Similco
887635

Copper Mountain and Ingerbelle

K. C. Fahrni,
Granby Mining Corporation,
Vancouver, B.C.

T. N. Macauley,
Newmont Mining Corporation of Canada Limited,
Vancouver, B.C.

V. A. G. Preto,
B.C. Department of Mines and Petroleum Resources,
Victoria, B.C.

Abstract

The Ingerbelle and Copper Mountain deposits are located 15 km south of Princeton in southern British Columbia. The property is owned by Newmont Mining Corporation's wholly owned subsidiary, Similkameen Mining Company Ltd., and includes the Copper Mountain mine, where production ceased in 1957. Mining of the Ingerbelle deposit commenced in 1972 at a rate of 13,600 tonnes per day. Ore reserves as of January 1, 1975 were 55,749,000 tonnes grading 0.53 per cent copper at the Ingerbelle and Copper Mountain Pit 1 and Pit 2 orebodies.

All of the known copper deposits in this camp lie in a 1,100 by 4,300-m belt of Upper Triassic Nicola volcanic rocks that is bounded to the south by the concentrically differentiated Copper Mountain stock and to the north by the Lost Horse intrusive complex.

Rock alteration in the camp involves widespread development of biotite followed by albite and epidote, with subsequent local potash feldspar and/or scapolite metasomatism. This alteration affects both the volcanic rocks and the intrusive rocks of the Lost Horse suite.

The orebodies are essentially disseminated sulphide deposits, although fracture fillings are also important in many areas. Total sulphide content is generally less than 5 per cent. In the Ingerbelle, Pit 2 and most of the Pit 1 orebodies, the sulphides are chalcopyrite and pyrite; in part of Pit 1 and in most of the former underground mine they are chalcopyrite and bornite.

The Copper Mountain deposits have been classified by some workers as complex porphyry deposits of the syenite clan, and the Ingerbelle as a skarn deposit gradational to a porphyry. Other workers have placed more emphasis on the characteristics that these deposits have in common with the pyrometasomatic class.

Location

THE INGERBELLE AND COPPER MOUNTAIN deposits are located in southern British Columbia, 15 km south of Princeton and 180 km east of Vancouver (Lat. 49°20′, Long. 120°31′, N.T.S. 92 H/7 E). Highway 3 crosses the Ingerbelle property, and Copper Mountain lies about 2 km to the east on the opposite side of the Similkameen River. Elevations in the vicinity of the deposits range from 1,050 to 1,300 m, with the river in a canyon-like valley at 770 m.

History

Copper was first discovered in the area in 1884 by a trapper named Jameson, but it was not until 1892 that R.A. (Volcanic) Brown staked the Sunset claim that later became the center of the Copper Mountain mine. Exploration, development and unsuccessful attempts at production were carried out by various companies up to 1923, when The Granby Consolidated Mining, Smelting and Power Co. acquired the property. Granby extracted 31,552,000 tonnes of ore containing 1.08 per cent copper from the orebodies east of the river in the periods from 1925 to 1930 and 1937 to 1957. Most of this ore came from glory-hole and underground mining, but included are 1,955,910 tonnes of 0.76 per cent copper from several open pits mined from 1952 to 1957.

To the west of Copper Mountain, across the Similkameen Canyon, the Ingersoll Belle and La Reine claims, which were later proven to contain most of the Ingerbelle orebody, were staked in 1897. Adjoining ground was soon staked and a number of adits were driven to explore the scattered indications of copper. From 1951 to 1953, the area was mapped as part of a regional study by Granby and seven holes were drilled. In 1966, Newmont Mining Corporation of Canada, on the recommendation of their geologist, Dr. R. H. Seraphim, optioned a group of claims to the west of the river, including the Granby ground, which had been assembled and was being explored by G. Burr and E. Mullin of Princeton. Bulldozer trenching soon partially delineated the mineralized zone in areas of shallow overburden, and drill holes to depth indicated sufficient reserves for production to be considered. During this time, Granby was drilling close to the old Copper Mountain mine and adding to its known reserves of open-pit ore, and Cumont Mines was making a vigorous effort to develop ore to the north of Copper Mountain. In December, 1967, Newmont purchased Granby's entire mining interests in the district, obtaining a much-needed tailings area, and with the exercise of the option on the Burr-Mullin claims consolidated both properties under Newmont's wholly owned subsidiary, Similkameen Mining Company. Geophysical surveys, trenching and drilling were continued by Similkameen for another two years before production plans for the joint development were finalized.

Mining

The combination of rugged terrain, widely separated orebodies, transportation of tailings and economic considerations required a great deal of investigation before the feasibility study was completed. Production from the Ingerbelle orebody commenced in 1972 at a rate of 13,600 tonnes of ore per day, and by December 31, 1974, 12,188,700 tonnes grading 0.46 per cent copper had been milled. Production of the camp, including the former Copper Mountain mine, now totals 325,523 tonnes of copper, 8,081 kg of gold and 146,241 kg of silver.

The Ingerbelle pit will have an eventual depth of 250 m. Bench height is 12 m and the final wall slope is 45 to 50 degrees. Mining equipment includes shovels with 7.6-cu-m buckets, and 91-tonne-capacity trucks. A unique grade control practice is the use of a mobile X-ray fluorescence analyser for rapid assays at the face. Muck samples from every fifth truck load are analysed to facilitate the sorting of ore (+ .30 per cent copper) from low-grade stockpile material (0.20 to 0.29 per cent copper) and waste (− 0.20 per cent copper). Other unusual features of this operation are semi-autogenous grinding, the relocation of 4 miles of highway in order to mine the Ingerbelle deposit, and

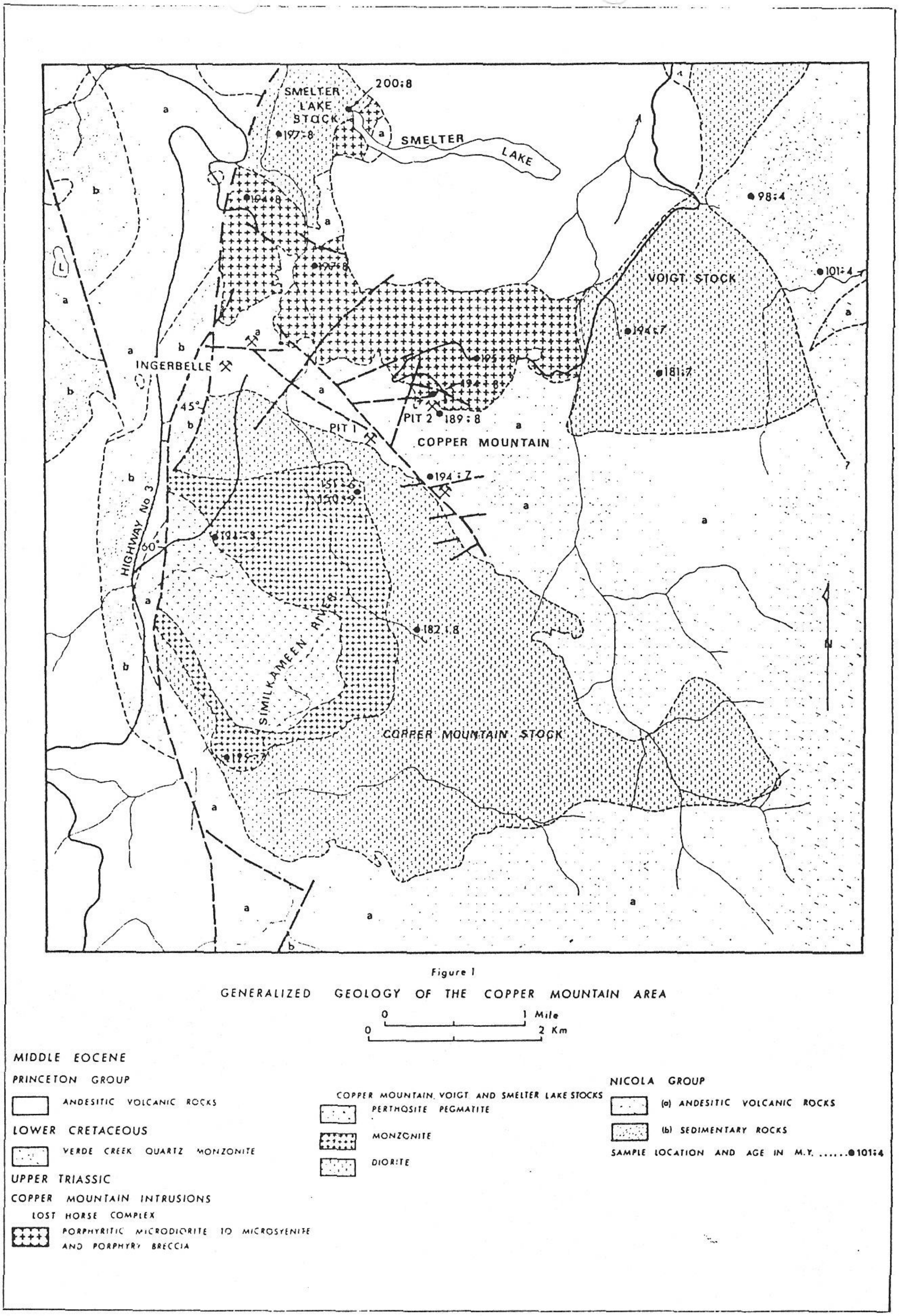

FIGURE 1 — Generalized geology of the Copper Mountain area.

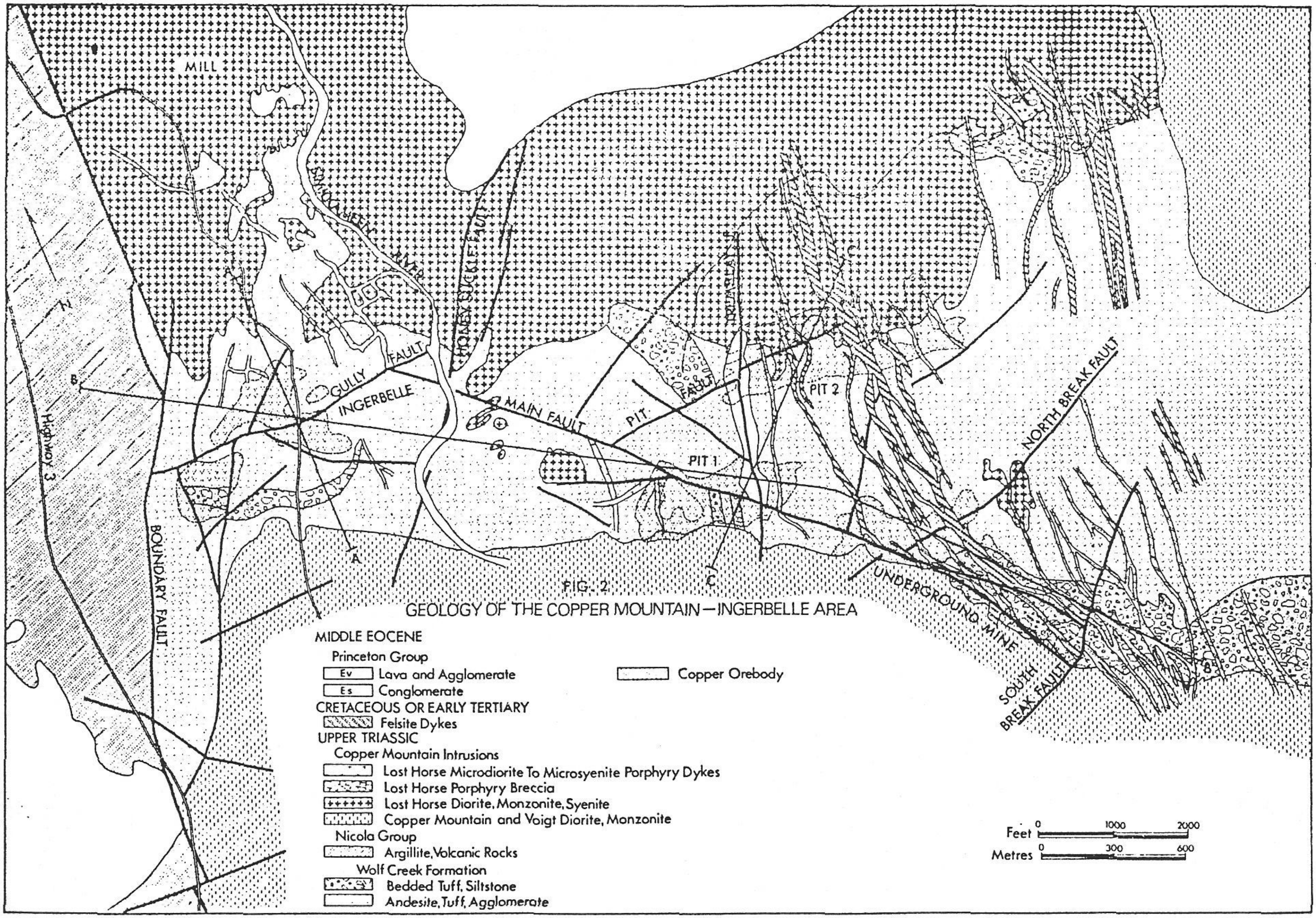

FIGURE 2 — Geology of the Copper Mountain and Ingerbelle deposits.

the plan for a separate crusher and suspension conveyor to bring the ore from the Copper Mountain deposits to the mill.

Ore reserves on January 1, 1975 were 55,749,000 tonnes containing 0.53 per cent copper in the Ingerbelle and Copper Mountain Pit 1 and Pit 2 orebodies. Additional open-pit ore will likely be recoverable from the caved area of the old underground mine. The stripping ratio remaining is estimated to be 2.0 waste to 1 ore, but it was higher in the early years of the operation.

Concern for the environment has influenced the design of this project. Tailings impoundment in a narrow rocky valley well out of public view required the difficult bridging of a canyon and the driving of a pipeline tunnel. Dams were erected at each end of the valley, and the decanted water is recycled to the concentrator. Experimental seeding with grass has commenced on the unused waste rock dumps.

Geology

GENERAL

The volcanic rocks that host the Copper Mountain orebodies were originally described as part of the Wolf Creek Formation (Dolmage, 1934) and they were considered to belong to the middle of the Nicola Group of Upper Triassic age.

The regional geological setting is characterized by major north-trending high-angle faults which form an ancient, long-lived rift system that extends from the U.S. border to at least 160 km north. This system was the locus of a long, narrow marine basin in which Nicola rocks were deposited during Triassic time, and it then accommodated basins of continental volcanism and sedimentation in Early Tertiary time. The central part of the Nicola basin is marked by an abundance of high-energy, proximal volcanic rocks (coarse breccias and flows) and contains a large number of coeval, comagmatic, high-level plutons with several associated copper deposits. A group of such plutons (Fig. 1), some of which are differentiated, are known as the Copper Mountain Intrusions (Montgomery, 1967).

SETTING OF THE COPPER MOUNTAIN CAMP

The mineral deposits of the Copper Mountain camp occur chiefly in a northwesterly trending belt of Nicola rocks, approximately 1,100 m wide and 4,300 m long, that is bounded on the south by the Copper Mountain stock, on the west by a major normal fault system known as the Boundary fault (Preto, 1972) and on the north by a complex of dioritic to syenitic porphyries and breccias known as the Lost Horse complex (Fig. 2). Copper mineralization diminishes markedly to the east, where the Copper Mountain stock and Lost Horse complex diverge sharply.

The Nicola rocks in the vicinity of Copper Mountain are andesitic to basaltic and are composed predominantly of coarse agglomerate, tuff breccia and tuff, with lesser amounts of massive flow units and some lensy layers of volcanic siltstone. The coarse fragmental rocks, which locally contain clasts up to 35 cm in diameter (Preto, 1972, p. 18), rapidly grade to the southeast and south into massive flows, abundant waterlain tuff and some pillow lava. This distribution of coarse fragmental volcanics, and their spatial association with the porphyry breccia complex and with the copper deposits indicate that one or more Nicola volcanic centers were localized close to the Lost Horse complex. It also indicates the close relationship between copper mineralization and Nicola magmatism in this camp.

West of the Boundary fault, the Nicola Group consists of intercalated volcanic and sedimentary rocks that include massive and fragmental andesites, tuff and generally well-bedded calcareous shale, siltstone and sandstone. These rocks are considered to be stratigraphically above those of the Wolf Creek Formation.

COPPER MOUNTAIN INTRUSIONS

The Copper Mountain intrusions include the Copper Mountain stock, the Smelter Lake and Voigt stocks, and the Lost Horse complex. Montgomery (1967) described these plutons as forming a continuous alkalic-calcic rock series ranging in composition from pyroxenite to perthosite pegmatite and syenite. The Copper Mountain stock is a concentrically differentiated intrusion elliptical in plan and approximately 17 sq. km in area. Its major axis is 10 km long and strikes N 60°W. The stock is zoned, with diorite at its outer edge grading through monzonite to syenite and perthosite pegmatite at the core. Montgomery (1967) described this zoning as the product of differentiation by thermal convection, chemical diffusion, crystal armouring and crystal settling from a single parent magma of dioritic composition. The two smaller satellites, the Smelter Lake and Voigt stocks, show no differentiation, but are similar in composition to the outer phase of the Copper Mountain stock.

The Lost Horse complex is approximately 4,300 m long and 760 to 2,400 m wide, and consists of porphyries and porphyry breccias which range in composition from diorite to syenite and show widespread but variable albitization, saussuritization and pink feldspar alteration. These porphyries are not a continuous mass, but are a complex of dykes, sills and irregular bodies, displaying various and complex contact relationships with rocks of the Wolf Creek Formation. Some phases of the complex are mineralized, but others, such as some major dykes, are clearly post-mineral.

RADIOMETRIC AGES

The close genetic relationships that are evident in the field between Nicola volcanism, Copper Mountain intrusions and mineralization are borne out by radiometric ages. The radiometric age of the Copper Mountain stock (Sinclair and White, 1968) was originally determined as 193 ± 7 m y. Further determinations (Preto, *et al.*, 1971) on the Lost Horse complex, the Smelter Lake and Voigt stocks, and on sulphide-bearing pegmatite veins produced a series of concordant apparent ages, the average of which is 195 ± 8 m y. These results indicate that the apparent age of all Copper Mountain intrusions and of the associated mineralization is Upper Triassic, the same as the age determined from fossils for the Nicola Group.

METAMORPHISM

Nicola rocks near Copper Mountain exhibit secondary mineral assemblages which are characteristic of subfacies B 1.1 and B 1.2 of the greenschist facies, or of albite-epidote hornfels (Winkler, 1965). This is indicated in the volcanic rocks by the widespread occurrence of epidote, chlorite, tremolite-actinolite, sericite, carbonate and, locally, b...te and prehnite. *In the immediate vicinity* of the Copper Mountain stock, a narrow aureole of contact metamorphism, generally less than 60 m wide, overprints the above assemblages and is characterized by a widespread development of granoblastic diopsidic pyroxene, green hornblende, brown to reddish brown biotite, abundant epidote, intermediate plagioclase and some quartz.

In the narrow belt of Nicola rocks between Ingerbelle and Copper Mountain, the alteration differs and, where best developed, involves widespread development of biotite followed by albite-epidote, with subsequent local potash feldspar and/or scapolite metasomatism in both Nicola rocks and Lost Horse intrusions. The feldspar and scapolite metasomatism is characterized by intense veining and is controlled by the presence and intensity of fractures and by the proximity of large bodies of Lost Horse intrusive rocks.

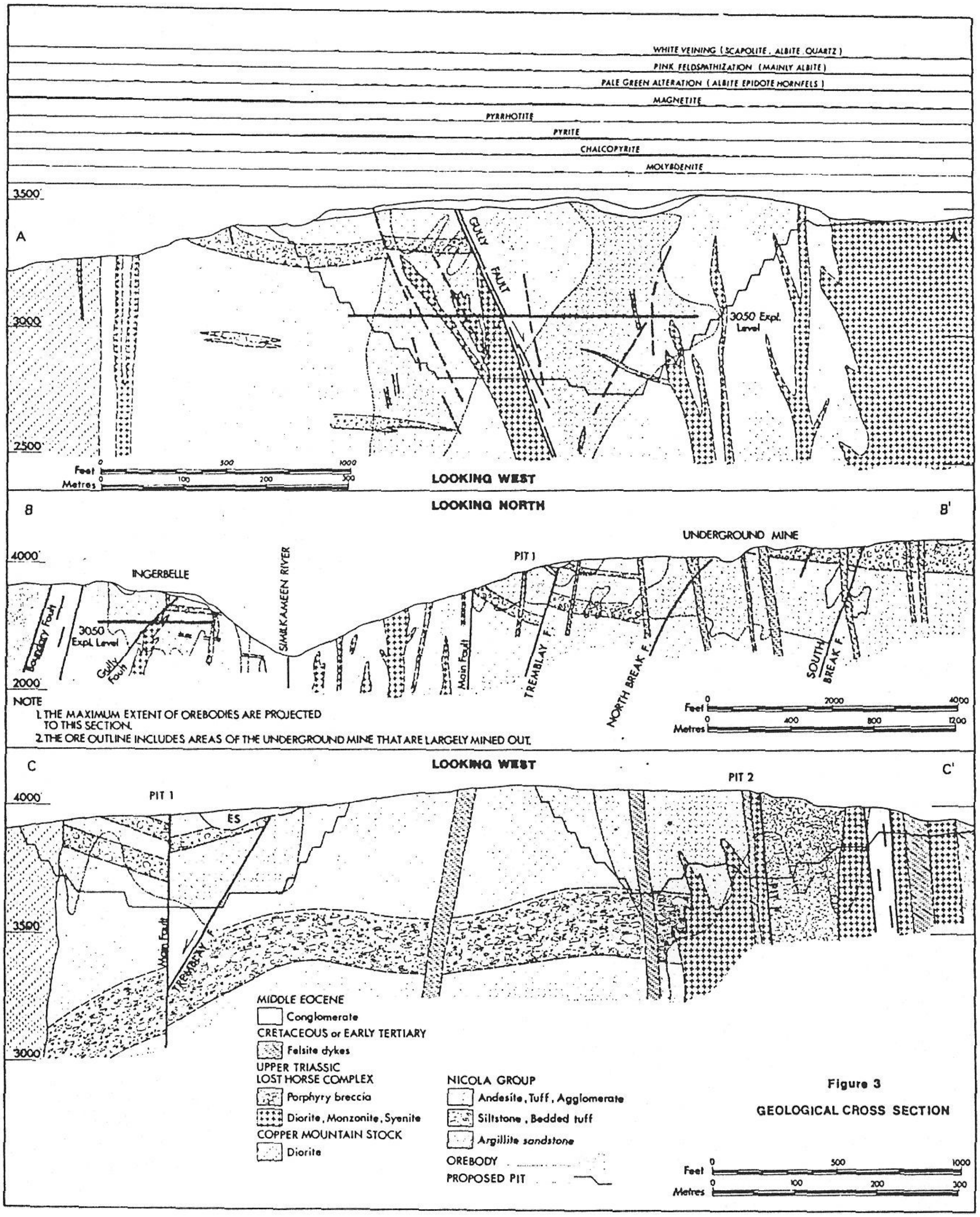

FIGURE 3 — Geological sections — Copper Mountain and Ingerbelle deposits.

STRUCTURE

The area near Copper Mountain is characterized by brittle deformation which produced a large number of faults and, locally, intense fracturing. Very broad, northerly trending folds have been recognized or postulated at widely spaced localities (Preto, 1972; Fahrni, 1966), but these folds decrease quickly in amplitude up and down section.

The area is dominated regionally by well-developed, northerly trending, high-angle faults which are best described as forming a rift system. The genetic relationship of this type of fault system with basins of Early Tertiary sedimentation and volcanism in south-central British Columbia and northern Washington has long been known (Church, 1973; Carr, 1962; Parker and Calkins, 1964). Recent work by one of the authors (Preto, 1975, in press) in the area between Merritt and Princeton indicates that these faults were active in Upper Triassic time and influenced the distribution of volcanic centers in the Nicola belt. Each center within the belt, however, is characterized by its own structural complexities. Copper Mountain is dominated by strong easterly and northwesterly faulting.

The narrow belt of Nicola rocks between Ingerbelle and Copper Mountain, confined between the Copper Mountain stock and the Lost Horse complex, is highly faulted and fractured, but does not appear appreciably folded. The strata are mostly flat lying or very gently dipping where marker beds exist, and the few areas of steep dips can best be explained as blocks tilted by faulting. Faults in this area have been grouped (Preto, 1972, p. 53) in order of decreasing relative age of their latest movement into: easterly faults (Gully, Pit), "mine breaks", northwest faults (Main), northeast faults (Tremblay, Honeysuckle) and Boundary fault. Of these, the Boundary fault is part of the regional rift system; the others appear to be local structures the genesis and history of which are closely related to the evolution of the Copper Mountain intrusions.

Mineralization and Alteration

GENERAL

The known orebodies are confined to a 1,100- by 4,300-m belt. Numerous other occurrences of copper mineralization related to the Copper Mountain intrusions are found over an area with maximum dimensions of 10 by 11 km. The deposits may be subdivided as follows (Dolmage, 1934; Preto, 1972):

(a) Disseminations and stockworks, mostly of chalcopyrite-pyrite, but also locally important bornite, in altered Nicola volcanic and/or Lost Horse intrusive rocks. This group includes all the past and present producers.

(b) Hematite-chalcopyrite, with minor magnetite and pyrite, replacements in the Voigt stock. These are locally higher grade in copper and gold than deposits of group (a), but the restriction of mineralization to narrow zones of shearing and brecciation has to date rendered them uneconomic.

(c) Bornite-chalcopyrite concentrations associated with pegmatite veins in rocks of the Copper Mountain stock. This group includes several prospects with small high-grade lenses, and numerous minor occurrences.

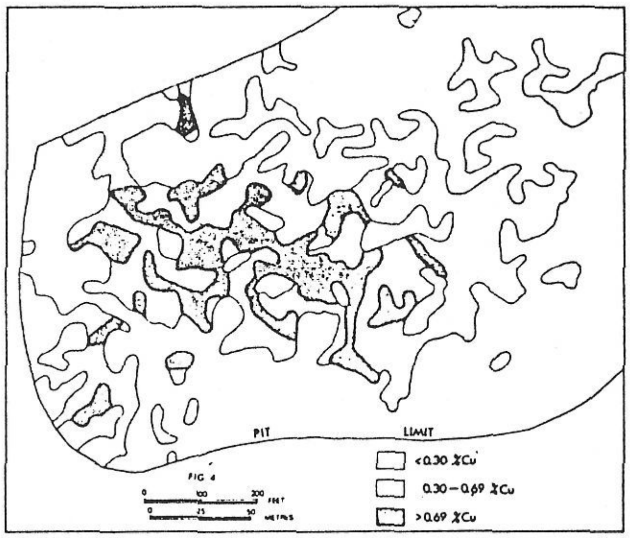

FIGURE 4 — Plan of copper distribution, 3370 bench, Ingerbelle orebody.

(d) Magnetite breccias and replacements in Lost Horse intrusive rocks, with copper sulphides generally scarce or lacking.

Primary sulphide mineralization extends to the present surface and oxidation is limited to the upper 15 m of fault and fracture zones. No secondary enrichment has taken place since Pleistocene glaciation.

INGERBELLE

The Ingerbelle orebody is crudely L-shaped, with arms oriented northeast and northwest and maximum dimensions of 520 by 760 m. It straddles the east-west-striking Gully fault and can be divided into three zones. The southwest zone is a steeply northerly plunging pipe-like body on the south side of the fault. The southeast zone dips steeply to the south and also lies immediately south of the Gully fault. The north zone includes all ore north of the fault, and may be the down-faulted extension of the southeast zone (Fig. 3). The host rocks are mainly altered tuffs and fragmental andesite, but approximately 15 per cent of the ore is found in small, irregular masses of Lost Horse monzonite or diorite. Subtle stratigraphic control is evident in that fragmental andesite is the most favourable host rock. The faults shown on Figure 2, as well as numerous discontinuous shears and intense mineralized fractures, indicate that thorough shattering occurred prior to alteration and mineralization. An important feature of Ingerbelle is the very irregular distribution of copper mineralization, requiring the continual sorting of inter-ore waste during mining (Fig. 4).

Chalcopyrite and pyrite are the dominant sulphide minerals, but their ratios change abruptly from place to place. Total sulphide content varies from 2 to 5 per cent, but some of the more pyritic material on the southern side of the ore zones carries up to 10 per cent sulphides. Pyrrhotite is found in the southeast zone. Sulphide mineralization occurs as fine disseminations and thin discontinuous fracture fillings, and less commonly as coarser blebs or veinlets of appreciable thickness. Sphalerite and other rare minerals have been enumerated by Johnson (in press). Molybdenite, in sub-economic quantities, is found most commonly in the north zone of Ingerbelle and very rarely at Copper Mountain. Precious metals recoverable with the copper have averaged 0.18 g/tonne gold and 0.81 g/tonne silver.

Alteration at Ingerbelle involved pervasive development of biotite, followed by albite, epidote and chlorite, which were, in turn, followed by the development, mostly along fractures, of pink feldspar and then scapolite. Secondary pyroxene, garnet and sphene are found in some places and appear to have formed during the albite-epidote stage. The two later stages of alteration, and especially the formation of scapolite, contributed to the healing of a large number of fractures and in many places produced a pale grey to pinkish grey, hard rock which is nearly devoid of sulphides. This rock is resistant to weathering and forms prominent ridges and cliffs on the steep slopes overlooking the Similkameen River. Sulphide mineralization favours the intervening, less altered, softer, greenish grey albite-epidote hornfels, which has only small amounts of pink feldspar and scapolite veining. Clay minerals and minor calcite are developed extensively along the Gully fault. The major difference between rock alteration at Ingerbelle and that at Copper Mountain is the extensive veining and flooding by pink feldspar and scapolite at Ingerbelle. Most of the pink feldspar is albite, with potash feldspar apparently limited to a later phase at the center of some of the veins. The alteration does not form a concentric pattern about the Ingerbelle orebody, but rather appears to be centered on the Lost Horse intrusions and diminishes in intensity with increasing distance away from the complex. The zone of volcanic rocks, 270 m wide, that lies between the orebody and the Copper Mountain stock has some of the least altered and most barren rocks in the area.

COPPPER MOUNTAIN

The geology of the former underground mine is best known through the work of Dolmage (1934) and Fahrni (1951). A zone of copper mineralization extends for 1,160 m along the contact of the Copper Mountain stock, and reaches a maximum width of 330 m. It was mined from surface at 1,300-m elevation down 450 m to the 850-m elevation. Within this zone, the orebodies were concentrated at intersections of either the northwestward-trending diorite contact or the Main fault and its branches, or a series of steeply dipping east-west Lost Horse porphyry dykes with northeast-trending breaks and pegmatite-sheeted zones. Mineralization penetrated only a meter or so into the diorite of the stock. The form of the orebody segments was pipe-like in many places, as a result of their control by steep planar elements and division by a series of barren north-south-trending felsite dykes. The diameter of the segments that were mined ranged from about 15 to 60 m. The contact orebody, which produced about half of the underground ore, was mined over widths of 9 to 38 m, along a length of 900 m and a maximum depth of 400 m. The influence of stratigraphy on the location of ore became evident to Fahrni when mapping showed that the most productive areas of the mine consisted mainly of sequences of fine-grained bedded tuffs. These rocks, being more brittle than the adjacent flows, tuffs and agglomerates, shattered readily and yielded more "ore fractures". The lower bedded unit warped downward near the contact of the stock, so that it also formed a host rock on deeper levels of the contact orebody. In addition, Lost Horse intrusions which occurred within the less favourable massive flows and coarse tuffs contained more fractures, and copper mineralization was concentrated in the contact areas of these irregular masses. Ore minerals were bornite and chalcopyrite in roughly equal proportions, with most of the bornite occurring within 60 m of the stock contact. Minor chalcocite occurred with the best bornite ore of the contact orebody. Pyrite existed in areas of chalcopyrite mineralization, but was absent in areas where bornite was present. The sulphide content of the rocks generally decreases sharply at the limits of the mine area.

The Pit 1 orebody lies in a chalcopyrite zone immediately northwest of the underground mine. It is 700 m long and up to 270 m wide, with open-pit ore extending to a maximum depth of 170 m. The bulk of the ore was emplaced along the Main fault in massive and fragmental volcanic rocks above the lower bedded tuff horizon (Fig. 3). Recognizable pre-ore porphyritic intrusive rocks are scarce. Sulphides occur mainly as fine disseminations of chalcopyrite and pyrite and only rarely as blebs and stringers. Mineralization at the west end of the orebody, between the stock contact and the fault, consists typically of thin fracture coatings of bornite and chalcopyrite in a fine-grained tuff bed.

The Pit 2 orebody is 900 m long, 90 to 360 m wide and appears to have a maximum mineable depth of 170 m. It lies along an indistinct and irregular contact of volcanic rocks with Lost Horse intrusive rocks, both rock types being host to ore (Fig. 3). Faults control the boundaries of the orebody to a considerable degree, but other imperceived factors are also important. The northern boundary is formed in part by a zone of faulting and crushing; the southern, although relatively straight, has not been related to any structure to date. To the west, the ore diminishes in grade in the vicinity of a strong northerly fault; to the east, the outline of the orebody becomes most irregular and mineralization grades to predominant pyrite with minor chalcopyrite. Within the orebody, ore-grade material is distributed irregularly, but several local trends and centers of copper mineralization occur. The sulphides are predominantly chalcopyrite and pyrite. Bornite is rare. The largest known breccia pipe in the area, 90 m in diameter and at least 150 m deep, lies in the north-central part of the orebody. Although fine disseminations and fracture coatings of sulphide are common, the Pit 2 orebody has a much greater proportion of coarse blebs and veinlets than have Ingerbelle or Pit 1.

Gold values are expected to decrease from Ingerbelle to Pit 2 to Pit 1, whereas the silver content varies inversely to gold, being highest at the underground mine.

Concentric patterns of rock alteration about individual orebodies at Copper Mountain are not evident. Alteration appears to be related mainly to the intrusive bodies and also controlled in distribution by faults and fractures. Biotite is well developed along the stock contact in the underground mine, appears to be associated with the orebodies and forms selvages on bigger veins. The pale green bleaching of both volcanic and intrusive rocks is best developed at Pit 2, but also occurs, and is locally intense, at several other localities throughout the camp — such as along the Lost Horse contact, in portions of Pit 1 and in the outer part of the underground mine. It appears to follow the biotite stage and involves the development of albitic plagioclase and epidote, and the destruction of biotite and disseminated magnetite. Pink potash feldspar developed along fractures in the latest stage of alteration and is often accompanied by pegmatite veins. These "veins", found in most orebodies and elsewhere at Copper Mountain, consist of potash feldspar, biotite, calcite, fluorite, apatite, and also some chalcopyrite and bornite. They are usually less than 0.3 m thick and have formed in part by replacement of the wall rock. Closely spaced thin pegmatite veins form the northeast sheeted zones of ore fractures. As at Ingerbelle, copper mineralization appears to have occurred during the intermediate and late stages of alteration.

Synthesis

The three most important factors to be considered in studying the formation of these deposits are as follows.

(1) Spatial Relationship to Copper Mountain Intrusions

The four orebodies lie in a narrow belt of volcanic rocks that is almost surrounded by the Copper Mountain intrusions.

(2) Genetic Relationship With the Porphyry Complex

Of the Copper Mountain intrusions, the Lost Horse complex is considered to have been more important in localizing the orebodies than the Copper Mountain stock. Lost Horse rocks at Ingerbelle and Pit 2 occur within the orebodies and form part of the ore. Virtually none of the Copper Mountain stock hosts any ore. Although similar rocks, alteration and faults are found at other places along the periphery of the Copper Mountain stock, Lost Horse rocks are not present and copper mineralization of an extent and grade comparable to that of the Copper Mountain - Ingerbelle area has not been found.

(3) Faulting and Fracturing

Numerous faults are found within the confined belt of Nicola rocks, and they are commonly best developed and intersect one another in the ore zones. Faults in places bound the orebodies and are paralleled by narrow zones of mineralization. Some of the deep-seated faults apparently acted as channelways for ore-bearing and alteration-forming solutions, and lesser faults and fractures influenced ore deposition in detail.

Genesis

The well-differentiated Copper Mountain stock is thought to have been emplaced at the roots of an active volcanic center. The various phases of the Lost Horse complex were intruded, with rapid uplift and erosion, as a series of separate injections from a differentiating magma. Their shallower, sub-volcanic level of emplacement is indicated by their finer-grained porphyritic texture, their highly variable contact relationships, including chilled margins, and the pipes and irregular bodies of breccia. The various characteristics of the orebodies suggest that they formed during the later stages of this magmatism. The Copper Mountain stock was probably not the immediate source of hydrothermal fluids at that time, but it most likely was still a hot mass and could easily have provided a temperature gradient as well as a physical and chemical barrier to the sulphide-bearing fluids which probably came from the same source as the Lost Horse rocks. This hypothesis might explain, at least in part, the crude sulphide zoning noted at Copper Mountain, which is characterized by a predominance of bornite and chalcopyrite near the Copper Mountain stock, and by a sharp decrease of bornite and an increase of pyrite toward the Lost Horse complex.

The Copper Mountain deposits have been classified as complex porphyry deposits of the syenite clan, and the Ingerbelle as a skarn deposit gradational to a porphyry (Sutherland Brown, *et al.*, 1971). Others (Dolmage, 1934, Macauley, 1973) have placed more emphasis on the characteristics that these deposits have in common with the pyrometasomatic class.

Acknowledgments

The authors acknowledge the contributions of the many engineers and geologists through the years which have helped us in reaching our conclusions. Thanks are due to the Newmont, Granby and Cumont companies for the use of their data and permission to publish this paper. Constructive criticism was provided by Dr. J. H. Montgomery and Dr. R. H. Seraphim.

References

Carr, J. M. (1962): Geology of the Princeton, Merritt, Kamloops Area of Southern British Columbia, Western Miner, Vol. 35, pp. 46-49.

Church, B. N. (1973): Geology of the White Lake Basin, B.C. Department of Mines and Petroleum Resources, Bulletin 61.

Dolmage, V. (1934): Geology and Ore Deposits of Copper Mountain, British Columbia, Geol. Surv. Canada, Mem. 171.

Fahrni, K. C. (1951): Geology of Copper Mountain, CIM Bulletin, Vol. 44, No. 469, pp. 317-324.

Fahrni, K. C. (1966): Geological Relations at Copper Mountain, Phoenix and Granisle Mines; Tectonic History and Mineral Deposits of the Western Cordillera, CIM Spec. Vol. No. 8, pp. 315-320.

Johnson, A. E. (in press): Mineralogical and Textural Study of Ores from the Copper Mountain Area, South-Central British Columbia, Department of Energy, Mines and Resources, Mines Branch, Circular I.C. 317.

Macauley, T. N. (1973): Geology of the Ingerbelle and Copper Mountain Deposits at Princeton, B.C., CIM Bulletin, Vol. 66, No. 732, pp. 105-112.

Montgomery, J. H. (1967): Petrology, Structure and Origin of the Copper Mountain Intrusions near Princeton, British Columbia, unpublished PhD thesis, UBC.

Parker, R. L., and Calkins, J. A. (1964): Geology of the Curlew Quadrangle, Ferry County, Washington, U.S. Geol. Survey, Bulletin 1169.

Preto, V. A. G., White, W. H., and Harakal, J. E. (1971): Further Potassium-Argon Age Dating at Copper Mountain, B.C., CIM Bulletin, Vol. 64, No. 708, pp. 58-61.

Preto, V. A. G. (1972): Geology of Copper Mountain, B.C. Department of Mines and Petroleum Resources, Bulletin 59.

Sinclair, A. J., and White, W. H. (1968): Age of Mineralization and Post-Ore Hydrothermal Alteration at Copper Mountain, B.C. CIM Bulletin, Vol. 61, No. 673, pp. 633-636.

Sutherland Brown, A., Cathro, R. J., Panteleyev, A., and Ney, C. S. (1971): Metallogeny of the Canadian Cordillera, CIM Bulletin, Vol. 64, No. 709, pp. 37-61.

Winkler, H. G. F. (1965): Petrogenesis of Metamorphic Rocks, Springer-Verlag, New York.