Geology of Copper Mountain

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GEOLOGY OF COPPER MOUNTAIN

SUMMARY

1. This bulletin describes the geology of a 50-square-mile area centred on Copper Mountain, 10 miles south of Princeton, British Columbia.

2. Particular attention is paid to the structure, stratigraphy, and alteration of volcanic and sedimentary rocks of the Nicola Group, to the Copper Mountain intrusions which cut them, and to the setting of copper deposits in this environment.

3. Nicola Group rocks consist of a volcanic succession that includes massive flow units, coarse to very fine-grained pyroclastic units and some pillow lava, and of a sedimentary succession that includes siltstone, argillite, conglomerate, and some reefoid limestone. The volcanic rocks are generally andesite to basaltic andesite in composition. Their age, as indicated by fossils, is Upper Triassic.

4. The Copper Mountain intrusions cut the Nicola rocks and consist of a series of differentiated quartz-poor calc-alkalic rocks that range in composition from pyroxenite to syenite. These intrusions include the Copper Mountain, Smelter Lake, and Voigt stocks and the Lost Horse intrusions, and have been dated radiometrically at 193±8 million years.

5. Copper deposits are found near Copper Mountain in a narrow belt of strongly altered and fractured Nicola rocks that is bounded on the south by the Copper Mountain stock and on the north by the Lost Horse intrusions. Mineralization is controlled by faulting and fracturing, suitable alteration, and, in most cases, by the proximity of rocks of the Lost Horse intrusions which appear to have been the immediate source of hydrothermal and mineralizing fluids. The copper deposits are regarded by some as being pyrometasomatic, and by others as being partly skarns

(Ingerbelle) and partly complex porphyry deposits (Copper Mountain). Typical rock alteration includes an early development of biotite followed by extensive albite-epidote replacement and later veining by potash feldspar and scapolite.

6. Post-mineral intrusions include a quartz monzonite mass that has been radiometrically dated at 99.5±4 million years and a later swarm of northerly trending felsitic dykes.

7. Middle Eocene sedimentary, volcanic, and intrusive rocks of the Princeton Group unconformably overlie and cut all the previously mentioned rock units.

8. Deformation in the area consisted of mostly broad northerly to northwesterly trending folds, and intense faulting. At Copper Mountain faults may be separated into distinct sets which, in order of decreasing relative age, trend east-west, northwest, and northeast. Later northerly trending normal faults dissected the area and divided it into two distinct blocks the western of which has been downdropped and appears to be devoid of intrusive rocks of the Copper Mountain type at the present level of erosion.

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INTRODUCTION

Mining was carried out intermittently at Copper Mountain from 1900 to 1957 with the gross value of metals produced exceeding 321 million dollars in copper, gold, and silver. More recently renewed interest in the area has led to the outlining of at least three large zones of copper mineralization. Two of these zones are on Copper Mountain and will be mined in the near future, the third, west of the Similkameen River, is the new Ingerbelle mine.

LOCATION, ACCESS, TOPOGRAPHY, AND DISTRIBUTION OF OUTCROP

The area mapped covers approximately 50 square miles and is roughly centred on Copper Mountain, 10 miles south of Princeton (Fig. 1). The Similkameen River flows from south to north through the middle of the area and divides it into two approximately equal parts. The western part can be easily reached by Highway 3 and a network of secondary roads connected to it. The eastern part is accessible by an excellent road which leaves Highway 3 immediately east of Princeton and leads south to Copper Mountain whence a number of secondary roads provide access to the southern portion of the map-area.

The topography in the area is characterized by relatively subdued and gentle upper slopes, generally covered by timber, and by steep slopes and huge cliffs along the valley of the Similkameen River and several east-west trending valleys north of Copper Mountain.

Rock exposures along these valleys are plentiful but become scarce at higher elevations, particularly where slopes are gentle. An exception to this rule, however, is Copper Mountain, where abundant rock exposures are found in pits, glory holes, and road cuts.

PHYSIOGRAPHY AND GLACIATION

The map-area is located at the southern end of the Thompson Plateau (Holland, 1964) and is part of a transitional belt between the Interior Plateau to the north and the Cascade Mountains to the south. Maximum relief in the area is about 3,600 feet, the

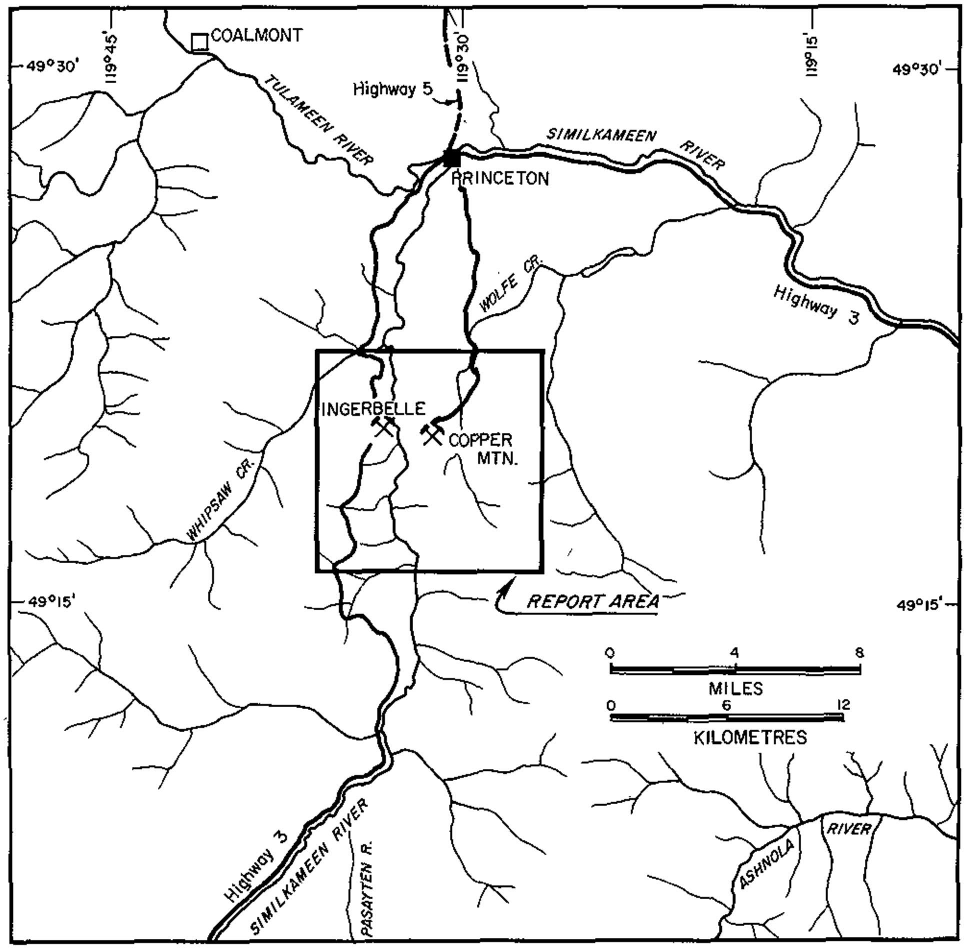

Figure 1. Location map of the Copper Mountain area.

lowest point being at 2,400 feet elevation near the confluence of Whipsaw Creek with the Similkameen River, and the highest point at 6,000 feet elevation in the extreme southeast corner of the map sheet.

The transitional character of the topography in the southern part of the Interior Plateau was described by Camsell (1914) and later by Rice (1947). In the Tulameen area Camsell placed the marked change from the gently undulating plateau topography of the upper slopes to the more youthful topography of the steep-sided valleys at approximately the 4,500-foot level (1914, p. 21). In the Copper Mountain area this line of topographic discordance appears to be higher, in keeping with the gradual rising of the land toward the southeast, and Montgomery (1967, p. 7) suggests it is close to the 5,500-foot level.

The main physiographic feature in the map-area is the canyon-like valley of the Similkameen River which, west of Copper Mountain, attains a depth of more than 1,000 feet and is flanked in places by nearly vertical cliffs 250 feet high. Several east-west trending, steep-sided valleys in the northern part of the map-area also attain depths in the order of 1,000 feet. The largest of these, previously described by Dolmage (1934, p. 6), are the following:—

1. Smelter Lake valley, which lies between the Similkameen River and Wolf Creek and has a counterpart to the west in a similar deep depression immediately south of Highway 3 at Whipsaw Creek.
2. Lost Horse Gulch, immediately north of Copper Mountain, which slopes gently easterly toward Wolf Creek and connects with the latter at Voigt's Camp. On the western side of the Similkameen River, opposite the west end of Lost Horse Gulch, a marked depression also drains eastward from marshes south of Kennedy Lake.
3. Victor Lake valley, which runs eastward from Victor Lake and deepens considerably toward the eastern edge of the map-area where it makes a large, sharp V-shaped bend before entering the valley of Willis Creek.
4. Verde Creek valley which runs eastward from the Copper Mountain road directly east of Smelter Lake and deepens sharply, becoming a canyon more than 500 feet deep at the eastern edge of the map-area.

The nature and positioning of these valleys leave little doubt that they represent former meltwater channels which ran along a northward retreating ice front and drained glacial lakes to the south.

In Pleistocene time this whole portion of southern British Columbia was buried by an ice sheet of unknown but sufficient thickness to cover mountains now 8,600 feet high (Rice, 1947, p. 4). In the Copper Mountain map-area all mountain tops are subdued and well rounded and, in most cases, are covered by an extensive mantle of drift. The thickness of this cover is said by Dolmage (1934, p. 8) to average 6 feet, reaching 20 feet in places. The average thickness of overburden in 27 drill holes on the Ingerbelle property was found by the writer to be approximately 40 feet, with a maximum of 120 feet. Similarly, 26 drill holes from Copper Mountain gave an average thickness of 14.5 feet, with a maximum of 33 feet. In the southern part of the map-area, especially west of the Similkameen River between Saturday and Friday Creeks, several exploration trenches show lenses of varved clay several feet thick interlayered with various types of drift. The presence and distribution of these clay layers should be taken into account by anyone doing geochemical soil surveys in the area.

The late-glacial history of the Princeton basin, of which the Copper Mountain map-area forms the southern part, has been described by Mathews (1944, pp. 41-42) and summarized by Montgomery (1967, pp. 9-11). It was characterized by the formation of ice-dammed lakes in the valleys of the Similkameen River and Wolf Creek. As the ice retreated northward, these lakes drained to the east through a series of gradually lowering spillways which now are marked by the east-west trending valleys mentioned in preceding paragraphs. Upon retreat of the ice the lakes finally disappeared and the northerly pattern of drainage was re-established, resulting in the formation of post-glacial canyons such as those of the Similkameen River and Whipsaw Creek. Such a disruption of the older east-west drainage is a phenomenon that was recognized by Rice (1947, p. 3) in most of the Princeton map-area. It indicates not only rejuvenation and uplift, but also tilting of the country to the north in Late Pleistocene time.

MINING HISTORY AND PREVIOUS GEOLOGICAL WORK

The mining history of the Copper Mountain area has been long and, at times, troubled. Copper was first discovered in the area in 1884 by a trapper named Jameson. Because of the excitement at that time created by the discovery of placer gold near Princeton, he failed to attract any interest in his find which remained virtually forgotten until R. A. (Volcanic) Brown located the Sunset mineral claim in 1892. During the following three years several more claims were located in the area, and various amounts of work were done on the different occurrences.

In 1900, R. A. Brown organized the Sunset Copper Company and carried out a programme of shaft sinking and underground development on the Sunset claim. In the meantime Emil Voigt had set up a camp on Wolf Creek at Lost Horse Gulch and had located a number of claims in that area. He held this property to his death in 1927, and had work done on the claims at various times.

In 1905, F. Keffer leased the Sunset and other claims and formed the South Yale Copper Company. Impetus in this organization, however, waned the following year and Keffer devoted his attention to Voigt's Camp for some time. In 1912 the Sunset and adjoining claims were taken up again, and the British Columbia Copper Company was organized, and soon renamed Canada Copper Corporation. Development on the claims continued until 1914 when it stopped because of the start of World War I. In 1916 work was resumed because of higher wartime copper prices, and the mine was equipped to produce at 2,000 tons per day. It was at this time that the concentrator was built at Allenby, 6 miles north of the orebodies, and agreements were signed with the Kettle Valley Railway to build a spur line from Princeton to Allenby and thence to Copper Mountain. The building of the line took until 1918 because of difficult terrain and labour problems. The concentrator was thus not ready to commence operations until the end of the war, when the price of copper fell causing a new shut down. Dolmage reports that "Up to this time over $4,000,000 had been spent on the enterprise, no copper had been produced, and the hope for operating the mine had dwindled to a mere spark" (1934, p. 3).

In 1923 The Granby Consolidated Mining, Smelting and Power Company Limited acquired the property and began re-organizing the concentrator and mine plants. This activity, however, terminated at the end of that year. In the winter of 1925-1926 operations started again and the concentrator finally began treating ore, continuing to do so until December, 1930. Another dormant period followed until the end of 1936. In 1937 successful operations were resumed and continued until 1957 when they finally came to an end. To this date the concentrator had treated 34,775,101 tons of ore, mostly from underground operations, producing 613,139,846 pounds of copper, 187,294 ounces of gold, and 4,384,097 ounces of silver.

From 1957 to 1965 only a moderate amount of work was done in the vicinity of Copper Mountain. In 1966, however, extensive exploration involving much trenching and drilling was initiated by The Granby Mining Company Limited on its holdings on Copper Mountain, by Newmont Mining Corporation of Canada Limited on the Ingersoll Bell, La Reine, and neighbouring claims west of the Similkameen River, and by Cumont Mines Limited on its holdings in the vicinity of Copper Mountain. The work done by Granby and Newmont continued uninterrupted through 1967. In September of that year Newmont began underground exploration on its property, now called the Ingerbelle, by driving an adit at the 3,050-foot level from the Princeton claim westerly toward the mineralization that had been intersected by surface drilling on the Invincible, Ingersoll Bell, and La Reine claims. In December, 1967, Newmont purchased all of the Granby holdings on Copper Mountain and was thus able to carry out an intensified large-scale unified exploration programme on both properties. This work, which continued uninterrupted until the end of 1969, outlined at least three large zones of low-grade copper mineralization, one on the Ingerbelle property, and two on Copper Mountain, the latter centred on old open pits. Ore reserves were estimated at 76 million tons averaging 0.53 per cent copper. In June, 1970, official notice was given of the Company's intention to put the Copper Mountain and Ingerbelle properties into production at a planned concentrator capacity of 15,000 tons per day. Capital cost of the project was estimated at 75 million dollars.

Early geological studies in the general area of Copper Mountain were made by Dawson (1877), Bauerman (1884), Camsell (1906 and later), Daly (1912), Keffer (1915), and Cairnes (1921 and later). The first comprehensive report on Copper Mountain was published by Dolmage in 1934, followed later by a report on the whole Princeton map-area by Rice in 1947. The geological work and thoughts of the Granby staff on Copper Mountain were briefly summarized by Fahrni (1951), whose work remains to date the most detailed public information on the geology of that mine. Still more recently, Montgomery (1967) did a detailed study on the petrology, structure, and origin of the Copper Mountain intrusions, including the Copper Mountain, Smelter Lake, and Voigt stocks, and Dolmage's Lost Horse Intrusives, parts of which he renamed Armstrong Bluffs complex (1967, p. 24).

PRESENT WORK

The writer spent a total of six and one-half months in the field, equally divided between the summers of 1968 and 1969. In addition, a brief visit was made to Copper Mountain and to the Ingerbelle property in September, 1967. The purpose of the project was to study in more detail the geology of the Nicola rocks surrounding the Copper Mountain intrusions, and in particular to try to reach a good understanding of the setting of the copper deposits in the vicinity of these intrusions. Because a recent and exhaustive study on the Copper Mountain intrusions had been completed (Montgomery, 1967), no attempt was made to study in detail the petrology and internal structure of the Copper Mountain, Smelter Lake, and Voigt stocks. The subdivision of the Copper Mountain stock into its various phases, information on their mutual relationships, texture, chemistry, etc., is largely the work of J. H. Montgomery. This writer, however, has examined in detail the contacts of the stocks with the surrounding volcanic rocks, and, because of their complex distribution and nature, has also studied in detail those intrusions which Dolmage termed Lost Horse and Montgomery designated as Armstrong Bluffs complex.

ACKNOWLEDGMENTS

The writer wishes to acknowledge the cooperation of J. H. Montgomery who kindly provided a copy of his thesis and topographic base map, which was extended to make a base map for the area covered by this report. The excellent cooperation of mining companies active in the area, namely the Newmont Mining Corporation of Canada Limited, The Granby Mining Company Limited, Noranda Exploration Company, Limited, and Cumont Mines Limited, and of their field staff is also acknowledged. These organizations allowed the writer free access to their ground, most of their maps, drill records and core, and thus greatly expedited and facilitated the work. Discussions with geologists of the Newmont Mining Corporation, namely Messrs. J. McCue, T. N. Macaulay, T. Takeda, and R. C. Pyper, were particularly helpful and welcome.

Determination of radiometric ages on biotite from a number of samples collected by the writer was done at the K-Ar laboratory of the University of British Columbia by J. E. Harakal in cooperation with W. H. White.

Chemical analyses and refractive index determinations of volcanic rocks were done by the Analytical Branch of the Department of Mines and Petroleum Resources in Victoria. The help given by Messrs. F. F. Karpick and L. E. Sheppard in some of this work is particularly appreciated.

During the summer of 1969 the writer was ably assisted in the field by John E. B. Wilkinson.

BIBLIOGRAPHY

Bauerman, H. (1884): Report on the Geology of the Country near the Forty-ninth Parallel of North Latitude west of the Rocky Mountains, *Geol. Surv., Canada*, Report of Progress, 1882-83-84, Pt. B, p. 18.

B.C. Dept. of Mines & Pet. Res., G.E.M., 1969, pp. 283-287.

Bostock, H. S. (1940): Map of Hedley area, *Geol. Surv., Canada*, Map 568A.

Cairnes, C. E. (1921): Coquihalla area, *Geol. Surv., Canada*, Sum. Rept., Pt. A, 1920.

Camsell, C. (1906): The Similkameen District, *Geol. Surv., Canada*, Sum. Rept., 1906.

..... (1914): Notes on Mining Developments in the Similkameen District, B.C., *Geol. Surv., Canada*, Sum. Rept., 1913, p. 127.

Carr, J. M. (1961): Geology of the Princeton, Merritt, Kamloops area of Southern B.C., *Western Miner & Oil Review*, Vol. 35, No. 2, pp. 46-49.

Daly, R. A. (1912): Geology of the North American Cordillera at the Forty-ninth Parallel, *Geol. Surv., Canada*, Mem. 38.

..... (1933): Igneous Rocks and the Depths of the Earth, *McGraw-Hill*, New York, 598 pp.

Dawson, G. M. (1877): Report on Explorations in British Columbia, *Geol. Surv., Canada*, Rept. of Progress, 1875-76, pp. 233-265.

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, *C.I.M.*, Bull., Vol. 44, No. 469, pp. 317-324.

..... (1962): Post Production Geology at Copper Mountain, *Western Miner & Oil Review*, Vol. 35, No. 2, pp. 53-54.

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

Hills, L. V. (1962): Glaciation, Stratigraphy, Structure and Micropaleobotany of The Princeton Coalfield, British Columbia, *U.B.C.*, Dept. of Geology, unpub. M.Sc. thesis.

Holland, Stuart S. (1964): Landforms of British Columbia, *B.C. Dept. of Mines & Pet. Res.*, Bull. 48.

Keffer, F. (1915): Notes on the Geology and Exploration of Copper Mountain in the Similkameen District of British Columbia, Trans., *C.I.M.*, Vol. XVIII, pp. 192-201.

Kulp, J. L. (1961): Geologic Time Scale, *Science*, Vol. 133, No. 3459, pp. 1105-1114.

Lowell, J. D. and Guilbert, J. M. (1970): Lateral and Vertical Alteration-mineralization

Zoning in Porphyry Ore Deposits, *Econ. Geol.*, Vol. 65, No. 4, pp. 373-408.

Macaulay, T. N. (1970): Geology of the Ingerbelle-Similkameen Deposits at Copper Mountain, B.C., *Similkameen Mining Co. Ltd.*, private report.

..... (1971): Geology of the Ingerbelle and Copper Mountain Deposits, paper presented at the 1971 Annual Western Meeting, *C.I.M.*, Vancouver, B.C.

Mathews, W. H. (1944): Glacial Lakes and Ice Retreat in South-Central British Columbia, Trans., *Roy. Soc. Canada*, Ser. 3, Vol. XXXVIII, Sec. IV, pp. 39-57.

Minister of Mines & Pet. Res., B.C., Ann. Repts., 1927, p. 253; 1928, p. 265; 1936, p. D58; 1937, pp. D24-26; 1938, p. D37; 1939, p. 89; 1959, pp. 53-54; 1960, p. 56; 1961, p. 56; 1962, pp. 61-62; 1963, pp. 59-61; 1964, p. 101; 1966, pp. 177-178; 1967, pp. 137-141, 178-182; 1968, pp. 181-182, 202-212.

Montgomery, J. H. (1967): Petrology, Structure and Origin of the Copper Mountain Intrusions near Princeton, British Columbia, *U.B.C.*, Dept. of Geology, unpub. Ph.D. thesis.

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

Rice, H.M.A. (1947): Geology and Mineral Deposits of the Princeton Map-area, British Columbia, *Geol. Surv., Canada*, Mem. 243.

Shaw, W. S. (1951): The Princeton Coalfield, British Columbia, *Geol. Surv., Canada*, Paper 52-12.

Sinclair, A. J. and White, W. H. (1968): Age of Mineralization and Post-Ore Hydrothermal Alteration at Copper Mountain, B.C., *C.I.M.*, Bull., 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, *C.I.M.*, Trans., Vol. LXXIV, pp. 121-145.

Titley, S. R. and Hicks, C. L. (1966): Geology of the Porphyry Copper Deposits, Southwestern North America, *The University of Arizona Press*, 287 pp.

Wanless, R. K., *et al.*, (1968): Age Determinations and Geological Studies, K-Ar Isotopic Ages, Report 8, *Geol. Surv., Canada*, Paper 67-2, Pt. A.

Winkler, H.G.F. (1965): Petrogenesis of Metamorphic Rocks, *Springer-Verlag New York*, 220 pp.

2

GENERAL GEOLOGY

INTRODUCTION

Copper Mountain is situated near the southern terminus of the so-called Nicola Belt, a northerly trending terrain some 25 miles wide extending from near the United States border to Kamloops Lake, united by similar stratigraphy and tectonics, and noted for its large number of copper mines and prospects. The terrain has as its fundamental rock unit the Upper Triassic Nicola Group, which is about 20,000 feet thick and appears to be composed mainly of basaltic andesite flows and pyroclastic rocks with greywacke, argillite, and reefoid limestone, although the stratigraphy is still poorly known. The belt is largely bounded by plutons but has older rocks on parts of its eastern periphery. Structurally it is characterized by much faulting which generally includes older east-west and northwest trending structures cut by later north trending ones, the largest of which belong to a belt that extends from Copper Mountain and Princeton northward through Summers Creek and Quilchena Creek to Nicola Lake and Moore Creek.

At the centre of the area covered by this report approximately 6.5 square miles (Fig. 2) are occupied by the Copper Mountain stock, a concentrically differentiated intrusion, elliptical in plan, the long axis of which strikes north 60 degrees west and is approximately 4 miles long. To the north and northeast of the main stock are two smaller satellite intrusions which show no differentiation, but are similar in composition to the outer phase of the Copper Mountain stock. The smaller of the two is the Smelter Lake stock, which lies at the western end of Smelter Lake and occupies less than 1 square mile. The Voigt stock occupies approximately 3.2 square miles and lies northeast of Copper Mountain and almost entirely east of Wolf Creek.

A complex of intrusive rocks ranging in composition from diorite to syenite and generally having a porphyritic texture occurs mostly in the tract of ground immediately north of Copper Mountain that extends from Wolf Creek westward to a fault called the Boundary fault near Highway 3. These rocks, designated as the Lost Horse Intrusives by Dolmage (1934) and renamed Armstrong Bluffs complex by Montgomery (1967), show a widespread degree of albitization, saussuritization, and pink feldspar alteration of variable intensity. They do not occur as a continuous mass, but as a complex of dykes, sills, and irregular bodies, and display variable and complex contact relationships with rocks of the Wolf Creek Formation. They are believed to be genetically related to the Copper Mountain stock, and, in fact, to be later phases of the stock, although contact relationships are nowhere clearly displayed in the field, and no difference in the radiometric ages of the two intrusions was detected. These rocks were named by Dolmage and Montgomery because the largest and best exposures are found in Lost Horse Gulch and at Armstrong Bluffs, on the west side of the Similkameen River. Henceforth in this report the name Lost Horse intrusions will be used for these rocks.

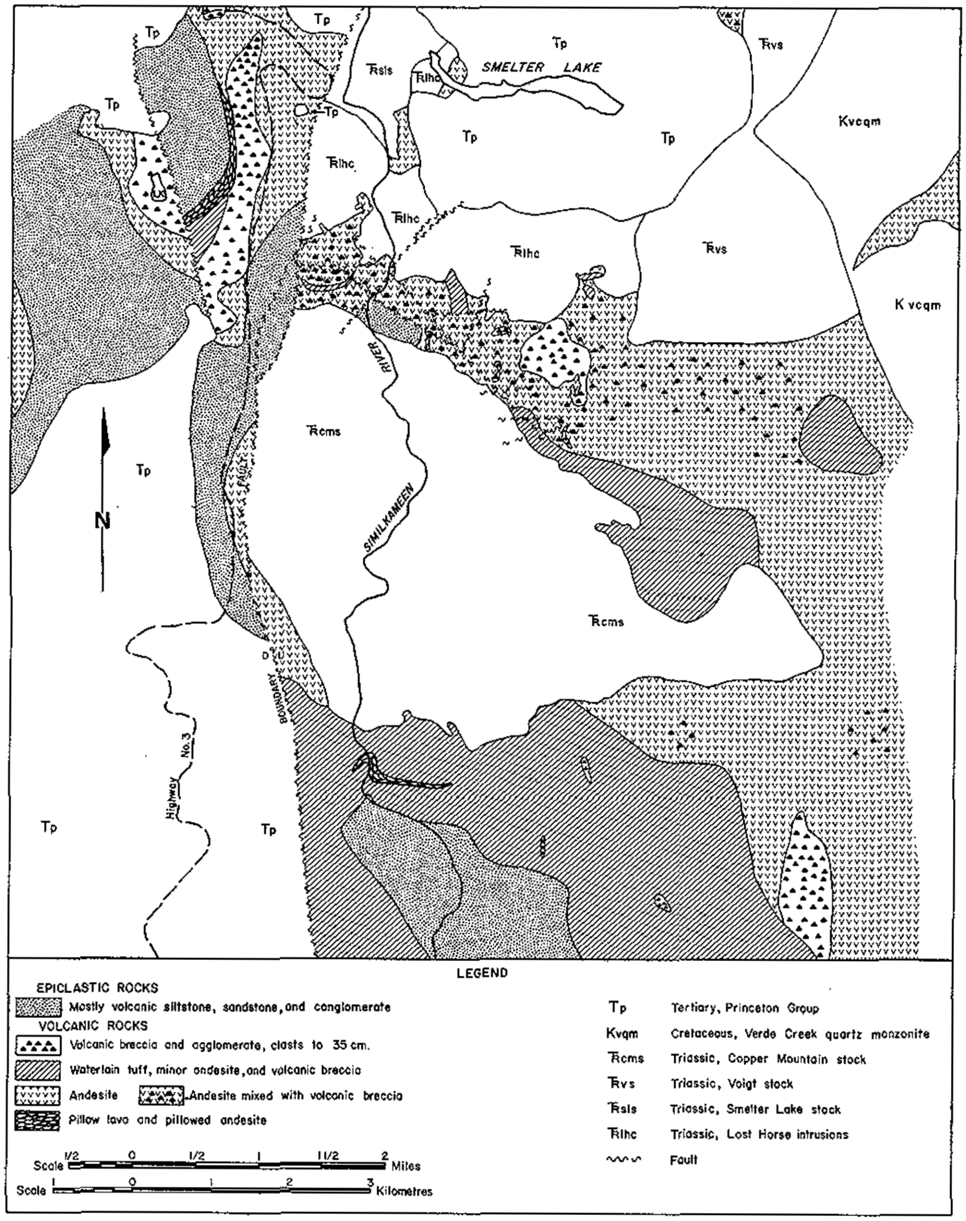

Figure 7. Generalized distribution of lithologies in Nicola rocks.

All of the above intrusive rocks, collectively known as Copper Mountain intrusions (Montgomery, 1967), are of Upper Triassic age (Sinclair and White, 1968, and this report). They cut and are surrounded by volcanic and sedimentary rocks of the Wolf

Creek Formation of the Nicola Group, which is also of Upper Triassic age. The northeastern corner of the map-area is occupied by a body of biotite-hornblende-quartz monzonite of late Lower Cretaceous age which Dolmage (1934) named Verde Creek granite and Rice (1947) included in the Otter intrusions. This pluton is cut by several northerly trending felsite, quartz-feldspar, and feldspar porphyry dykes which are the eastern extension of the 'Mine dykes' swarm of Copper Mountain.

All of the above intrusive, volcanic, and sedimentary rocks are cut and unconformably overlain by intrusive, volcanic, and sedimentary rocks of the Princeton Group of Middle Eocene age.

A major northerly trending and westerly dipping normal fault, designated by the writer as the Boundary fault, crosses the full width of the map-area in its western half and divides the Nicola rocks into two parts. Within each of these portions a fairly consistent succession of mappable units has been established. Although the lithologic successions east and west of the Boundary fault are similar in a general way, sufficient differences exist to justify dealing with the two successions separately. It is agreed that volcanic rocks may, and commonly do, display rapid lateral changes such as could account for the differences between the two successions, but it is also possible that the rocks found west of the Boundary fault belong to a separate sedimentary-volcanic sequence of the Nicola Group than those found east of the fault, thus representing somewhat similar conditions of deposition but not time equivalent units.

NICOLA GROUP

The Nicola Group within the map-area includes a variety of volcanic rocks, sedimentary rocks that are largely of volcanic derivation, and minor dykes, sills, and irregular intrusive bodies that are directly related to the volcanic suite. The volcanic rocks are generally uniform in chemical composition regardless of their nature, and 90 per cent are basalts or andesites. The average composition is that of basaltic andesite as indicated by refractive indices of fused beads of 124 specimens from the volcanic suite (Fig. 8). Chemical

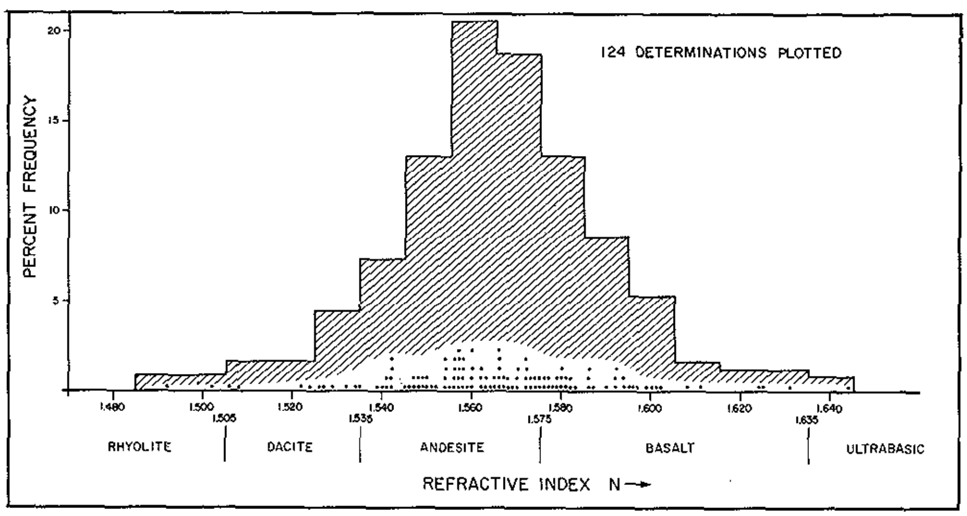

Figure 8. Per cent frequencey distribution of refractive indices of volcanic rocks of units 1, 2, and 4.

Table 1. Comparison of chemical analyses of volcanic rocks.

		VP-69-376	VP-69-106	Average A and B	A	B	L	Average A and L
				Oxides recalculated to 100 for water-free rock				
SiO_2	wt. per cent	51.90	56.96	54.26	58.65	49.87	58.18	58.41
Al_2O_3	wt. per cent	17.78	17.50	16.81	17.67	15.96	16.84	17.25
Fe_2O_3	wt. per cent	5.87	1.53	4.66	3.85	5.47	2.31	3.08
		11.15	6.41	9.74	7.54	11.94	6.42	6.98
FeO	wt. per cent	5.28	4.88	5.08	3.69	6.47	4.11	3.90
P_2O_5	wt. per cent	0.37	0.31	0.38	0.30	0.46	0.36	0.33
CaO	wt. per cent	6.39	6.48	7.00	5.92	9.09	5.79	5.85
MgO	wt. per cent	4.03	2.95	4.53	2.90	6.27	3.25	3.07
TiO_2	wt. per cent	0.72	0.62	1.09	0.80	1.38	1.01	0.90
MnO	wt. per cent	0.23	0.17	0.26	0.22	0.32	0.10	0.16
Na_2O	wt. per cent	4.51	5.56	3.38	3.60	3.16	3.62	3.61
K_2O	wt. per cent	3.92	3.03	1.97	2.40	1.55	4.43	3.41
		100.00	100.00	99.62	100.00	100.00	100.00	99.97
				Oxides as determined				
H_2O-		0.02	0.02					
				1.75	1.88	1.62	0.91	1.39
H_2O+		1.28	2.31					
CO_2		0.01	0.02					
BaO		0.12	0.16					
SrO		0.06	0.06					
Total Fe_2O_3		9.01	6.76					
SO_3		0.01	0.03					
Refractive index of glass		1.566	1.556					

A Augite andesite - Analysis No. 49, Table 1, page 16, Daly, 1933.
B Average basalt - Analysis No. 58, Table 1, page 17, Daly, 1933.
L Average latite - Analysis No. 31, Table 1, page 13, Daly, 1933.

NOTE: Samples VP-69-376 and VP-69-106 represent rocks, the refractive index of which is close to the mode of the distribution curve of Figure 8. VP-69-376 – massive plagioclase andesite, map unit 2e, northeast corner of map-area; VP-69-106 – massive plagioclase andesite, map units 2c and 2d, east of Wolf Creek. Analyses by S. W. Metcalfe and R. S. Young, B.C. Department of Mines and Petroleum Resources.

analyses of two fresh specimens selected from near this average composition are shown on Table 1.

Within the map-area Nicola rocks are divided into two main blocks by the northerly trending Boundary fault. The sedimentary and volcanic rocks found east of this fault and comprising map units 1 and 2 are part of the Wolf Creek Formation originally described by Dolmage (1934, pp. 10-11) and later briefly discussed by Rice (1947). These rocks have been and are considered part of the Upper Triassic Nicola Group essentially on the basis of their lithology and older age relative to all other rocks in the area, since no useful fossils have to date been found in them, and they form a block which is essentially isolated from the rest of Nicola rocks by faults, intrusions, and Tertiary cover rocks. Map unit 1 is composed of well-bedded tuffaceous and marine sedimentary rocks of volcanic origin. Unit 2, which overlies unit 1 conformably, is a volcanic unit which, in the north near Copper Mountain, is dominated by coarse pyroclastic rocks and, in the south part of the map-area, contains abundant well-bedded tuff as well as some coarser pyroclastic rocks and some massive pillow lava. Map unit 5 is also found only east of the Boundary fault in the southeast corner of the area and is composed of dykes, sills, and small bodies which though intrusive into rocks of the Wolf Creek Formation are also considered to be of Nicola age on the basis of lithology and relation to younger rocks.

Nicola rocks west of the Boundary fault have not been correlated to any specific formation but merely subdivided on the basis of lithology into map units 3 and 4. Unit 3 is sedimentary and consists of well-bedded argillite, siltstone, sandstone, and minor conglomerate, breccia, and limestone. Unit 4 is volcanic and consists mainly of coarse breccia with some pillow and massive lava and bedded tuff. This subdivision is purely lithological and not stratigraphic for there is considerable likelihood that there are in fact two sedimentary and two volcanic units involved. Units 3 and 4 are assumed to be part of the Nicola Group on the basis of similar lithology, alteration, and on scant fossil collections, only one of which, in unit 4 near Kennedy Lake, was definitive.

AREA EAST OF THE BOUNDARY FAULT – WOLF CREEK FORMATION

UNIT 1: Rocks of unit 1 are found on both sides of the Similkameen River from Saturday Creek to the southern boundary of the map-area. The best exposures are along the river, and are most conveniently examined during low-water periods in late summer and early fall. They are characteristically well-bedded volcaniclastic rocks ranging in grain size from fine-grained siltstone to boulder conglomerate with rare clasts 3 to 4 feet in greatest dimension. Some of these rocks are likely truly pyroclastic whereas most are epiclastic rocks of volcanic origin. These volcaniclastic rocks have intercalated, rare, dark grey, impure limestone as small pods and lenses of local extent; limestone is however fairly common as clasts in boulder conglomerate found in cliffs east of Similkameen River between Saturday and Sunday Creeks.

The most common rock type of unit 1 consists of thinly bedded grey and dark grey volcanic siltstone and fine-grained sandstone. Under the microscope these rocks are seen to be fairly well sorted and always to contain an appreciable amount of broken crystals of andesine-labradorite and some quartz set in a fine-grained matrix which may or may not contain finely disseminated carbonate (Plate I). Crystal fragments may form up to 50 or 60 per cent of some thin beds, and show a remarkable similarity in composition, relative abundance, and state of preservation over the whole outcrop area of unit 1. The plagioclase fragments generally display little alteration, are zoned and, in part, angular in outline, as are some of the quartz fragments. The above suggests that these broken crystals came from a common source and they probably underwent very little if any secondary transport and reworking. They probably represent crystal ash falls from nearby volcanoes, and were deposited directly in the sedimentary basin, but are intercalated with similar but reworked material which was transported to the basin from nearby positive areas or was provided by subaqueous processes.

Other beds, with grain size ranging from that of lapilli or granules to coarse boulders, contain large numbers of generally well-rounded pebbles 25 to 30 per cent of which may be of fine-grained volcanic rocks, the rest being of epiclastic rocks very similar to those described above, with some fine-grained, grey, impure limestone. Occasionally pebbles and boulders of conglomerate are also found. The conglomerate beds are massive and rarely display any sign of bedding, but appear to be interlayered with the fine-grained sediments.

Areas of massive, dark grey-green volcanic breccia and/or massive lapilli crystal tuff or of fine-grained andesitic lava are found in the predominantly sedimentary sequence of unit 1, but in most instances are too small to map.

Throughout the section excellent bedding attitudes, commonly showing tops, are provided by the silt and sand-sized beds. Graded bedding, crossbedding, and sole marks are common and widespread. They indicate that the strata trend for the most part north-northwest or northwest and dip steeply, facing west (Plate II).

Rocks of unit 1 are usually remarkably unaltered. The layered rocks occasionally show a moderate amount of sericitization of the feldspar fragments and the more mafic volcanic rocks show a slight to moderate amount of saussuritization.

Rocks of map unit 1 are believed to be part of the Nicola Group, and are thus considered to be of Upper Triassic age. They are cut by dykes of microdiorite and latite porphyry which are believed to be related to the Copper Mountain stock for which an average radiometric age of 193±7 million years has been determined (Sinclair and White, 1968).

At one locality, on the east side of the Similkameen River approximately 2,400 feet northeast of the mouth of Sunday Creek, some fossils were found in a small lens of fine-grained, dense, grey limestone. The collection was examined by Dr. E. T. Tozer of the Geological Survey of Canada (Report TR-1, 1970, collection 84294) and proved to consist of crinoid columnals and cerioid corals of undetermined age.

The great range of grain size displayed throughout the section of unit 1, and the common mixing with true pyroclastic rocks, suggest that the sediments were deposited in an unstable basin, probably of relatively shallow water, into which material was introduced from nearby positive areas of volcanic rocks accompanied from time to time by falls of crystal ash and of coarser volcanic ejecta from nearby vents.

UNIT 2: Rocks of map unit 2 are primarily volcanic in origin and deposition, in contrast to those of unit 1. They are distributed around the Copper Mountain stock on the north, east, and south as far as the limits of the map-area and beyond. They form a complex assemblage that includes massive andesite, tuff and tuff breccia, volcanic breccia and agglomerate, and pillow lava, and overlies unit 1 with apparent conformity. Except for pillow lava, rocks of any of the above types may be found at various localities and, although very similar in appearance, they cannot be correlated stratigraphically with any degree of certainty. Their irregular distribution is considered to be evidence of non-cyclic repetitions of somewhat similar conditions. For example, at Copper Mountain and Ingerbelle well-bedded water-laid tuffs and/or volcanic siltstones are found which locally constitute excellent marker horizons and are very similar; however they cannot be reliably correlated across the Similkameen River for the following reasons:

1. At Ingerbelle there is one bed of tuff, 50 to 120 feet thick. This unit is overlain by an unknown thickness of volcanic breccia and underlain by some 550 feet of similar breccia that is in turn underlain by massive augite andesite with a few thin tuffaceous lenses that extends below the deepest drill holes.
2. At Copper Mountain there are two beds of similar tuff, an upper one approximately 100 feet thick and a lower one 250 feet thick. These are 300 to 400 feet apart and are overlain, separated, and underlain, within the depth reached by drilling, by a variable mixture of massive and fragmental andesite.
3. Though very similar to the Ingerbelle tuff, the Copper Mountain beds are somewhat more variable in texture and composition and may have interbeds of coarser grain size.
4. The two tuff beds at Copper Mountain, and especially the lower one, appear to have a fair continuity to the east and northeast but seem to grade laterally into massive and fragmental volcanics to the west.

Though one could arbitrarily choose to correlate either of the Copper Mountain beds with the one at Ingerbelle and thereby arrive at some statement of the displacement across such structures as the Copper Mountain fault, this writer prefers not to do so because of the uncertainty involved in such correlation.

Massive Andesite (Unit 2a): Massive volcanic rocks are comparatively rare and are found sparsely along the southern boundary of the Copper Mountain stock as small, isolated outcrops. To the north of the stock massive andesitic rocks are found on the high ridge east of Wolf Creek, associated with fragmental rocks on Copper Mountain, and in an embayment in Tertiary volcanic rocks at the west end of Smelter Lake. Dense, massive, brownish grey pyroxene andesite is also known to occur at Ingerbelle below several hundred feet of fragmental andesite. In general, rocks which at first glance appear to be massive and featureless, are found on closer examination to be fragmental, or mixtures of fragmental and massive rocks of similar composition. Such mixtures where too complex to be differentiated have been mapped collectively as unit 2e.

Rocks of unit 2a along the south boundary of the Copper Mountain stock are dense, medium to dark green, fine-grained andesite, occasionally with disseminated tiny grains of augitic pyroxene or tiny feldspar laths, and commonly extensively saussuritized. On the ridge east of Wolf Creek and immediately south of the Voigt stock, a fairly large area mapped as unit 2a is underlain by massive, fine to medium-grained porphyritic pyroxene-hornblende-plagioclase andesite, in part agglomeratic. The rock is in places extensively saussuritized, with replacement of the plagioclase phenocrysts by epidote and sericite, and strong replacement of pyroxene by a light green amphibole. A similar amphibole also occurs as fresh, euhedral phenocrysts, suggesting that the rock originally contained both amphibole and pyroxene. In hand specimen the rock is characterized by brilliant dark green hornblende phenocrysts occasionally 7 millimetres long, and by fracture planes coated with light yellow-green epidote. Although generally fine grained, it becomes coarser toward the centre of the outcrop area, and although it may resemble an intrusive rock all is considered to be most likely part of the volcanic succession.

Massive andesitic rocks that are found in the vicinity of the Copper Mountain and Ingerbelle mines generally occur associated with fragmental rocks of similar composition that are either volcanic breccia or agglomerate. The massive rocks are fine to medium grained, dense, dark to medium green in colour, and may contain phenocrysts of black augite or white plagioclase up to 2 millimetres long. The degree of alteration of these rocks varies considerably from place to place and ranges from very intense and pervasive saussuritization, albitization, and pink feldspar and scapolite replacement to slight or moderate saussuritization.

The small area of massive andesite found at the west end of Smelter Lake consists of a very dense, medium green porphyritic rock with tiny phenocrysts of dark green augite and light greenish grey plagioclase. The rock is generally considerably saussuritized and in many places contains up to 10 or 12 per cent finely disseminated pyrite. Magnetite is not conspicuously present and is generally insufficient for the rocks to attract a suspended hand magnet. This is also true for many of the massive and fragmental volcanic rocks in the rest of the map-area; iron not in silicate minerals tends to occur as disseminations of pyrite, pyrrhotite, or both, rather than as magnetite.

Pillow Lava (Unit 2b): A unit of pillow lava ranging from less than 100 feet to approximately 300 feet thick is found in the southern part of the map-area, immediately north of Saturday Creek. The rock occurs on both sides of the Similkameen River and is best exposed on the precipitous slopes and cliffs of the Similkameen Canyon 1,000 feet northeast of the confluence of Saturday Creek with the Similkameen River. Although exposures become small and sparse on the forested slopes 300 feet above river level, the unit can be traced eastward from the river for at least 3,000 feet. To the west of the river, however, no pillow lava was observed beyond a gravel-covered terrace which is found 1,000 feet north of the confluence of Saturday Creek and 200 feet above river level. Beyond this terrace, all the exposures that could be found were of fine-grained bedded tuff and minor volcanic sediments of map unit 2d and of intrusive rocks of map unit 10.

Where it is best exposed in the river canyon, the rock weathers to a dark grey-green to brownish colour, and may be recognized in outcrop by a characteristic lumpy appearance. Pillows are generally poorly to moderately well formed, and tend to be squeezed or elongated parallel to the general attitude of the unit thus producing a crude foliation. They range in size from less than 1 foot to 4 feet or more, and generally have a well-developed skin or rind of dark green aphanitic material enclosing amygdaloidal material of andesitic to basaltic composition. In most places the amygdules become markedly more numerous toward the centre of the pillow, and may be filled with carbonate or, occasionally, epidote. Interpillow matrix is generally rich in carbonate.

The pillow lava is conformable with the general bedding of the volcanic and sedimentary rocks above and below it, and was used as a marker horizon outlining a very steeply plunging anticlinal warp centred on the Similkameen River some 1,000 feet north of

Saturday Creek. The fold is considered to be an anticline on rather scant evidence: On the west side of the Similkameen River one pillow was found which showed a fairly well-developed convex upper surface and cuspate underside, indicating that tops on this side of the fold are to the northwest. No where else was evidence found to indicate the top or bottom of the unit.

Volcanic Breccia and Agglomerate (Unit 2c): Coarse fragmental volcanic rocks that may be described as volcanic breccia and/or agglomerate are found sparsely in the southern part of the map-area but more abundantly in the vicinity of Copper Mountain and Ingerbelle. South of the Copper Mountain stock these rocks are irregularly distributed in the volcanic succession of map unit 2 as relatively small lenses associated with tuff or massive andesite, but north of the stock they appear to be thicker and more systematically distributed. For example, at Ingerbelle andesitic volcanic breccia and agglomerate at least 800 feet thick, with minor intercalations of massive and tuffaceous rocks and a consistent marker bed of massive siltstone or tuff 50 to 120 feet thick, are known to overlie a massive andesite unit of unknown thickness (Plate III).

Where least altered, the fragmental andesite at Ingerbelle is a massive brownish green or greenish rock with a medium-grained green-grey matrix rich in saussuritized intermediate plagioclase, epidote, and altered augitic pyroxene. The most common fragments are of a fine-grained brownish porphyritic augite plagioclase andesite, but other types of fine-grained andesite and tuff are occasionally found (Plate IV). The fragments are generally subrounded to subangular in outline, and not larger than 8 to 10 centimetres in diameter. Rarely, however, the maximum size of fragments reaches 15 to 20 centimetres in diameter. The rock generally contains abundant fine disseminations, patches, and veinlets of sulphides, mostly pyrite, but in places, such as in the south crosscut on the Ingerbelle 3050 drift, an appreciable amount of pyrrhotite also (Plate V).

At Copper Mountain the coarser fragmental rocks range considerably in character, though all are of andesitic composition. Both agglomerate and volcanic breccia with angular fragments are found. All rocks are dense, massive, and, where least altered, dark green or brownish green in colour. The fragments in the breccia are almost exclusively of andesitic volcanic rocks, and only occasionally fragments of sedimentary or volcaniclastic rocks are found. Although the majority of fragments range in size from 1 centimetre to 10 centimetres, occasionally blocks of 25 or more centimetres may occur.

South of the Copper Mountain stock volcanic breccia is very similar to that described above, but contains a larger proportion of fragments of fine-grained tuff and, locally, limestone.

The degree and type of alteration of volcanic breccia and agglomerate of unit 2 varies considerably from place to place. At Ingerbelle, where the most intensely altered rocks of the whole map-area are found, breccia can be so intensely replaced by albite, epidote, scapolite, and pink feldspar that no sign of the original fragmental texture can be recognized, even in the most continuous and clean exposures in underground workings (Plate VI).

South of the Copper Mountain stock the fragmental rocks show only a moderate amount of replacement by epidote and chlorite, mostly confined to the finer grained matrix material.

Tuff and Fine-grained Volcanic Sediments (Unit 2d): The most common types of volcanic rocks found in the map-area east of the Similkameen River consist of a sequence of fairly well-bedded fine-grained tuff, well-bedded volcanic siltstone, and rather massive lapilli tuff. Locally within this succession units can be found that can be used as good marker beds.

South of the Copper Mountain stock on both sides of the river unit 2d consists of fine-grained pyroclastic rocks that range from poorly bedded to massive lapilli tuff containing chips of fine-grained volcanic rocks up to 4 centimetres in diameter set in a fine-grained matrix of altered volcanic ash, pumice, tiny volcanic rock chips, and broken crystals of zoned intermediate plagioclase and minor quartz. Fine to medium-grained lithic-crystal and crystal tuffs are also common. These contain abundant broken crystals of plagioclase, augitic pyroxene, and minor quartz, as well as some very fine-grained, generally delicately bedded, cherty tuff and/or volcanic siltstone, which may rarely contain tiny clasts of volcanic rocks or broken feldspar and pyroxene crystals.

Rocks of any of these three general types may occur interlayered with one another on a relatively small scale, or a single type may underlie large areas, grading laterally into the other types. West of the Similkameen River, for instance, and just south of the southern boundary of the map-area, massive lapilli tuff and volcanic breccia are the predominant rock type within map unit 2. Along strike at Sunday Creek, however, one finds mostly lithic-crystal or crystal tuff, largely composed of sand-sized particles, and displaying fairly good bedding. Proceeding along strike northward toward Saturday Creek there is a gradual change to generally finer grained, and in places extremely fine-grained, bedded tuff and/or volcanic siltstone with thin interbeds of lapilli tuff or lithic tuff. At and north of the lower reaches of Saturday Creek unit 2d rocks include a large amount of very fine-grained, well-bedded, 'cherty' tuff and/or volcanic sediments. Microscopic examination of these rocks indicates that they actually consist of very fine, altered volcanic ash with clasts of volcanic rocks or of feldspar crystals mostly less than 1 millimetre in diameter. Thin interbeds of lithic tuff and some of lapilli tuff confirm the volcanic origin of all these rocks, and their generally good bedding and occasional suggestions of graded bedding indicate that they were probably water-laid.

East of the Similkameen River and to the south, east, and northeast of the Copper Mountain stock, rocks of unit 2d are primarily greenish grey and green crystal and lithic-crystal tuff and, locally, volcanic siltstone. These rocks are generally well and thinly bedded, and at several localities show graded bedding and poorly developed crossbedding strongly suggesting subaqueous deposition. They are characterized by beds of very fine-grained silt and finer sized material alternating with beds of slightly coarser, sand-sized material consisting for the most part of broken plagioclase and some pyroxene crystals. Quartz is notably scarce or absent, and the rocks are generally of andesitic composition. In the extreme southeast corner of the map-area a small area was found of more massive dacitic lithic-crystal and crystal tuff in which quartz is a prominent constituent occurring as crystals up to 5 millimetres in diameter and generally showing rounded, deeply embayed borders.

In the area between the Copper Mountain and Ingerbelle mines finely bedded tuff and volcanic siltstone are common although they are poorly exposed. Their general surface distribution is shown on Figure 2, but from a large number of drill holes they are known to extend over a much larger area.

In the region along the Copper Mountain stock contact between Pit No. 3 and the IXL mineral claim, thinly bedded tuff and volcanic siltstone are common. They may occur as an unbroken series of thin beds and laminations of fairly consistent attitude over several tens of feet, or may show sudden changes in attitudes over a small area without any obvious indications of folding. A good example can be observed along the northeast wall of Pit No. 3 where bedding attitudes vary so abruptly that it appears that the unit might consist here of large blocks of bedded tuff, rotated with respect to one another. Such a rock may have been produced by some process of subaqueous slumping of consolidated or partly consolidated tuff and volcanic sediment. In spite of continuous exposure along the pit wall the true nature and origin of the rocks and structures here could not be determined.

Farther to the northwest on Copper Mountain at least two beds of fine-grained well-bedded volcanic siltstone and/or tuff are found that can be used as marker horizons in outlining the structure of the volcanic succession for this area. The upper unit is about 100 feet thick, and the lower unit is in the order of 250 to 300 feet thick. They are separated by 300 to 400 feet of massive and fragmental andesite. The lower and thicker of the two beds crops out immediately west and north of an elongated swamp which occupies the west end of Lost Horse Gulch, and may be traced with some difficulty southward for a distance of approximately 1,800 feet to the Pit fault. At the northern end of its area of outcrop the unit shows clearly defined graded bedding indicating that the strata here are right-side-up and dip at 20 to 25 degrees to the west. This same bed may be traced by a large number of diamond-drill holes and underground development workings from the intersection of the Tremblay and Copper Mountain faults northeastward for some 2,500 feet, and probably for another 2,500 feet to the No. 18 mineral claim where similar rocks crop out in an embayment of the contact of unit 11 (Fig. 2).

Immediately north of Pit No. 1 in a small fault-bounded block, another thin layer of tuff is exposed in small, glacially polished outcrops at the north end of an open cut. It displays excellent bedding showing that here the strata trend northwestward, dip vertically, and face northeast. Immediately west of Pit No. 7, however, and on the opposite side of the Copper Mountain fault, some other thin horizons of bedded tuff and lapilli tuff indicate that here the strata trend northwestward to northeastward in an arcuate pattern around the west end of the pit, and dip easterly at 25 degrees.

A short distance west of Pit No. 7 and immediately north of the Copper Mountain stock, is an area underlain by another unit of finely laminated, very fine-grained metasiltstone and/or tuff which, near the southern branch of the Copper Mountain fault, grades northward into lithic lapilli tuff and volcanic breccia. The finely laminated rocks, locally known as the 'Railway Unit,' are best exposed in cuts along the abandoned railway grade. They occupy a belt at least 600 feet wide, which lies immediately north of the stock contact and terminates to the northwest on the Honeysuckle break, and to the southeast against a northerly trending porphyry dyke of map unit 13 which probably follows a fault. To the northeast they are truncated by a branch of the Copper Mountain fault.

Rocks of the 'Railway Unit' are characterized by an extensive growth of fine-grained, reddish brown biotite on the planes of foliation, which gives them a phyllitic appearance, and by a marked lineation developed on the foliation planes and caused by almost imperceptible crinklings of the thin micaceous layers. This lineation plunges gently to the east-southeast. No obvious microfolding or cleavage appears to be associated with the development of the lineation, and it seems that the extensive development of biotite might be due to the parallelism of the foliation planes with the intrusive contact, which favoured biotite growth on these planes. Microscopically these rocks show a simple assemblage of very fine-grained quartz and feldspar with lesser amounts of reddish brown biotite, minor carbonate, chlorite, and opaque minerals. Within a few tens of feet of the stock contact, thin discontinuous lenses of light green augitic pyroxene are developed in some places in the plane of foliation. No evidence of penetrative deformation of any kind was observed in thin sections of the metasiltstone. The lamination, well displayed for some 600 feet north of the contact, also strikes parallel to it and dips steeply northeastward. It is believed to be parallel to bedding because the finer grained rocks grade northeastward and upward into coarser grained lithic lapilli tuff and volcanic breccia. The same relationship, as well as a flattening of dip to the north, are indicated by some drilling that has been done in the northern part of the unit.

The rocks of the 'Railway Unit' appear to be a sequence of metamorphosed, thinly bedded tuff and/or siltstone overlain by coarser pyroclastic rocks, and now part, either of a tilted fault block, or of a truncated and faulted northwesterly trending antiform, the southern limb and axis of which have been destroyed by the Copper Mountain stock.

AREA WEST OF THE BOUNDARY FAULT: Volcanic and sedimentary rocks of the Nicola Group west of the Boundary fault are found almost exclusively in the northern half of the map-area. In the southern half they form only a few small exposures along and near Highway 3, immediately south of Deep Gulch. Although the volcanic-sedimentary succession is somewhat similar to that of rocks east of the Boundary fault, some major differences exist, and may be summarized as follows:

1. Nicola rocks are divided into two map units west of the Boundary fault as they are east of it, and these also consist of a primarily sedimentary unit (unit 3) and a volcanic unit (unit 4). The terms unit 3 and unit 4 as used in this report, however, have little stratigraphic meaning because it is relatively certain that there are actually two separate volcanic members designated as unit 4 and probably two sedimentary members designated as unit 3, the sequence being an intercalaction of volcanic and sedimentary members.
2. Sedimentary rocks of unit 3 though similar to those of unit 1 east of the Boundary fault are generally richer in disseminated carbonate and lack any extensive development of conglomerate. They also appear to contain less truly pyroclastic tuffs and to have undergone a greater degree of reworking than most of unit 1.
3. Rocks of unit 4 are mostly coarsely fragmental or massive. There is no extensive development of well-bedded tuff such as found in unit 2. They also appear to consist of two successions: A lower succession found east of Kennedy Lake and characterized by abundant pyroxene phenocrysts, and an upper succession found only west of Kennedy Lake and characterized by abundant plagioclase phenocrysts.
4. A true pillow lava appears to be either lacking or to be very restricted in unit 4. In the lower volcanic succession, unit 4b, found east of Kennedy Lake and at other localities, is an andesite with only sporadically and very poorly developed pillow structures.

SEDIMENTARY ROCKS (UNIT 3): Sedimentary rocks of unit 3 are found in three separate areas. Well-bedded sedimentary rocks are found at the Ingerbelle mine immediately west of the Boundary fault, and as a block bounded on the west by the Boundary fault and on the east by an unnamed fault which strikes northerly and dips at 45 degrees to the west. This latter fault, though not exposed in outcrop, was penetrated by several diamond-drill holes and was found to bring unmineralized and virtually unmetamorphosed siltstone and sandstone over highly altered and mineralized metavolcanic rocks of unit 2. In drill core the fault is marked by a zone several feet wide of intense and extensive shearing which at depth is interpreted to connect with the Boundary fault. The sedimentary rocks immediately west of the Boundary fault are in turn in contact with coarsely fragmental volcanic rocks of unit 4 along a fault which dips westerly at moderate to steep angles. If one considers these two lesser faults which are located on either side of the Boundary fault to be subsidiaries of it, and to have the same type of normal movement, then it follows that the volcanic rocks found to the west of the westernmost of these faults must overlie the sedimentary rocks, and thus two sedimentary members must exist: One immediately west of the Boundary fault and one southwest of Kennedy Lake. If it is assumed that the westernmost fault of the Boundary system is a reverse fault, then only one sedimentary unit is necessary to explain the outcrop patterns. Well-bedded rocks of unit 3 are also sporadically exposed in an area of heavy overburden which extends from Whipsaw Creek south for approximately 2 miles. Immediately west of Kennedy Lake these rocks are overlain by a volcanic succession of bedded fossiliferous tuff and of massive and fragmental plagioclase andesite. To the south they are overlain by Tertiary sedimentary and volcanic rocks of the Princeton Group.

Identical sedimentary rocks occupy an area which extends from Kennedy Mountain, immediately east of Kennedy Lake, northward to just beyond Whipsaw Creek where they are also overlain by the Princeton Group with definite unconformity. This sedimentary member of the Nicola Group is considered to be correlative with that found west of Kennedy Lake. On Kennedy Mountain it grades downward with apparent conformity into a sequence of volcanic rocks consisting of poorly pillowed andesite, lithic tuff, and abundant massive and coarsely fragmental pyroxene andesite. This volcanic succession is similar to that found west of Ingerbelle where it is thought to overlie, though with fault contact, the lower sedimentary member.

Rocks of map unit 3 of all three areas consist for the most part of well-bedded grey and dark grey thinly interlayered shale, siltstone, and sandstone. Locally beds of pebble and boulder conglomerate and breccia several feet thick are found, but are not extensive. Grey and dark grey, impure limestone is found locally in small, discontinuous beds. All rocks of the unit are characterized by a widespread and appreciable amount of finely disseminated carbonate, and by abundant volcanic detritus in the form of pebbles of fine-grained volcanic rocks and of generally well-rounded feldspar grains. Bedding is generally well developed throughout the unit, and tops can be determined at many localities through graded bedding, crossbedding, and cut-and-fill structures. No fossils were found in the unit, except for a few fragments of carbonized wood collected in a massive, slightly calcareous, gritty volcanic sandstone, of what is thought to be the upper sedimentary succession, approximately 1,600 feet due east of the north end of Kennedy Lake.

The generally well-developed bedding found in rocks of unit 3 helps in outlining a broad syncline, herein termed the Kennedy Lake syncline, the axial trace of which passes close to Kennedy Lake and strikes slightly west of north, the axis plunging gently northward. In its northern part the fold is dislocated by a steeply dipping longitudinal fault subparallel with its axial plane which has moved the west block down and brought Tertiary rocks in contact with Nicola rocks. This fault is well exposed on the steep south side of Whipsaw Creek valley but can only be traced southward and northward for a short distance because of deep overburden. However, the fault probably continues south for a much greater distance, and may account for the presence of the upper volcanic succession of unit 4 only on the downthrown western block.

VOLCANIC ROCKS (UNIT 4): As mentioned above, it is believed that lower and upper members of volcanic rocks exist that are included in unit 4, and that some appreciable lithologic differences exist between these two groups. Rocks of the lower member crop out in a belt as much as 5,000 feet wide which extends from just west and slightly south of Ingerbelle to the northern boundary of the map-area. Smaller, mostly fault bound exposures, are also found south-southwest of Ingerbelle and south of Deep Gulch. Rocks of the upper assemblage are found only west of Kennedy Lake and occupy an area at most 1,800 feet wide and extending from immediately southwest of the lake northward to Whipsaw Creek. An isolated exposure of assorted volcanic rocks found along the western boundary of the map-area about 8,000 feet southwest of Kennedy Lake was only cursorily examined, and cannot be discussed in any detail.

Rocks of the lower volcanic member are generally medium to light green and include: Massive porphyritic augite andesite, breccia, and agglomerate of augite andesite, locally with clasts having a maximum dimension of 30 to 35 centimetres; varicoloured tuff breccia and lithic tuff with olive green, purplish, and light green fragments of volcanic rocks; minor amounts of crystal and vitric-crystal tuff; and on Kennedy Mountain a bed of pillowed andesite and/or pillow lava approximately 100 to 150 feet thick. This latter rock is greenish grey, fine grained, and contains many amygdules filled with grey calcite. In bulldozer trenches on Kennedy Mountain the unit shows fairly well-developed pillow structures, but elsewhere it appears to consist mostly of poorly pillowed andesite. Along the eastern edge of the outcrop area of unit 4 the rocks found within 1,500 feet of the trace of the Boundary fault, regardless of their lithology, are generally chloritic and consistently display a marked schistosity which trends northerly and dips to the west at moderate angles. The development of this schistosity spatially associated with the Boundary fault may owe its origin to the existence of that fault.

Rocks of the upper volcanic succession found west of Kennedy Lake are somewhat different from those of the lower member. Whereas augite is found consistently and almost exclusively in the lower member as well-formed phenocrysts in flows or in breccia clasts, in the upper member plagioclase is the predominant mineral forming phenocrysts both in massive and in fragmental rocks of andesitic composition and pyroxene phenocrysts are scarce or absent. Furthermore, the lower volcanic member in its central part consists predominantly of coarsely fragmental rocks, and on Kennedy Mountain appears to grade upward through a sequence of lithic tuff and pillowed andesite to the finer grained sedimentary rocks of unit 3, and hence indicates a general and gradual decrease in volcanic activity. The upper member, on the other hand, overlies sedimentary rocks with apparent conformity and grades upward from fossiliferous, fine-grained bedded tuff into massive andesite and coarse breccia and agglomerate with some fragments 30 to 35 centimetres in diameter, thus indicating a gradual increase in volcanic activity.

The only fossils found in map unit 4 came from the upper volcanic succession. The collections were examined by Dr. E. T. Tozer of the Geological Survey of Canada who reported as follows:

Collection No. 84295 – Taken from a small bioclastic limestone lens 600 feet due north of the north end of Kennedy Lake contains *Pleurotomaria* of undetermined age.

Collection No. 84296 – Taken from fine-grained bedded tuff 2,000 feet northwest of the centre of Kennedy Lake contains *Halobia* of Upper Triassic age.

Collection No. 84297 – Taken at the same locality as No. 84296 but from a small lens of bioclastic limestone. It contains no identifiable fossils.

AUGITE BASALT PORPHYRY SOUTH OF COPPER MOUNTAIN STOCK (UNIT 5): Map unit 5 is found only south of the Copper Mountain stock, and mostly east of the Similkameen River. It is best exposed along the Similkameen River at Sunday Creek and on the east bank of the river south of Saturday Creek. Good exposures are also found on the top of an unnamed rounded hill in the southeastern part of the map-area 6,000 feet southeast of the Marquis of Lorne mineral claim (Lot 2572).

The rock is massive, dense, grey-green to medium and dark green pyroxene basalt porphyry consisting of 25 to 40 per cent phenocrysts of euhedral augite ranging from less than 1 millimetre to 1 centimetre in diameter set in a fine-grained matrix. Finer grained phases are generally darker in colour, in places nearly black, but maintain abundant augite phenocrysts. Specimens examined microscopically show excellent porphyritic texture with euhedral crystals of twinned augite set in a very fine-grained to aphanitic matrix (Plate VII). Occasionally some hornblende phenocrysts are also present. In one specimen prehnite was found in a carbonate veinlet cutting altered and sheared porphyry. Determinations of indexes of refraction of glass beads from five specimens indicate that the porphyries are basalt.

Rocks of unit 5 occur as dykes and probably as sills that cut rocks of units 1 and 2. The intrusive relationship of larger bodies is inferred from their shape and from the fact that several smaller dykes of identical material were found clearly cutting through sedimentary and volcanic rocks. Though later than volcanic and sedimentary rocks, the porphyry of map unit 5 is cut by microdiorite and latite porphyry dykes of map unit 10 which are considered to be part of the Copper Mountain intrusions. The augite porphyry thus probably represents an intrusive phase of Nicola volcanic rocks which overlaid rocks of units 1 and 2.

METAMORPHISM AND METASOMATISM OF NICOLA ROCKS: Rocks of the Nicola Group, both east and west of the Boundary fault, generally exhibit secondary mineral assemblages which are characteristic of subfacies B 1.1 and B 1.2 of the greenschist facies, or of the albite-epidote hornfels facies (Winkler, 1965). An exception to this generalization is found in the Copper Mountain-Ingerbelle area, which will be discussed later.

In general, the volcano-sedimentary and sedimentary rocks of units 1 and 3 exhibit a very mild type of alteration consisting essentially of moderate saussuritization of feldspar grains and of variable degrees of replacement of the matrix by carbonate.

Volcanic rocks of units 2 and 4, being in general of basaltic andesite composition, nearly everywhere contain epidote, chlorite, sericite, carbonate, and, very commonly, tremolite-actinolite. Biotite is found only sporadically. Late prehnite-filled veinlets are found occasionally in the volcanic rocks south of the Copper Mountain stock.

In the immediate vicinities of the contact of the Copper Mountain stock a narrow aureole of contact metamorphism is developed which apparently overprints the lower grade metamorphism previously mentioned. This zone is generally less than 200 feet wide, but occasionally may extend to 500 feet from the contact. All rocks within this area are characterized by a widespread development of granoblastic diopsidic pyroxene, green hornblende, brown to reddish brown biotite, abundant epidote, intermediate plagioclase, and locally, minor quartz.

In the Copper Mountain-Ingerbelle area a different kind of rock alteration is found which involves removal or addition of material in greatly variable amounts, depending on the intensity of metasomatism. Both volcanic and sedimentary rocks of the Nicola Group and intrusive rocks of the Lost Horse suite are affected. In general, rocks east of the Honeysuckle break appear to have been subject to somewhat less alteration than rocks at Ingerbelle, and differ from them in the metasomatic mineral assemblages. Metasomatic alteration bears a close spatial relationship to fractures and in part to bodies of Lost Horse intrusive rocks. It may range from a slight bleaching along thin fractures to intense and pervasive albitization, pink feldspar alteration, and scapolite veining of bodies of rock several hundreds of feet wide.

At Copper Mountain, one of the most common and widespread types of alteration is a light grey bleaching along northeast trending fractures in biotitized volcanic rocks. Commonly, and especially close to the Copper Mountain stock contact, veins of biotite-potash feldspar pegmatitic material and/or sulphides follow these fractures which, over the years, have been known as the 'ore fractures.' Occasionally, as in the area of the old glory holes, these pegmatite-sulphide veins reach widths of 1 foot or more, with selvages of coarse biotite along the edges and massive bornite and chalcopyrite at the centre. Elsewhere, however, such as at and near Pit No. 2, a very marked bleaching follows these fractures as an envelope that, at its extreme, converts magnetic, agglomeratic, dark green augite andesite or brownish biotitized andesite to a nondescript medium-grained, massive, greenish grey, non-magnetic, dioritic looking rock with no visible fragmental texture. Where the alteration has proceeded further, the rock becomes light grey in colour, is generally non-magnetic, and has veinlets or patches of light green epidote, pink feldspar, minor biotite, and pyrite and pyrrhotite. A similar kind of alteration is also found in Lost Horse intrusive rocks such as occur on the steep west-facing slopes immediately to the north of the west end of Lost Horse Gulch. In the intensely altered volcanic rocks such as those close to the large bodies of Lost Horse intrusions, thin veinlets of scapolite are found, that are inconspicuous and never as abundant as at Ingerbelle. Pink potash feldspar alteration on Copper Mountain is generally closely associated with pegmatite veins and is either confined to such veins or occurs as a flooding of the rock between closely spaced veins. In summary, volcanic and some intrusive rocks at Copper Mountain are considered to have undergone metasomatism which is physically controlled by the presence and intensity of fractures and by the proximity of large bodies of Lost Horse intrusive rocks. Such alteration overprints a generally widespread earlier biotitization of the rocks. It involves bleaching, as a result of destruction of ferromagnesian minerals, such as biotite and pyroxene, and of magnetite, as well as albitization and later growth of epidote, minor biotite, pink potash feldspar, and, in places, pyrite and chalcopyrite.

At Ingerbelle and west of the Honeysuckle break the metasomatic character of the alteration and its close relationship to fractures is even more clearly displayed. Numerous sub-vertical fractures, many of which trend northeast and northwest, exist at Ingerbelle. These are followed not only by films of alteration and veins of sulphide mineralization but also by most of the relatively late Lost Horse dykes. Along the 3050 underground level and over most of the area west of the Honeysuckle break and north of the Copper Mountain stock all volcanic and most of the older of the Lost Horse intrusive rocks have been subjected to some biotitic alteration which in many places was followed and replaced by epidote and secondary diopsidic pyroxene, sphene, apatite, and carbonate. In areas of intense veining and alteration the latter minerals are extensively replaced by scapolite and pink feldspar along veins and as a pervasive flooding (Plate VIII). Both low-calcium plagioclase and potash feldspar have been identified as constituents of pink feldspar masses. Occasionally small grains of garnet were identified microscopically in the more strongly altered rocks. In outcrop, the intensely scapolitized and albitized rocks form hard, resistant, small ridges that generally trend northwesterly. In areas of copper mineralization these rocks are either barren or nearly so, most likely because of the sealing of fractures by scapolite and albitic feldspar. Intervening portions of relatively less altered, softer, and more chloritic rock tend to carry the bulk of the sulphide mineralization. South of the Gully fault, although alteration can be locally very intense, the various units of the volcanic succession and most intrusive rocks can be distinguished with relative ease in outcrop and drill core. North of the Gully fault pink feldspar alteration and albitization increase rapidly so that in most places no vestige remains of the original rock. This zone of strong alteration is a border phase of the large mass of Lost Horse intrusive rocks which lies north of Ingerbelle and has been referred to as the Armstrong Bluffs complex (Montgomery, 1967). Throughout this complex, zones of albitization and strong pink feldspathization occur as thin films and as floodings, as well as rare scapolite veining that may be accompanied by pyrite and some chalcopyrite.

In summary, it appears that in the area west of the Honeysuckle break in both volcanic and sedimentary rocks, an early period of isochemical metamorphism involving formation of biotite and, somewhat later, diopsidic pyroxene, epidote, sphene, apatite, and some garnet, was followed by extensive and locally very intense soda, potash, and chlorine metasomatism related to steeply dipping fractures. This process resulted in partial or total replacement of pink sodic plagioclase, pink potash feldspar, and scapolite and was followed and/or partly accompanied by sulphide mineralization. Such metasomatism must have involved removal, or at least redistribution of large quantities of calcium and iron from the rocks, and is believed to be genetically related to the crystallization history of the mass of Lost Horse intrusive rocks known as the Armstrong Bluffs complex.

COPPER MOUNTAIN INTRUSIONS

INTRODUCTION AND DEFINITION OF TERMS: The term 'Copper Mountain intrusions' as used in this report refers to those four main bodies of intrusive rocks which are known as Copper Mountain stock, Voigt stock, Smelter Lake stock, and Lost Horse intrusions. The first three of these names refer essentially to the same bodies described by Dolmage (1934), by Rice (1947), and, with some difference in the outline of the Voigt stock, by Montgomery (1967). The term 'Lost Horse Intrusives' was introduced by Dolmage (1934) who distinguished two main types: (1) a light-coloured augite diorite, and (2) a pinkish grey biotite monzonite or syenite. Dolmage considered these rocks to be genetically related to the three stocks, but to be perhaps somewhat older, in view of their generally more altered and in places mineralized condition. Montgomery (1967) discontinued the usage of the term 'Lost Horse Intrusives' and considered Dolmage's type (1) rocks to be related to Nicola volcanism and type (2) rocks to be part of the Copper Mountain intrusions. He proposed the name Armstrong Bluffs complex to "describe the group of intrusive masses including the body immediately southwest of the Smelter Lake stock and the monzonites and syenites north of the main stock" (Montgomery, 1967, p. 24). The present writer proposes that the term 'Lost Horse Intrusives' first used by Dolmage be reinstated as 'Lost Horse intrusions' for the following reasons:—

1. With reference to the distribution of his type (1) rocks, Dolmage writes "the acid diorite forms part of the large body at the west end of Lost Horse Gulch, and entirely composes all the areas shown on the map west of this to Similkameen Canyon" (1934, p. 12). A comparison of the geological maps accompanying reports by Dolmage, Montgomery, and the present writer shows that not only are the above areas considered by this writer to be underlain by intrusive rocks, but that Montgomery's map also shows intrusive rocks in most of the area described by Dolmage as being underlain by type (1) rocks. Thus the general consideration by Montgomery of type (1) rocks as being related to Nicola volcanism does not seem to be justified.
2. Although it is agreed that some alteration of Nicola andesites may produce rocks which fit Dolmage's general type (1) description, the same product is also obtained by a similar alteration of clearly intrusive medium-grained monzonite that Montgomery mapped as part of his Armstrong Bluffs complex.
3. In view of recent information from drilling and trenching which was not available at the time of Montgomery's work, it is believed that the largest mass of monzonitic and dioritic rocks is found north of Copper Mountain on both sides and along most of the length of Lost Horse Gulch.

Thus the term Lost Horse intrusions as used in this report refers to that complex of rocks which range in composition from augite diorite to syenite and which occur in the area between Wolf Creek and the Boundary fault and between the Copper Mountain stock to the south and the Smelter Lake stock and a large area of Princeton volcanic rocks to the north. These rocks include all of Montgomery's Armstrong Bluffs complex as well as many other rocks, some of which were mapped by Montgomery and by Dolmage as Nicola volcanics. Two main subdivisions are proposed for the Lost Horse intrusions. Map unit 11 includes a complex of intrusive rocks of generally dioritic to monzonitic composition which display great variation in state of alteration and which occur as ill-defined irregular masses, some of which might include intensely altered volcanic rocks. Map unit 12 includes clearly recognizable dykes of latite to syenite porphyry that definitely cut rocks of unit 11. Isotopically, the ages of rocks of map units 11 and 12 and of the three main stocks of the Copper Mountain intrusions are indistinguishable (Preto, *et al.*, 1971).

COPPER MOUNTAIN STOCK: In view of the recent and extensive work carried out by Montgomery (1967) on the petrography and mineralogy, chemistry, structure, and origin of the Copper Mountain stock, no attempt was made by this writer to remap the stock in any detail. For a more elaborate treatment of these intrusions reference should be made to Montgomery's thesis. The subdivision into diorite (map unit 6), pyroxenite and gabbro (map unit 7), monzonite (map unit 8), and pegmatite (map unit 9) is that of Montgomery and the distribution and arrangement of these phases are taken, with a few very minor changes, directly from Montgomery's map. A careful examination made of the contact of the stock with Nicola rocks, however, led to several, though for the most part minor, modifications to the outer boundary of the stock as given by Montgomery. The greatest change is the addition to the extreme southeastern part of the stock of an area east of upper Wolf Creek which is underlain by medium-grained massive augite diorite but was previously shown to be underlain by Nicola rocks.

The Copper Mountain stock was mapped by Dolmage (1934) and later by Montgomery (1967) as a roughly concentrically differentiated intrusion grading from augite diorite at the border through monzonite to perthosite pegmatite* at the core. Within the outer diorite zone a ring of small elongated bodies of gabbro and pyroxenite is shown by Montgomery to follow the general outline of the stock. All phases of the stock are said by Montgomery to be completely gradational into one another, and to have been produced from a single magma of basic diorite composition. Figure 9 is a ternary plot of 79 modal analyses performed by Montgomery on the various phases of the intrusion.

The contact of the stock with Nicola rocks wherever observed has been found by many workers to be sharp and to dip very steeply, generally inward, mostly at 75 to 80 degrees. At one place on the IXL mineral claim, an inward dip of 60 to 65 degrees can be calculated from drill hole and surface data. Fahrni (1951) reports an inward-dipping contact of 40 degrees or less in the area about 1 mile southeast of the Copper Mountain mine workings. As for the mechanism of emplacement of the stock, Montgomery (1967, pp. 144-147) believes that it was one of forceful injection which is said to be suggested by distortion in the regional trend of the Nicola rocks that on Copper Mountain are reported by Fahrni (1966) to be characterized by gentle north trending folds. Montgomery also presents the argument that, once emplaced, the original dioritic magma differentiated in place from the walls inward by "...fractional crystallization effected through a combination of convection, diffusion, crystal zoning, and crystal settling" (1967, p. 157), thus producing the concentric arrangement of phases observed in the field. Mineralogical considerations based on feldspar geothermometry suggest to Montgomery (1967, pp. 156-157) that the minimum temperatures of crystallization ranged from above 820 degrees centigrade for the outer parts of the stock to about 500 degrees centigrade for the pegmatitic core. However, the contact metamorphic assemblages observed along the border of the intrusion are of hornblende hornfels facies thus indicating equilibrium temperatures ranging from 540 to 630±20 degrees centigrade at 2,000 bars, according to Winkler (1965, p. 59).

*Perthosite pegmatite contains about 97 per cent perthite with minor amounts of leucoxene or sphene, quartz, and fine-grained colourless micas.

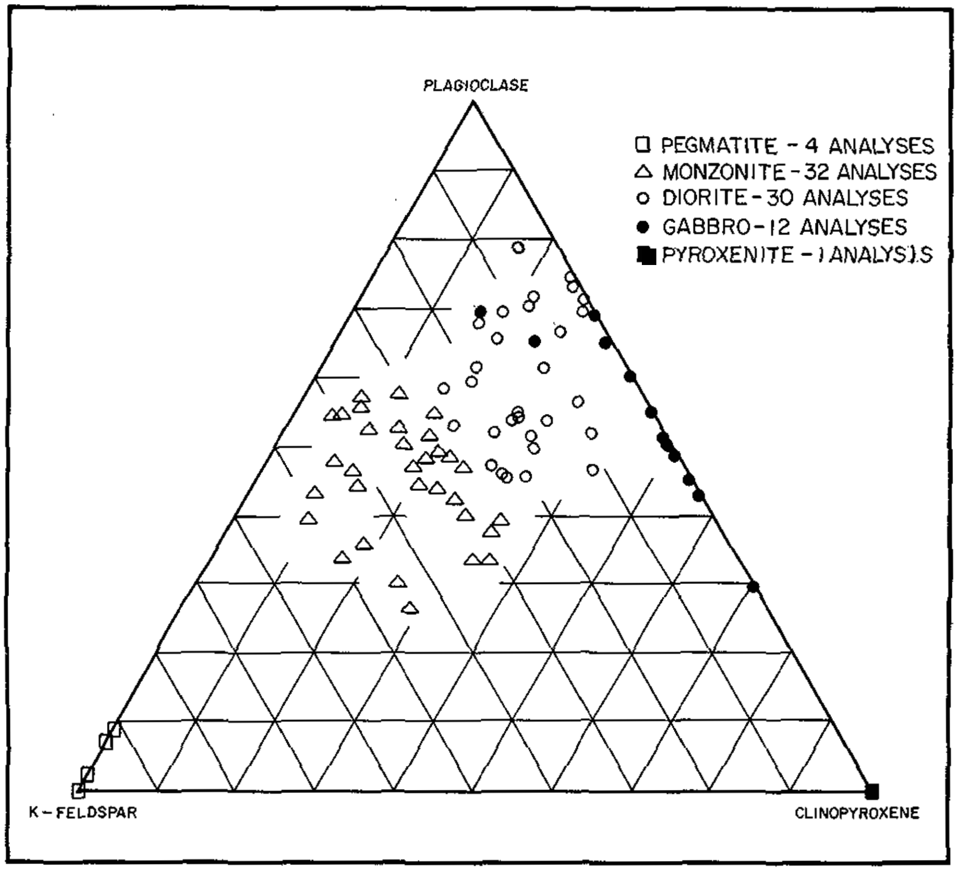

Figure 9. Ternary plot of the essential minerals (modal volume per cent) of 79 specimens from the Copper Mountain stock. [After Montgomery, 1967, p. 52.]

SMELTER LAKE AND VOIGT STOCKS: The Smelter Lake stock is located approximately 2 miles north-northeast of Copper Mountain. It occupies less than 1 square mile of area between the west end of Smelter Lake and the Similkameen River. Its contacts with Nicola rocks to the north and south are generally poorly exposed and complicated by faulting. The contact with Lost Horse rocks to the east of and at Armstrong Bluffs is confused and somewhat inaccessible on the precipitous slopes of the Similkameen Canyon.

The Voigt stock is located almost entirely east of Wolf Creek and lies mostly to the east, northeast, and north of Voigt's camp. The stock is estimated to occupy approximately 3.2 square miles, two-thirds of which lie within the map-area. To the north, west, and south the stock intrudes Nicola rocks and is unconformably overlain by volcanic rocks of the Princeton Group. To the east it is intruded by the Verde Creek quartz monzonite. The contacts of the stock are generally poorly exposed, and the above relationships, though almost certainly correct, are for the most part inferred from indirect evidence.

Both stocks are nearly uniform in composition and consist of medium-grained, generally massive, grey-green biotite-clinopyroxene diorite. The Smelter Lake stock is usually richer in biotite than the Voigt stock, but contains approximately the same amounts of all other accessory minerals. Such a relationship is suggested by Figure 10 which is a ternary plot of modal analyses performed by Montgomery on diorites from both stocks.

Montgomery considers both stocks to consist of the undifferentiated magma which produced the Copper Mountain intrusions (1967, p. 144). He attributes the apparent lack of differentiation in these two bodies to be due, perhaps, to relatively fast cooling and loss of volatiles (1967, p. 147), and suggests that the stocks may be somewhat differentiated at a deeper level not exposed by erosion.

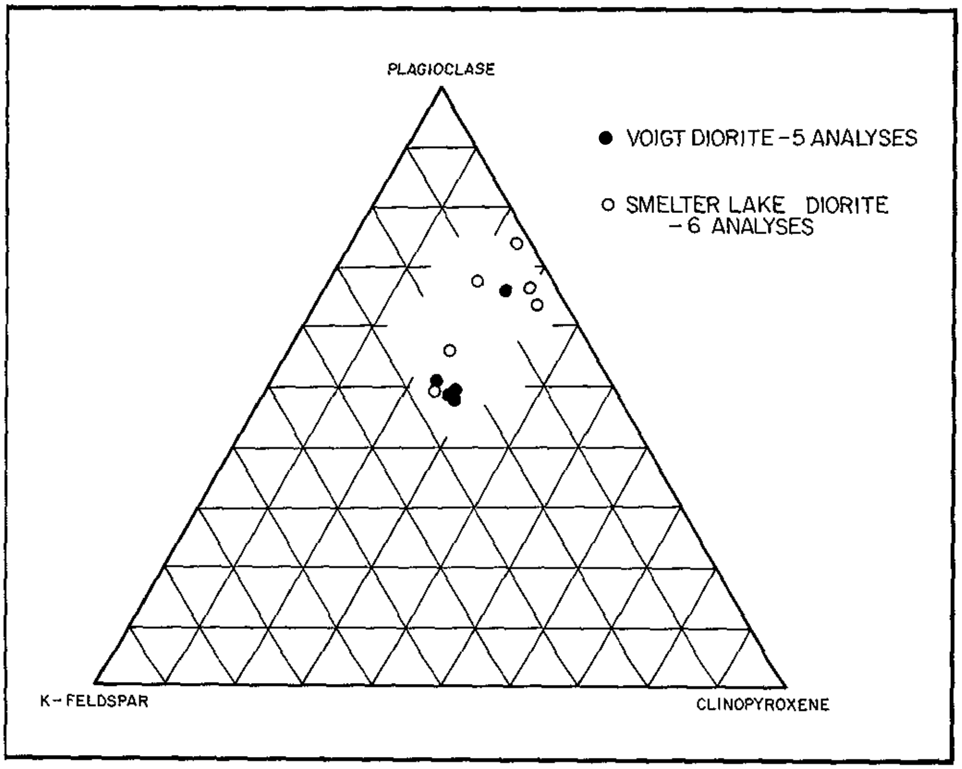

Figure 10. Ternary plot of the essential minerals (modal volume per cent) of specimens from the Smelter Lake and Voigt stocks. [Analyses by Montgomery, 1967, p. 46.]

DYKES OF MICRODIORITE AND LATITE PORPHYRY (UNIT 10): Dykes that range in composition from andesite to acid basalt are found almost exclusively south of the Copper Mountain stock, and mostly west of the Similkameen River and south of Friday Creek. They range from a few feet to 300 feet wide and trend mostly north-northeast. In texture they range from dark grey, fine-grained, trachytoid, latite porphyry with phenocrysts of plagioclase and pyroxene, to massive fine to medium-grained pyroxene microdiorite which, though apparently homophanous in hand specimen, shows a markedly porphyritic texture in thin section. Hornblende is found in some of the dykes, and is commonly strongly altered to biotite. Alteration ranges from a moderate amount of uralitization and saussuritization, probably of late magmatic origin, to a strong albitization and bleaching, found at some localities north of Saturday Creek, associated with pyrite, pyrrhotite, and minor chalcopyrite mineralization.

Rocks believed to be part of unit 10 are also found in the northern part of the map-area. At Ingerbelle, along the Boundary fault, there are three occurrences of a strongly crushed and, in places, mylonitized, crumbly, brownish weathering, fine-grained rock which in hand specimen and in thin section closely resembles some of the darker microdiorites found south of the Copper Mountain stock. Northeast of Kennedy Lake one northerly trending dyke of rusty weathering, massive microdiorite porphyry was found which, in places, contains up to 7 per cent disseminated pyrite and pyrrhotite.

Rocks of map unit 10 cut Nicola rocks including those of map unit 5. Their crosscutting relationships with the Copper Mountain stock are unknown, but their composition suggests a genetic relationship with the stock, and they are thus considered to be part of the Copper Mountain intrusions.

LOST HORSE INTRUSIONS (UNITS 11 AND 12): The problem of nomenclature concerning these rocks has been discussed in previous pages and the writer's views expressed. By such criteria, rocks of the Lost Horse intrusions are found exclusively on or north of Copper Mountain and from Wolf Creek west to the Boundary fault. On Copper Mountain proper, and especially close to the main stock contact, they are relatively rare and occur as dykes, sill-like bodies, and irregular masses, mostly too small or poorly defined to map. North of the Copper Mountain fault, however, they become progressively more abundant and eventually form a more or less continuous mass. In the vicinity of Pit No. 2 this body has an east-west trending southern contact and continues northward beyond Lost Horse Gulch where it is unconformably overlain by volcanic rocks of the Princeton Group. Laterally it extends from the east end of Lost Horse Gulch across the Similkameen River to the Boundary fault. Within this mass are a large number of 'rafts' or pendants of Nicola rocks mostly difficult to recognize and too small to map. In all of the bodies of Lost Horse intrusions is found a great and confusing variety of compositions, textures, grain sizes, degrees of alteration, and modes of occurrence. However, almost invariably, all rocks were found to have a porphyritic texture and to contain disseminated apatite crystals which can be seen either readily with the naked eye or somewhat more laboriously with the help of a good pocket magnifier.

According to their mode of occurrence in the field, rocks of the Lost Horse intrusions have been subdivided into two mappable units. Map unit 11 includes all those rocks, altered or not, which do not form obvious dykes and which may range in composition from diorite to monzonite or syenite. Map unit 12 consists mostly of biotite latite porphyry and of biotite-pyroxene microsyenite porphyry that are generally fresh and cut rocks of map unit 11 as well-defined dykes up to 100 feet wide.

UNIT 11: The bulk of rocks of map unit 11 are monzonites, but compositions range from diorite to syenite. Figure 11 is a ternary plot of modal content of essential minerals for 46 specimens of Lost Horse intrusive rocks. Rocks of map unit 11 are fine to medium grained and almost invariably porphyritic. They range in colour from grey-green to salmon pink and are essentially composed of intermediate plagioclase, clinopyroxene, and varying amounts of potash feldspar. Microscopically plagioclase commonly occurs as euhedral, zoned, and extensively sericitized crystals. Pyroxene crystals are generally anhedral to subhedral and variably altered to chlorite, epidote, biotite, and hornblende. Potash feldspar occurs either entirely interstitially or in veins. At several localities examples of flooding of potash feldspar outward into the rock from relatively narrow veins can be seen. *In some instances coalescence of alteration from nearby veins* permeates the whole rock, producing a metasomatic syenite which initially was a fine-grained monzonite or diorite. Because of the abundance and widespread occurrence of such metasomatism it is difficult to estimate what portion of the rocks of map unit 11 can be classed as true syenite. It is the writer's opinion that probably the most abundant rock type is monzonite, with diorite and syenite forming not more than 20 to 25 per cent of the complex.

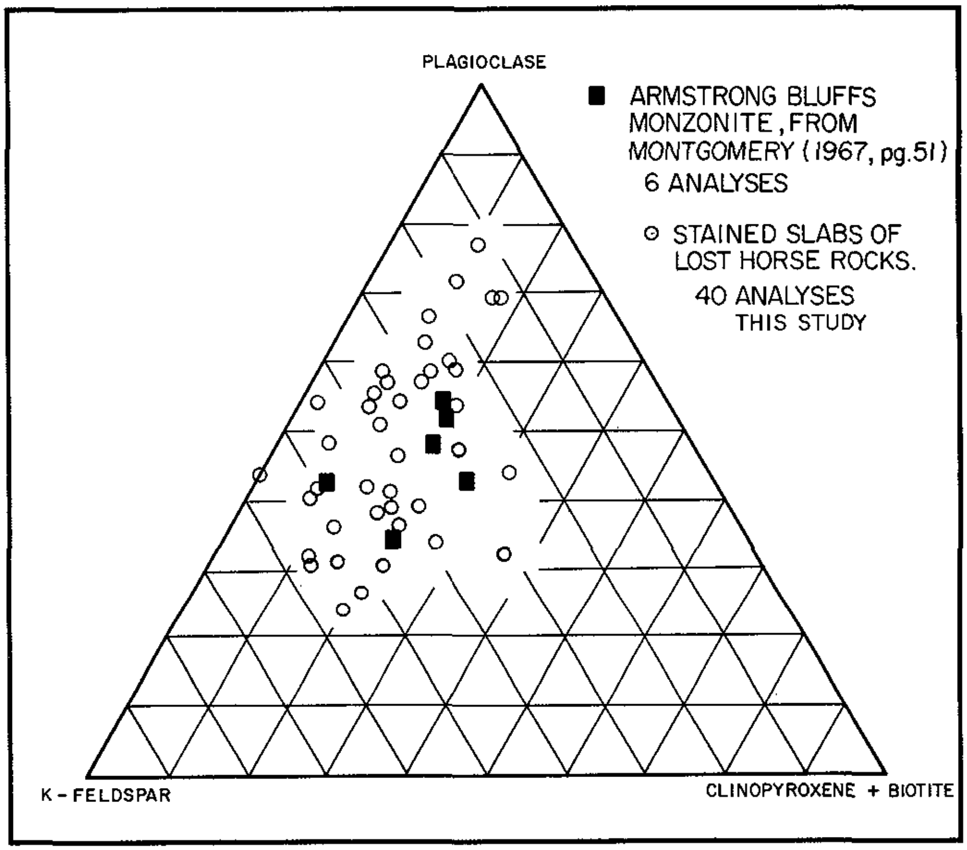

Figure 11. Ternary plot of the essential minerals (modal volume per cent) of specimens of Lost Horse intrusive rocks.

Extensive and pervasive albitization and bleaching of ferromagnesian minerals are found commonly in map unit 11. The result of these processes produces the 'very light-coloured, acid augite diorites' of Dolmage (1934, p. 12). This bleaching of Lost Horse and Nicola rocks is commonly observed in areas of mineralization, distributed either along fractures or pervasively, so that it may be related to sulphide deposition. Extensive areas of thoroughly albitized, nearly white rock are however also found where

Table 2. Modal analyses of stained slabs of Lost Horse intrusive rocks. Figures are volume per cent.

Specimen No.	K-feldspar	Plagioclase	Pyroxene	Biotite	Apatite	Metallics	Points Counted
68- 1	34.1	54.1	11.8	---	Tr.	Tr.	500
68- 2	26.7	53.0	15.5	3.0	---	1.8	500
68- 60	16.5	66.5	10.4	---	4.7	1.9	462
68- 62	23.8	56.0	16.8	---	1.0	2.4	500
68- 65	12.6	68.4	---	17.6	Tr.	1.4	500
68- 66	24.7	59.7	10.5	3.6	---	1.5	392
68- 67	39.2	36.8	17.4	---	2.4	4.2	552
68- 68	25.0	61.5	9.2	1.3	1.0	2.0	391
68-110	23.4	41.9	28.1	1.6	Tr.	5.0	500
68-113	37.2	32.8	22.2	3.6	---	4.2	500
68-114	35.2	47.7	11.3	---	0.7	5.1	520
68-116	44.3	28.2	4.3	16.5	1.9	4.8	515
68-118	32.6	56.8	7.4	---	0.6	2.6	500
68-119	53.4	28.9	12.3	---	3.5	1.9	456
68-121	50.2	25.4	6.6	13.6	2.1	2.1	529
68-122	35.5	37.3	20.6	---	2.5	4.1	510
68-124	50.7	29.9	5.7	9.2	2.7	1.8	500
68-129	40.2	40.4	17.2	---	---	2.2	500
68-132	28.8	54.6	12.4	---	0.8	3.4	500
68-133	41.6	36.2	17.7	2.5	---	2.0	500
68-134	22.8	65.4	9.2	0.6	Tr.	2.0	500
68-135	29.8	31.9	31.5	4.0	Tr.	2.8	500
68-139	48.6	35.0	10.2	2.4	1.4	2.4	500
68-140	53.5	23.0	4.8	14.4	1.5	2.8	396
68-142	13.5	68.6	16.7	---	---	1.2	430
68-143	42.8	36.4	13.8	2.4	1.0	3.6	500
68-169	28.0	44.2	14.0	7.8	3.0	3.0	500
68-170	36.6	45.1	8.0	7.2	1.2	1.9	511
68-171	42.0	40.0	12.2	2.2	0.8	2.8	500
68-180	55.0	43.4	---	---	1.6	---	500
68-193	49.7	28.4	---	11.0	8.2	2.7	465
68-267	27.2	57.4	11.2	3.2	0.5	0.5	438
69-404	44.0	48.0	4.4	1.2	1.4	1.0	500
69-406	49.0	40.6	7.2	1.2	0.6	1.4	500
68-585	12.4	76.6	10.2	---	0.8	---	500
68-596	51.2	39.8	---	8.0	Tr.	1.0	600
68-597	43.0	52.6	---	2.0	1.0	1.4	500
68-598	34.6	53.0	6.2	2.2	2.4	1.6	500
68-600	36.1	52.1	6.7	1.7	1.7	1.7	405
68-637	33.2	55.6	5.6	3.6	0.6	1.4	500

no sulphides are present, for example on the steep west-facing slopes immediately northwest of the west end of Lost Horse Gulch.

Zones of intense veining and some brecciation accompanied by pink feldspar, scapolite, calcite, epidote, and sericite replacement of the rock are also found within map unit 11. This type of alteration is most common immediately north of the Red Butte fault and the

Ingerbelle adit portal. Several good exposures may be observed along the road which leads to the portal. The same alteration is also commonly found in the southern part of the large mass of Lost Horse rocks which lie north of the Gully fault. At all places such alteration is characteristic of zones of strong fracturing and some faulting.

Zones of breccia, generally with a high content of magnetite, are also found in map unit 11 and appear to be associated with the later stages of intrusion. Two types of breccia have been distinguished. The first type, magnetite-healed breccia, consists of angular and subangular fragments of monzonite and syenite in a matrix of coarse-grained magnetite. These breccias are found at Ingerbelle, on the Copper King mineral claim (Lot 403), and immediately to the north where they underlie a more or less circular area about 300 feet in diameter, and east of the Similkameen River on the Diamond Dot (Lot 3265) and June Bug (Lot 3029) mineral claims. Other smaller occurrences are found within map unit 11. The only mineralization found in this type of breccia appears to be magnetite and minor pyrite. Copper is essentially absent.

The second type of breccia occurs as a large body at the north end of Pit No. 2 on Copper Mountain. Exposures on pit walls and diamond-drill intersections indicate that the breccia forms a pipe-like body, semicircular in plan, some 400 feet in maximum width, and plunging steeply to the north. The breccia terminates to the south against the Pit fault. It is characterized by angular to rounded fragments of Lost Horse rocks, including grey and pink monzonite, latite porphyry, and light-coloured albitized rock, set in a fine-grained green to dark grey matrix rich in epidote and magnetite (Plate IX). Fragments range in size from a few millimetres to 50 centimetres, and may have well-developed light-coloured reaction rims. Rare fragments of breccia with magnetite veinlets occur as clasts in a magnetite-rich matrix. Magnetite content may vary from a few per cent to 30 or 40 per cent of the rock, the mineral occurring as disseminations in the matrix, well-developed coatings around rock fragments, and veins cutting both matrix and fragments. Pyrite and chalcopyrite occur as disseminated grains and small masses in or rimming rock fragments and in the matrix. Some textures of sulphide patches indicate possible brecciation after mineralization, but, in many other instances, the sulphides clearly replaced and rimmed rock fragments and replaced the matrix after formation of the breccia. The contacts of the breccia pipe with the surrounding rocks of map unit 11 are ill defined and appear to be mostly gradational with massive rocks similar in composition and appearance to those found in the fragments and in places veined by dykelets of pinkish latite porphyry. The above suggests that the body of breccia is part and probably a late phase of the Lost Horse intrusions which occurred along the edge of the larger intrusive mass to the north, in an area where internal pressure of volatiles and/or hydrothermal fluids exceeded the confining pressure, perhaps in an explosive fashion. The fact that magnetite and sulphide mineralization occurs both in fragments which were later enclosed in the breccia and as disseminations, veins, and patches later than the breccia suggests that the body of breccia was emplaced sometime while mineralization was in progress, and can thus be regarded as being intramineral in age.

UNIT 12: Rocks of map unit 12 include latite and trachyte in approximately equal amounts and are invariably porphyritic, commonly trachytoidal. Texturally they range from latite or trachyte porphyry to porphyritic micromonzonite or microsyenite. Plagioclase occurs typically as euhedral, strongly zoned crystals which may be 5 to 7 millimetres or more long and variably sericitized. Pyroxene is found in subhedral to euhedral crystals, commonly in clusters, and usually strongly corroded and altered to epidote, hornblende, biotite, and carbonate. Biotite is generally brown and also commonly occurs in well-formed books probably of primary origin. Potash feldspar is always interstitial to pyroxene and plagioclase. Apatite is a prominent accessory mineral commonly occurring in sparse anhedral grains as much as 2 to 3 millimetres in diameter and easily visible in hand specimen. Although generally less altered than rocks of map unit 11, the porphyries of map unit 12 may be considerably replaced by albite, pink feldspar, and, in places, scapolite. Similarly, in places, they may be barren and post-sulphide in age whereas in others they may carry appreciable sulphides even in ore-grade concentration. The above suggests that the dykes of map unit 12 must have been emplaced during a period of time which overlapped and probably outlasted the later stages of hydrothermal alteration and sulphide deposition. Thus the earlier dykes are generally more altered and in places mineralized, whereas the later ones are fresher and cut through altered and mineralized rock.

EXTERNAL STRUCTURAL RELATIONS: The contact of rocks of map unit 11 with Nicola rocks is nowhere sharply defined. It occurs generally in a zone of intense fracturing and alteration where volcanic rocks are laced with intrusive dykes and intrusive rocks crowded with large blocks of volcanic rocks. In effect, the contact is gradational and may occur over several scores or even hundreds of feet. The confused contact relationships are largely due to the fact that Lost Horse rocks appear to have been emplaced as a series of separate injections of material from a differentiating magma, probably the same one that produced the Copper Mountain, Smelter Lake, and Voigt stocks. The Nicola rocks were probably already highly fractured and faulted when invaded by the Lost Horse intrusions so that the resulting contact pattern was complex and digitated. Moreover, bodies of breccia found along the edges of larger intrusive masses suggest that in some places fluid pressures were high enough to locally exceed confining pressure, thus producing an environment favourable to repeated and sudden intrusive pulses which would produce irregular contacts with the country rocks. An additional factor contributing to the indistinct contact zoning is granitization or fenitization of the volcanic rocks adjacent to the digitated margin.

The contacts of Lost Horse rocks with other rocks of the Copper Mountain intrusions are also not clearly defined. Montgomery (1967, p. 25) states that "The Armstrong Bluffs complex intrudes the Smelter Lake and Voigt stock and the Nicola volcanics." He produces photographic evidence of an angular fragment of diorite in monzonite of the Armstrong Bluffs complex (1967, p. 57). He also considers the complex "to have formed by repeated tapping of a differentiating magma which was emplaced at intervals after crystallization of diorite in Voigt and Smelter Lake stocks" (1967, pp. 164-165). This writer did not see definite intrusive relationships of Lost Horse rocks with the Smelter Lake and Voigt stocks, but small inclusions of diorite, much like that of the three stocks, were observed at several localities in Lost Horse rocks, both in outcrop and in diamond-drill core from Copper Mountain. Moreover, on the slopes north of the west end of Smelter Lake a small dyke of pink trachyte porphyry, much like those of map unit 12, was found cutting through diorite of the Smelter Lake stock. This writer also agrees with Montgomery in considering Lost Horse rocks to be genetically related to and probably a late differentiate of the magma which produced the Copper Mountain, Smelter Lake, and

Voigt stocks. A further confirmation of this concept results from radiometric dating of rocks of map units 11 and 12 which are indistinguishable from those of the three stocks (Preto, *et al.*, 1971).

AGE AND CORRELATION OF THE COPPER MOUNTAIN INTRUSIONS: Field relationships define the age of the Copper Mountain intrusions only within wide limits. In the area mapped they are known to cut volcanic and sedimentary rocks of the Upper Triassic Nicola Group, and are cut by the Verde Creek granite (Dolmage, 1934, p. 17), which has been correlated by Rice (1947) with the Otter intrusions of Upper Cretaceous or Early Tertiary age. The Copper Mountain intrusions are also overlain unconformably by volcanic and sedimentary rocks of the Middle Eocene Princeton Group.

Preliminary potassium-argon age determinations on the monzonite phases of the Copper Mountain stock and on biotite from mineralized veins on Copper Mountain yield a mean age of 193±7 million years (Sinclair and White, 1968), which, according to Kulp's time scale, corresponds to the Upper Triassic (Kulp, 1961). Further samples collected by the writer for radiometric dating and analysed at the laboratories of the University of British Columbia Department of Geology by W. H. White and J. E. Harakal yield the ages presented in Table 3 (also Preto, *et al.*, 1971). From these it is evident that the radiometric ages of biotites from the Smelter Lake and Voigt stocks, from the Lost Horse intrusions, and from pegmatitic sulphide veins are indistinguishable and yield a mean age of 193.5±8 million years which is in very close agreement with the mean age obtained by Sinclair and White (1968) for biotite from the Copper Mountain stock. The radiometric ages of 101±4 and 98±4 million years obtained from the two samples of Verde Creek granite also suggest that this intrusion is of late Lower Cretaceous age, and that those dykes of map unit 14 which cut it and which are considered an eastward extension of the 'Mine dykes' are of post late Lower Cretaceous age and not 150 million years old as initially suggested by Sinclair and White (1968).

In summary it can be concluded that radiometrically the Copper Mountain intrusions are of roughly the same age as the Nicola rocks which they intrude. A somewhat similar situation is found at the Iron Mask batholith near Kamloops which is also a barely saturated quartz-poor and somewhat differentiated intrusive that cuts sedimentary and volcanic rocks of the Nicola Group. Biotite from a mineralized pegmatitic vein from that pluton, occurring in a shear zone on the Fargo mineral claim, yields an age of 176±8 million years (Wanless, *et al.*, 1968, p. 39) suggesting that the age of that batholith is Lower Jurassic. In view of the age, composition, textures, and structural setting of late intrusive phases such as the Lost Horse rocks at Copper Mountain and the Cherry Creek and Sugarloaf intrusions at Iron Mask (*Minister of Mines, B.C.*, Ann. Rept., 1967, pp. 137-141), it is the writer's opinion that these intrusions were emplaced in an epizonal subvolcanic environment and, though themselves cutting rocks of the Nicola assemblage, may have supplied magma for Nicola flows higher in the section. The porphyry dykes, bodies of breccia, and extensive alteration associated with these late intrusive phases also suggest a shallow, near-surface environment where confining pressure was in places repeatedly exceded by increasing volatile pressure during crystallization of the magma, giving rise to repeated, short-lived, magmatic pulses and creating an environment suitable for the formation of mineral deposits.

Table 3. Analytical data and isotopic ages of Lost Horse, Smelter Lake, Voigt, and Verde Creek intrusive rocks.

Sample No.	Rock Unit	Rock Type	Mineral	%K $\pm\sigma$	$\frac{A^{40}\text{ rad}}{A^{40}\text{ total}}$	A^{40} rad (10^{-5} cc STP/g)	$\frac{A^{40}\text{ rad}}{K^{40}}$	Apparent Age
VP-69KA- 1	Lost Horse	Latite porphyry	Biotite	6.88 ± .02	0.92	5.578	0.01198	194 ± 8
VP-69KA- 2	Smelter Lake	Diorite	Biotite	7.11 ± .03	0.89	5.830	0.01211	197 ± 8
VP-69KA- 3	Smelter Lake	Diorite	Biotite	*4.49 ± .01	0.87	3.758	0.01236	200 ± 8
VP-69KA- 4	Verde Creek	Quartz monzonite	Biotite	5.39 ± .02	0.84	2.210	0.006057	101 ± 4
VP-69KA- 5	Verde Creek	Quartz monzonite	Biotite	6.26 ± .01	0.82	2.499	0.005899	98 ± 4
VP-69KA- 6	Voigt	Diorite	Biotite	5.48 ± .01	0.85	4.112	0.01109	181 ± 7
VP-69KA- 7	Voigt	Diorite	Biotite	7.14 ± .02	0.91	5.788	0.01198	194 ± 7
VP-69KA- 8	Lost Horse	Micromonzonite porphyry	Biotite	*7.82 ± .04	0.88	6.340	0.01198	194 ± 8
VP-69KA- 9	Lost Horse dyke	Latite porphyry	Biotite	7.45 ± .04	0.86	6.111	0.01212	197 ± 8
VP-69KA-10	Lost Horse	Micromonzonite porphyry	Biotite	6.62 ± .02	0.87	5.390	0.01203	195 ± 8
VP-69KA-13		Biotite-sulphide pegmatite vein	Biotite	6.44 ± .04	0.84	5.071	0.01163	189 ± 8

Constants used in model age calculations:

$\lambda e = 0.585 \times 10^{-10}\ yr^{-1}$

$\lambda B = 4.72 \times 10^{-10}\ yr^{-1}$

$K^{40}/K = 1.181 \times 10^{-4}$

σ = standard deviation

*Done in triplicate only. All other potassium analyses done in quadruplicate.

VERDE CREEK QUARTZ MONZONITE (UNIT 13)

The northeast corner of the map-area is occupied by a body of quartz-bearing granitic rocks originally described by Dolmage as the Verde Creek granite (1934, p. 17). The portion within the map-area is the western extension of a much larger body which extends southeastward for more than 10 miles and occupies an area of approximately 45 square miles. Within the map-area the rock is best exposed along the steep walls and bluffs of two valleys which extend eastward from Verde Creek and Victor Lake and become deep and canyon-like in their eastern parts.

Although the rock has been described by both Dolmage (1934) and Rice (1947) as granite, within the map-area it is mostly quartz monzonite with approximately one-third to one-half of the total feldspar being potash feldspar. The rock is generally medium grained, grey to pinkish grey, and porphyritic. White subhedral to euhedral plagioclase phenocrysts 4 to 5 millimetres long occur in a matrix of plagioclase, evenly distributed grey quartz, and interstitial potash feldspar. The most common mafic mineral is brilliant brown biotite which generally forms 7 to 10 per cent of the rock and occurs as evenly distributed flakes 2 to 3 millimetres in diameter. Dark green to nearly black, brilliant hornblende is also commonly found in phases which usually contain less biotite. True granite is found locally and is generally pink and miarolitic.

In the south-central part of its outcrop area, the quartz monzonite encloses a northeasterly trending body of Nicola volcanic rocks more than 6,000 feet long and as much as 2,500 feet wide. This mass, probably a pendant, is composed mostly of massive, fine-grained, dark green, commonly trachytoidal plagioclase-pyroxene porphyritic andesite, characterized by white plagioclase laths 1 to 2 millimetres long that are normally preferentially oriented, and by subhedral dark green pyroxene grains, poorly defined in the dark background.

Because of the distribution and quality of exposures, the contact relationships of the intrusive rocks of map unit 13 are poorly known. The quartz monzonite clearly encloses the Nicola volcanics, but its contacts with diorite of the Voigt stock are everywhere masked by overburden. Dolmage (1934, p. 17) states that the Verde Creek granite cuts the Voigt stock, and Rice (1947, p. 50) states that the rock is "...unmistakably related to the Otter granite..." and assigns to it an 'Upper Cretaceous or later' age. The radiometric ages of 101±4 and 98±4 million years obtained from biotite of map unit 13 (Table 3) tend to confirm these relationships and strongly suggest that the intrusion is of late Lower Cretaceous age.

DYKES

'MINE DYKES' (UNIT 14): A characteristic feature of Copper Mountain is a swarm of northerly trending, very steeply to vertically dipping, buff to cream-coloured dykes of felsite, quartz porphyry, and feldspar porphyry, known as the 'Mine dykes' (Plate X). On Copper Mountain most are found east of the Tremblay fault, and they extend eastward to the end of the map-area. South of the Copper Mountain stock they are found only sparsely east of the Similkameen River. As shown on the map, the dykes appear to be most plentiful on Copper Mountain and in the western part of the Voigt stock, but this apparent concentration is believed to be largely due to the extensive trenching and drilling done in these areas. In the area mostly covered by overburden between Copper Mountain and Wolf Creek, for example, diamond drilling indicates the presence of probably as many of these dykes as are known to occur in the mine area. The 'Mine dykes' range from less than 1 foot to 200 feet or more wide, and on Copper Mountain have a peculiar habit of splitting and coalescing, enclosing large lens-shaped bodies of rock, in places mineralized, thus creating considerable dilution problems in areas that have been or will be mined.

In composition the dykes range from trachyte to rhyolite. They are very rich in potash feldspar, may contain considerable quartz as phenocrysts or in the ground mass, and lack or are deficient in ferromagnesian minerals.

The age of the 'Mine dykes' is known within fairly narrow limits. Fahrni (1962, p. 54) considers them related to the Otter intrusions. On Copper Mountain the dykes are clearly post-mineral in age. Elsewhere within the map-area they cut rocks as young as the Verde Creek quartz monzonite, for which a mean radiometric age of 99.5±4 million years is indicated (Table 3), and are cut, in turn, by andesite dykes that are believed to be related to the Middle Eocene Princeton volcanic rocks. No 'Mine dykes' have anywhere been found cutting through Princeton Group rocks within the map-area. It appears therefore that the dykes were emplaced sometime in Late Cretaceous or Early Tertiary time.

GREY ANDESITE AND ANDESITE PORPHYRY DYKES (UNIT 15): At several places on Copper Mountain and reportedly (Dolmage, 1934, p. 19) in the western part of the Voigt stock, dykes of fine-grained dark grey andesite a few feet wide, or larger ones of grey plagioclase, hornblende, or pyroxene andesite porphyry are found. Only the larger ones are shown on the map, but several smaller ones occur. Dolmage (1934, p. 19) reports that these dykes usually trend at right angles to the 'Mine dykes' which they cut. The writer actually found them trending anywhere from northerly to easterly, but certainly concurs with Dolmage in that they are younger than the 'Mine dykes.' Their origin is unknown, but their texture and composition suggest that they are related to the Tertiary rocks of the Princeton Group.

PRINCETON GROUP

The writer devoted only a limited amount of time to the study of Tertiary volcanic and sedimentary rocks in the map-area, and confined himself to outlining the boundaries of Tertiary rocks and to running widely spaced traverses within these areas. All Tertiary rocks encountered belong to the Princeton Group and occupy parts of two basins, the Princeton basin to the north and another basin to the southwest of Copper Mountain. As the Princeton Group has been studied in some detail by other workers (Shaw, 1951; Hills, 1962) this writer will limit himself to a brief description and general correlation of sedimentary, volcanic, and intrusive rocks as they were encountered in the course of mapping.

CONGLOMERATE AND SANDSTONE (UNIT 16): A north trending trough of coarse boulder conglomerate and minor sandstone has been outlined on Copper Mountain by closely spaced diamond drilling and some trenching. The trough is centred on the Tremblay fault, extends from the Copper Mountain fault northward for 2,500 feet to shortly beyond the Ada fault, and ranges from 300 to 600 feet wide. The conglomerate is less than 100 feet thick and contains rounded pebbles, cobbles, and boulders of altered and mineralized intrusive and volcanic rocks, but is not mineralized itself. The almost complete lack of exposure makes it difficult to know whether structures such as the Copper Mountain, Pit, Tremblay, and Ada faults cut or are unconformably overlain by the conglomerate. Its mode of occurrence in a long trough-like depression which closely follows the course of the Tremblay fault suggests that the conglomerate probably occupies an ancient stream course which followed the fault, but the sharp truncation of the trough against the Copper Mountain fault could indicate that it may have been affected by late movements along that fault.

The fact that boulders of altered and mineralized rocks occur as clasts in the conglomerate, which is in itself barren, suggests that it is probably correlative with similar rocks found in the Tertiary basins north and west of Copper Mountain.

Other small areas of coarse sandstone and boulder conglomerate are found south of Friday Creek, mostly in road cuts along Highway 3. The larger of these exposures are found in highway cuts between Saturday and Sunday Creeks, where the rock is a green pebble to coarse boulder conglomerate with thin interbeds of green sandstone.

LOWER VOLCANIC FORMATION (UNIT 17): East of the Boundary fault rocks of the Lower Volcanic Formation are found north and south of Smelter Lake. West of the Boundary fault they are found over a large area mostly south of Deep Gulch in the southwestern part of the map-area. Between Deep Gulch and Whipsaw Creek they form only small isolated exposures, but along Whipsaw Creek and the northern boundary of the map-area they are again abundant. Both extrusive and intrusive phases are present in the formation and can be briefly described as follows.

EXTRUSIVE ROCKS (UNIT 17a): The most common rock type in map unit 17a is a fine-grained oxyhornblende andesite porphyry. This rock is grey to brownish grey where fresh, but can be pink, brick red, or light green depending on the degree and type of oxidation and weathering. It is typified by a fine-grained, quartz-poor matrix with needles of basaltic hornblende, commonly preferentially oriented and up to 5 millimetres long. Where vuggy the andesite contains white amygdules generally filled with natrolite and analcite (Montgomery, 1967, p. 31). Associated with the andesite flows are subordinate amounts of tuff, lapilli tuff, and, in places, coarse volcanic breccia. The latter rock type is found mostly on the steep slopes to the south and north of Smelter Lake and along Whipsaw Creek approximately 1 mile upstream from the Highway 3 bridge. At both localities the breccias form impressive cliffs of red, purple, buff, and mauve-coloured coarsely fragmental rocks, variably well bedded, deeply weathered, and laced with seams of chalcedony and agate. Montgomery (1967, p. 29) suggested that the deep red weathering may be due to the proximity to a volcanic vent, a possibility which further field work has indeed confirmed.

INTRUSIVE ROCKS (UNITS 17b, 17c, AND 17d):

UNIT 17b: Two bodies of massive, commonly trachytoidal, hornblende andesite porphyry have been outlined by field mapping and are believed to represent volcanic vents. The larger of the two was outlined by T. N. Macauley of Newmont Mining Corporation of Canada Limited. It is centred 4,800 feet north of the west end of Lost Horse Gulch, immediately to the east of and above the abandoned railway grade. The body is crudely kidney shaped and is approximately 3,000 feet long and as much as 1,000 feet wide. It is composed entirely of grey hornblende andesite porphyry that is typically trachytoidal. It is surrounded to the north, east, and south by coarse, deeply weathered volcanic breccia with which it appears to have a vertical or very steep contact. The foliation in the rock, as produced by preferentially oriented hornblende and plagioclase phenocrysts, crudely follows the contact and dips very steeply outward. At one point, approximately 400 feet away from the contact, the porphyry was penetrated by a vertical diamond-drill hole for 500 feet with no change in the composition or texture of the rock being noticed in the core.

Another body of similar andesite porphyry, also believed to represent a volcanic neck, is found on Whipsaw Creek, 5,600 feet upstream from the Highway 3 bridge. The body is irregular, approximately 1,200 feet long, and not completely exposed, but is in part truncated by a fault. It can be traced from creek level to the top of a bluff 850 feet higher in elevation with no obvious change in lithology. Its northeastern contact with an impressive succession of moderately dipping, strongly coloured, coarse volcanic breccia is poorly exposed but appears to be steep.

UNIT 17c: A small area of massive, fine-grained, brownish weathering, very dark brownish black augite basalt porphyry is found astride Highway 3 approximately 6,000 feet north of Ingerbelle. The rock forms small, broken and deeply weathered, isolated outcrops immediately west of the Boundary fault, and is thought to be probably intrusive.

UNIT 17d: Sparse, isolated, generally small dykes of fine-grained, grey, flaggy andesite are found at several localities within the map-area. The largest of these dykes is found in the extreme southeastern corner of the map-area where it can be traced for approximately 1,500 feet. The texture, composition, and field relationships of these dykes strongly suggest that they are part of the Princeton Group.

ALLENBY FORMATION (UNIT 18): Rocks which have been correlated by Montgomery (1967) with the Allenby Formation are found on the high ridge north of Smelter Lake, and as steep bluffs along the Similkameen River, just beyond the northern boundary of the map-area. The outline of these bodies has been taken from Montgomery's work (1967), since his map extended farther to the north where more of these rocks are found. Though the Allenby Formation has been described as consisting mostly of sedimentary rocks (Hills, 1962, p. 22), the part found within the map-area is mostly buff-coloured fine-grained tuff and coarse volcanic breccia which north of Smelter Lake is of a deep rusty brown colour and contains blocks 18 inches in diameter.

EXTERNAL STRUCTURAL RELATIONS OF THE PRINCETON GROUP: Within the map-area dykes of map unit 17d intrude rocks as young as the Verde Creek quartz monzonite. Sedimentary and volcanic rocks overlie unconformably Nicola rocks and rocks of the Copper Mountain intrusions, and on Copper Mountain they contain boulders of these rocks which are altered and mineralized. No sulphide mineralization has anywhere been observed to have affected Princeton Group rocks. Rocks of the Lower Volcanic Formation have, however, been affected by northerly trending, steeply dipping normal faults, the largest of which is the Boundary fault. This structure, which crosses the entire map-area, has raised the eastern block south of Deep Gulch sufficiently in post-Princeton time to limit present-day occurrence of such rocks to the western block. Two other smaller, northerly trending faults, probably part of the same system as the Boundary fault, can be seen clearly cutting Princeton rocks along Whipsaw Creek approximately 3,500 and 6,000 feet upstream of Highway 3 bridge. These two faults essentially bound a block of Princeton rocks which has been downdropped and is flanked to the east and west by Nicola rocks.

AGE OF THE PRINCETON GROUP: Hills (1962) has dated the sedimentary rocks of the Allenby Formation by means of plant and insect fossils as Middle Eocene. The age of rocks of the Lower Volcanic Formation and of map unit 16 is not exactly known, but field relationships suggest that these rocks are younger than map unit 14 and older than the Allenby Formation.

3

STRUCTURAL GEOLOGY

The area in the vicinity of Copper Mountain is characterized by a type of brittle deformation which expressed itself in the development of a large number of faults and, locally, intense fracturing. Partly because of the nature of the rocks involved and partly because of the general lack of marker horizons, folds have been recognized only at widely separated localities. They appear to be poorly developed and to wane quickly up and down section. Nevertheless the two definite folds in Nicola rocks have closely aligned axes oriented about north 15 degrees to 25 degrees west indicating an early mild deformation unrelated to the emplacement of Copper Mountain intrusions.

FOLDS

FOLD NEAR SATURDAY CREEK: An anticlinal fold apparently of very local extent is outlined by a unit of pillow lava 1,200 feet north of the confluence of Saturday Creek with the Similkameen River. The fold has a very steeply plunging axis and is probably slightly overturned to the east. It is interpreted to be an anticline from the scant evidence of one single pillow with a convex top and cuspate underside which indicates that the west limb dips steeply and faces west.

KENNEDY LAKE SYNCLINE: Bedding plane attitudes in rocks of map units 3 and 4 indicate the existence of a large open syncline in the vicinity of Kennedy Lake. The fold plunges gently to the north-northeast and, at least in its northern part, is known to be complicated by a steeply dipping longitudinal fault which closely follows the axial trace. Wherever the sense of movement on this fault could be determined, it is apparent that the west block has moved downward relative to the east block. Though exposed only in the northern part of the Kennedy Lake syncline, the fault is inferred to continue for a considerable distance to the south, thus explaining the presence of the upper volcanic sequence of unit 4 only west of Kennedy Lake (p. 30).

POSSIBILITY OF FOLDS ON COPPER MOUNTAIN: Though the statement has been made by Fahrni (1966, p. 317) that "...at Copper Mountain the Nicola series is folded on north-south axes, the mine corresponding with an open anticline...," no clear evidence of such folding was observed by this writer. The lower and most continuous of the two

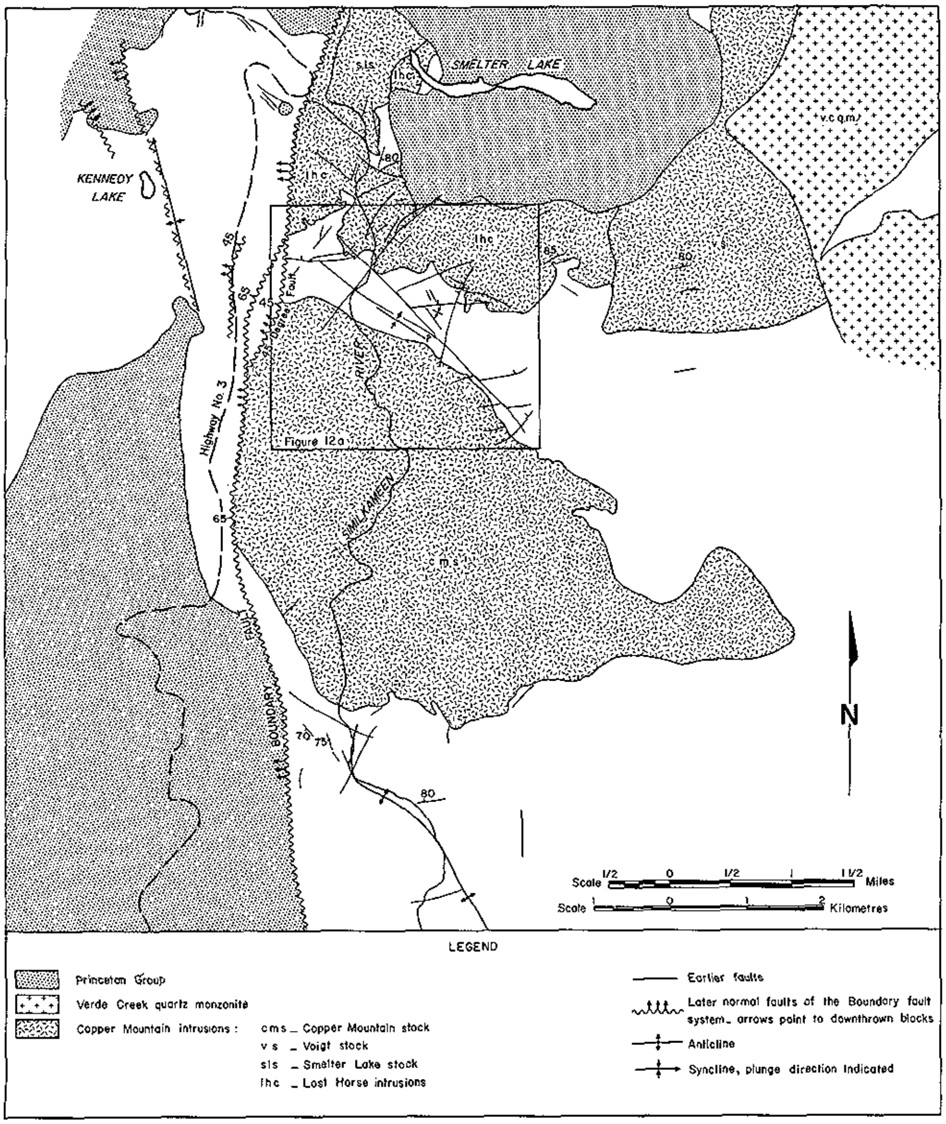

Figure 12. Distribution of major faults and folds in Copper Mountain map-area.

marker beds of volcanic siltstone and/or tuff that have been identified by drilling on Copper Mountain has a flat to gentle northeasterly dip south of Pit No. 2. This unit probably extends northeastward to crop out on the No. 18 zone. Between Pit No. 2 and the Copper Mountain stock the unit assumes a southwesterly dip and in some places within the mine area it appears to dip fairly steeply inward toward the stock. This relationship, however, is by no means constant as very flat dips can also be observed at several places close to the stock contact. In fact the very abrupt changes in attitude of bedded rocks in the general vicinity of Pit No. 7 are believed to be due to block faulting rather than to folding. Similarly the steep northeasterly dips observed in the fault bound block of unit 2d that parallels the stock contact from just northwest of Pit No. 7 to the Similkameen River could represent either a tilted fault panel, or the northeastern limb of a northwesterly trending antiform, the southwestern half of which was obliterated by the Copper Mountain stock.

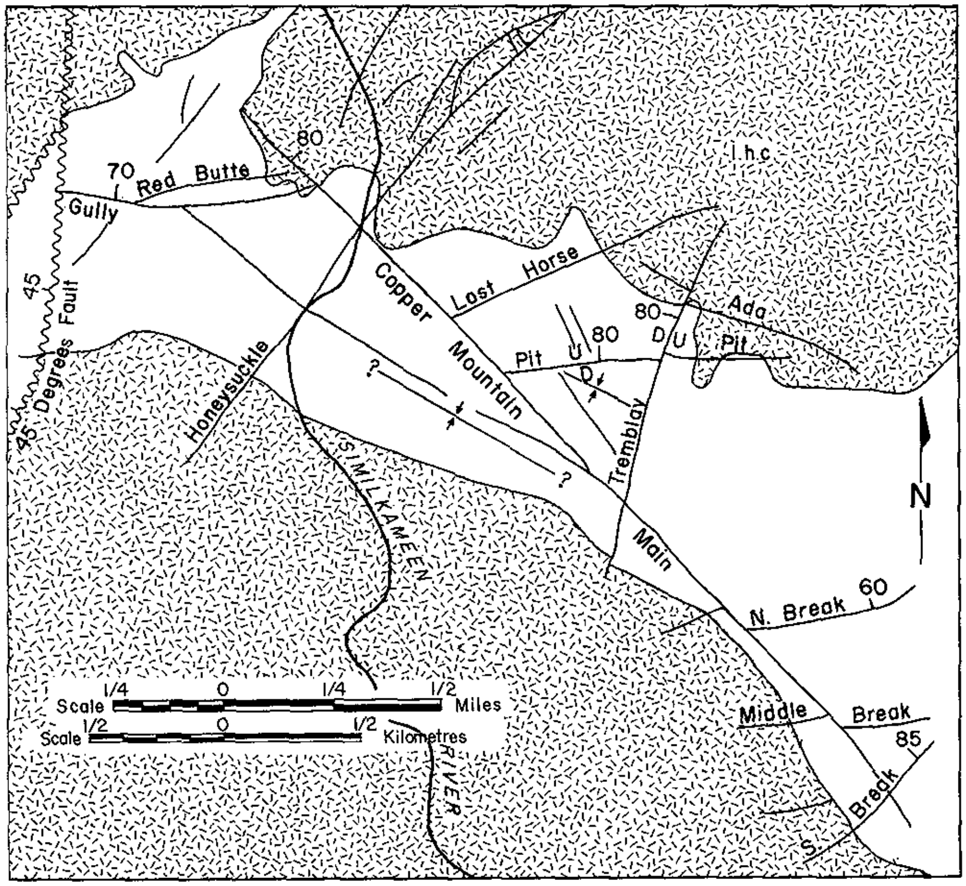

Figure 13. Detail of major faults and folds in Copper Mountain map-area (*see* Figure 12).

FAULTS

More faults are known to occur on Copper Mountain and at Ingerbelle than in the rest of the map-area (Fig. 12). This may be partly due to the greater amount of information available for this segment, but is undoubtedly also due to the fact that the narrow belt of Nicola rocks which is here caught between the Copper Mountain stock and the Lost Horse intrusions has suffered more intense deformation than the rest of the map-area. Outside of the Copper Mountain-Ingerbelle area, with the exception of the Boundary fault, few and relatively minor faults have been mapped. Though most still remain unsolved, faults can be classified into several groups, and in some cases relative ages of movement can be established. Referring chiefly to the Copper Mountain-Ingerbelle area, faults can be subdivided as follows: East-west faults, the 'Mine breaks,' northwest faults, northeast faults, and Boundary fault.

EAST-WEST FAULTS: These structures appear to be relatively old, and to have originated in pre-mineralization time. Later dilation in Tertiary time is, however, indicated, as some of the faults are followed by Tertiary dykes, for example, the Gully and Pit faults. The following structures are included in this group.

GULLY AND RED BUTTE FAULTS: The Gully fault is the larger of these two and an important structure at Ingerbelle as it runs through the middle of the ore zone. It trends almost exactly east-west and dips north at 70 degrees. This structure has been traced from the Boundary fault eastward for some 3,600 feet to the Main fault. As seen underground in the 3050 exploration adit, the Gully fault forms a zone of heavy clay alteration and gouge as much as 75 feet wide. The Red Butte fault is a northern strand of the Gully fault which underground is also prominent for its zone of clay alteration and gouge. Like the Gully fault, the Red Butte fault appears to end against the Main fault. The movement on the Gully fault is not clearly known. North of it no trace has been found of the bedded volcanic siltstone and/or tuff which is an excellent marker horizon in the southern part of the Ingerbelle property. This might indicate that the northern block has moved upward, thus allowing the marker bed to be removed by erosion. However, the possibility of a downward movement of several hundred feet is suggested for the northern block if one tries to match mineralized zones across the fault. Like similar structures to the east, the Gully and Red Butte faults are considered to have been active at a relatively early stage in the history of the Ingerbelle deposit. Though barren, they could have acted as channelways for mineralizing solutions, as they are centrally located in the orebodies. Late post-mineral movement however must have occurred as indicated by crushed and broken sulphide veinlets that are found in the altered zone along the faults, and by the Tertiary feldspar porphyry dyke which follows the Gully fault for a short distance south of the 3050 adit portal.

PIT FAULT: The Pit fault is a major structure on Copper Mountain, and in nearly all respects is a direct counterpart of the Gully fault. It trends slightly north of east and dips to the north at 80 degrees. It has been traced from the Main fault eastward for 3,400 feet to the northeast corner of Pit No. 2 where it becomes lost in a group of late dykes of map unit 14. Drill holes indicate that the Tremblay fault cuts the Pit fault and displaces it left laterally by some 100 feet. Both these faults are probably overlain unconformably by the conglomerate of map unit 16, but for the sake of clarity their locations under this unit as indicated by drilling are shown on the map. The Pit No. 2 ore zone is elongated in an east-west direction, the Pit fault running longitudinally through it. West of the Tremblay fault a narrow zone of mineralization follows the Pit fault for several hundred feet thus indicating that the fault was probably active before and during the period of mineralization, and may have acted as a channelway for ore-bearing solutions. In the western portion of the Pit fault drill holes indicate a reverse movement (north side up) of 100 to 250 feet, based on offsets of marker beds. Though the fault appears to be sharply truncated to the east by dykes of map unit 14, some dilation must have occurred in Tertiary time to allow emplacement of a small Tertiary dyke. The similarities between the Pit and Gully faults in attitude, age, and relationship to mineralized areas are perhaps more than coincidental. It is possible that these two faults are parts of the same structure that has been offset by the Main fault. If this were the case, then a right lateral horizontal component of movement of approximately 3,000 feet is indicated for the Main fault.

ADA FAULT: The Ada fault lies roughly along the north side of the Pit No. 2 ore zone. It trends slightly south of east and has been traced by drilling for more than 2,000 feet eastward from the Tremblay fault. It consists of a zone of crushing and alteration as much as 100 feet wide, the movement along which is not known. Several dykes of map unit 14 cross the Ada fault with no apparent displacement. Because of its close parallelism with the Pit fault it is assumed that the Ada fault is also a relatively old structure.

THE 'MINE BREAKS': A system of faults which trend slightly north of east to northeast with northerly dips of roughly 60 degrees has been known for many years in the old Copper Mountain mine area. The three largest of these have been referred to as the North, Middle, and South breaks. They have been reported to carry several feet of gouge locally, and to show right lateral displacement upon crossing the Main fault. Though unmineralized themselves they have been considered to be ore controls by the mine staff. These are probably relatively old structures as suggested by their relation to mineralization. Though of slightly different attitude, they could belong to the same set as the east-west faults.

NORTHWEST TRENDING FAULTS: The main Copper Mountain fault system is the most important structure of this group and has been known and mapped for many years by those who have worked in the area. Throughout its known length of more than 12,000 feet it trends northwest and dips vertically. At some places in the mine area the fault approaches within 150 feet of the stock contact but never cuts the intrusive. In the vicinity of Pit No. 1 the Main fault splits into two branches. The southern of these swings slightly to the westward and appears to weaken considerably and eventually to merge with the Gully fault at Ingerbelle. The northern branch continues on a straight northwesterly course and appears to truncate the Gully and Red Butte faults west of the Similkameen River. To the southeast the fault disappears in a swarm of 'Mine dykes' (unit 14). In the Copper Mountain mine area the development of a marked schistosity and of biotite alteration is reported to have developed in the volcanic rocks over widths of more than 50 feet on either side of the fault (Fahrni, 1951, p. 208). In the same area the fault itself is reported to change rapidly from a 3 to 4-foot gouge zone to a 20-foot zone of chloritic alteration or "... to a 60-foot zone of narrow, branching gouge seams..." (Fahrni, 1951, p. 208). The history of the Main fault system has been said to have been long and complex (Fahrni, 1951), and rightly so. The structure closely parallels the long axis of the Copper Mountain stock and the trend of major regional faults in the Princeton area. Fahrni has stated that roughly "...one half of the known orebodies in the mine are grouped along the Main fault or its branches..." (1951, p. 205). The conglomerate of map unit 16 closely follows the trace of the Tremblay fault, but ends abruptly against the Main fault, giving the impression that it has either been truncated by late movements on this fault which, if they did occur, must have downdropped the northeastern block, or terminated against a sharp fault scarp that may have existed at the time of deposition of the conglomerate, also indicating a relative downdropping of the northeastern block. Other smaller, northwesterly trending faults are found west of the Similkameen River and in other parts of the map-area. These structures might be related in origin to the Main fault system, but nothing more can be said on the kind and age of movement along them.

NORTHEAST TRENDING FAULTS: At least two definite and one possible major structure, as well as a number of smaller ones, are included in this group. As in the case of the northwest and east-west trending faults, the history of these faults has probably been relatively long and complex.

TREMBLAY FAULT: The Tremblay fault strikes 20 degrees east of north and dips steeply to the west. It can be traced from the Copper Mountain stock contact in the vicinity of Pit No. 1 northward for more than 4,100 feet. The fault is not exposed over most of its length, but has been intersected by a sufficiently large number of closely spaced drill holes to narrowly define its course. It consists of a fault zone up to 50 feet wide across which the western block has moved down about 200 feet relative to the eastern block. A right lateral offset of approximately 100 feet is indicated where the fault crosses the stock contact, but a left lateral offset of roughly the same magnitude is indicated where it crosses the Pit fault. No offset is indicated where the Tremblay fault crosses the Main fault. Considering that the Pit fault dips to the north, the stock contact dips steeply southwest, and the Main fault is vertical, the observed offsets are in agreement with a normal displacement on the Tremblay fault. Some movement on the Tremblay fault is thus considered to have post-dated intrusion of the Copper Mountain stock and establishment of the Pit and Main faults. It is not known whether the conglomerate of map unit 16, which follows the Tremblay fault for most of its length, was affected by any late movement on this structure. None of any great amount is indicated. Appreciable post-mineral movement is however indicated as the fault offsets the base of the Pit No. 1 mineralized zone and cuts across the west end of the Pit No. 2 zone.

LOST HORSE FAULT: This structure is inferred to follow the western part of Lost Horse Gulch. It has not been observed on the surface and evidence for it from drill holes is sparse and fragmentary.

HONEYSUCKLE BREAK: This structure is partly known and partly inferred to exist in the area between the Fraser and Oronoco claims. The southwestern half of the Honeysuckle break is not exposed, but shearing and faulting along the rest of its course can be observed on the Honeysuckle, Oronoco, and contiguous claims. Immediately north of the stock contact along the Similkameen River the projection of the Honeysuckle structure marks the northwestern limit of the sequence of steeply dipping bedded rocks of unit 2d. On the steep slopes west of the river dips in other types of bedded rocks are flat or gentle to the north. Because of the apparent lack of offset of the stock contact by the Honeysuckle break, it is inferred that the truncation of unit 2d must have preceded emplacement of the stock. On the Oronoco claim however, Tertiary volcanic rocks of unit 17a are in fault contact with rocks of unit 11, indicating that at least this portion of the structure was active in post-Middle Eocene time.

THE BOUNDARY FAULT SYSTEM: The Boundary fault system consists of a major structure, termed the Boundary fault, and several other similar but smaller faults that are found in the western part of the map-area. The Boundary fault trends northerly and has been traced from south of Sunday Creek to the Similkameen River at the northern edge of the map-area. Although the fault has never been observed exposed in outcrop, its course has been outlined with a fair degree of accuracy, and its location in several places has been defined within a few feet. At and directly west of Ingerbelle, the fault system consists of the main Boundary fault, a fault lying east of it and termed the '45 Degrees fault,' and an unnamed fault to the west. Proceeding from east to west the structural and lithologic changes across the Boundary fault system at Ingerbelle may be described as follows.

The *'45 Degrees fault'* trends northerly and dips 45 degrees to the west. It is interpreted as merging with the main Boundary fault to the north, south, and down dip. Where best known in areas of closely spaced drilling this fault is marked by a zone of mylonitization, intense shearing, and alteration as much as 100 feet thick. The upper plate consists of a sequence of broken and sheared andesites, siltstones, and argillites which are strongly altered to chlorite and clay minerals, but contain none of the pink feldspar and scapolite alteration, sulphide mineralization, or altered Lost Horse intrusive rocks which are so characteristic of the volcanic rocks below the fault. In the southern part of the upper fault panel, however, a small monzonite dyke poorly exposed in two trenches has been tentatively correlated on poor lithologic evidence with unit 12, and might be an exception to the conditions stated above. In general, however, the sequence of rocks above the '45 Degrees fault' resembles much more closely in type and alteration, rocks of units 3 and 4 than rocks of unit 2.

The *Boundary fault* at Ingerbelle brings calcareous argillite, siltstone, and conglomerate of unit 3, some pillowed andesite of unit 4b, and some Tertiary rocks in contact with rocks of the upper panel of the '45 Degrees fault.' Though never exposed, the Boundary fault is here marked by a well-pronounced linear and in areas of better outcrop can be located fairly closely. It is interpreted to dip westerly at some 65 degrees. A short distance south of Deep Gulch and immediately east of Highway 3, the projection of this fault is known from drilling to dip westerly at some 45 to 60 degrees, and to truncate mineralized diorite of the Copper Mountain stock, bringing sheared and chloritized pillowed andesite, argillite, and siltstone of the upper panel in contact with the intrusive rocks.

An *unnamed fault* located a short distance to the west of the Boundary fault and inferred to merge into it to the north and south brings massive and coarsely fragmental volcanic rocks of unit 4 to the west in contact with the sedimentary rocks of unit 3. This fault is exposed on the north side of the gully that runs westward from Ingerbelle, and here it dips westerly at 45 degrees.

All three of the above faults are known or are inferred to dip to the west, and are interpreted to be normal faults, so that their respective upper plates have moved downward in step fashion. Suggestions have been made by Montgomery (1967, p. 21) that the Boundary fault is a reverse fault, and that the sedimentary rocks west of Ingerbelle could be correlated with part of the Henry Formation (Bostock, 1940) and were thrust upward from the west. For the following reasons, however, it is this writer's opinion that the movement on the Boundary fault is normal, and that the western block was dropped down and thus represents a volcano-sedimentary sequence higher in the Nicola succession than unit 2.

(1) In the region between Saturday Creek and the southern edge of the map-area and beyond, the Boundary fault marks the eastern boundary of Tertiary volcanic and sedimentary rocks which to the west form a considerable and continuous succession to the top of Friday Mountain. No Tertiary rocks, other than a few small dykes of grey andesite, are found east of the fault in this area.

(2) Along Whipsaw Creek, directly north of Kennedy Lake, a northerly trending, nearly vertical fault is exposed which brings sedimentary rocks of unit 3 to the east in contact with volcanic rocks of unit 17a to the west. Approximately 2,400 feet upstream on the same creek, another fault, which here trends almost northwest and dips steeply east, brings altered volcanic rocks of unit 4e to the west in contact with buff hornblende porphyry of unit 17b to the east. These two faults are considered to outline a small graben of Tertiary volcanic rocks, and to be part of the same system and generation of faults as the Boundary fault.

(3) An attempted correlation, on purely lithologic grounds, of rocks of unit 3 with part of the Henry Formation several miles to the east is, in this writer's opinion,

unjustified at this stage. As shown by the limited amount of mapping done during this project, many volcanic rocks are found interbedded with sedimentary rocks west of the Boundary fault. This succession, in all its intricacies, merely represents changes in the intensity of volcanism in what was most likely a very changeable and unstable part of the crust over which the Nicola rocks were deposited during the Upper Triassic. Knowledge of Nicola rocks and structure is still so limited that correlation of somewhat similar looking rocks over a distance of 22 miles is probably unwarranted.

FRACTURING

Fracturing of Nicola rocks within the map-area varies from moderate to intense, and is strongest in the Copper Mountain-Ingerbelle segment. In the area of the old Copper Mountain mine, in the general vicinity of the stock contact, a prominent set of parallel, northeasterly trending, steeply dipping fractures, called the 'Ore Fracture System' (Fahrni, 1951), has been known for many years to have played an important role in the localization of orebodies. Much of the bornite in the old stopes occurred in these fractures and in pegmatite veins filling them, so that the presence and frequency of these fractures and veins was the governing factor of the size and grade of orebodies. An excellent example of such fracturing and associated mineralization can be seen along the walls of Pit No. 3 and in the area of subsidence overlying the old mine stopes near the stock contact.

Farther away from the Copper Mountain stock, such as in the area of Pit No. 2, the direction of fracturing varies more widely. Several large, fairly continuous fractures with prominent sulphide and calcite-potash feldspar-biotite pegmatite veins trend northeasterly and dip moderately to steeply to the northwest, but a large number of other fractures

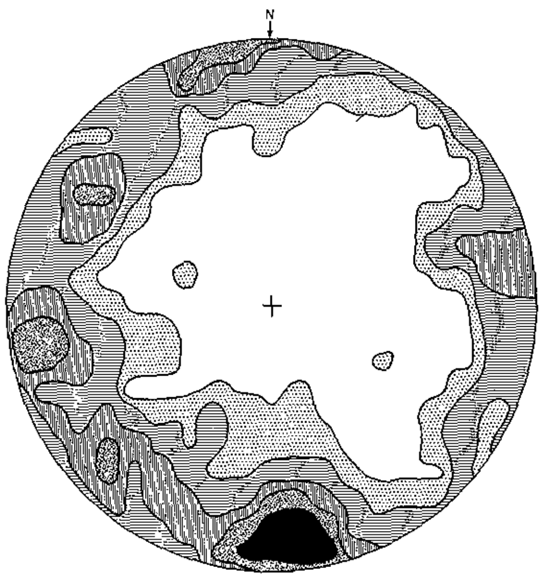

Figure 14. Ingerbelle 3050 adit. Lower hemisphere equal area plot of poles to mineralized and barren fractures.

with and without sulphides and pegmatite strike at random azimuths and generally dip steeply. Throughout the Copper Mountain area, and for a considerable distance to the east and southeast a prominent set of northerly trending near vertical dilation fractures is occupied by the late dykes of map unit 14.

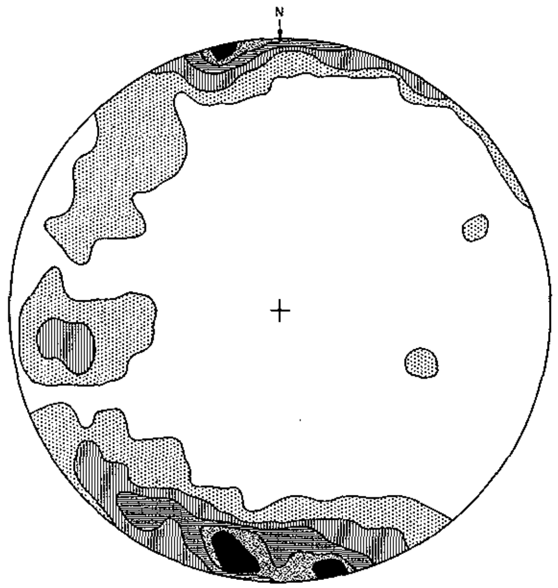

Figure 15. Ingerbelle 3050 adit. Lower hemisphere equal area plot of poles to mineralized fractures.

At Ingerbelle fracturing is strong to intense. A cursory glance at the geological map (Fig. 2) or at the most prominent rock exposures might suggest that the main fracture sets dip steeply and trend northeast and northwest, since zones of intense scapolite alteration and most dykes of map unit 12 follow these directions. A closer examination of unweathered exposures, drill core, and underground workings over a large area, however, indicates that fractures dip steeply but strike nearly at random. A detailed study of fractures in the 3050 level exploration adit at Ingerbelle was done by T. Takeda on behalf of the Similkameen Mining Company Limited for a pit slope stability study. He subdivided the fractures as follows: (1) sulphide veinlets, (2) chlorite-coated fractures, (3) calcite-filled fractures, (4) fractures and faults with argillic alteration and clay gouge, and (5) fault breccias and pebble dykes. Figure 14 is a synoptic plot of the poles to all types of fractures measured by Takeda over the whole underground workings. It shows that most fractures dip steeply or very steeply and strike nearly at random, with a modest concentration of fractures that strike approximately east-west and dip steeply to the north. This concentration is probably in part due to the fact that a major portion of the adit is close to and nearly parallel with the east-west trending Gully and Red Butte faults, thereby introducing a bias in the sampling due to the large number of fractures that parallel these faults. Figure 15 is a plot of poles to mineralized fractures only, as measured by Takeda in the same sample area. This plot indicates an appreciable concentration of steeply dipping fractures trending approximately east-west, but, like Figure 14, is probably biased in the sample area.

In summary, the narrow belt of Nicola rocks that in the Copper Mountain-Ingerbelle area is caught between the Copper Mountain stock and the Lost Horse intrusions is a zone of intense fracturing. With the exception of certain areas, such as in the vicinity of the Copper Mountain stock contact in the old mine workings or close to major faults, where the fractures have a very prominent preferred orientation, fractures tend to dip steeply and to have a near random orientation.

SUMMARY

In summary it appears that in the area mapped most of the faults and fractures are concentrated in the vicinity of Copper Mountain and Ingerbelle. An early set of east-west oriented faults was followed and probably displaced by two other sets oriented northwesterly and northeasterly. All these structures, especially those of the east-west and northwest sets, are most likely deep seated and probably acted as channelways for mineralizing solutions. If this is the case, then these faults are intimately related in their origin to the evolution of the Nicola rocks and of the Copper Mountain intrusions in this area and represent the response of a heterogeneous volcanic pile to the system of stresses set up by the emplacement of the intrusive bodies. Though such sets of faults were established, fracturing in the volcanic rocks at an early stage was probably close to a random crackling, at least in the Ingerbelle area (Figs. 14 and 15). Slightly later, however, and perhaps because of a doming effect produced by rising magma on an already constricted belt of volcanic rocks, fractures oriented in a northeasterly and northwesterly direction must have reopened and were occupied by dykes of map unit 12, while others remained sealed by various alteration products (Fig. 2). All these events are interpreted as having taken place toward the end of the Triassic.

At a much later date, probably in Late Cretaceous or Early Tertiary time, a system of northerly trending normal faults and open fractures was established in the area. To this stage belong the Boundary fault system and the fractures occupied by the 'Mine dykes.' These structures are related to a much larger system of gravity faulting and open fracturing that affected most of southern British Columbia at this time (Carr, 1962).

4

MINERAL DEPOSITS

GENERAL DISCUSSION

Dolmage (1934) subdivided the copper deposits of Copper Mountain area on the basis of mineral composition, genesis, and geographic position into three main types which, in order of decreasing economic importance at that time, were:

(1) *Bornite Deposits* – These concentrations occur mostly in altered rocks close to the Copper Mountain stock and are characterized by a high bornite to chalcopyrite ratio, near absence of pyrite, and small amounts of magnetite. Associated gangue minerals are orthoclase, albite, augite, biotite, epidote, and zoisite (Dolmage, 1934, p. 21).

(2) *Chalcopyrite-hematite Deposits* – These deposits, much smaller and less important than the bornite deposits, are found within the Voigt stock. They consist of coarse-grained hematite with lesser amounts of pyrite, chalcopyrite, and magnetite in a gangue of calcite, orthoclase, and some quartz. The main deposits of this type, located on the Automatic Fraction, Frisco, and No. 14 claims are confined to an east-west trending shear zone within the Voigt stock.

(3) *Chalcopyrite-pyrite Deposits* – These deposits which were rated by Dolmage as being those of least economic importance were originally reported to be widely distributed and large, but of very low grade. They were said by Dolmage to consist of large amounts of pyrite with some chalcopyrite, to occur in altered Nicola volcanic and Lost Horse intrusive rocks, and to be spatially associated with the latter.

Though Dolmage's original subdivision is still generally valid, the order of economic importance of the types of deposits has changed, and more has been learned about their geology. Thus those metal concentrations which at present are of interest are subdivided and will be discussed as follows:

GROUP A — Disseminations and stockworks mostly of chalcopyrite and pyrite in altered Nicola volcanic and/or Lost Horse intrusive rocks.

GROUP B — Hematite-chalcopyrite and magnetite-chalcopyrite replacements in rocks of the Voigt stock.

GROUP C — Bornite-chalcopyrite concentrations associated with pegmatite veins in rocks of the Copper Mountain stock.

GROUP D — Magnetite breccias and replacements in Lost Horse intrusive rocks.

DESCRIPTION OF PROPERTIES

GROUP A — DISSEMINATIONS AND STOCKWORKS MOSTLY OF CHALCOPYRITE AND PYRITE IN ALTERED NICOLA VOLCANIC AND/OR LOST HORSE INTRUSIVE ROCKS: This broad group of deposits is by several orders of magnitude the most important in the Copper Mountain area. It includes the deposits of Copper Mountain and Ingerbelle that are at present being prepared for production, as well as the ores mined at the old Copper Mountain mine. Mineable reserves as estimated at present for the Ingerbelle and Copper Mountain orebodies are 76 million tons containing 0.53 per cent copper, having a gross value roughly of 400 million dollars. To this must be added more than 321 million dollars for the gross value of metals produced at the Copper Mountain mine.

In addition to the deposits of Copper Mountain and Ingerbelle, other concentrations of copper, such as those found on the Duke of York, No. 18, and Red Buck claims and in their vicinity and in the vicinity of Saturday Creek, are included in this group because of common broad characteristics in the type of sulphide mineralization, wallrock alteration, and their origin.

If the term 'porphyry type' deposit were to be taken loosely, as done recently, to mean "large, low-grade, epigenetic, hypogene copper deposits that can be mined by mass-mining methods" (Titley and Hicks, 1966, p. ix) it could be applied to most of the deposits in this group. If a somewhat more rigid definition of a porphyry deposit were adapted, such as that used by Lowell and Guilbert (1970, p. 374), then some serious reservations to the applicability of this term to this group of deposits are necessary, and the term perhaps should not be used at this time.

The Copper Mountain deposits have recently been specifically classified as complex porphyry deposits of the syenite clan, and those of Ingerbelle, as skarn deposits gradational to porphyry deposits (Sutherland Brown, *et al.*, 1971, pp. 124-125). Other workers (Macauley, 1971) place more emphasis on the extensive metasomatism, evidence of pneumatolitic activity, and the formation and redistribution of magnetite associated with the Copper Mountain and Ingerbelle deposits, and consider them pyrometasomatic.

All deposits in this group are spatially and, it is believed, genetically associated with late phases of the Copper Mountain intrusions, by far the most productive of which are those of the Lost Horse suite. The sulphide deposits, be they in volcanic or in intrusive rocks, are associated with zones of extensive and locally intense wallrock alteration which include development of biotite, albite, epidote, pyroxene, actinolite, potash feldspar, and scapolite. Secondary garnet, sphene, and apatite are also found in very small amounts in some of the deposits. Quartz is scarce in all these deposits and was observed only rarely in minor amounts in some thin sections.

COPPER MOUNTAIN (A-1)

OWNER: Similkameen Mining Company Limited.

DESCRIPTION: Following their purchase of the Granby holdings in 1967, the Newmont Mining Corporation of Canada Limited continued and expanded the drilling and trenching programme initiated in 1966 by The Granby Mining Company Limited, and carried it to completion in 1969.

The programme was successful in outlining two areas of copper mineralization of economic grade which are centred on Pit No. 1 and Pit No. 2 (Fig. 2). These two zones are roughly rectangular in plan, with the longer dimension oriented in an east-west direction. Their approximate maximum plan dimensions, respectively, are 2,300 by 900 feet and 3,200 by 1,000 feet. Pit No. 2 zone has the more irregular outline. A third zone of mineralization, some 3,800 feet long and as much as 1,100 feet wide, is known to occur in the area of subsidence between Pit No. 5 and the contact of the Copper Mountain stock to the southwest. This zone, though extensive, is still inadequately known as to its exact shape and grade, and is at present considered only as a possible orebody. The boundaries of the Pit No. 1 and Pit No. 2 zones, as crudely outlined on Figure 2, are arbitrary vertical assay boundaries and merely encompass volumes of mineralized ground which are mostly of economic grade. Copper mineralization extends far beyond these boundaries and is in fact widespread on Copper Mountain, but, at present, nowhere else in the camp is it known to occur in sufficient amount and grade to be economic.

The geology of Copper Mountain can be briefly summarized as follows. A zone of volcanic rocks of the Nicola Group extends in a northwesterly direction from Wolf Creek to the Similkameen River and beyond, and is confined to the southwest by the Copper Mountain stock and to the north by part of the Lost Horse intrusions. Both volcanic and intrusive rocks are cut by a swarm of northerly trending felsitic dykes, known as the 'Mine dykes.' These dykes appear to be more numerous in the immediate vicinity of the Copper Mountain mine. This, however, is largely an erroneous impression, because the ground near the mine workings has been explored in much greater detail than elsewhere, and the dykes do not have a prominent surface expression. In fact, dykes identical in composition and trend to the 'Mine dykes' have been found several miles east and southeast of Copper Mountain, but not for any appreciable distance to the west of it. Sedimentary and volcanic rocks of the Princeton Group overlie unconformably all the intrusive and volcanic rocks mentioned above. On Copper Mountain, a narrow trough of boulder conglomerate, less than 100 feet thick, follows the course of the Tremblay fault from the Copper Mountain fault northward to the Ada fault. The conglomerate contains boulders of altered and mineralized intrusive and volcanic rocks, but is itself not mineralized. This rock unit is very poorly exposed, and although it is almost certainly not cut by the Tremblay, Pit, and Ada faults, these important structures are shown on Figure 2 as crossing it, solely for purposes of clarity. The conglomerate appears to stop against the Copper Mountain fault, suggesting some late movement along this structure. Similarly, volcanic rocks of the Princeton Group are cut by the northeast trending Honeysuckle break on the No. 15 fractional claim (Lot 1598).

Although most of the Nicola volcanic rocks on Copper Mountain are structureless massive flows and breccias, at least two units of generally well-bedded tuff and/or volcanic siltstone exist and, through drilling and underground development work, their extent is sufficiently known to outline the structure of the volcanic succession. The two marker beds, designated as unit 2 on Figure 5, are approximately 100 and 300 feet thick, are separated by some 300 to 400 feet of massive and fragmental volcanics, and resemble very closely unit 3 of Ingerbelle (Fig. 6). They indicate that most of Copper Mountain is underlain by gently to moderately dipping strata in their original upright position. Exceptions to this rule are found in at least two places: (1) On the Triangle fractional claim a small fault-bounded area of generally massive rocks contains a thin, well-bedded marker unit which shows that the strata are here nearly vertical, trend northwestward, and face northeast (Fig. 2). These rocks are considered to be part of a tilted fault block shown on Figure 2. (2) In the area bounded by the Copper Mountain fault, the contact of the Copper Mountain stock, the northerly trending dyke of map unit 12 (Fig. 2) and the Honeysuckle break, a sequence of thinly laminated schistose metasiltstone, tuff, and volcanic breccia strikes parallel to the intrusive contact and dips steeply to the northeast. These rocks have a well-marked mineral lineation which plunges gently to the east-southeast, and is made easily recognizable by the widespread presence of an appreciable amount of metamorphic biotite. Secondary clinopyroxene becomes a major metamorphic mineral very close to the intrusive contacts, and the rock is slightly less schistose. The schistosity, however, is here paralleled by a light grey to nearly white alteration banding which continues to the southeast beyond the dyke of unit 12, truncating the bedding where it dips gently to the northeast. West of this dyke, the schistosity parallels the general compositional layering of the rocks. It appears that the dyke probably follows an older northerly trending fault, and thus the area west of it is probably bounded on three sides by faults and on the fourth side by the Copper Mountain stock. The rocks in this area are thus either part of a tilted fault block or are the limb of a faulted northwesterly trending fold which pre-dated the emplacement of the Copper Mountain stock.

As shown on Figure 2, a great number of faults cut intrusive and volcanic rocks on Copper Mountain. Of these, the largest ones have been given a name, and show the general pattern of fracturing. Innumerable other smaller faults, shears, and fractures exist especially in the central part of the area. Northwesterly trending structures such as the Copper Mountain fault and fractures parallel to it, or northeasterly trending faults and fractures such as the 'Mine breaks' and the ore fractures, have been known and referred to for a long time (Fahrni, 1951). Recent work has brought into focus the existence and importance of more northerly trending faults such as the Tremblay fault, which is almost entirely concealed by the Tertiary conglomerate, and of easterly trending faults such as the Pit and Ada faults, which have similarly trending structures (Gully and Red Butte faults) as their counterpart at Ingerbelle, west of the Similkameen River. It would appear that easterly tending faults, such as the Ada and Pit faults and the 'Mine breaks' are at least in part older than northerly and northwesterly trending structures as they are either cut by them or stop against them.

It is believed that all faults mentioned above and, to a lesser extent, subsidiary structures parallel to them originated before the main period of mineralization and played an important part as ore controls, probably acting as avenues along which much of the ore-bearing solutions moved. This is suggested by the prominence of the long-known northeasterly trending 'ore fractures' in some parts of the camp, by the fact that all of the major faults run through or along the edges of orebodies (Fig. 2) at least for a good part of their course, and by the fact that structures such as the Pit and Copper Mountain faults have definite 'tails' of copper mineralization, albeit not economical, leading out along them from known orebodies. Most of the best known mineralization on Copper Mountain occurs where all the above-mentioned faults are strongest, best developed, and intersect one another.

Another factor that is believed to have played an important role in the localization of copper mineralization at Copper Mountain is rocks of the Lost Horse intrusions. This complex of intrusive rocks, all quartz poor, medium to rather fine grained and porphyritic, includes phases that range in composition from diorite to syenite, and show a great variation in amount of alteration. Lost Horse type rocks are known to occur from Wolf Creek west to the Boundary fault at Ingerbelle. The complexity of rock types and alteration, and the lack of adequate exposures are such that only two main subdivisions can be made in the Lost Horse intrusions. One group, encompassing the larger amount of rocks, includes all those, altered or not, which do not form obvious dykes. The other group, consisting mostly of biotite latite porphyry and biotite-pyroxene microsyenite porphyry, includes rocks which are generally fresh and which cut older Lost Horse rocks as well-defined dykes up to 100 feet wide. Copper mineralization may occur in both groups, but is found to be best and most common in the older rocks. All Lost Horse rocks, whether fresh or extensively albitized, mineralized, or barren, have as a distinguishing characteristic the presence of disseminated, distinct phenocrysts of apatite which may be seen either with the naked eye or by using a good pocket magnifier.

For the following reasons it is suggested that rocks of the Lost Horse intrusions played a more direct role in the localization of copper mineralization than rocks of the Copper Mountain stock.

1. Lost Horse type rocks both at Copper Mountain and at Ingerbelle occur within or very close to orebodies and at several places form ore.
2. Orebodies such as the one at Pit No. 2 crudely follow the contact between Lost Horse and Nicola rocks and include rocks of both units. At the north end of Pit No. 2 a body of intrusive breccia, roughly circular in plan and apparently forming a pipe-like body which plunges steeply to the north, contains as fragments exclusively Lost Horse rocks, and has chalcopyrite-pyrite-magnetite mineralization both in the matrix and in some of the fragments.
3. At Ingerbelle a crude zoning of rock alteration and mineralization extends southward from the large mass of Lost Horse rocks lying north of the Gully fault. A poorly mineralized zone of intense pink feldspar, albite, and scapolite alteration separates the intrusive rocks from the orebody. Within the deposit, chalcopyrite is predominant in its northern part whereas pyrite is more abundant in the southern part and along the east, south, and west borders. Southeast of the orebody a considerable amount of pyrrhotite with minor pyrite and chalcopyrite is also found in dark, moderately altered volcanic rocks. Between the orebody and the Copper Mountain stock several hundred feet to the south, the volcanic rocks are considerably less altered and contain no appreciable amounts of sulphides.

4. Although Nicola rocks, rock alteration, and faults somewhat similar to those present at Copper Mountain and Ingerbelle are found at other places along the periphery of the Copper Mountain stock, Lost Horse rocks are not present nor is copper mineralization of comparable extent and intensity to that of the Copper Mountain-Ingerbelle area.

At Copper Mountain, a characteristic which is not well understood is the changing ratio of bornite, chalcopyrite, and pyrite away from the Copper Mountain stock. Bornite is confined almost entirely to the immediate vicinity of the stock contact, mostly in zones where the northeast trending ore fractures are prominent. Bornite ore also contains an appreciable amount of chalcopyrite, but is deficient or lacking in pyrite. Generally less than 200 feet away from the stock contact the amount of bornite decreases drastically, and the ore changes to the chalcopyrite-pyrite type. Thus, in the Pit No. 1 zone itself, bornite is confined to the southwestern part of the orebody, the bulk of which is made up of chalcopyrite-pyrite ore. A simple explanation for this distribution of sulphides would be that the ore-forming fluids came from the Copper Mountain stock and that the zoning merely represents a decreasing copper gradient away from the source. For the many other reasons that have been set forth in this report, however, this writer does not believe that the immediate source of the copper is the Copper Mountain stock. Insufficient quantitative information is available at this time on the distribution of copper and of sulphides at Copper Mountain to embark on a discussion of mineral zoning. A complex interrelation of temperature gradients, as well as of compositional gradients for the major ingredients required in the formation of sulphides, must have existed and interacted in a unique manner at the time of ore deposition. Although the Copper Mountain stock was probably not the immediate source of hydrothermal fluids at that time, 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 Lost Horse rocks along deep-seated faults.

The following is a brief description of the three mineralized zones that are presently known to be of economic significance on Copper Mountain. Some of the information presented here was the result of the writer's study, but much is from company reports (Macauley, 1970, private report).

(1) Pit No. 1 Zone

The Pit No. 1 zone is centred on Pit No. 1 but extends eastward for approximately 1,300 feet and westward for approximately 1,000 feet to Pit No. 7. Elevations of surface mineralization range from 4,100 feet on the east to 3,500 feet on the west. The maximum width of the zone is approximately 1,000 feet at the west end, but this includes a 500-foot wide irregular mass of waste rock surrounded by ore-grade material. The eastern part of the zone, where mineralization is more continuous, is as much as 900 feet wide. Drilling indicates that most ore-grade material, especially in the east end of the deposit, lies above the lower bedded tuff unit (Fig. 5). This crude stratigraphic control is lacking at the west end of the ore zone, closer to the Copper Mountain stock contact, where mineralization is much more obviously associated with steeply dipping fractures. Here the sulphides are typically bornite and chalcopyrite coating fractures, with pyrite nearly absent. Bornite disappears very rapidly a short distance away from the stock contact, and pyrite becomes more prominent. Thus the central, northern, and eastern parts of the deposit consist of chalcopyrite fracture fillings and disseminations.

The most common host rocks in the Pit No. 1 zone are massive and coarsely fragmental volcanic rocks. Recognizable pre-ore porphyritic intrusive rocks are scarce. Albitization, either as light grey veins or as disseminations, and development of epidote are the most common types of rock alteration. Remnants of an earlier development of biotite, subsequently replaced by albite and epidote, can be recognized in places. Within a few feet of the stock contact a very narrow zone of pyroxene hornfels is commonly present. The development of pink potash feldspar alteration is absent in the Pit No. 1 zone, and biotite-sulphide pegmatite veins, which are common elsewhere on Copper Mountain, are rare and generally small.

(2) Pit No. 2 Zone

The Pit No. 2 ore zone is centred on Pit No. 2 and extends for roughly 3,200 feet in an east-west direction and for as much as 1,000 feet in a north-south direction. Both altered Nicola volcanic rocks and intrusive rocks of the Lost Horse suite are hosts to sulphide mineralization in this zone. The southern boundary of the deposit is in Nicola rocks and trends fairly regularly north 80 degrees west. It cannot readily be related to any known structure. The northern boundary is of irregular outline, lies for the most part in Lost Horse rocks, and is in part marked by the Ada fault. The eastern end of the deposit is very irregular and not too well known. To the west the zone ends a short distance west of the Tremblay fault where it fingers out rapidly into a series of narrow zones of mineralization, some of which follow faults in the area, particularly the Pit fault. Drilling indicates that sulphide mineralization extends to depths of more than 1,000 feet, but at present it is only mineable to roughly half that depth. There are also indications that the south boundary of the ore zone and the contact between Nicola and Lost Horse rocks might dip steeply to the north. Most of the mineralization in this deposit consists of fracture fillings of pyrite and chalcopyrite. Bornite is rare. The ratio of pyrite to chalcopyrite and the grade of the ore may vary drastically and abruptly over a short distance. Though most mineralized fractures that can be seen along the walls of Pit No. 2 and nearby are only a fraction of an inch thick, occasional veins of nearly massive chalcopyrite as much as 4 or 5 feet thick have been found. A similar distribution of sulphides over the rest of the mineralized zone is indicated by drill intersections.

Wallrock alteration of volcanic rocks in the Pit No. 2 zone is characterized by a pale green bleaching of the volcanic and intrusive rocks. At several places remnants of an original fragmental texture and of a pervasive biotite alteration can be seen in the volcanic rocks (Plate XI). These features are generally partially or totally obliterated by the pale green alteration, which involves development of epidote and albitic plagioclase and removal of biotite and disseminated magnetite in the rock. In areas where the albite-epidote alteration is only moderate, it can be seen clearly in hand specimens how the development of these minerals originated along fractures and, as it became more intense, gradually spread outward from these fractures, eventually to permeate the whole rock (Plate XII). Where this has occurred, the rock is massive and uniform looking and has a texture that makes it very difficult to distinguish from the altered pyroxene microdiorite or micromonzonite of the Lost

Horse suite. The development of pink potash feldspar, generally along fractures, is a later stage of alteration that can be seen in Pit No. 2. It is usually accompanied by pegmatite veins consisting of potash feldspar, biotite, calcite, chalcopyrite, and bornite.

The contact of the volcanic rocks with the Lost Horse rocks to the north at Pit No. 2 is confused and complicated by faults and late dykes. Most Lost Horse rocks are altered to a pale green to pinkish green albite-epidote hornfels and can be difficult to identify. The breccia pipe that is found at the entrance to the present pit is bounded to the south by the Pit fault, and appears to have gradational contacts with Lost Horse rocks on all other sides. Within the pipe the matrix of the breccia may be moderately to very strongly altered to propylite and, accordingly, ranges from moderately hard to soft and crumbly. Magnetite is a conspicuous mineral in the breccia pipe, and may occur disseminated in the matrix, as veinlets in fragments which were truncated by brecciation, or as later veins which cut both matrix and fragments. Pyrite and chalcopyrite are commonly found as coatings around rock fragments or as rounded patches which may have resulted from selective replacement of certain clasts. Bornite appears to be absent.

Although the grade of mineralization in the Pit No. 2 zone varies considerably and does not appear to relate in any obvious way to the proximity of the contact of volcanic and Lost Horse rocks, it is believed that an important ore control for this deposit is its proximity to the Lost Horse complex of intrusive rocks in a place where late phases such as the breccia pipe are found. The presence of major faults such as the Pit, Ada, and Tremblay faults, and of fracturing related to them, has undoubtedly also played an important role in the formation of this deposit.

(3) Subsidence Area Zone

This zone comprises that portion of ground overlying the underground workings at Copper Mountain which caved and subsided because of the collapse of old open stopes and ground removal (Plate XIII). For a description of the geology and mineralization in this area the reader is referred to better informed accounts (Fahrni, 1951; Dolmage, 1934). The zone of mineralization exposed at present is approximately 3,800 feet long and as much as 1,100 feet wide. It follows closely the contact of the Copper Mountain stock but lies almost entirely in volcanic rocks. Orebodies within this zone lie either along the intrusive contact or along major faults such as the Main fault or the 'Mine breaks.' Fracturing of the volcanic rocks in this area is strong and of paramount importance in determining the tenor of the ore. Other ore controls have been described by Fahrni (1951). The main ore mineral is bornite.

An extensive chip sampling and diamond, rotary, and percussion drilling programme recently carried out by Similkameen Mining Company Limited has indicated that a considerable portion of the zone contains ore or near ore-grade material. Though an accurate estimate of the amount and distribution of ore-grade material has not yet been made due to the difficult nature of the ground, the subsidence area zone remains as an important potential open-pit operation.

REFERENCES: Dolmage, 1934, pp. 50, 51; Fahrni, 1951; Rice, 1947, pp. 82-87; *Minister of Mines, B.C.*, Ann. Repts., 1967, pp. 178-180; 1968, p. 206; *B.C. Dept. of Mines & Pet. Res.*, G.E.M., 1969, pp. 283-287.

INGERBELLE (A-2) (18)

OWNER: Similkameen Mining Company Limited.

DESCRIPTION: *Copper mineralization at Ingerbelle is found in a crudely L-shaped area* which straddles the Gully fault and has arms oriented northeast and northwest (Figs. 2 and 4). Within this area three zones have been distinguished: The southwest, north, and southeast zones respectively (Fig. 2). Of these the north and southeast zones merge into *one another across the Gully fault. The southwest zone is separate, and lies south of this* fault. Though most boundaries of the zones have been arbitrarily chosen as marking a decreased amount of ore-grade material, the following is worthy of note.

(1) The west wall of the southwest zone is marked by the '45 Degrees fault.' *Mineralization is truncated by this fault and is found only below it.*

(2) The southern wall of the southwest zone appears to dip steeply to the north, whereas the other two walls are nearly vertical. Most of the ore in this zone appears to be concentrated below the bedded tuff unit (unit 3, Fig. 6).

(3) The north zone is the largest of the three and has a nearly vertical, abrupt northwest wall. It has been traced to a depth of more than 1,000 feet below surface and has the bulk of the known ore concentrated in its lower 350 feet.

(4) The southwest zone trends south 70 degrees east and appears to consist essentially of two steeply dipping lenses 100 to 250 feet wide. These lenses can be traced from the Gully fault southeastward for some 1,000 feet, where they are lost on the steep cliffs on and near the Magnetic mineral claim (Plate XIV).

The block of generally strongly altered Nicola volcanic rocks within which all of the economic copper mineralization at Ingerbelle is found is bounded to the north by the Lost Horse intrusions, to the west by faults of the Boundary system, to the south by the Copper Mountain stock, and to the east by the steeply dipping and northeasterly trending Honeysuckle break. The Gully fault cuts this block of rocks in two markedly different parts. The northern part consists almost entirely of intensely altered volcanic and intrusive rocks within which only a few lenses of fine-grained bedded material are recognizable and indicate gentle northeasterly dips. To the south of the Gully fault the volcanic rocks consist of a pile of brownish to greenish massive and fragmental andesite at *least 800 feet thick and cut by a host of dykes and sills of fine to medium-grained* monzonite and syenite that belong to the Lost Horse intrusions. On Figure 6 the volcanic rocks are designated as unit 2 and are characterized in their upper part by an excellent marker horizon of delicately laminated metasiltstone and/or tuff which is designated as unit 3 (Plate III). *In sections 14,660 N and 13,800 E this horizon ranges from 70 to 100* feet thick; it has been intersected by virtually every hole drilled south of the Gully fault and west of the old Highway 3. The thickness of the unit is greatest to the southwest and decreases gradually to the northeast. The locus of the unit in each drill hole and the bedding angles in the cores indicate that the layer dips gently to the northeast. Thinly laminated tuffaceous layers and/or lenses found at several other places within the andesitic rocks above and below the main marker bed also indicate the same general attitude. The deepest drill holes of sections 14,660 N and 13,800 E indicate that some 600 feet below unit 3 the fragmental andesite of unit 2 changes rather sharply into massive finely porphyritic dark brownish grey andesite.

Gentle northeasterly dips of the Nicola rocks at Ingerbelle are found within a very short distance of the Copper Mountain stock contact immediately east of the old Highway 3. To the east of the Honeysuckle break, however, the lithology changes abruptly and the strata trend northwesterly and dip vertically or steeply to the northeast for a distance of more than 1,200 feet away from the intrusive contact. This may mean either that there has been considerable lateral movement along the Honeysuckle break or that the Nicola rocks were folded along northwesterly trending axes and then faulted in a northeasterly direction prior to the intrusion of the stock. The second alternative is presently favoured because of other indications of pre-intrusion folding of Nicola rocks to the south, in the vicinity of Saturday Creek.

Alteration at Ingerbelle involved pervasive development of biotite, followed by albite, epidote, and chlorite, which were, in turn, followed by the development of pink feldspar and scapolite in that order and mostly along fractures. 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. Such rock is very resistant to weathering and forms prominent ridges and cliffs on the steep slopes overlooking the Similkameen River. Sulphide mineralization favours the intervening, less altered, somewhat softer, greenish grey albite-epidote hornfels which has only a modest amount of pink and scapolite veining.

The major difference between rock alteration at Ingerbelle and Copper Mountain is the presence of extensive veining by pink feldspar, which includes both sodic plagioclase and potash feldspar, and by scapolite. Ingerbelle ore consists typically of fine disseminations and delicate fracture fillings of pyrite and chalcopyrite. Bornite is very rare. Molybdenite is also very rare and is virtually confined to one occurrence in the north crosscut of the 3050 exploration level. The grade of the ore in all the three zones can change drastically and abruptly for no apparent reason and with little change in the outward appearance of the rock. This characteristic will require careful selective mining in some places. At Ingerbelle alteration and sulphide mineralization do not appear to be spatially directly related to the Copper Mountain stock. They are more widespread and best developed near major faults, such as the Gully, Red Butte, and Main faults, and in that portion of ground between the Gully fault and the Lost Horse intrusions to the north. The 900-foot wide zone of volcanic rocks that lies between the Ingerbelle orebodies and the Copper Mountain stock has some of the least altered and most barren rocks in the area.

REFERENCES: *Minister of Mines, B.C.*, Ann. Repts., 1966, pp. 177, 178; 1967, pp. 181, 182; 1968, pp. 208-212.

RED BUCK (A-3) (4)

OWNER: Similkameen Mining Company Limited.

DESCRIPTION: The Red Buck zone is found in an area underlain by a complex and confused mixture of altered volcanic and Lost Horse intrusive rocks. Pale green alteration and pink feldspar veining of the same type as that found at Ingerbelle are very intense in the volcanic and some of the intrusive rocks. Mineralization is irregular and spotty and consists of locally coarse disseminations and veinlets of pyrite and chalcopyrite. Recently, drilling by the Similkameen Mining Company Limited has indicated widespread alteration and erratic mineralization in the general vicinity of the old Red Buck adits, but no material of current economic interest.

The following is part of the description of the geology of the Red Buck area as given by Dolmage (1934, p. 36):

> "....At this point the side of the valley is very steep, the western boundary of the Red Buck claim being 500 feet higher than the eastern boundary which is only 100 feet above the river. The deposits occur in latite and andesite of the Wolf Creek formation where it is extensively impregnated with pegmatite and intruded by irregular masses of Lost Horse intrusives. The pegmatite consists of orthoclase, albite, and quartz, thus closely resembling that on the Duke of York. The pegmatite veins generally trend in a northwesterly direction following the general strike of the Wolf Creek formation. The ore-bodies are very irregular in form and indistinct as to limits, but tend roughly to follow the strike of the pegmatite. The ore consists of irregular disseminations of chalcopyrite and pyrite with much feldspar and other pegmatitic material distributed through andesite and latite over a large section of the Red Buck and adjoining claims. The deposits have not been sufficiently exposed and their limits are too indefinite to enable them to be accurately delineated.
>
> "The development work consists of two tunnels and several drill holes. The lower, which is also the longer, of the two tunnels is on the northern boundary of the Red Buck claim adjacent to the Mogul fraction. It extends in a direction a few degrees south of west for 100 feet exposing ore for 90 feet. The first 50 feet exposes ore averaging 3 per cent copper and the first 25 feet of ore averages 4.02 per cent copper."

To the above description M. S. Hedley adds the following (*Minister of Mines, B.C.*, Ann. Rept., 1937, pp. D24-D26):

> "To this [Dolmage's description] the writer can add nothing, except that during his examination he found many intergrading rock-types of the varieties named, in a complex area of intrusion. He failed to see, on the ground, any systematic arrangement of intrusion or mineralization, and little to account for the localization of mineralization.
>
> "The property, principally the *Red Buck* claim, has been known for many years, having been staked prior to 1895. Most of the early development-work was done by 1900 and some time not long after the ground was drilled by B.C. Copper Corporation. In 1910 a shipment of 40 tons of sorted ore returned: Gold, 0.14 oz. per ton; silver, 1.5 oz. per ton; copper, 6.63 per cent.; and in 1915 a 30-ton shipment returned: Gold, 0.08 oz. per ton; silver, 0.9 oz. per ton; copper, 6.63 per cent. The *Red Buck* was optioned by Fred Foster and associates in 1928, and later Red Buck Mines, Limited, was formed. The two lowest adits and the raise were driven by hand-work by this company.
>
> "There are a number of old open-cuts, chiefly about No. 3 adit, but as none of these is deep, some are filled in, and all are badly oxidized, nothing much can be learned from them beyond the presence of copper-stain and some unoxidized chalcopyrite.

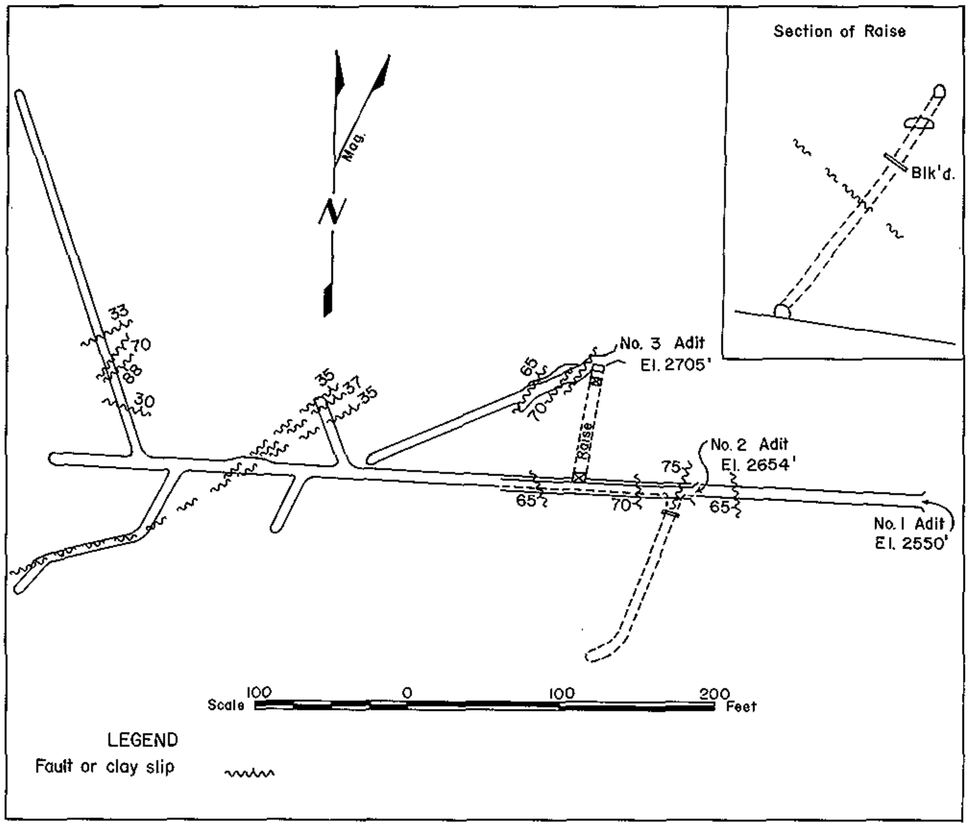

Figure 16. Red Buck. Plan of principal workings after company surveys. [After *Minister of Mines, B.C.*, Ann. Rept., 1937, p. D25.]

"An old adit, elevation 2,695 feet, is some 400 feet south of No. 3, across slide-rock in bluffs. This is driven south 15 degrees west for 30 feet, then south 50 degrees west for 43 feet to the face in dark-grey volcanic rock. This rock has been minutely shattered, along some of the individual planes of which has been introduced pink feldspar, from paper-thin films to several inches in width. There has been (hydrothermal) alteration also on some planes, producing a light bleaching in an irregular and coalescent pattern, from paper-thin films to patches several inches across. This altered material is mineralized with chalcopyrite and pyrite as scattered grains and short, tiny films. The feldspar films and masses and the alteration appear to be related; most, but not all, of the mineralization is related to the alteration, and scattered grains of chalcopyrite can be seen in most rocks in this vicinity. Some 100 feet north and north-west of the portal is greenstone.

"About the portal of No. 3 adit are copper-showings in monzonitic rocks over an area 50 feet each way, and also for 100 feet north-west of the adit. There does not seem to be any regular or continuous body, but rather discontinuous patches of mineralization, and the total amount of copper present, while not large, is impossible to estimate. No. 3 adit is 180 feet long, 23 feet below which is a sub-level 40 feet long driven from a winze, in monzonitic rock cut by pegmatite.

Mineralization, consisting of chalcopyrite and some pyrite, is almost entirely restricted to the outermost 100 feet of the adit, and in this section is locally heavy, particularly in the outermost 30 feet. Oxidation partly obscures the geology, and it is not possible to form an opinion of the shape, attitude, or controlling factors of the deposit. Both in the adit and in the sub-level strong mineralization is locally, but only locally, limited by shear- or joint-planes striking north-east and dipping 60 degrees north-westerly; in one or two places mineralization is bounded by a plane striking north-west. Beyond this fact the relations are obscure. A raise from No. 1 level, the upper part of which is now inaccessible, is said to have encountered no significant mineralization until a relatively few feet below the No. 3 adit sub-level.

"No. 2 adit, elevation 2,654 feet, was driven west 130 feet at the time of the writer's visit, early in August. The rock is pale-greenish diorite which, in the inner 20 feet, is locally altered in light-coloured, siliceous seams and patches and is lightly mineralized with chalcopyrite and pyrite. A large fault-plane crosses the adit diagonally about 80 feet from the portal. Two sets of steep joint-planes, probably unrelated to the mineralization, strike north 30 degrees west and north 30 degrees east. Mineralization is restricted to the innermost 20 feet of the adit, and is erratic, discontinuous, and not heavy.

"No. 1 adit, elevation 2,550 feet, consists of a section driven west for 560 feet, from which are two branches to the north and three to the south. One drift, 155 feet from the portal, follows a major fault to the south, but is bulkheaded off, as shown on the accompanying map. The outer 110 feet of the adit is in greenstone, then to 350 feet is in grey diorite, and then to 425 feet is in greenstone, cut by red pegmatite and locally crushed. The inner section of the adit, past the major fault-zone, is in monzonitic and dioritic rock, and some pegmatite. From about 255 to 300 feet from the portal is a section fairly well mineralized with pyrite and a little chalcopyrite; a chipped sample on the north wall, across 5 feet horizontal, at the east end of this section assayed: Gold, trace; silver, trace; copper, *nil*; and another sample over a 4½-foot interval at the centre of this section assayed: Gold, 0.01 oz. per ton; silver, trace; copper, 0.2 per cent. The raise, which connects with No. 3 level above, is accessible only to a bulkhead 120 feet above the adit, which is at a fault-zone. A fault-zone 90 feet above the adit is evidently the same as that cut and then drifted on in the inner section of No. 1, and the same as that cut in No. 2. Some pyrite mineralization is seen beneath the bulkhead, and worth-while copper mineralization is reported to have been encountered by the raise a few feet below the sub-level beneath No. 3 adit.

"Nos. 1 and 2 adits do not add materially to the knowledge of mineralization on the property. They do show the presence of faults of perhaps major importance. Until more work is done it is impossible to estimate the value of the copper body in No. 3 adit, regarding which size, attitude, and continuity are matters for conjecture, and concerning which it can only be said that high assays in copper are obtainable.

"The company during the summer made arrangements with the Canadian Pacific Railway for a 600-foot spur on the railway opposite camp, and were engaged in putting in a 112-horse-power Diesel engine, a 550-cubic-foot compressor, and drill-sharpener, etc. From a 100-ton bin at No. 1 adit-portal a Riblett Airline tram of 750 tons daily capacity was constructed to a 350-ton bin at the switch, a distance of approximately 1,300 feet, with a vertical rise of 375 feet; the tram to be electrically driven with Diesel-generated power. At the time of the writer's visit, early in August, No. 2 adit was being driven by hand-work."

REFERENCES: *Minister of Mines, B.C.*, Ann. Repts., 1927, p. 253; 1928, p. 265; 1936, p. D58; 1937, pp. D24-D26; 1938, p. D37; 1939, p. 89; Rice, 1947, p. 89; Dolmage, 1934, p. 36.

DUKE OF YORK, NO. 15, ORONOCO, HONEYSUCKLE (A-4) (5, 6, 40, 19)

OWNER: Cumont Mines Limited.

DESCRIPTION: The geology in the area of these claims is shown on Figure 17. The most common rock type is a complex of porphyritic, medium-grained rocks of the Lost Horse intrusions which originally probably ranged in composition from diorite to syenite. Pink potash feldspar alteration of these rocks, both along veins and pervasive, is common and in many places very strong, making it difficult to determine the original composition of the rock. It appears that most rocks are of monzonitic to syenitic composition. Other than the general, widespread, moderate to strong potash feldspar alteration, two other zones of alteration may be distinguished. In the central part of the area is a zone at least 1,500 feet long and 800 feet wide where the rocks have been totally or almost totally replaced by potash feldspar to produce a deep pink to brick red, fine to medium-grained rock devoid of mafic minerals in which only the outlines of the original plagioclase phenocrysts can be seen. The south-central and southeastern part of the area is underlain by Lost Horse rocks which have undergone an intense albite-epidote alteration. The altered rocks are here pale green to light grey or nearly white and devoid of magnetite. The original plagioclase and pyroxene have been reduced to irregular, ragged patches of albitic plagioclase, sericite and epidote, and chlorite and epidote respectively. Altered andesitic volcanic rocks of the Nicola Group are found as inclusions in the Lost Horse rocks. Massive and fragmental andesite found along the abandoned railway grade in the northern part of the area is part of a larger zone of volcanic rocks which lies to the north. A northeast trending zone of altered and mineralized tuff and andesite found on the Honeysuckle claim is bounded by two parallel faults.

Intrusive, extrusive, and sedimentary rocks of the Princeton Group are found in the northeastern part of the area. Worthy of note is a volcanic neck or plug of massive hornblende andesite porphyry. This body forms a vertical grey cliff on the Blue Bird mineral claim. It is roughly kidney-shaped in plan and has vertical contacts with the surrounding succession of gently dipping volcanic rocks. The extrusive Princeton Group rocks in the area consist of a sequence of grey andesite and/or basalt and reddish, coarse volcanic breccia. On the Blue Bird claim Lost Horse rocks are unconformably overlain by a thin flow of Tertiary andesite or basalt which is in turn overlain by coarse breccia. In the southern part of the No. 15 claim, Tertiary volcanic rocks are in fault contact with altered Lost Horse intrusive rocks along the Honeysuckle break. Faulting in the Duke of York area is moderate to strong, and mostly oriented in a northeasterly and northwesterly direction. Mineralization consists exclusively of pyrite-chalcopyrite fracture fillings and some disseminations and is found both in altered Nicola and Lost Horse rocks preferably in zones of stronger northeast faulting. Notable are the Honeysuckle and Oronoco zones where a considerable amount of mineralization is found along the Honeysuckle break and subsidiary faults in altered volcanic and intrusive rocks. On the

Duke of York claim, copper mineralization is in Lost Horse rocks which are strongly to totally replaced by potash feldspar. Though a considerable amount of mineralization is found in the area of Figure 17, and an appreciable amount of work including tunnelling, diamond drilling, and trenching has been done in both recent and past times, no mineralization of current economic interest has yet been outlined.

REFERENCE: Dolmage, 1934, pp. 35-37.

NO. 18, NO. 18 FRACTION, VIRGINIA, ALABAMA, JUNE BUG (A-5) (13, 8, 41, 7)

OWNER: Cumont Mines Limited.

DESCRIPTION: The geology in the area of these claims is shown on Figure 18. The most common rock types in the central and northern part of the area belong to the Lost Horse intrusions. These can here be divided into two broad groups. One group consists of dark greenish grey, medium-grained, commonly porphyritic pyroxene monzonite which is found in parts of the Virginia, Alabama, and June Bug claims. This rock is probably an older phase of the Lost Horse suite and in places is clearly cut by latite and microsyenite porphyry dykes of younger phases. The second group includes a variety of rocks which can be designated as micromonzonite, latite, and microsyenite porphyry. These rocks range in colour from grey to pink and brick red, and contain both biotite and pyroxene. The group admittedly includes rocks of a variety of ages, some forming clearly defined dykes, others occurring as larger, ill-defined masses. Within this group is included a striking microsyenite porphyry with large tabular phenocrysts of both plagioclase and potash feldspar. This rock occurs as dykes at the north end of the largest trench on the Alabama claim, and on the June Bug claim, where it is associated with a zone of magnetite breccia. In the southwestern corner of the Alabama claim is also exposed a zone of strongly magnetic breccia with a fine-grained dark pinkish grey matrix and subrounded clasts of various types of Lost Horse rocks. The rock is believed to be an intrusive or explosion breccia, part of the Lost Horse suite of rocks, and analogous in age and origin to the breccia pipe found at the entrance of Pit No. 2 on Copper Mountain. Nicola rocks have been subdivided into two broad groups, one consisting of very fine-grained tuff and the other including both massive and fragmental andesite. These rocks are found mainly in the south-central part of the area, near and south of the Copper Mountain road, and in two small areas on the Alabama and St. Elmo claims. A number of northerly trending late dykes of felsite and feldspar porphyry occur throughout the area, and are the northern continuation of the 'Mine dykes' swarm of Copper Mountain. Alteration of Lost Horse intrusive rocks and, in places, of Nicola rocks consists mainly of a moderate to strong veining and local pervasive replacement by pink potash feldspar. Epidote, calcite, and ankerite veining is widespread but nowhere predominant. Pink feldspar veining and replacement are clearly stronger in, and probably controlled by, zones of shearing and fracturing which, for the most part, have an east-west to northeast orientation and dip steeply. Mineralization consists of pyrite-chalcopyrite disseminations and fracture fillings in rocks of both the Lost Horse and Nicola suites, and appears to be best developed in areas of strong northeast fracturing and potash feldspar alteration. Exploration in this area has been done intermittently since the beginning of the century and has included considerable tunnelling, trenching, diamond drilling, and geochemical and geophysical surveys. The best mineralized zones so far outlined are on the No. 18, Virginia, and Alabama claims, and have all to date failed to warrant a mining operation.

REFERENCES: Dolmage, 1934, pp. 37, 38; *Minister of Mines, B.C.*, Ann. Rept., 1964, p. 101.

COPPER OCCURRENCES NEAR SATURDAY CREEK (A-6)

OWNER: Kalco Valley Mines Ltd.

DESCRIPTION: Disseminations of pyrrhotite, pyrite, and chalcopyrite are found at several localities south of the Copper Mountain stock in the vicinity of Saturday Creek. Nicola rocks in this area consist of massive andesitic volcanics, fine-grained bedded tuffs, and pillow lava. These are cut by numerous northerly trending dioritic dykes, believed to be related to the Copper Mountain stock. Low-grade metamorphism has produced widespread biotite, epidote, chlorite, and actinolite in the volcanic rocks. Within roughly 200 feet of the stock contact, pyroxene hornfels is developed and appears to replace the more widespread low-grade metamorphic assemblage. At a few places near dioritic dykes and along faults, the volcanic rocks are more strongly altered and may locally contain some garnet, sphene, traces of scapolite, and possibly cordierite. Here the dyke rocks generally also show much biotite and albite alteration. Mineralization is found near and within dykes, in zones of more strongly altered volcanic rocks, and along northeasterly trending faults. Recent geophysical and geochemical surveys, trenching, and diamond drilling by several companies have outlined an area some 5,000 feet long and 2,000 feet wide, straddling the Similkameen River, along which sparse sulphide mineralization is found (Fig. 4). Though at some places, such as in parts of the Reco mineral claim, sulphides may be present in considerable amounts, no zone has been outlined to date that shows promise of being developed into an orebody.

REFERENCE: *Minister of Mines, B.C.*, Ann. Rept., 1968, p. 214.

GROUP B – HEMATITE-CHALCOPYRITE AND MAGNETITE-CHALCOPYRITE REPLACEMENTS IN ROCKS OF THE VOIGT STOCK: This group of mineral deposits is distinctive both in its mineralogy and in its association with diorite of the Voigt stock. Although the mineralization is locally of higher grade than in deposits of Group A, metal concentrations of this group have so far failed to be of commercial value, and have a much lower potential of being so. The main reason for this is that mineralization is confined to narrow zones of shearing and brecciation, and even within these zones is generally irregularly distributed and variable.

FRISCO AND NO. 14 ZONES (B-1) (10, 11)

OWNER: Cumont Mines Limited.

DESCRIPTION: The workings on the Frisco and No. 14 claims outline what for many years have been known to be the most important showings in that group of prospects that has collectively been known as Voigt's camp. The main Frisco working is an east-directed adit, the Automatic No. 1, collared on the Automatic claim immediately east of the Copper Mountain road a short distance north of Wolf Creek (Fig. 19). Dolmage (1934, p. 42) reports the tunnel to be 342 feet long and entirely in diorite of the Voigt stock, except for a number of northerly trending late dykes.

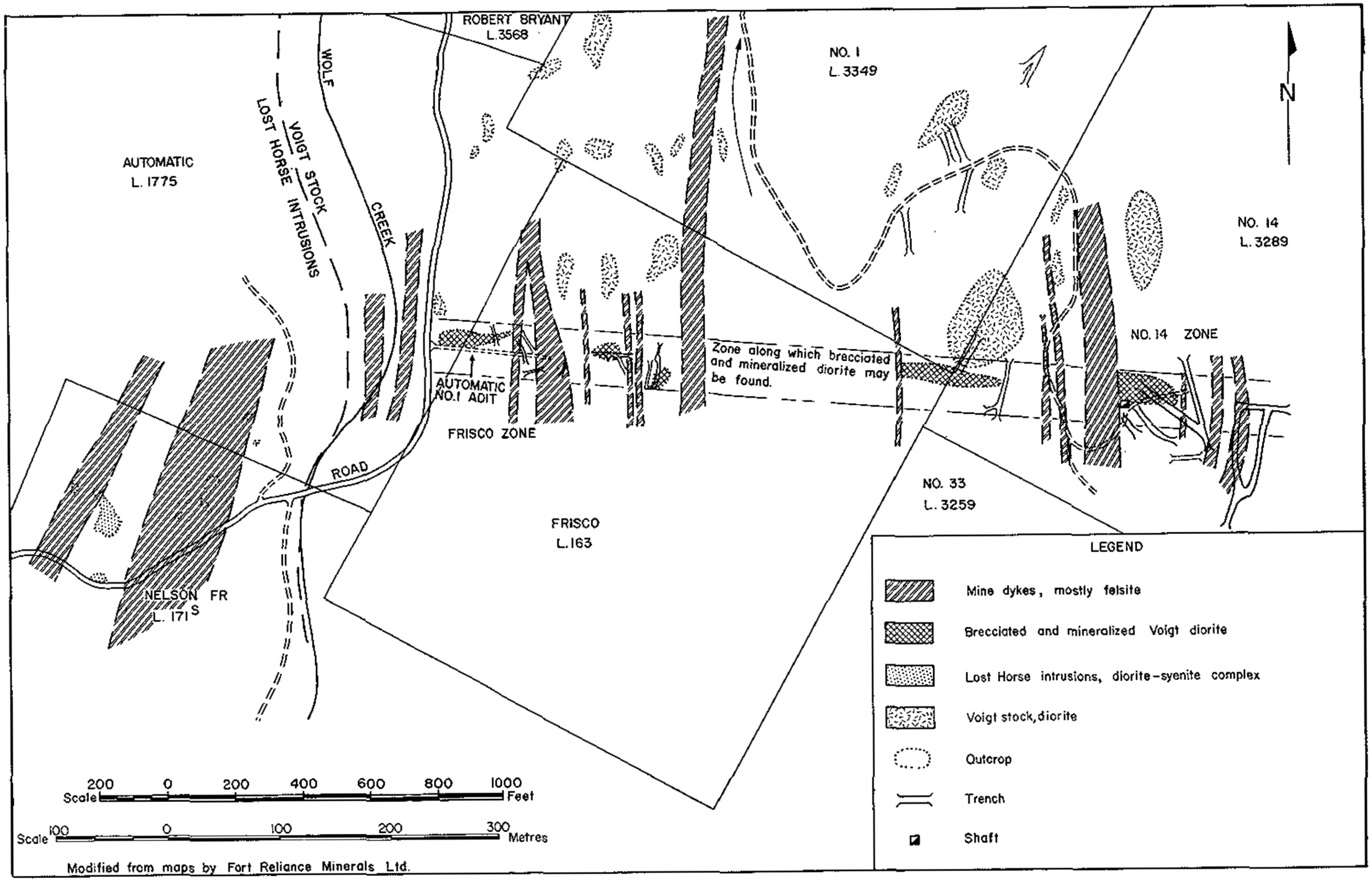

Figure 19. Geology of the Frisco and No. 14 claims area.

The No. 14 workings lie 2,000 feet directly east of the Frisco adit and consist of an old shaft, some 200 feet of drifts, and a number of hand-dug trenches. Recent bulldozer trenching has obliterated the old shaft and other workings without appreciably changing the extent of the known mineralization. In both zones mineralization consists of coarse hematite, magnetite, chalcopyrite, pyrite, red potash feldspar, calcite, and epidote in brecciated and bleached pyroxene diorite of the Voigt stock. The mineralized zones shown on Figure 19 have been outlined over many years by diamond drilling, underground workings, trenching, and other means of exploration which clearly indicated that mineralization occurs along an east-west trending zone of shearing and brecciation which might be in the order of 150 feet wide and dips steeply. Outside this zone no mineralization of this type is known to the writer. Numerous late northerly trending 'Mine dykes' cut through the mineralized zones and create considerable difficulties in tracing and outlining them.

Dolmage (1934, p. 42) reports on two other short adits, the Automatic No. 2 and No. 3 located immediately west of Wolf Creek and a short distance to the north of the Automatic No. 1 adit. Both adits are now caved, but from Dolmage's report it appears they did not contain any of the very characteristic hematite-chalcopyrite mineralization of the Frisco and No. 14 zones.

REFERENCES: Dolmage, 1934, pp. 41-43; Rice, 1947, p. 88.

AZURITE AND COPPER GLANCE (B-2) (25)

OWNER: Cumont Mines Limited.

DESCRIPTION: These two showings are located near the southern contact of the Voigt stock, in massive, dioritic looking Nicola andesite and breccia. Mineralization consists of magnetite-epidote veinlets with some chalcopyrite. No development work has been done recently on these showings which do not appear to be of any great extent.

REFERENCES: Dolmage, 1934, p. 43; Rice, 1947, p. 88.

FALUM (B-3) (12)

OWNER: Cumont Mines Limited.

DESCRIPTION: This prospect is in Voigt diorite 5,000 feet due east of the No. 14 zone. The workings consist of an old shaft and a number of trenches. Mineralization examined by the writer on the dump of the shaft is strikingly similar to that found at the Azurite and Copper Glance workings. However, both Dolmage (1934, p. 43) and Rice (1947, p. 88) report the presence of hematite and Rice (1947, p. 88) considers this mineralization to be "...quite similar to that on the Number 14 claim..." and to be "...probably on the extension of the same easterly striking shear zone."

REFERENCES: Dolmage, 1934, p. 43; Rice, 1947, p. 88.

GROUP C – BORNITE-CHALCOPYRITE CONCENTRATIONS ASSOCIATED WITH PEGMATITE VEINS IN ROCKS OF THE COPPER MOUNTAIN STOCK: Concentrations of this type are found at several places in the Copper Mountain stock. Mineralization is always associated with or occurs in veins and dykes of red potash feldspar pegmatite. Though grades in small lenses or shoots may be high, no orebody has yet been developed in mineralization of this type, and the writer believes that the potential of so doing is low. Only the most important prospects in this group are listed below. There are many other places within the Copper Mountain stock where pegmatite veins with chalcopyrite and bornite may be found, but these are too numerous and irregularly distributed to deal with them all.

FRIDAY CREEK (C-1) (42)

OWNER: Kalco Valley Mines Ltd.

DESCRIPTION: This prospect is one of the most important in the group and has been explored to a considerable extent. The following is the description given by J. M. Carr (*Minister of Mines, B.C.*, Ann. Rept., 1963, pp. 59-61).

> "The property lies between the Hope-Princeton highway and the Similkameen River, about 17 miles by road south of Princeton. The main showings are astride Friday Creek at a distance from the river of about 1,500 feet and are reached from the north by 2 miles of dirt road which leaves the highway by a point almost opposite the Kennedy Lake turn-off. In previous years an area on the south bank was stripped, measuring about 250 feet across with about 150 feet of relief. In 1963 the present company drove an adit due south under the stripped area for 100 feet, did 195 feet of underground diamond drilling in four holes and about 300 feet of surface drilling in four holes, all near the adit, and stripped on both sides of the creek. The showings have partly been described in the Annual Reports for 1960 and 1962 and are in the Copper Mountain stock near its western margin. Figure 20 illustrates the geology and is based on a pace and compass survey of the showings. Pyroxenite, gabbro, monzonite, and porphyritic monzonite are all parts of the stock and were probably emplaced successively in that order. A separate, probably later intrusion of monzonite porphyry occurs between the stock and sheared Nicola volcanic rocks farther southwest. Small dykes of red feldspar pegmatite cut the stock and possibly the monzonite porphyry also, and are older than dykes of andesite or diorite porphyry which cut the same rocks. The pegmatite dykes occur either singly or, more often, in groups and networks, and they are especially numerous in pyroxenite and gabbro. Their widths range from a fraction of an inch to as much as several feet, and their attitudes are both flat and steep. Many of the steep pegmatites strike northeastward and cannot be traced for more than a few feet. Faults near the showings are mostly in pyroxenite or gabbro and are either flat or steep. Only the steep faults are shown in Figure 20; they strike predominantly northeastward and dip either way. Flat faults are rather irregular in attitude; some of them end at steep faults, whilst others continue across the latter and seem to offset them. Some faults lie along pegmatite dykes, and others cut and displace the pegmatites. Near faults the rocks are brecciated and altered and contain plentiful biotite and epidote. Pyroxenite altered in this way contains much disseminated pink feldspar. Many faults carry a thin seam of brown gouge that formed after brecciation of the wallrock.
>
> "Mineralization is localized chiefly near faults. It consists principally of bornite and chalcopyrite as fracture fillings and local disseminations in brecciated, altered rocks and as bunches and stringers in calcite or quartz veins in faults. Pyrite is disseminated, partly adjacent to copper mineralization. Most mineralized exposures are moderately or slightly oxidized and contain malachite or azurite. Where strongly oxidized, they contain limonite without copper minerals.

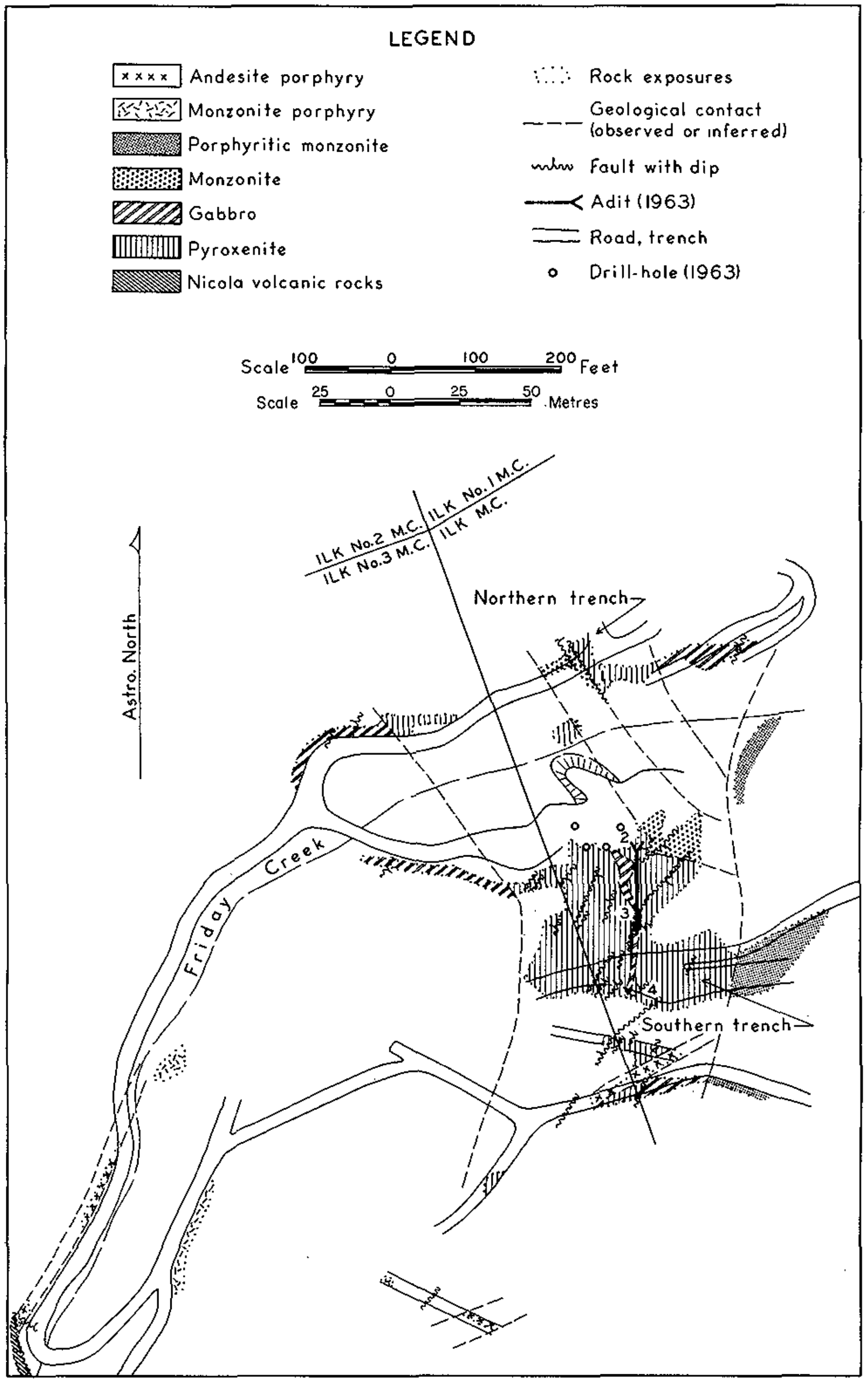

Figure 20. Geology of Friday Creek showings. [After *Minister of Mines, B.C.*, Ann. Rept., 1963, p. 60.]

"The best mineralization seen is all in pyroxenite and occurs at the following four places, which are numbered on Figure 20 and lie approximately on a north-south line passing through the adit. (1) North of the creek in new stripping near an old caved glory-hole, mineralization extends eastward for about 15 feet from a faulted monzonite contact and lies about 50 feet to the west of another mineralized exposure, which is about 9 feet across. (2) South of the creek in the adit, a steep irregular lens of mineralization extends north-northeastward from a steep northeasterly fault near the portal, and may join below rail-height a flat mineralized body that is exposed just north of the adit, where it lies close to a flat fault and is several feet thick in drill-holes. (3) In the west wall of the adit, between 70 and 90 feet from the portal, mineralization is part of a shoot that lies in the north wall of a steep northeasterly fault and is intersected for about 14 feet by a flat hole diamond drilled westward. From 85 to 90 feet a sample collected across the fault and its north wall assayed: Gold, trace; silver, 1.2 ounces per ton; copper, 4.21 per cent. This shoot apparently extends to surface, where the exposed rock is mineralized. An inclined hole was drilled from near the adit portal but was stopped short of the distance required to intersect the shoot in depth. (4) Farther south a small, partly oxidized body of mineralization was exposed temporarily in the south wall of the southern trench and apparently occurs in the western hangingwall of a northeasterly fault at its intersection with a flat fault."

REFERENCES: *Minister of Mines, B.C.*, Ann. Repts., 1960, p. 56; 1961, p. 56; 1962, pp. 61, 62; 1963, pp. 59-61; Dolmage, 1934, pp. 47, 48; Rice, 1947, pp. 89, 90.

DEEP GULCH (C-2) (33)

OWNER: Deep Gulch Mines Ltd.

DESCRIPTION: This prospect is located a short distance south of Deep Gulch, immediately east of Highway 3. Mineralization is entirely in diorite, monzonite, and pegmatite of the Copper Mountain stock and consists of lenses, veinlets, and disseminations of chalcopyrite and bornite associated with pegmatite veins of red potash feldspar. A very short distance east of the highway the intrusive rocks are truncated by the northerly trending Boundary fault which here dips to the west at 50 to 65 degrees. West of the fault are sheared and chloritized tuff, pillowed andesite, and siltstone-argillite of the Nicola Group. The following is part of the description of this prospect as given by J. M. Carr (*Minister of Mines, B.C.*, Ann. Rept., 1959, p. 54):

"The main area explored by trenches measures 2,500 feet in a northerly direction and ranges in width from 400 to 1,200 feet. It is underlain principally by syenogabbro, or syenodiorite, and monzonite of the Copper Mountain stock. These rocks contain veins, streaks, and patches of pink orthoclase feldspar. Biotite occurs as a normal constituent of the rocks and also in fractures. White feldspar-pegmatite which forms a core to the stock is exposed in the northeastern trenches and possesses sharp, irregular contacts against monzonite.

"The best mineralization is exposed in the southern part of the area and consists of bornite and some chalcopyrite as lenses, veinlets, and disseminations accompanying pink feldspar. Partial oxidation has produced malachite and limonite. Pyrite is inconspicuous or absent. Numerous low-grade sections of mineralization are haphazardly exposed in trenches, each of a width measurable in feet or tens of feet. Since most of the feldspar and sulphide veins and some faults strike northeast with steep dips, at least some of the mineralized sections may lie in northeasterly zones.

"Mineralization is most conspicuous to the west, within about 200 feet of the assumed southern continuation of a major fault. This fault is exposed in the northern part of the area, where it strikes slightly west of north, dips west at 45 degrees, and contains gouge 5 feet thick. It separates syenogabbro or syenodiorite containing some pink feldspar veins and bornite from sheared and sericitized tuffs presumably belonging to the Nicola group. The tuffs are rusty and contain traces of pyrite and malachite. A diamond-drill hole was drilled at −45 degrees westward from the most southwesterly trench with mineralization. Poor recovery was obtained and the hole ended at 435 feet without reaching the expected fault. It intersected some widely spaced lengths of mineralization.

"In the north part of the area some trenches failed to reach bedrock. The most northerly trenches expose sheared and rusty monzonite, which is cut by offshoots of white feldspar-pegmatite and by a later quartz-porphyry dyke. Pyrite is disseminated in the porphyry as well as in the monzonite, and traces of malachite are present.

"Two other exposures of quartz porphyry occur in the area, one being pyritized and sheared. Possibly these dykes are comparable to some of the post-ore dykes at Copper Mountain, 2 miles to the northeast, in which case there may be two periods of mineralization represented on the Deep Gulch property. The first would be associated with pink feldspar veins and biotitization, as at Copper Mountain, and the second, more pyritic mineralization, would be subsequent to the intrusion of quartz-porphyry and felsite dykes."

REFERENCE: *Minister of Mines, B.C.*, Ann. Rept., 1959, pp. 53, 54.

HAMILTON, FRASER, AND FRASER FRACTION (C-3) (21)

OWNER: Cumont Mines Limited.

DESCRIPTION: These showings, which were worked early in the history of the Copper Mountain camp, are all within the Copper Mountain stock west of the Similkameen River and 1,000 to 2,000 feet south of the northern contact. The following description of the showings is given by Dolmage (1934, pp. 48, 49):

"....On or near the Hamilton and Fraser fraction three shafts have been sunk, and down in the canyon of Similkameen River two tunnels have been driven on the Fraser claim and one immediately below it on the Copper Cliff claim. This lowest tunnel, however, extends for some distance into the Fraser claim.

"All of the workings are well within the stock, the shafts being 1,300, 1,850, and 2,050 feet, respectively, south of its contact; the tunnels are all within 500 feet of the main contact but within 100 feet of an inclusion of Wolf Creek breccias. All workings are in gabbro which is normal in every respect except for a slight excess of biotite and the presence of a considerable amount of bornite and chalcopyrite. The gabbro is cut by a few small veinlets of orthoclase, along some of which it is slightly impregnated with small crystals of magnetite. The only other rock of the vicinity is a 6-foot dyke, near the face of the upper tunnel, which consists of pink micaceous monzonite having abundant magnetite. Scattered irregularly through the gabbro are small areas in which bornite, chalcopyrite, and chalcocite are disseminated or spread out in thin films along minute fractures. In some of these areas pegmatitic material is present, but in others the gabbro is fresh and normal. Samples taken in the tunnel failed to reveal any ore of workable grade, though specimens were found on the dumps which, judged by the large amount of bornite visible, would carry more than 2 per cent copper. The section of the stock contact nearest these occurrences is especially worthy of intense prospecting."

REFERENCES: Dolmage, 1934, pp. 48, 49; Rice, 1947, p. 89.

GROUP D – MAGNETITE BRECCIAS AND REPLACEMENTS IN LOST HORSE INTRUSIVE ROCKS: A number of occurrences of magnetite breccia are found in rocks of the Lost Horse suite, and are commonly associated with later phases of this suite. The rock at this locality is usually a brecciated monzonite or syenite porphyry that shows a considerable degree of pink potash feldspar metasomatism and has been healed by interlacing veins of coarse magnetite. Copper sulphides are generally scarce or lacking at these localities.

Some of the better examples of this type of mineralization are found on the Ray 1 and 5 mineral claims approximately 1,000 feet northwest of the Similkameen Mining Company Limited's concentrator and to the south on the Copper King mineral claim (Lot 403). Similar occurrences are also found east of Similkameen River on the Diamond Dot (Lot 3265), June Bug (Lot 3029), and One Strike Fraction (Lot 2156) mineral claims.

COPPER OCCURRENCES ON KENNEDY MOUNTAIN: An isolated copper prospect is found on Kennedy Mountain, approximately 6,000 feet west of Ingerbelle, in pillowed andesite of map unit 4b. This showing has been explored intermittently by a number of bulldozer trenches and some diamond drilling over the past several years, but little is known to the writer on the results obtained from this work. The mineralization as exposed in the workings consists of lenses and veins of chalcopyrite and bornite with abundant malachite stain, in pillowed andesite with lenses and interbeds of impure limestone and volcanic breccia. Sulphide minerals appear to be confined to narrow zones of shattering and shearing that are laced with coarsely crystalline white calcite and epidote.

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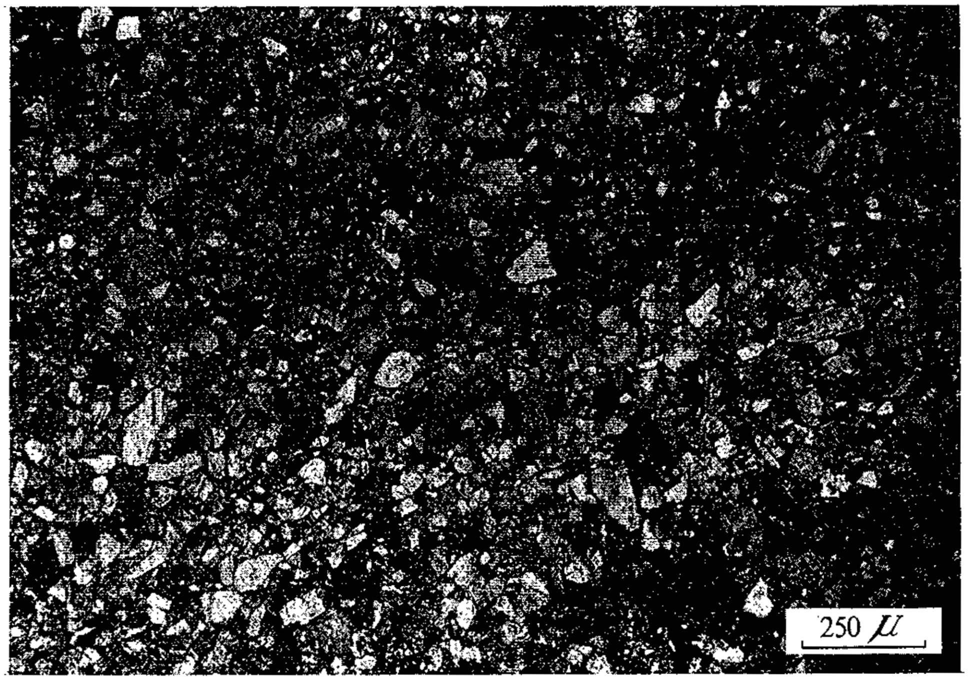


Plate I. Photomicrograph of volcanic siltstone, map unit 1. Plane polarized light.

Plate II. Graded and crossbedded sequence of volcanic siltstone and sandstone of map unit 1 along Similkameen River, looking south.

Plate III. Thin-bedded volcanic metasiltstone and/or tuff from Ingerbelle. Graded bedding indicates tops to right, beds right-side-up. Core diameter is 1.5 inches.

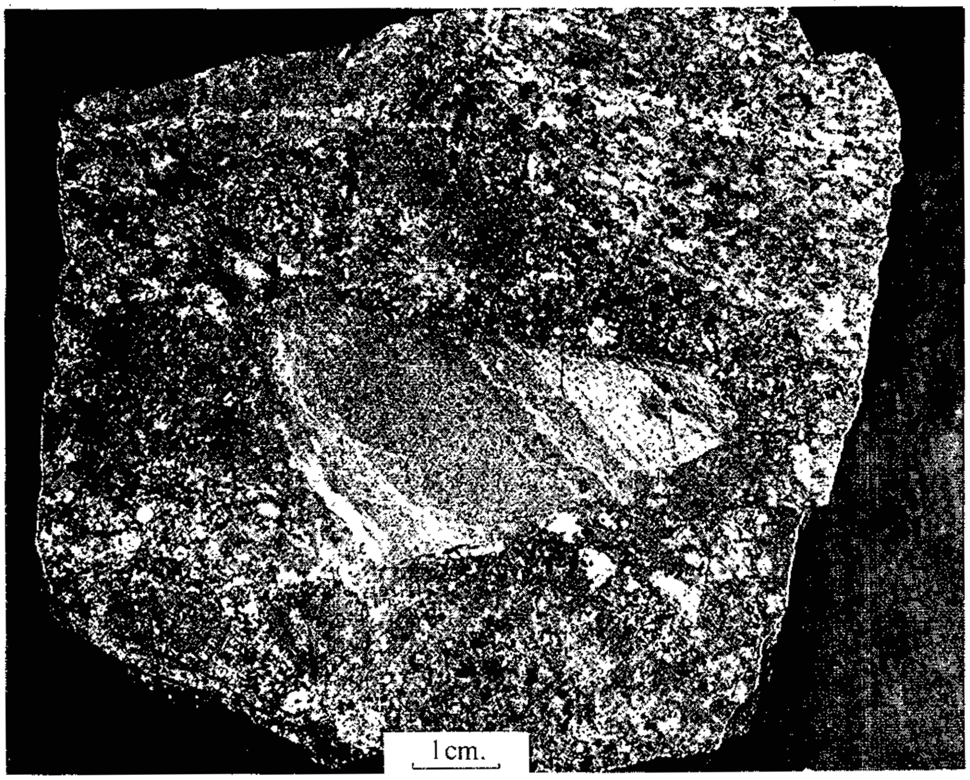


Plate IV. Volcanic breccia from Ingerbelle 3050 north crosscut. The matrix is recrystallized and peppered with pyrite and pyrrhotite.

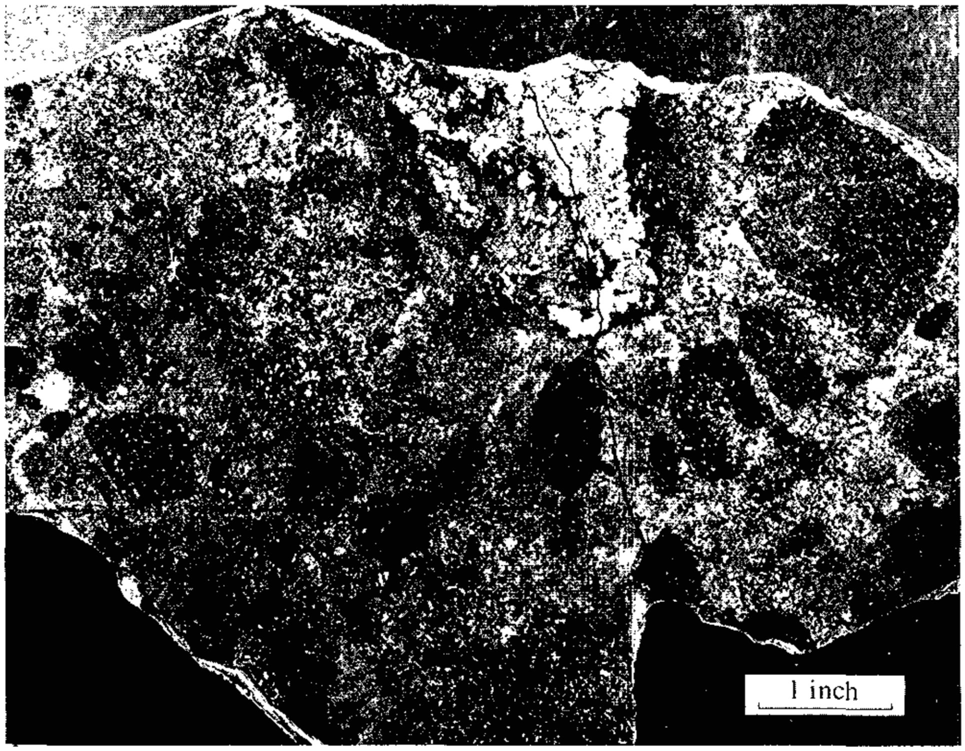


Plate V. Volcanic breccia from Ingerbelle 3050 south crosscut, with pyrite-pyrrhotite mineralization.

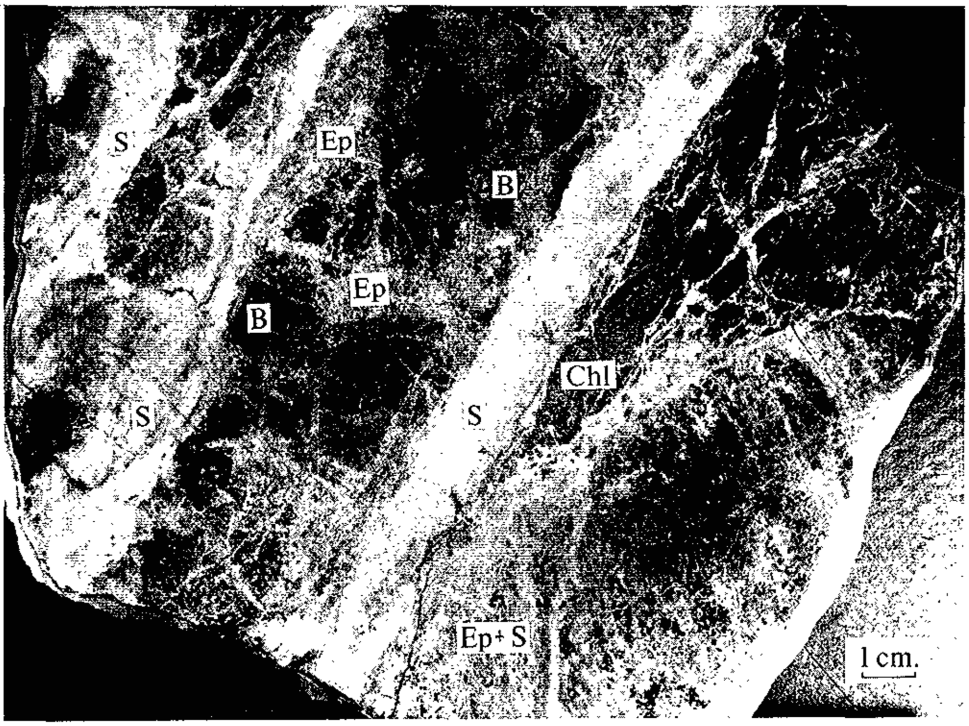


Plate VI. Heavily scapolitized equivalent of rock shown in Plate V showing possible relict fragmental texture. Specimen from Ingerbelle 3050 level. Sequence of alteration shown: Biotite-chlorite and epidote-scapolite.

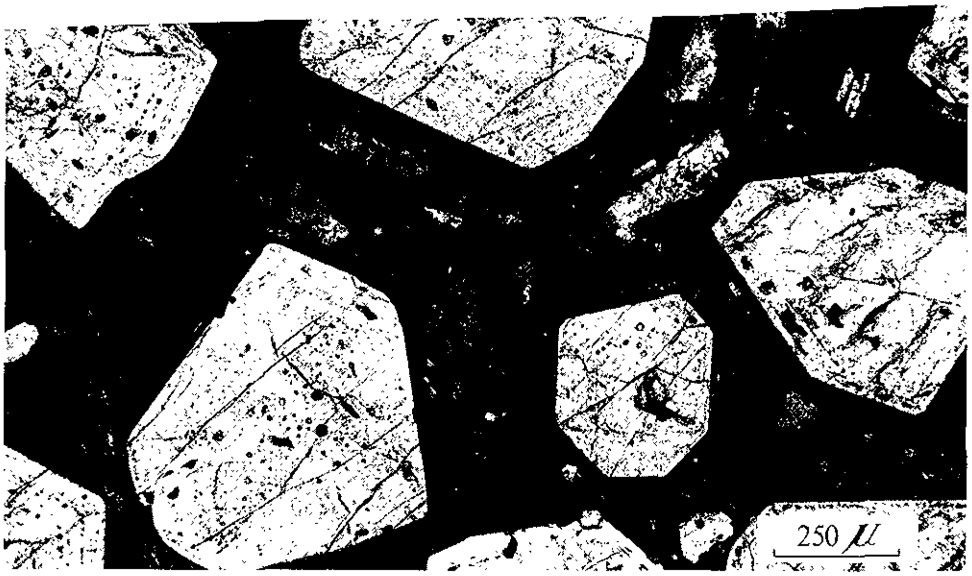


Plate VII. Photomicrograph of augite basalt porphyry of map unit 5.

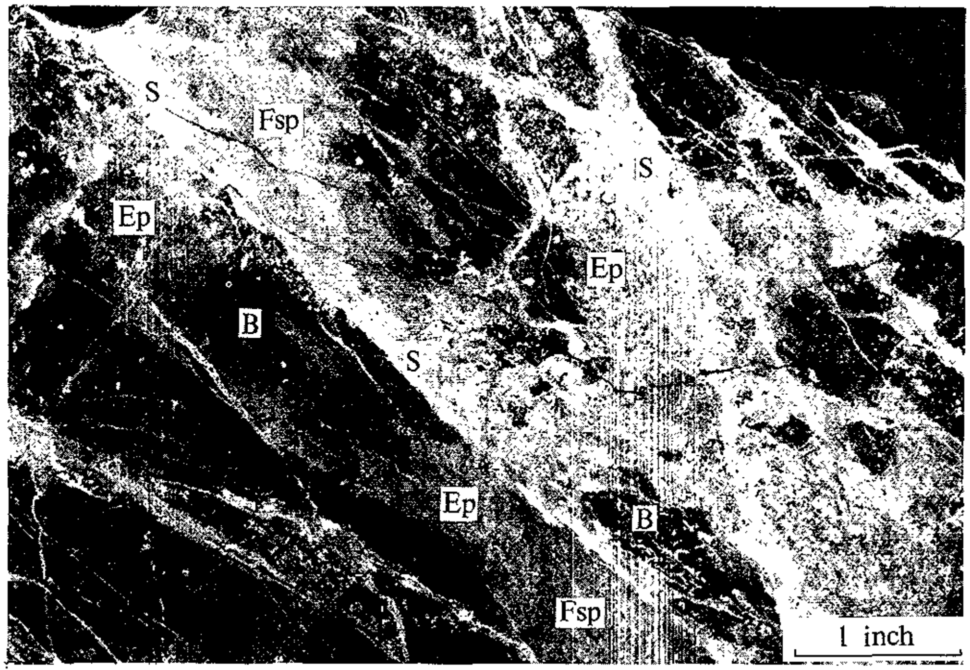


Plate VIII. Ingerbelle 3050 level. Pink-veined rock showing the alteration sequence: Biotite-chlorite and epidote-pink feldspar-scapolite.

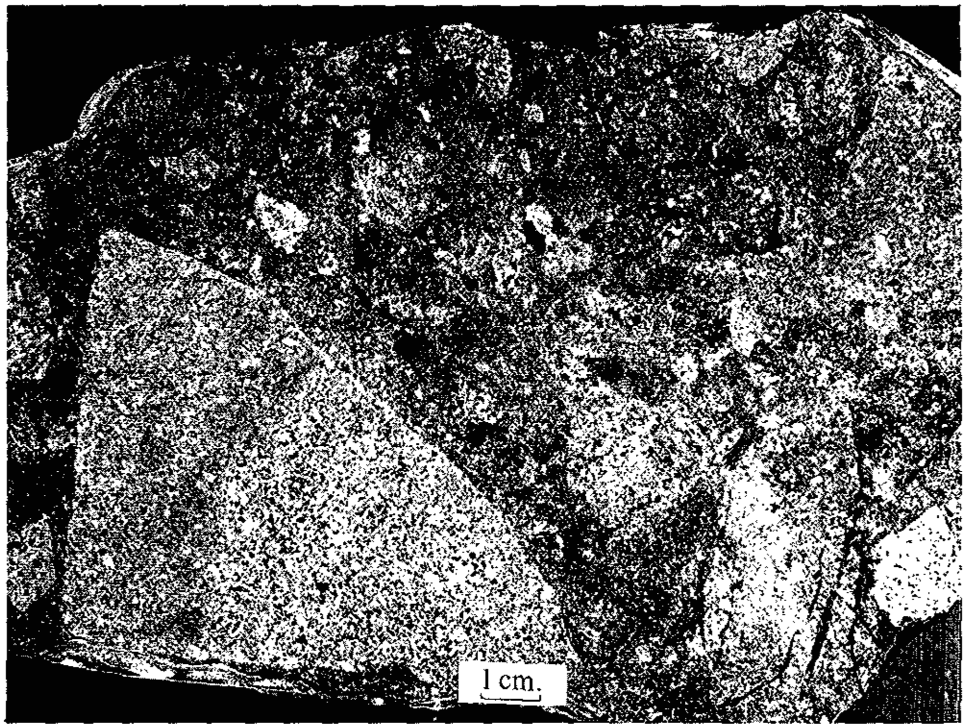


Plate IX. Lost Horse breccia, from body at the entrance of Copper Mountain Pit No. 2.

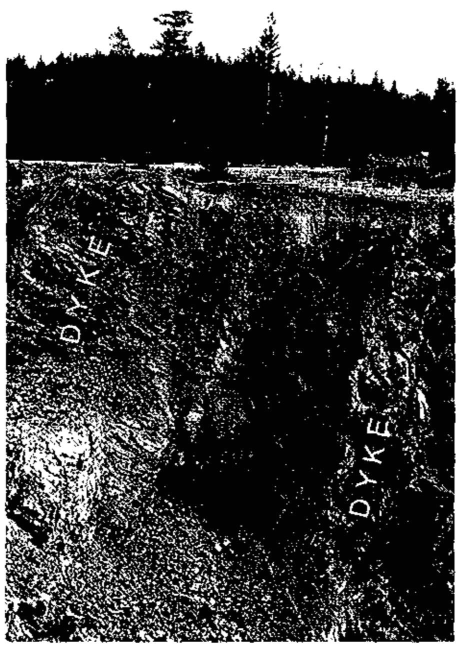


Plate X. Felsite 'Mine dykes' in altered volcanics. East end of Pit No. 2, Copper Mountain, looking south.

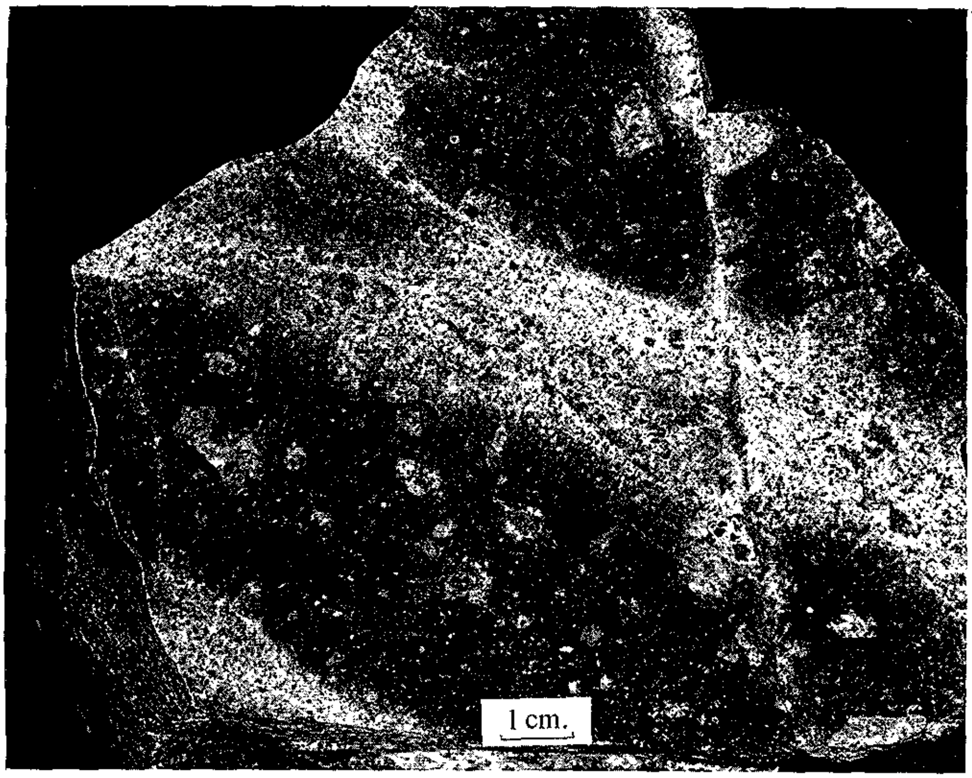


Plate XI. Fracture controlled epidote-albite alteration in biotitic fragmental andesite. Pit No. 2, Copper Mountain.

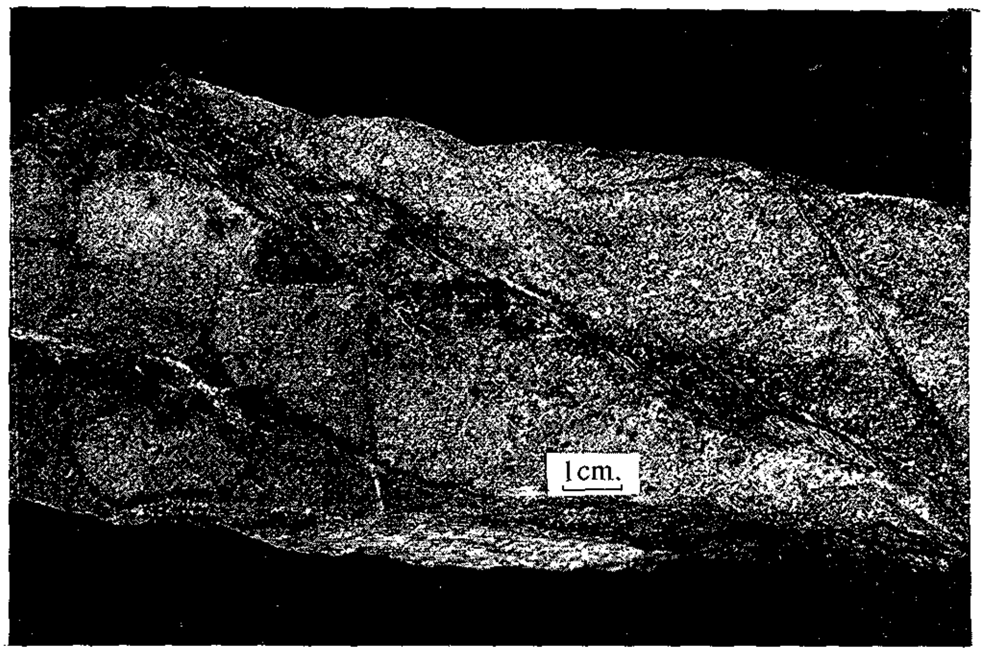


Plate XII. Typical chalcopyrite veins in the same rock of Plate XI that has been completely permeated by epidote-albite alteration. Pit No. 2, Copper Mountain.

Plate XIII. Subsidence area at Copper Mountain.

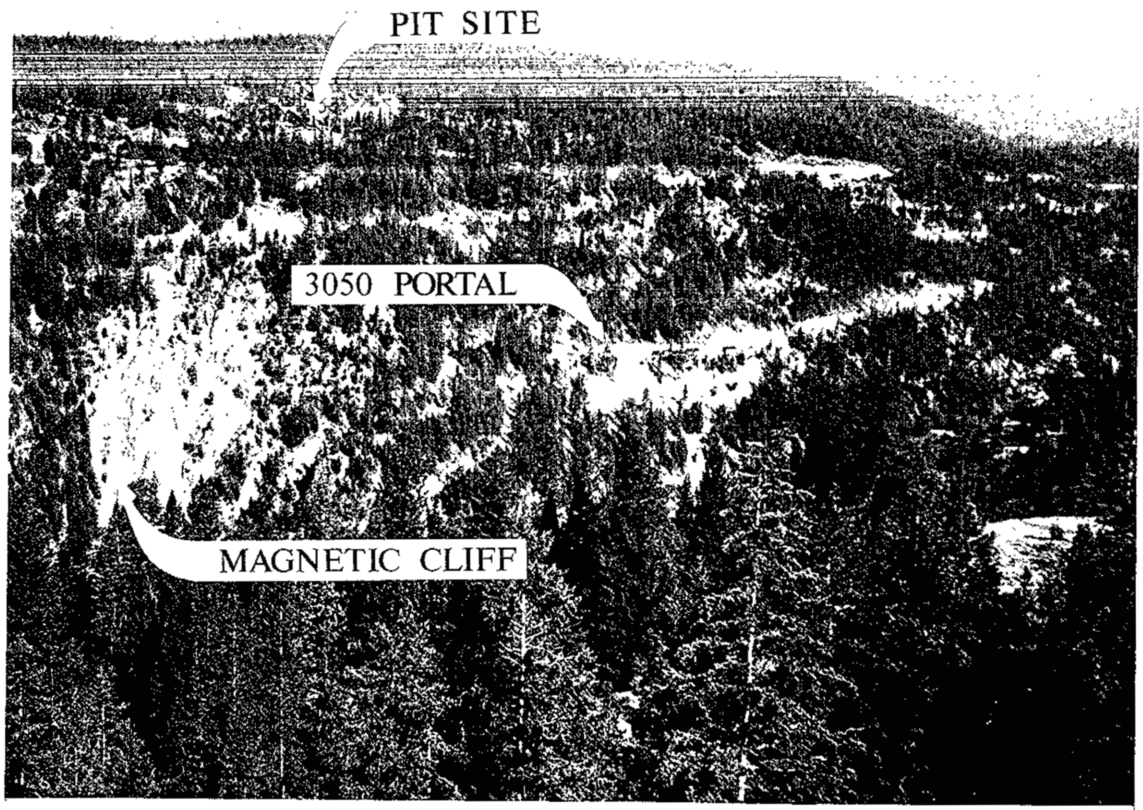


Plate XIV. View of Ingerbelle from Copper Mountain, showing the 3050 level adit portal, the cliffs of the Magnetic mineral claim in the left foreground and early clearing of the pit site in the left background.

Sheet A

LEGEND

TERTIARY

MIDDLE EOCENE

PRINCETON GROUP

- 18 — ALLENBY FORMATION, dacite tuff, breccia, flows
- 17 — LOWER VOLCANIC FORMATION
  - 17a Varicoloured andesite and basalt flows, breccia, and tuff
  - 17b Massive grey and buff hornblende andesite porphyry
  - 17c Nearly black augite basalt porphyry
  - 17d Grey andesite and dark mafic dykes
- 16 — Conglomerate, minor sandstone

POST LOWER CRETACEOUS

- 15 — DYKES, grey andesite feldspar porphyry
- 14 — MINE DYKES, light grey and buff felsite, quartz, quartz-feldspar, and feldspar porphyry

UPPER LOWER CRETACEOUS

- 13 — VERDE CREEK QUARTZ MONZONITE, porphyritic biotite-hornblende quartz monzonite and/or granite

UPPER TRIASSIC

COPPER MOUNTAIN INTRUSIONS

LOST HORSE INTRUSIONS

- 12 — Latite, microdiorite, and microsyenite porphyry
- 11 — Porphyritic augite and biotite-augite microdiorite, micromonzonite, and microsyenite

COPPER MOUNTAIN, VOIGT, AND SMELTER LAKE STOCKS

- 10 — Microdiorite and latite porphyry dykes
- 9 — Pegmatite, syenite, perthosite
- 8 — Monzonite
- 7 — 7a Pyroxenite; 7b Gabbro
- 6 — Diorite

AGE UNKNOWN (Older than Unit 10 and younger than Unit 2)

- 5 — Massive augite basalt porphyry

UPPER TRIASSIC

NICOLA GROUP

- 4 — VOLCANIC ROCKS
  - 4a Massive andesite, minor basalt and dacite
  - 4b Pillow lava and/or pillowed andesite
  - 4c Volcanic breccia and agglomerate
  - 4d Tuff
  - 4e Undifferentiated
- 3 — SEDIMENTARY ROCKS, grey and dark grey, graded bedded, calcareous siltstone and sandstone; minor conglomerate and breccia
- 2 — WOLF CREEK FORMATION
  - 2a Massive andesite, minor basalt and dacite
  - 2b Pillow lava
  - 2c Volcanic breccia and agglomerate
  - 2d Grey, green, buff, and brownish, commonly graded bedded, andesitic tuff; minor volcanic siltstone and sandstone
  - 2e Undifferentiated
- 1 — Grey and dark grey, graded and/or crossbedded, volcanic siltstone and sandstone; polymictic conglomerate, minor bioclastic limestone
  - 1a Volcanic breccia, tuff, and massive andesite

SYMBOLS

Geological contact
- located
- approximate
- assumed

Fault
- located
- approximate
- assumed

Attitude of bedding
- right-side-up
- overturned
- top unknown
- horizontal

Primary foliation in intrusive rocks

Fossil locality

Joint
- inclined
- vertical

Cleavage

Schistosity

Lineation

Syncline

Adit

Open pit

Area of some rock exposure

Paved highway

Secondary road

K-Ar isotopic age in m.y. ● 194±8

Location of chemically analysed sample ● VP69±106

BRITISH COLUMBIA DEPARTMENT OF MINES AND PETROLEUM RESOURCES (1972)

Figure 2

GEOLOGY OF COPPER MOUNTAIN

GEOLOGY BY V. A. PRETO 1968 - 1969

SCALE 1:12,000

scale 0 1,000 2,000 3,000 4,000 5,000 feet

scale 0 250 500 750 1,000 metres

(1 inch equals 1,000 feet)

#59 ①


SMELTER
LAKE
SIMILKAMEEN
RIVER
KENNEDY MTN
Kennedy
Lake
KENNEDY
LAKE
SYNCLINE
New
Highway
FAULT
BOUNDARY
Hope-Princeton
Highway
Deep
Gulch
Creek
Wolf
Creek
Whipsaw
Creek
Abandoned Railway Grade
LOST HORSE FAULT
SECTION 10,500N
Southwest
Zone
SECTION 13,800 E
200±8
197±8
194±8
195±8
101±4
98±4
VP-69-376
VP-69-106
SOUTH
MIDDLE
NORTH

#59 (2)

Sheet B

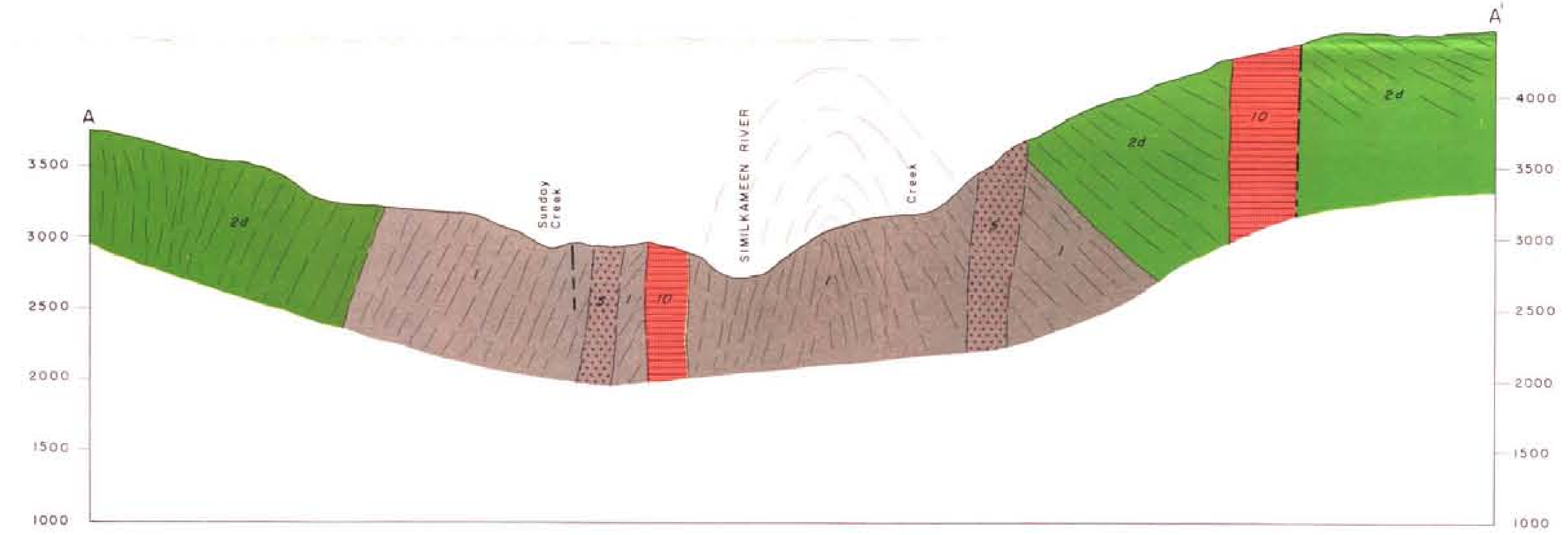


Figure 3

GEOLOGICAL CROSS-SECTIONS OF COPPER MOUNTAIN

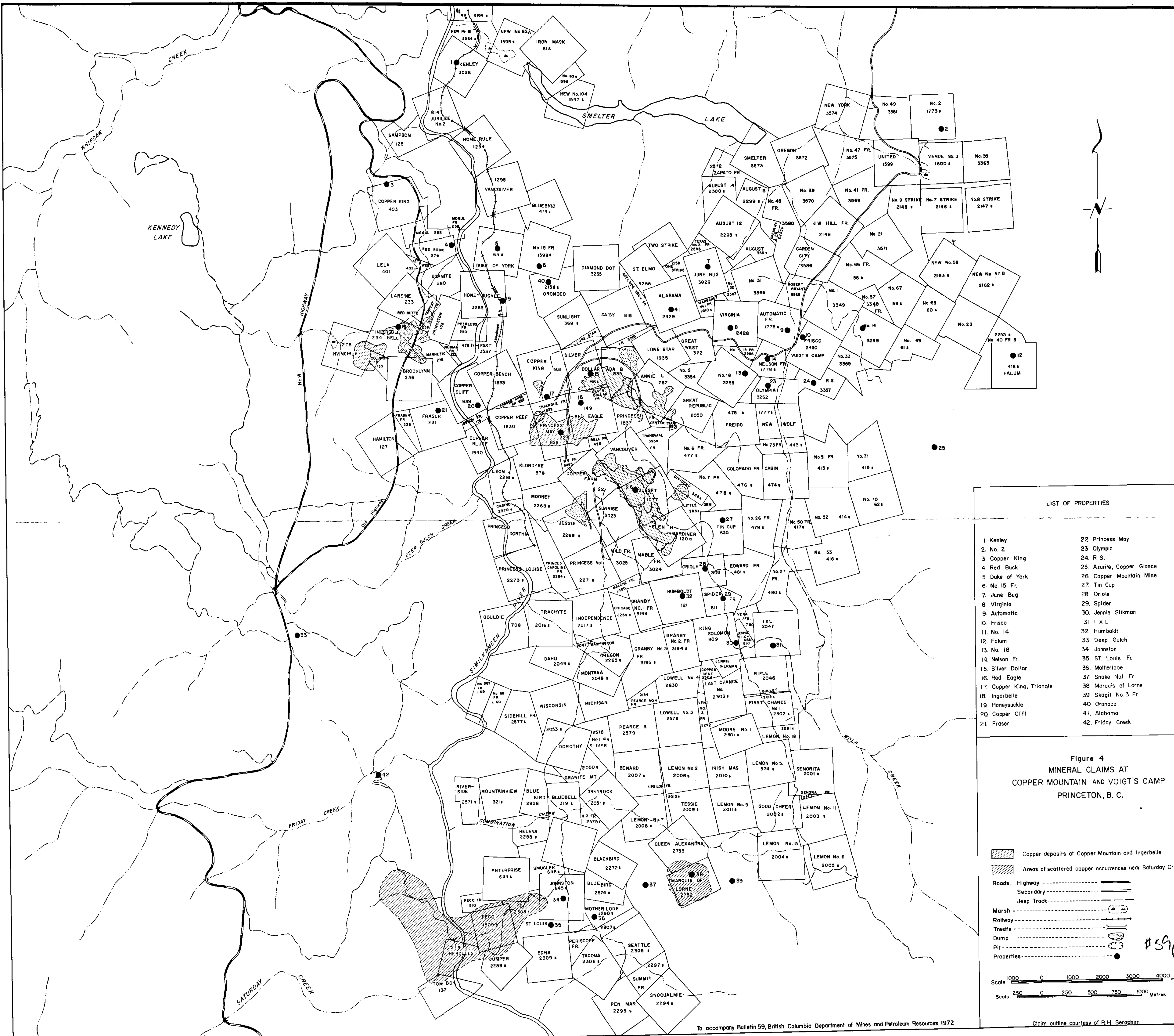
(See Figure 2)

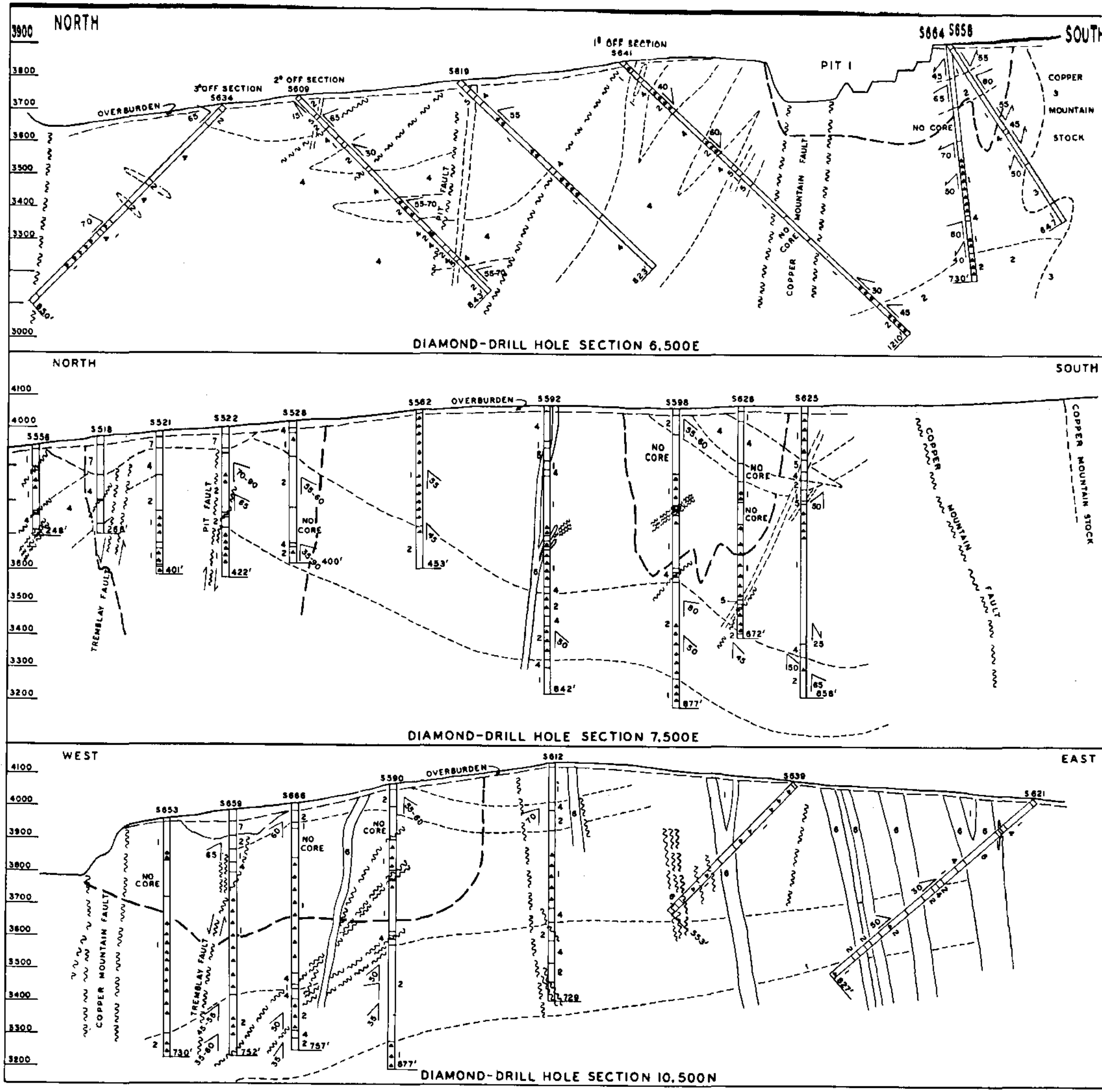
scale 0 1,000 2,000 3,000 4,000 5,000 feet

scale 0 250 500 750 1,000 metres

#59 (3)

TO ACCOMPANY BULLETIN 59


LIST OF PROPERTIES
1. Kenley
2. No. 2
3. Copper King
4. Red Buck
5. Duke of York
6. No. 15 Fr.
7. June Bug
8. Virginia
9. Automatic
10. Frisco
11. No. 14
12. Falum
13. No. 18
14. Nelson Fr.
15. Silver Dollar
16. Red Eagle
17. Copper King, Triangle
18. Ingerbelle
19. Honeysuckle
20. Copper Cliff
21. Fraser
22. Princess May
23. Olympia
24. R.S.
25. Azurite, Copper Glance
26. Copper Mountain Mine
27. Tin Cup
28. Oriole
29. Spider
30. Jennie Silkman
31. I X L
32. Humboldt
33. Deep Gulch
34. Johnston
35. ST. Louis Fr.
36. Motherlode
37. Snake Nal Fr.
38. Marquis of Lorne
39. Skagit No. 3 Fr.
40. Oronoco
41. Alabama
42. Friday Creek
Figure 4
MINERAL CLAIMS AT
COPPER MOUNTAIN AND VOIGT'S CAMP
PRINCETON, B. C.
Copper deposits at Copper Mountain and Ingerbelle
Areas of scattered copper occurrences near Saturday Creek
Roads, Highway
Secondary
Jeep Track
Marsh
Railway
Trestle
Dump
Pit
Properties
Scale 1000 0 1000 2000 3000 4000 Feet
Scale 250 0 250 500 750 1000 Metres
Claim outline courtesy of R.H. Seraphim
To accompany Bulletin 59, British Columbia Department of Mines and Petroleum Resources, 1972
#59 (4)



LEGEND

PRINCETON GROUP

7	Boulder conglomerate

UNMINERALIZED INTRUSIVE ROCKS

6	Mine dykes: felsite, feldspar and quartz feldspar porphyry
5	Grey feldspar porphyry

MINERALIZED INTRUSIVE ROCKS

4	Lost Horse intrusions: porphyritic pyroxene and biotite-pyroxene microdiorite, micromonzonite and/or microsyenite. Minor trachyte, latite porphyry, and intrusive breccias.
4a	Porphyritic augite-plagioclase microdiorite
3	Copper Mountain and Voigt stocks: biotite-pyroxene diorite

NICOLA GROUP

2	Generally well bedded volcanic siltstone and/or tuff with minor lithic tuff
1	Mostly massive and fragmental andesitic volcanic rocks. Minor siltstone and/or tuff (1a)- schistose metasiltone, tuff and volcanic breccia

Fault

Bedding- showing measured angle with core axis

Schistosity- showing measured angle with core axis

Generalized boundaries of mineralized zones

FIGURE 5

DIAMOND-DRILL HOLE CROSS-SECTIONS

COPPER MOUNTAIN CAMP

SCALE 200 0 200 400 FEET

SCALE 100 0 100 METRES

#59 (5)

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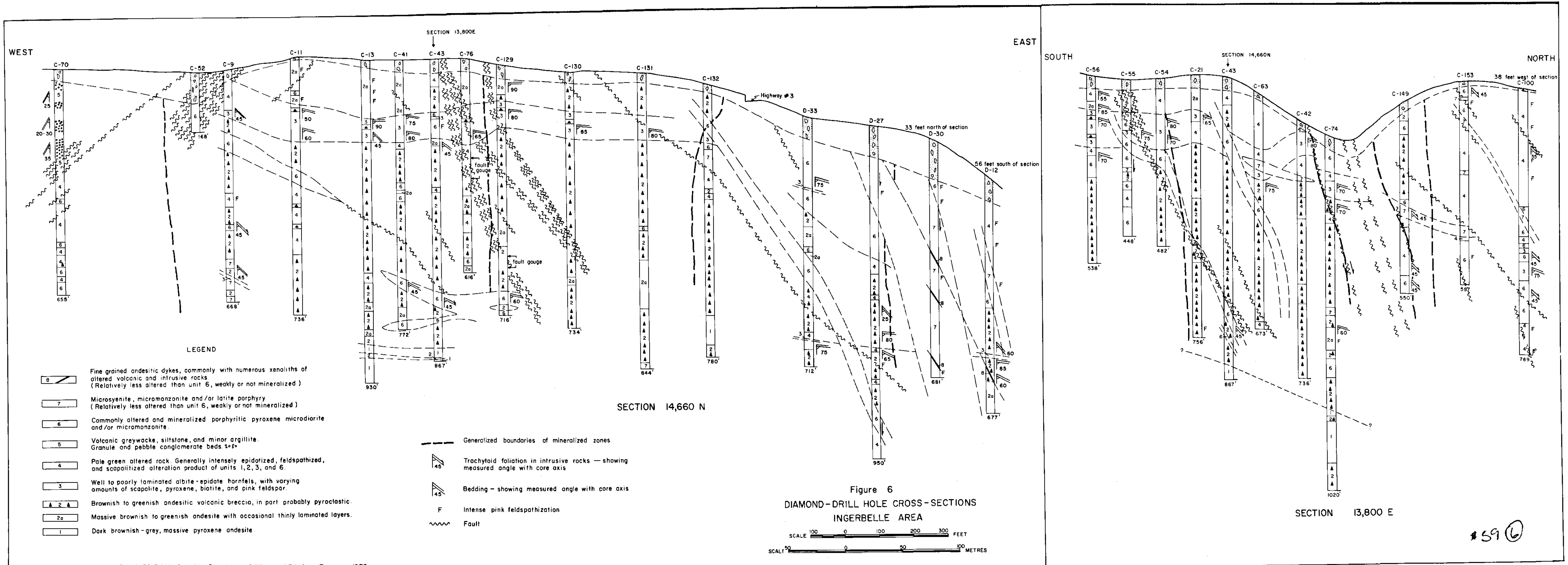


Figure 6
DIAMOND-DRILL HOLE CROSS-SECTIONS
INGERBELLE AREA

To accompany Bulletin 59, British Columbia Department of Mines and Petroleum Resources, 1972

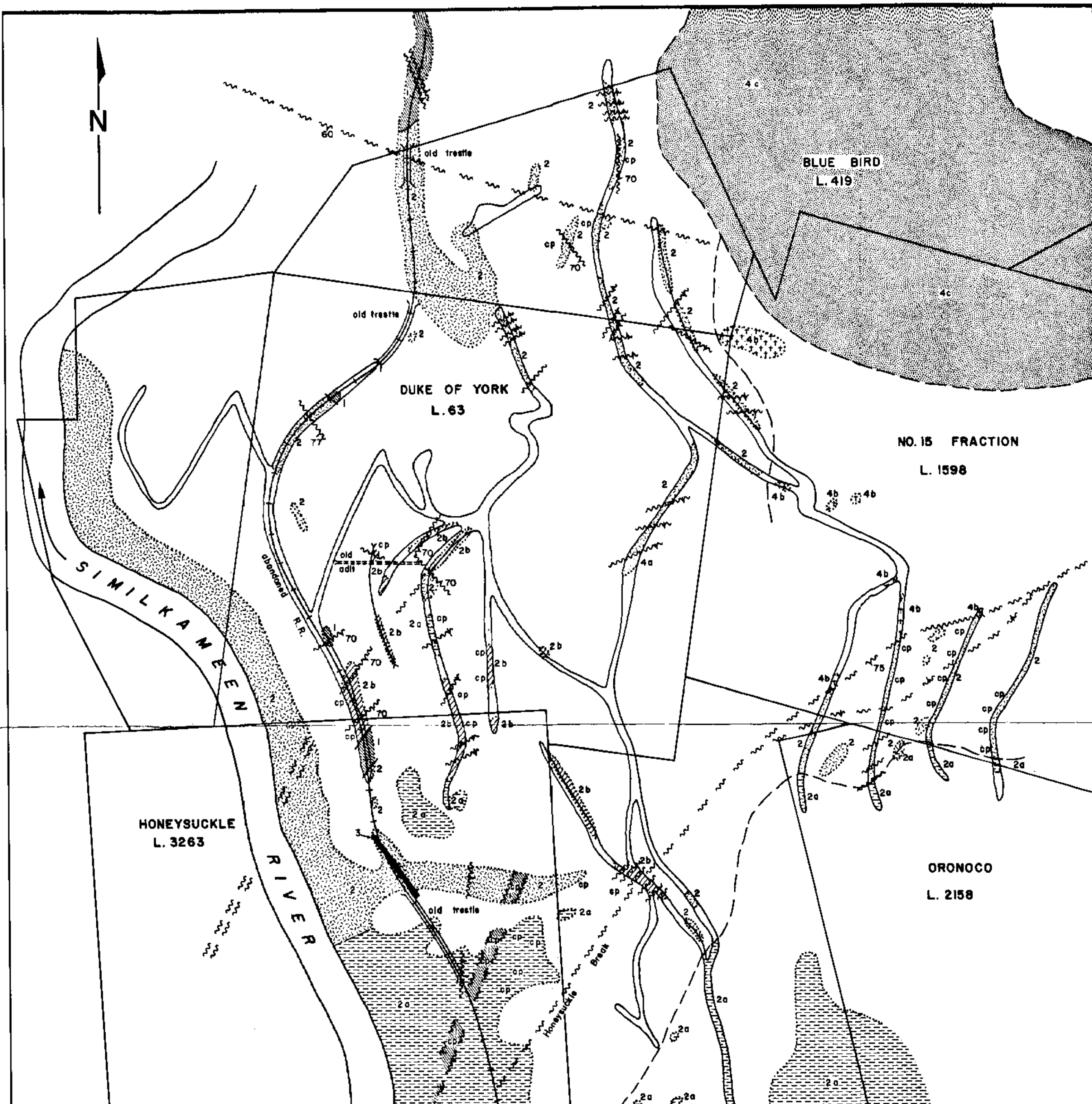


Figure 17

GEOLOGY OF THE DUKE OF YORK, ORONOCO, AND HONEYSUCKLE CLAIMS AREA

LEGEND

PRINCETON GROUP

- 4c — Hornblende andesite porphyry
- 4b — Volcanic breccia, basalt (?), andesite
- 4a — Sandstone
- 3 — Hornblende porphyry

LOST HORSE INTRUSIONS

- 2b — Equivalent of unit 2 with intense K-feldspar alteration
- 2a — Equivalent of unit 2 with intense pale green alteration
- 2 — Complex of medium-grained porphyritic diorite, monzonite, and syenite; some latite porphyry

NICOLA GROUP

- 1 — Altered andesite
- cp — Zone of chalcopyrite-pyrite mineralization

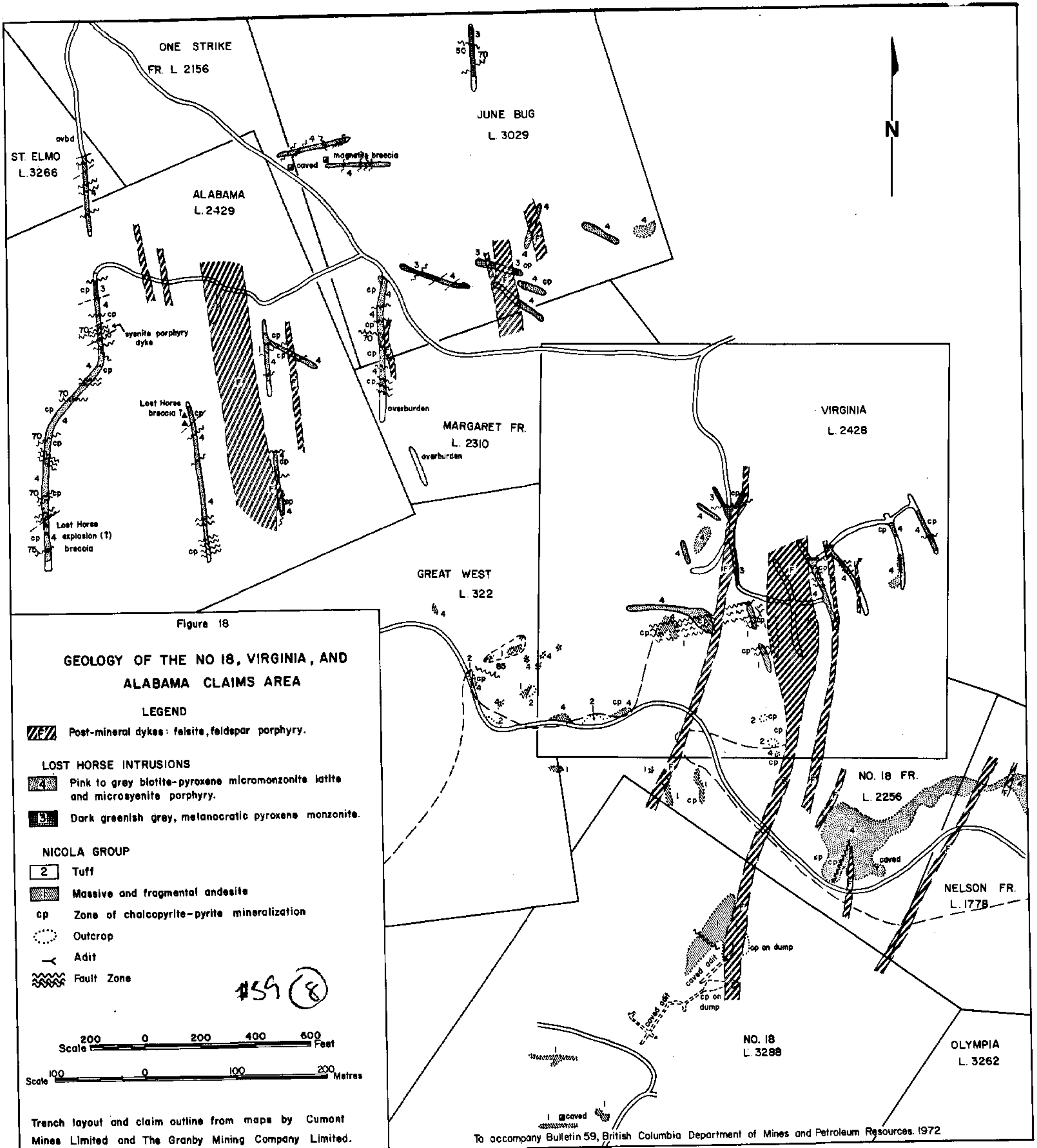
Scale 200 0 200 400 600 Feet

Scale 100 0 100 200 Metres

#59 (7)

Roads, trench, and claim plans from maps by Cumont Mines Limited.

To accompany Bulletin 59, British Columbia Department of Mines and Petroleum Resources. 1972



ONE STRIKE
FR. L. 2156
JUNE BUG
L. 3029
ST. ELMO
L. 3266
ALABAMA
L. 2429
ovbd
magnetite breccia
caved
syenite porphyry dyke
Lost Horse breccia
Lost Horse explosion (?) breccia
overburden
MARGARET FR.
L. 2310
VIRGINIA
L. 2428
GREAT WEST
L. 322
NO. 18 FR.
L. 2256
NELSON FR.
L. 1778
NO. 18
L. 3288
OLYMPIA
L. 3262
cp on dump
caved adit
N
Figure 18
GEOLOGY OF THE NO 18, VIRGINIA, AND ALABAMA CLAIMS AREA
LEGEND
Post-mineral dykes: felsite, feldspar porphyry.
LOST HORSE INTRUSIONS
4 Pink to grey biotite-pyroxene micromonzonite latite and microsyenite porphyry.
3 Dark greenish grey, melanocratic pyroxene monzonite.
NICOLA GROUP
2 Tuff
1 Massive and fragmental andesite
cp Zone of chalcopyrite-pyrite mineralization
Outcrop
Adit
Fault Zone
#59 (8)
Scale 200 0 200 400 600 Feet
Scale 100 0 100 200 Metres
Trench layout and claim outline from maps by Cumont Mines Limited and The Granby Mining Company Limited.
To accompany Bulletin 59, British Columbia Department of Mines and Petroleum Resources. 1972