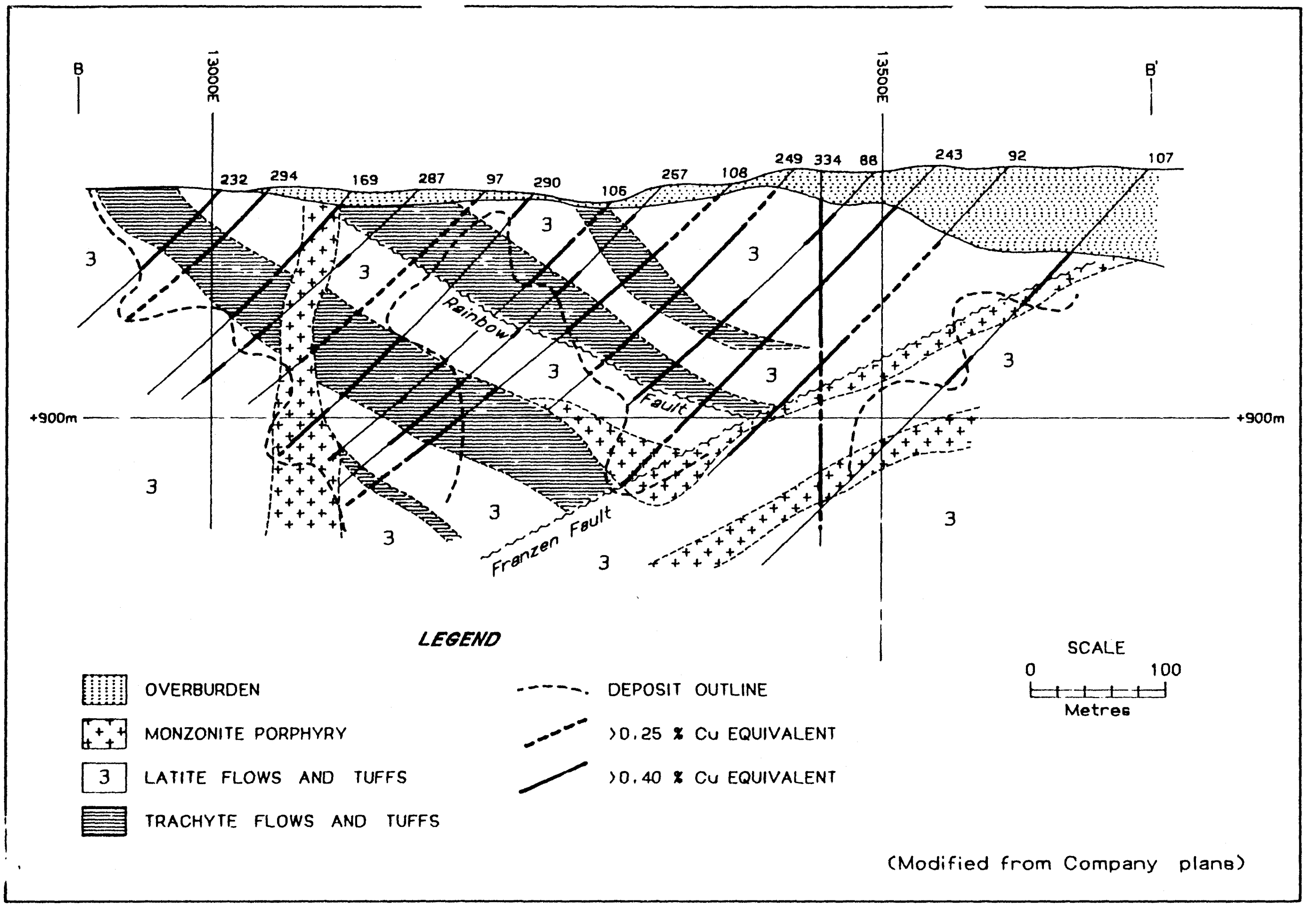


Figure B-12-6. Mount Milligan deposit cross section: 9100N.

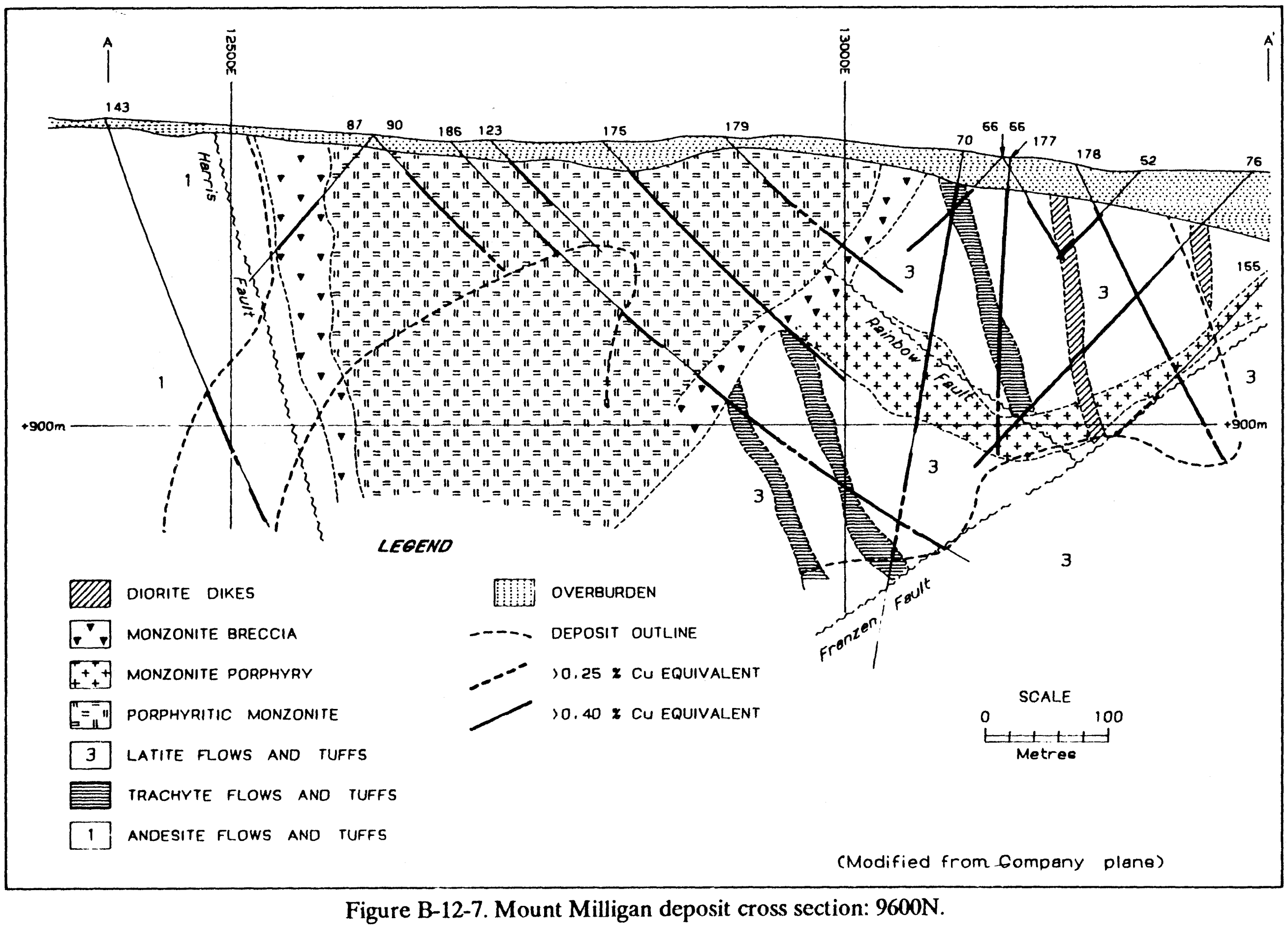
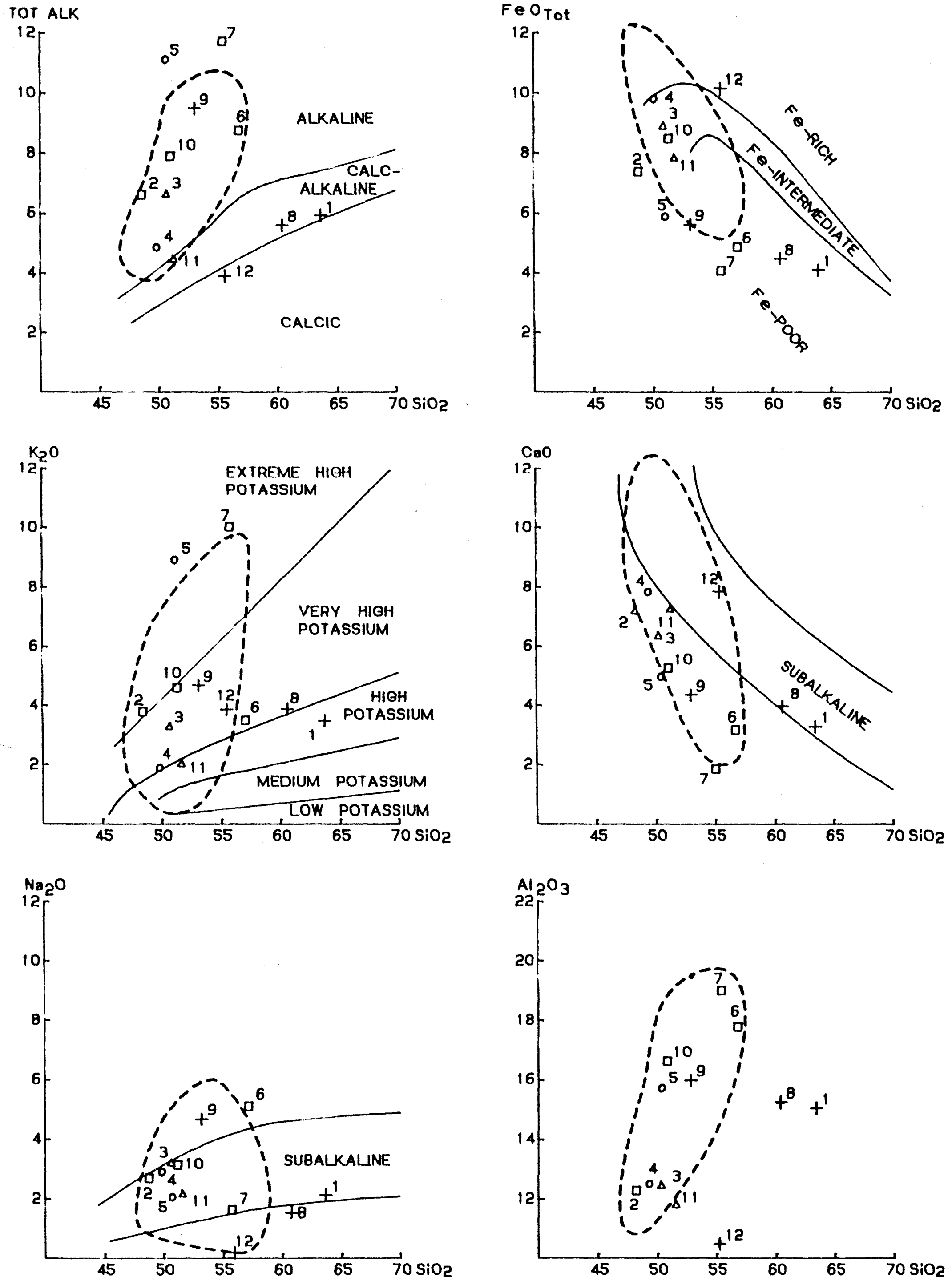


Figure B-12-7. Mount Milligan deposit cross section: 9600N.



Sample numbers are as in Table 1. Fields (solid lines) are those of Spence (1985). Fields (dashed lines) are for the majority of samples (9 of 10) of Upper Triassic shoshonites as determined by Spence (1985)

Symbols: □ = Intrusive rocks, ○ = Volcanic flows, Δ = Fragmentals, + = Post-ore dikes

Figure B-12-8. Chemical Plots: Mount Milligan samples.

from an earlier structural level of several kilometres depth to a subvolcanic level of only several hundred metres depth in the final stages. The porphyry stocks of alkaline-suite systems invariably contain bodies of explosion breccia which commonly exhibit evidence of multiple stages of brecciation and mineralization. Intrusive offshoots and fragments of the porphyry stocks are also commonly found in the volcanic rocks hosting or surrounding the porphyry deposits indicating that the intrusive system vented through and invaded its own earlier volcanic products during its evolution.

With some notable exceptions (Similco, Galore Creek), most alkaline-suite porphyry deposits are in the 25 to 35 million tonne class and have tenors that range from 0.3 to 1.1 per cent copper and 0.17 to 0.86 gram of gold per tonne (0.005 to 0.025 oz/t). Until Mount Milligan was discovered the largest known deposit of this type was Galore Creek with indicated and inferred reserves of 125 million tonnes grading 1.06 per cent copper, 0.445 gram per tonne gold and 8.57 grams per tonne silver (Barr *et al.*, 1976, page 363).

Although present knowledge of the Mount Milligan deposit is based almost entirely on examination of drill còre and on geophysical data, the system appears to exhibit all of the fundamental characteristics of alkaline-suite porphyries. It is, however, significantly above average in its size and gold grade, while being well below average in copper grade. In short, Mount Milligan is a large, bulk-mineable gold deposit.

The deposit is also well above average in respect of the area affected by hydrothermal alteration and mineralization. Most porphyry systems of this type are confined to an area of less than 5 square kilometres (Barr *et al.*, 1976, page 365) whereas at Mount Milligan, porphyry stocks and anomalous sulphides are known to occur over an area well in excess of 10 square kilometres (Figure B-12-4) thus suggesting that the MBX and Southern Star stocks and the several small stocks found as far west as Heidi Lake are continuous below the level of current drilling.

ACKNOWLEDGMENTS

Material presented in this paper is the result of the work of one of the authors (C.M.R.) while providing geological consulting services to Continental Gold Corp., and of information gathered by the other authors in the course of several visits to the Mount Milligan property. The cooperation of Continental Gold Corp. management and staff in providing information and ready access to company plans and reports is greatly appreciated. In particular, thanks are given to the field staff for taking the time from their busy schedules to accommodate our visits.

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