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GEOLOGY OF THE VALLEY COPPER DEPOSIT

BY

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ABSTRACT

The Valley Copper porphyry deposit is located in the Highland Valley of B.C., about 370km northeast of Vancouver, B.C. Reserves are 790 million tonnes of 0.48 percent copper.

The rocks which host this deposit are mainly porphyritic Bethsaida phase granodiorites, the most central and youngest phase of the 198 m y old Guichon Creek batholith. Minor dyke phases include: pre-mineralization granodiorite and quartz diorite porphyries and aplite, syn-mineralization Tan felsite porphyry and post-mineralization lamprophyres.

Localization of the deposit is related to the formation of a zone of intense fracturing near the intersection of the northerly trending Lornex fault and the easterly trending Highland Valley fault. Predominant orientations of faults, fractures and quartz veinlets in the deposit are parallel to these two regional faults.

The alteration types recognized are: propylitic, pervasive sericitic and kaolinitic, vein sericitic, K-feldspathic, biotitic, silicic and post-mineralization veining (principally gypsum). K-feldspathic alteration is dominant in the central, deeper part of the deposit, where it is intimately associated with and enveloped by an extensive zone of moderate to strong vein sericitic and pervasive sericitic and kaolinitic alteration, which grades outward into a zone dominated by weak to moderate pervasive sericitic

and kaolinitic alteration. This latter zone, in turn, grades outward into a zone with areas of weak to moderate propylitic alteration and areas with no hydrothermal alteration. A well developed silicic zone (in the form of barren quartz veinlets) occurs in the southeastern part of the deposit. Elsewhere quartz veinlets (principally mineralized but some barren) are only moderately developed within the deposit. The age of hydrothermal alteration, calculated by averaging several potassium-argon analyses of hydrothermal sericites, is 191 m y.

The sulfides present in the deposit are, in order of relative abundance: bornite, chalcopyrite, digenite, covellite, pyrite, pyrrhotite, molybdenite, sphalerite, galena and gudmundite (FeSbS). The greater part of the copper mineralization is associated with areas of abundant vein sericitic alteration and quartz veinlets. Bornite is the dominant sulfide in this sericitic association, whereas chalcopyrite is the dominant sulfide accompanying K-feldspathic alteration. Bornite/chalcopyrite ratios show highest values in the central part of the deposit, where they exceed 3 to 1 and decrease away from the core to the fringes of the deposit where chalcopyrite predominates. The deposit has a weakly developed pyrite halo.

Geochemical patterns related to hydrothermal alteration show a decrease in CaO, Na_2O, MgO, Sr, Ba and Mn and a corresponding increase in K_2O, SiO_2, Rb and TiO_2 from the periphery to the centre of the deposit. Patterns related to mineralization show that the deposit (as defined by copper values exceeding 0.30 percent) is roughly oval in plan, with a broad halo of lower copper grades around it. Molybdenum and zinc form annular, geochemically enriched zones around the deposit.

Sericite stabilities and fluid inclusion compositions as well as sulfur, oxygen and hydrogen isotopic data, suggest both that sulfur in the sulfides is of sub-crustal or magmatic derivation and that the deposit was formed at a shallow depth from saline, hydrothermal fluids. The fluids had the following range in characteristics during the alteration sequence:

$$T = 260 \text{ to } 480^{\circ}C$$

$$pH = 1.7 \text{ to greater than } 4.0$$

$$-\log fS_2 = 1.5 \text{ to } 4.5$$

$$-\log fO_2 = 21.6 \text{ to } 23.4$$

The main period of copper mineralization occurred at about $400^{\circ}C$ from a solution of about pH 2.2 to 3.1 which exhibited -log fugacities of oxygen and sulfur of 21.8 to 23.0 and 1.8 to 2.7 respectively. The controlling factor in the deposition of sulfides was apparently an increase in the sulfide ion concentration. Mixing of magmatic water and seawater probably occurred throughout the various stages of hydrothermal alteration and is estimated to be about 25 percent SMOW (Standard Mean Ocean Water) during the main period of mineralization.

INTRODUCTION

The Valley Copper porphyry deposit is located in the Highland Valley area, near Ashcroft, B.C., about 370km northeast of Vancouver (NTS 92 I/6E, Latitude 50° 29'N Longitude 121° 02'W). The deposit has been extensively explored by drilling and underground workings for testing but development has not been started. Published reserves, to a depth of 442m, are 790 million tonnes of 0.48 percent copper. A historical summary of the discovery of the deposit may be found in Allen and Richardson (1970). Except where otherwise acknowledged data in this paper are from Osatenko and Harris (1973), Jones (1975) and Cominco Exploration files.

The geological setting of the Valley Copper deposit is dealt with in a regional paper by McMillan (this volume). In this paper the mineralogy and geochemistry of the Valley Copper deposit and surrounding rocks will be described with special reference to alteration patterns associated with mineralization. Data about the host rocks and alteration assemblages were derived from an examination of 700 samples of core taken from 46 diamond drill holes. Specimens showing features such as cross-cutting veinlets and fractures were slabbed, stained with sodium cobaltinitrite and thin-sectioned to study alteration mineral relationships. Maps showing distribution of various dykes and major alteration types were constructed using data from 19,500 metres of drill core (56 holes). The locations of drill holes studied are shown in Figure 1.

Plots showing distributions of alteration types are given for the 1158m level and for a vertical section (A-B), which trends northeast through the exploratory decline (Figure 1). These particular reference planes were chosen to provide the best opportunity to study variations throughout the deposit and into adjacent areas of low-grade mineralization. Data shown only approximates the true picture on the 1158m level because topographical features on the west side and deep overburden on the east side of the deposit made it necessary to project data from holes in these areas onto the level.

The geochemical data on the figures were obtained by analysis of assay pulp composites from various percussion and vertical diamond drill holes. Percussion hole composites represent the bottom 15m of each hole. In the diamond drill holes 30m composites were made at 76m intervals down the holes. Copper sulfide ratios and pyrite contents were found by point-counting polished sections made of sulfide concentrates from the composites.

HOST ROCKS

1. Bethsaida Granodiorite

The rocks which are host to the Valley Copper deposit are mainly porphyritic granodiorites of the Bethsaida phase of the Guichon Creek batholith (Figure 1). These rocks are medium to coarse grained, with coarse phenocrysts of quartz and biotite. A typical modal composition (volume percent) is plagioclase 56, K-feldspar 10, quartz 29 and biotite 4. Accessory hornblende, magnetite, hematite, sphene, apatite and zircon make up the remaining 1 percent.

All the major intrusive phases of the Guichon Creek batholith have been dated by the potassium-argon method and found to group about 198 $\pm$ 8 m y (Northcote, 1969).

2. Granodiorite and quartz diorite porphyries

Granodiorite and quartz diorite porphyry dykes occur in the western, central and southern parts of the deposit (Figure 1). These dykes, which vary in width from about 0.6 to 35m, dip steeply eastward in the western and central areas and northward in the southern area.

Granodiorite porphyry consists approximately of 60 percent medium to coarse grained plagioclase phenocrysts with minor quartz in a fine grained matrix consisting of quartz, K-feldspar and minor plagioclase with trace amounts of magnetite, hematite and biotite. An average modal composition (volume percent) is plagioclase 63, K-feldspar 13, quartz 23 and iron oxides plus biotite 1.

Quartz diorite porphyry which ranges from fine to coarse grained contains 50 percent plagioclase and 8 percent quartz phenocrysts in a fine grained matrix of quartz and plagioclase with minor K-feldspar, magnetite and hematite. Its modal composition (volume percent) approximates plagioclase 70, quartz 28, K-feldspar 1 and iron oxides 1.

These dykes are invariably cut by mineralized fractures and quartz veinlets. A single potassium-argon determination on biotite gave an age of 204 $\pm$ 4 m y.

3. Aplite

Aplite dykes, up to 30.5cm in width, occur throughout the deposit. An average modal composition (volume percent) is K-feldspar 45, quartz 44, plagioclase 10 and biotite 1. The aplite dykes are of pre-mineralization age because they are invariably cut by mineralized fractures.

4. Tan felsite porphyry

A swarm of tan colored felsite porphyry dykes intrude the Bethsaida granodiorite in the northwestern part of the deposit. These dykes are up to 4.5m in width and are characterized by a higher proportion of matrix (about 80 percent) than the porphyry dykes of granodiorite and quartz diorite composition. The matrix of the Tan felsite porphyry dykes is light tan in colour and consists primarily of K-feldspar and quartz. Phenocrysts make up 20 percent of the rock and include quartz, plagioclase, K-feldspar and biotite.

Tan felsite porphyry dykes may have been intruded during the waning stages of mineralization. Some unaltered dykes contain inclusions of sericite-veined Bethsaida granodiorite, but others contain disseminated chalcopyrite and bornite and are sparsely veined by mineralized quartz.

5. Lamprophyre

Three types of lamprophyre dykes, spessartite, hornblende vogesite and vogesite are intersected in drill holes. Alteration and mineralization are cut by these dykes, hence, they post-date mineralization. Further, the vogesite lamprophyre has a potassium-argon age of 132 ± 3 m y.

STRUCTURE

A summary of about 14,000 structural measurements on faults, fractures and quartz veinlets from the exploratory declines is given in Table 1. Faults comprise four distinct sets represented by the following orientations: N 07°W/75°E, N 04°E/90, N 72°W/84°S and N 00°/16°E. Fractures include corresponding sets at N 11°W/80°E, N 000°/90° and N 72°W/85°S plus additional sets at N 73°E/18°S and N 35°E/70°NW. Quartz veinlets show well developed sets at N 19°W/80°E and N 69°W/79°S that are parallel to the earlier formed (McMillan, 1971) principal sets of fractures and faults. The main structural orientations that occur in the declines are parallel to the Lornex and Highland Valley faults (Allen and Richardson, 1970).

ALTERATION

The alteration types recognized at Valley Copper are: propylitic, pervasive sericitic and kaolinitic, vein sericitic, K-feldspathic, biotitic, silicic and post-mineralization veining. These alteration types are often intimately associated and, indeed, several can occur within a single hand specimen. A generalized diagram of the distribution of dominant alteration types, on the 1097m level, is depicted in Figure 2. A major zone of K-feldspathic alteration occurs in the west-central part of the deposit. This is intimately associated with and enveloped by an extensive zone of moderate to strong vein

TABLE I

DOMINANT STRUCTURAL ORIENTATIONS FROM THE DECLINES OF THE VALLEY COPPER DEPOSIT

	FAULTS	FRACTURES	QUARTZ VEINLETS
DECLINE A	N 07°W/75°E (1)	N 11°W/80°E (1)	N 19°W/65°E (1)
	N 00°/16°E (2)		
			N 34°E/20°SE(3)
		N 72°W/80°S (1)	N 76°W/80°N (2)
	N 04°E/90° (1)	N 00°/90° (2)	
DECLINE B	N 20°W/50°E (2)	N 17°W/75°E (1)	N 24°W/65°E
	N 72°W/84°S (1)	N 69°W/75°S (2)	N 70°W/80°S (2)
		N 37°E/42°SE(3)	
		N 38°E/54NW	N 35°E/65°NW(3)
	N 00°/90° (1)		
DECLINE C	N 20°W/50°E (2)	N 20°W/60°E (1)	N 28°W/65°NE(2)
	N 72°W/84°S (1)	N 62°W/84°S (1)	N 69°W/79°S (1)
			N 54°W/80NE (3)
		N 73°E/18°S (2)	
		N 35°E/70°NW(2)	
	N 00°/90° (1)		

N.B.: Ranked in order of relative abundance sericitic and pervasive sericitic and kaolinitic alteration, which grades outward into a zone dominated by weak to moderate pervasive sericitic and kaolinitic alteration. This zone, in turn, grades outward into a zone with areas of weak to moderate propylitic alteration and areas with no hydrothermal alteration. This outer zone locally contains small areas of vein sericitic and pervasive alteration as well as quartz veining. An area of well developed barren quartz veinlets occurs in the southeastern part of the deposit. Elsewhere quartz veinlets (principally mineralized but some barren) are only moderately developed within the 0.30 percent copper contour.

1. Propylitic

Propylitic alteration (as defined by Lowell and Guilbert, 1970) occurs in relatively small areas within the deposit and in zones peripheral to it. It is characterized by weak to moderate alteration of plagioclase to clay, some sericite, epidote, clinozoisite and calcite, and by alteration of biotite to chlorite and epidote. Thermogravimetric analyses of composite samples, suggest that a calcite-rich zone, with calcite contents up to 4.2 percent, surrounds the deposit. By comparison calcite contents within the deposit are about 1 percent. Despite these data, a zone of propylitic alteration spatially associated with the Valley Copper deposit is difficult to define because propylitic minerals have been developed in the country rocks on a regional scale.

2. Pervasive sericitic and kaolinitic

Pervasive sericitic and kaolinitic alteration is gradational from the propylitic type. It includes rocks in which plagioclase has been altered to a soft, white or green, very fine grained variable mixture of sericite and kaolinite, and biotite which has been chloritized or partly to completely sericitized.

X-ray and thermogravimetric analyses showed kaolinite to be the dominant clay mineral species in the deposit, although some montmorillonite occurs on its west side (Jones, 1975). Pervasive alteration tends to be strongest where fractures are most closely spaced whereas propylitic alteration characterizes areas of little or no fracturing. Where pervasive sericitic and kaolinitic alteration is most intense (Figure 5) plagioclase has been completely altered to a mixture of sericite, kaolinite, quartz and calcite. In these areas biotite has been completely altered to sericite, siderite, kaolinite and quartz; K-feldspar weakly altered to sericite and kaolinite; and magnetite pervasively hematitized. Chalcopyrite, pyrite and sphalerite are present in trace amounts.

The distribution of pervasive sericitic and kaolinitic alteration on the 1158m level is shown in Figure 3. The strongest alteration, with greater than 40 percent plagioclase alteration, occurs in a horseshoe-shaped zone which closely coincides with the distribution of areas of copper content greater than 0.50 percent. Zones of moderate pervasive sericitic and kaolinitic alteration, plagioclase alteration ranging from 15 to 40 percent, extend an average of 100m beyond the 0.30 percent copper contour. Beyond this point propylitic alteration becomes dominant. Thermogravimetric data suggests that kaolinite is preferentially concentrated relative to sericite in the peripheral regions of the deposit.

The vertical section (Figure 4) shows moderate to strong pervasive alteration in the zone where copper content exceeds 0.30 percent. Pervasive sericitic and kaolinitic alteration weakens and is replaced by propylitic alteration towards the peripheral regions of the deposit and, to some extent, below the 853m level on the west side of the deposit. A large low-grade embayment in the central part of the section corresponds to a zone of strong K-feldspathic alteration (Figure 10).

3. <u>Vein sericitic</u>

Vein sericitic alteration, manifested by replacement zones and envelopes around quartz veinlets (Figure 5), is the most common alteration type associated with copper mineralization at Valley Copper. Sericite replacement zones follow fractures and range in width from about 0.5 to 30mm. They typically show irregular, diffuse contacts with adjacent rock (Figure 5) and are often vuggy. Occasionally they contain narrow, discontinuous quartz veinlets, thus grading into the veinlet envelope type. Sericitic envelopes marginal to quartz veinlets range in width from 0.5 to 25mm. Envelope widths do not correlate well with the thickness of associated quartz veinlets.

Sericite replacement zones and veinlet envelopes consist predominantly of fine grained quartz and medium grained sericite ($2M_1$ type). Minor constituents are calcite, brick-red hematite, highly sericitized and kaolinitized feldspar, sericitized biotite, bornite, chalcopyrite and trace amounts of pyrite and molybdenite.

The mineralogy and contact relationships between vein sericitic replacement zones and sericitic envelopes are very similar and transitional types are occasionally observed. It may be that the only difference between them is that, in the case of veinlet envelopes, reopening of the original fracture controlling the alteration zone allowed the passage of later solutions which deposited quartz. The sharpness of the contact between the quartz veinlet and its envelope and the common development of a thin selvage of oriented sericite flakes along the contact support this hypothesis.

The relationship of vein sericitic alteration zones to the adjacent pervasively altered rock is not entirely clear. It might be argued that the two represent different products of the same process. The fine grained pervasive sericitic and kaolinitic alteration zones which grade outward from areas of vein sericitic development might constitute transitional zones between vein sericite and weakly propylitized to unaltered rocks. However, occasionally replacement zones and veinlet envelopes have sharp contacts and apparently cross-cut pervasively altered rock. This suggests that solutions causing pervasive sericitic and kaolinitic alteration preceded solutions causing the coarser grained vein sericitic alteration but both followed the same channelways.

The distribution of vein sericitic alteration on the 1158m level is shown in Figure 6. The zone of moderate vein sericitic alteration (5 to 15 percent) closely follows the 0.30 percent copper contour but extends slightly beyond it. The areas of strongest vein sericitic alteration (greater than 15 percent) are closely coincident with areas of greater than 0.50 percent copper. Distributions in the vertical section are similar (Figure 7).

4. <u>K-feldspathic</u>

K-feldspathic alteration is common at Valley Copper, especially at deeper levels. It occurs in association with vein sericite in some replacement zones, as veinlet envelopes, along fractures and disseminated in quartz veinlets.

K-feldspar associated with vein sericitic alteration typically forms thin, discontinuous selvages (about 1mm thick) at the outer margins of sericitic replacement zones where it apparently replaces sericitized plagioclase or vein sericite. Secondary K-feldspar also occurs as thin, fracture-controlled replacement zones (Figure 8) but is more common in quartz veinlets. In the latter K-feldspar is either disseminated in the veinlet or forms well-defined envelopes marginal to it (Figure 9). The envelopes consist of 70 percent K-feldspar, 15 percent quartz, 10 percent sericitized plagioclase, 4 percent medium grained sericite and minor amounts of anhydrite. Copper mineralization is typically sparse with this type of alteration and consists of chalcopyrite with trace amounts of bornite and molybdenite.

The composition of secondary K-feldspar in the Valley Copper deposit ranges from Or_{88} to Or_{98}. This is very similar to the compositional range of primary K-feldspar of the host rocks (Or_{85} to Or_{95}).

The distribution of K-feldspathic alteration in vertical section is shown in Figure 10. Here the upper part of the zone of moderate K-feldspathic alteration (5 to 15 percent), which forms a lensoid or mushroom-shaped body with an upper surface largely below the 1036m level, conforms closely to the gypsum line. Within the lense are found scattered areas of more intense alteration (15 to 35 percent). The low grade copper zone in the central part of the section is a clear expression of the poor correlation of copper mineralization and K-feldspathic alteration.

5. Quartz veinlet stockworks and silicic alteration

Quartz veinlets in the form of a stockwork are a common feature at Valley Copper and typically are about one to two centimetres in width, although some are up to 25cm. Silicic alteration is restricted to secondary quartz produced by the sericitization and kaolinitization of plagioclase.

The quartz stockwork consists of two main classes of quartz veinlets. The first, which is commonly vuggy, usually has envelopes of medium grained sericite, intergrown sericite/K-feldspar or K-feldspar. Veinlets of this class are closely associated with mineralization. They vary in grain size from 0.4 to 2.5mm (average 1.5mm). The veinlets often contain minor amounts of sericite, sericitized plagioclase, secondary K-feldspar, calcite, hematite, bornite, chalcopyrite, pyrite, molybdenite, digenite and covellite.

The second class of quartz veinlets have no alteration envelopes and carry essentially no sulfides. Veinlets of this class are most abundant in the southeastern part of the deposit where they comprise two types: a fine grained variety, varying in grain size from 0.2 to 1.0mm (average 0.5mm) and a medium grained variety (Figure 11) with grain sizes from 1.0 to 1.5mm (average 1.3mm). Both types have sharp contacts with the unaltered or pervasively altered country rocks. They usually contain minor K-feldspar but medium grained sericite is notably absent.

The distribution of silicic alteration and quartz veinlets on the 1158m level (Figure 12) is based on the abundance of secondary quartz. Quartz contents are expressed as the actual percentage minus the background primary quartz content of the unaltered country rock (29 percent). The 10 percent secondary quartz contour outlines the deposit. In areas of greater than 0.50 percent copper levels of secondary quartz range up to about 20 percent. The very low grade zone in the southeastern corner of the deposit is highly silicic with secondary quartz contents ranging from 19 to 27 percent. It should be stressed that these secondary quartz percentages comprise both barren and mineralized quartz veinlets and a component, which is approximately three quarters of the total secondary quartz content, formed by the liberation of SiO_2 during alteration of plagioclase to sericite and kaolinite.

6. Biotitic

Minor amounts of secondary biotite (brown to green) replace primary biotite and less commonly plagioclase, or form thin veinlets and replacement patches. Secondary biotite does not appear to form distinct alteration zones.

7. Post-mineralization veining

Late stage gypsum, anhydrite, kaolinite and fluorite veinlets occur at Valley Copper. Gypsum veinlets, which are the commonest type, are fracture-fillings generally less than 2mm in width. They form white to orange, fibrous, crystal aggegates which are oriented perpendicular to wall rock contacts. Gypsum is most common in areas with K-feldspar alteration. It is rare above the 1036m level (See Figure 10).

8. Alteration history

The main alteration types at the Valley Copper deposit display, to some extent, overlapping periods of formation. However, certain general trends, as indicated by cross-cutting relationships, can be defined:

i) fracture-controlled vein sericitic alteration appears to be younger than pervasive sericitic and kaolinite alteration but is consistently cross-cut by quartz veinlets with vein sericitic alteration envelopes.

ii) pervasive sericitic and kaolinitic alteration and vein sericitic alteration are typically cut by quartz veinlets with associated secondary K-feldspar.

iii) gypsum veinlets cut all alteration types.

The age of barren quartz veinlets with no alteration envelopes is uncertain. They generally cut both vein sericitic and K-feldspathic replacement zones, but in some cases are cut by vein sericitic alteration. That is, there are at least two generations of barren quartz veinlets.

Potassium-argon ages of hydrothermal alteration from hydrothermal sericites range from 198 $\pm$ 4 m y (Jones, 1975) to 189 $\pm$ 6 m y and 186 $\pm$ 8 m y (Blanchflower, 1971 and R. Wanless pers. comm., 1971 respectively). These results suggest that the age of the hydrothermal alteration (average 191 m y) although slightly younger is not significantly different from the age of crystallization of the batholith which is 198 $\pm$ 8 m y (Northcote, 1969).

SULFIDE MINERALOGY

Sulfides in the Valley Copper deposit occur chiefly as disseminations in quartz veinlets and in vein sericitic and K-feldspathic alteration zones. The greater part of the copper mineralization is in areas with abundant vein sericitic alteration and associated quartz veinlets. Bornite is the dominant sulfide in this sericitic association, whereas chalcopyrite is the dominant sulfide associated with K-feldspathic alteration.

1. Primary sulfides

Primary sulfides in the Valley Copper deposit are bornite and chalcopyrite along with minor amounts of digenite, covellite, pyrite, pyrrhotite, molybdenite, sphalerite and galena. In polished sections bornite and chalcopyrite have simple mutual boundary relationships, as well as atoll-like textures in which bornite surrounds a core of chalcopyrite. Exsolution lamellae of chalcopyrite in bornite are common. Digenite and covellite occur as irregular rim-like replacements of bornite and, to a lesser degree, of chalcopyrite. Some pyrite grains are brecciated and cemented with chalcopyrite. Pyrrhotite, sphalerite and galena often occur together and exhibit mutual boundary relationships. Molybdenite occurs chiefly with chalcopyrite with or without pyrite in quartz veinlets which cross-cut zones of vein sericitic alteration (M. Casselman, pers. comm., 1975). Petruk (1970) reported minor amounts of gudmundite (FeSbS) and native gold. The sequence of the sulfide formation based on cross-cutting, filling, and rimming relationships is as follows: pyrite I; chalcopyrite I; bornite; molybdenite, pyrite II and chalcopyrite II; sphalerite with minor pyrrhotite and galena; digenite and covellite. The position of sphalerite, pyrrhotite and galena in the sequence is not certain.

Bornite/chalcopyrite ratios and pyrite content on the 1158m level plan are shown in Figures 13 and 14. Bornite/chalcopyrite ratios on the 1158m level show a distinct high zone (greater than 3.0) in the central part of the deposit. Smaller highs occur in the southern and southwestern parts of the deposit. Bornite/chalcopyrite ratios decrease progressively away from the centre of the mineralized zone until outside the 0.30 percent copper contour bornite is uncommon.

Pyrite abundance on the 1158m level in the central part of the deposit (Figure 14) is less than 5 percent of the total sulfides. There is, however, a pronounced halo around the periphery of the deposit where pyrite ranges up to 62 percent of the total sulfides. Even in this halo pyrite rarely exceeds one volume percent of the rock.

2. Oxidized zone

The typical mineral assemblage in the oxidized zone consists of limonite, malachite, pyrolusite, digenite, native copper and possibly tenorite. It generally varies in thickness from 0.3 to 14m and averages 4.5m. However, in the southeastern corner of the deposit where the thickness ranges from 18 to 98m it averages 33m. Profiles of copper grades in the southeastern area show a slight depletion of copper from 0.45 to 0.35 percent in the unoxidized and oxidized zones respectively. Grades range up to 0.65 percent copper in a zone 3 to 6m thick that occurs just below the oxidized zone; this probably represents a poorly developed zone of supergene enrichment.

GEOCHEMISTRY

The chemical uniformity of the host rocks of the Valley Copper deposit greatly facilitates the study of chemical variations resulting from mineralization and hydrothermal alteration. Gains and losses of various elements are described in the following section as weight percent variations rather than the more conventional gm/cc, because only partial analyses are available. Density variations throughout the deposit range only from 2.67 gm/cc for fresh Bethsaida granodiorite to 2.62 gm/cc for typical altered zones and are not considered significant.

Table 2 shows the contents of major and trace elements in fresh Bethsaida granodiorite, relative to those in composite samples of different alteration types from various parts of the deposit.

1. Geochemical patterns related to hydrothermal alteration

i) Elements depleted in the deposit

CaO, Na_2O, MgO, Sr, Ba and Mn decrease from the peripheral zone of the deposit, where propylitic and pervasive sericitic and kaolinitic alteration are present, to the central area where vein sericitic and pervasive sericitic and kaolinitic alteration are best developed (see Table 2). The percentage decrease is 4.5 to 2.4 for Na_2O, 2.9 to 1.5 for CaO and 588 to 396 ppm for Sr. Manganese forms a distinct halo, about 300m wide, peripheral to the deposit, in which values are double those in the central part of the deposit and up to one and a half times those of unaltered Bethsaida granodiorites.

The distribution of CaO and Na_2O on the 1158m level and in vertical section A-B are shown in Figures 15 and 16 respectively. These diagrams closely resemble the distribution diagrams for pervasive sericitic and kaolinitic alteration (Figures 3 and 4) and demonstrate that this type of alteration extends up to 300m beyond the 0.30 percent copper contour. CaO and Na_2O depletion and mineralization bottom out on the western side of the deposit (around hole 68-4) whereas on the eastern side (between holes 68-30 and 68-18), the zone of strong CaO and Na_2O depletion and copper mineralization extends downward below the 792m level.

TABLE 2

CHEMICAL VARIATIONS OF SELECTED ELEMENTS

IN ALTERATION ZONES OF THE VALLEY COPPER DEPOSIT (1097 and 1158m levels)

			Fresh Bethsaida granodiorite (typical values)	Propylitic (peripheral)	Pervasive sericitic and kaolinitic (marginal)	Vein sericitic (central)	K-Feldspathic (central)	Silicic (southeast, barren quartz veinlets)
	Number of composite samples			6	8	8	2	5
1.	SiO_2	(weight percent)	68.9	71.2* (69.1-73.3)	71.6 (68.8-74.4)	73.1 (71.7-74.5)	74.9	77.0 (74.6-78.4)
2.	Fe	"	1.5	1.5 (1.2 - 1.8)	1.6 (1.2 - 2.0)	1.7 (1.5 - 1.9)	1.5	1.3 (1.0 - 1.6)
3.	MgO	"	0.5	0.5 (0.4 - 0.6)	0.4 (0.3 - 0.5)	0.5 (0.4 - 0.6)	0.4	0.3 (0.2 - 0.4)
4.	CaO	"	3.2	2.9 (2.6 - 3.2)	2.6 (2.2 - 3.0)	1.5 (0.9 - 2.1)	1.3	2.1 (1.7 - 2.5)
5.	Na_2O	"	4.8	4.5 (4.2 - 4.8)	2.9 (2.3 - 3.5)	2.4 (2.0 - 2.8)	2.9	3.1 (2.5 - 4.[illegible])
6.	K_2O	"	1.9	2.0 (1.7 - 2.3)	2.7 (2.3 - 3.1)	3.8 (3.7 - 3.9)	3.7	2.0 (1.2 - 2.8)
7.	Cu	(ppm)	10	640 (380 - 900)	2060 (1210-2910)	4456 (3535-5415)	3550	2300 (900-3690)
8.	Mo	"	1	72 ($<$1 - 151)	95 (45 - 145)	36 (24 - 48)	26	40 (8 - 72)

			Fresh Bethsaida granodiorite (typical values)	Propylitic (peripheral)	Pervasive sericitic and kaolinitic (marginal)	Vein sericitic (central)	K-Feldspathic (central)	Silicic (southeast, barren quartz veinlets)
9.	Zn	(ppm)	29	427 (< 1-1055)	95 (< 1- 227)	34 (< 1 - 85)	32	37 (12 - 62)
10.	Mn	"	370	380 (310 - 452)	520 (350 - 690)	297 (293 - 401)	320	340 (195 - 485)
11.	Ag	"	0.1 to 0.6**	< 1	1.5	2.4	2.3	1.0
	Number of composite samples			6	11	12	10	7
12.	B	(ppm)***	5	5	9 (4 - 19)	8 (5 - 13)	6 (4 - 9)	7 (4 - 12)
13.	TiO_2	"	3000	980 (650 -1140)	1450 (1140-1800)	1660 (1120-2420)	1640 (1110-2420)	1930 (1350-2730)
14.	V	"	15	15 (10 - 20)	24 (17 - 33)	31 (21 - 44)	34 (24 - 40)	24 (17 - 33)
15.	Ba	"	520	520 (500 - 700)	556 (470 - 659)	481 (389 - 594)	564 (447 - 711)	535 (446 - 541)
16.	Rb	"	36	35 (33 - 37)	57 (45 - 71)	69 (62 - 75)	61 (46 - 76)	45 (39 - 52)
17.	Sr	"	732	588 (550 - 627)	641 (418 - 980)	396 (161 - 969)	617 (391 - 975)	529 (420 - 665)
18.	Hg	(ppb)	10	n.d.	3 (1 - 8)	3 (1 - 8)	2 (1 - 4)	2 (1 - 4)
19.	F	(ppm)	188	n.d.	301 (219 - 415)	428 (334 - 547)	384 (257 - 573)	347 (236 - 510)

	Fresh Bethsaida granodiorite (typical values)	Propylitic (peripheral)	Pervasive sericitic and kaolinitic (marginal)	Vein sericitic (central)	K-Feldspathic (central)	Silicic (southeast, barren quartz veinlets)
20. Cl (ppm)	115	n.d.	264	312	223	245
			(207 - 335)	(233 - 418)	(186 - 276)	(174 - 344)

Footnotes:

* Figures given are arithmetic mean and (in brackets) range of 1 standard deviation
** Brabec (1973)
** Elements 12-20 Olade (1974)
n.d. No data

N.B. Coefficient of variations for analyses of major elements do not exceed 5.8 percent and in general are about 2.4 percent. Trace and minor elements show coefficients of variation of up to 15 percent (1 standard deviation). Olades values for B, Ti, V, Ba, Rb, Sr, Hg, F and Cl are given to supplement data of Osatenko and Harris (1973) on chemical variations in different areas and alteration zones within the Valley Copper deposit (central and western parts). These data are not from the same samples as the major element data, but are from a similar part of the deposit which has remarkably similar major element contents.

ii) Elements enriched in the deposit

SiO_2, K_2O, Rb and TiO_2 increase from the peripheral regions of the deposit to its centre. K_2O which varies from 2.0 to 3.8 percent and Rb which varies from 35 to 69 ppm show the most pronounced increases.

K_2O contents on the 1158m level (Figure 17) show a strong concentric pattern in which the highest K_2O contents generally correspond to areas of best copper grades. This clearly reflects the close association of copper sulfides with vein sericitic alteration zones. The K_2O distribution in vertical section (Figure 18) shows a strong enrichment extending below the 792m level. The contacts of the K_2O enriched zone are subparallel to the outer contacts of the deposit.

The contents of SiO_2 rise from 71.2 percent in the periphery to 75.6 percent in the core zone coincident with good copper grades and reaches 77.0 percent in the area with abundant barren quartz veinlets in the southeastern part of the deposit (Figures 19 and 20).

2. Chemical patterns related to mineralization

i) Ore elements

The diagram of copper distribution for the 1158m level (Figure 21) shows that the zone containing greater than 0.30 percent copper is roughly oval in plan (1372m by 914m, long axis striking 130°). Several areas of greater than 0.50 percent copper occur within the 0.30 percent copper contour and a zone about

300m in width containing between 0.10 and 0.30 percent copper is peripheral to it. In vertical section (Figure 22) the zone of greater than 0.30 percent copper shows two distinct extensions to depths around a west-central low grade zone.

Molybdenum and zinc (Figures 23 and 24 respectively) form distinct halos marginal to and generally outside the 0.30 percent copper contour. Values in the molybdenum halo range from 50 to 530 ppm over a width of 300m while values in the zinc halo range from 50 to 1700 ppm. Within the deposit molybdenum averages about 30 and zinc 20 ppm respectively.

Silver values are less than 1 ppm outside the deposit and range to 2.4 ppm in the zone of strong vein sericitic alteration. Analyses of sulfide concentrates suggest that silver is concentrated in bornite, which contains about 270 ppm, relative to chalcopyrite with 30 ppm.

ii) Pathfinder elements

Elements referred to by Olade (1974) as "pathfinder" elements are Hg, B, Cl and F. Mercury values range from 1 to 52 ppb and average 3 ppb. Boron dispersion is erratic, although values exceeding 11 ppm are generally confined to the outer margins of the deposit, especially along its northwestern fringe. Chlorine values are generally in the range of 160 to 350 ppm whereas the regional background is 115 ppm; however, the few erratic values which exceed 300 ppm are confined to the deposit. Fluorine values exceeding 564 ppm occur principally in the area immediately northwest of the deposit; elsewhere fluorine contents are more typically between 250 and 500 ppm. Regional background is about 188 ppm.

3. Isotopic studies

i) Sulfur isotopes

The $\delta\ S^{34}$ permil values of 12 sulfide and 4 sulfate mineral concentrates are as follows: pyrite - 3.08, sphalerite - 4.11, chalcopyrite - 3.30 to + 1.53, bornite - 0.94 to + 1.45, molybdenite + 0.50, anhydrite + 11.76 and + 14.48 and gypsum + 13.13 and + 15.22.

The isotopic composition of Valley Copper sulfides are characteristic of Cordilleran hydrothermal deposits with magmatic associations which formed at relatively high temperatures in having near zero permil mean values and small standard deviations (Field, 1966; Jensen, 1967 and Field and others, 1971). A deep or mantle source (typical range of $\delta\ S^{34}$ values for mantle sulfur is - 0.3 to + 3.0 permil) for the sulfur in sulfides is consistent with the probably deep source of the Guichon Creek magma based on Sr^{87}/Sr^{86} ratios (Chrismas and others, 1969).

The $\delta\ S^{34}$ value of about + 13.6 permil in the sulfates precludes their derivation by supergene oxidation of sulfides. More likely the sulfates precipated from a hydrothermal solution that contained seawater sulfate. This is substantiated by the $\delta\ S^{34}$ value of + 13.1 permil for late Triassic seawater (Holser and Kaplan, 1966 and Sangster, 1971).

ii) Oxygen and hydrogen isotopes

The $\delta\ O^{18}$ permil values of hydrothermal mineral concentrates from 9 quartz, 6 K-feldspar, 6 sericite and 4 kaolinite samples show the following respective ranges: + 8.74 to + 12.51, + 7.65 to + 8.74, + 6.60 to + 7.56 and + 6.73 to

+ 11.31. Corresponding ranges of δ D permil values of 6 sericite, 3 kaolinite and 2 primary biotite samples are - 64.8 to - 53.1, - 116.0 to - 95.2 and - 94.5 to - 73.6 respectively.

Equilibration temperatures calculated from oxygen isotope pairs of co-existing minerals (Jones, 1975) suggests a range of temperatures from 260°C for early pervasive sericitic alteration to 480°C for K-feldspathic alteration. Temperatures calculated from three sulfur isotope pairs range from 266°C for pyrite-sphalerite in a zone of pervasive sericitic and kaolinitic alteration to 480°C for anhydrite-bornite in secondary K-feldspar. The bulk of the vein sericitic alteration and mineralization apparently took place at about 400°C, with a range from 370°C to 500°C, over a depth interval of 550m. Temperatures ranged from about 500°C in the deeper, central part of the deposit to about 300°C near the periphery.

The isotopic compositions of hydrothermal fluids and average magmatic water at Valley Copper were calculated from the oxygen and hydrogen isotopic values of 6 samples of sericite and 2 samples of primary biotite, respectively. The sericite and fluid compositions, along with the isotopic compositions of meteoric, ocean (SMOW) and magmatic waters (Craig, 1966, 1969; Taylor, 1967) are plotted in Figure 25. The isotopic compositions of Valley Copper hydrothermal waters plot on or near a line that connects SMOW with the average composition of primary magmatic water. That is, the hydrothermal fluid was apparently a mixture of seawater and magmatic waters. The degree of mixing is estimated to range from 16 to 44 percent SMOW for the main period of sulfide deposition (average is about 25 percent).

It is noteworthy that a mixing model of meteoric and magmatic waters is proposed for some porphyry copper deposits in Arizona (Sheppard and others, 1969 and Sheppard, 1971).

4. Geochemistry of the hydrothermal fluid

i) Fluid inclusions

Fluid inclusions in mineralized quartz veinlets from the Valley Copper deposit are extremely small, about 0.005mm in diameter, and tend to occur in planar clusters and linear zones. Most are composed of 70 to 80 percent liquid and 20 to 30 percent gas phases, although daughter crystals of chloride and carbonate have been optically identified. Average salinity as indicated by freezing techniques is 5 weight percent (R. Schmuck, pers. comm., 1975). A few inclusions contain liquid CO_2 indicating pressures up to 100 to 300 bars and a depth of formation of about 1 to 2 km.

The structurally dependent arrangement and low homogenization temperatures ($< 200^\circ C$) of the fluid inclusions suggest formation by dominantly secondary processes, perhaps during the waning stages of hydrothermal activity (R. Schmuck, pers. comm., 1975).

ii) Sericite stability

The three principal alteration minerals at Valley Copper are kaolinite, sericite and K-feldspar. Of these sericite is the most directly associated with copper mineralization and accordingly, the chemical environment during the main period of copper deposition must have been in the stability field of sericite. Conditions of fO_2, fS_2 and pH of the hydrothermal fluid that deposited sericite are estimated from a diagram by Field and others (1971) and shown in Jones (1975) on page 219. This diagram is for the system Cu-Fe-S-O and shows the stability fields of alteration silicates and sulfides contoured for pH (Figure 26).

A summary of the apparent conditions of the hydrothermal fluid during the main period of copper mineralization is as follows:

$$- \log fO_2 = 21.8 \text{ to } 23.0$$
$$- \log fS_2 = 1.8 \text{ to } 2.7$$
$$pH = 2.2 \text{ to } 3.1$$

Ranges over the whole of the alteration sequence are: $- \log fO_2$ of 21.6 to 23.4, $- \log fS_2$ of 1.5 to 4.5 and a pH of 1.7 to greater than 4.0.

GENETIC SYNTHESIS

The copper-rich magma of the Guichon Creek batholith was probably derived from a subcrustal source with the ore metals and hydrothermal fluids probably derived from it by processes of differentiation. It is likely, however, that seawater was contributed to the magmatic hydrothermal system.

The purpose of this part of the paper is to summarize the sequence of major events leading to formation of the Valley Copper deposit. They are believed to have been as follows:

1. The Bethsaida granodiorite was intruded in Upper Triassic time about 198 ± 8 m y ago.

2. Movement on the Lornex and Highland Valley faults initiated a zone of intense fracturing in Bethsaida granodiorite near the fault intersection.

3. Pre-mineralization aplite, granodiorite and quartz diorite porphyry dykes were injected along northerly and easterly trends.

4. Hot, saline fluids moved upward in the zone of fracturing and mixed with downward percolating seawater to produce a fluid with a temperature of about 260°C, pH about 1.7 and $-\log fS_2$ of about 4.5. This fluid reacted with and leached Na_2O and CaO while adding K_2O and H_2O to the wall rocks. This stage of alteration produced extensive pervasive sericitic and kaolinitic alteration with associated trace amounts of pyrite and chalcopyrite.

5. A continued influx of magmatic hydrothermal fluids and seawater gave rise to a hydrothermal fluid with a temperature about 400°C, slightly higher pH of 2.2 to 3.1, and a lower $-\log fS_2$ of 1.8 to 2.7. These fluids reopened many of the access channelways used by previous hydrothermal fluids and produced vein sericitic alteration. Deposition of main stage copper mineralization occurred during this stage, probably as the result of increased sulfur ion concentration.

   Tan felsite dykes, of syn-mineralization age, were also intruded at this time.

6. In the main part of the deposit a further influx of fluids again reopened the old channelways and formed quartz veinlets containing vugs lined by or filled with bornite and chalcopyrite.

7. Continued fracturing of the rock mass occurred along with formation of quartz veinlets with disseminations and envelopes of secondary K-feldspar. The pH of the hydrothermal fluid at this stage probably continued to increase to about 4.0, while - log fS_2 probably increased slightly to about 3.5. Mineralization of this stage was limited to minor amounts of chalcopyrite, probably as a result of further decreased sulfur fugacity. Chemically, this stage is characterized by a pronounced increase of K_2O and SiO_2 and a marked decrease of H_2O, relative to zones with pervasive and vein sericitic alteration.

8. Further fracturing occurred followed by deposition of essentially barren quartz veinlets from hydrothermal fluids of still further increased pH and - log fS_2.

9. In close spatial association with previously formed secondary K-feldspar fractures were re-opened and gypsum deposited. The hydrothermal solutions were rich in seawater sulfate.

10. Lamprophyre dykes were intruded about 132 $\pm$ 3 m y ago.

11. During subsequent uplift and erosion the overlying rocks and the upper part of the deposit were removed and an oxidized zone and weak supergene

blanket developed. Glaciation followed by glaciofluvial deposition and continued erosion produced the present day surface.

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VALLEY COPPER

A CASE HISTORY

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By

J. Allen
Cominco Limited

MINING

J. M. Allen

Mr. Allen was born in Toronto and grew up in Southern Ontario. After brief service with the R. C. A. F. in World War II he entered Queens University graduating with a B.Sc. (Geology) in 1949. On leaving University Mr. Allen went to work for Dominion Gulf Company and worked in various parts of Quebec and Ontario until 1953. In 1953 taking the opportunity to work in Africa he accepted a position with Union Carbide and Carbon Corp. and for the next two years worked in Angola and Surinam. On returning from South America in 1955 Mr. Allen entered Syracuse University graduating with an M. A. in 1956. This was followed by three years at Yale University where he earned the Ph.D. Degree in 1959.

On graduation from Yale Mr. Allen accepted a position with Steep Rock Iron Mines and remained with that company until 1963 when he left to join Cominco Limited in British Columbia.

Mr. Allen became associated with the Valley Copper project in 1965 and has remained with it to the present developmental stage.

Mr. Allen is married and has a 17 year old daughter. The family lives in West Vancouver and their main hobby is Vancouver.

During the past five years, the Highland Valley area of British Columbia has been the site of two major copper discoveries, Valley Copper and Lornex. A third discovery, Highmont, may also prove to be of major importance. Taken with the existing producers, Bethlehem and Craigmont, these potential orebodies suggest that the Highland Valley area may become one of the major copper areas of the world.

The location of the major discoveries, current producers and more promising showings is shown on the accompanying sketch (Fig. 1). All of these are within or at the contact of the Guichon batholith, a concentrically zoned body of quartz diorite composition emplaced about 200 million years ago in Upper Triassic time. The deposits and showings discovered to date have many features in common and all are genetically linked to magmatic processes in the Guichon batholith. The purpose of this paper is to comment on the discovery of one of them, Valley Copper, and to describe what is presently known about the deposit.

GEOLOGICAL SETTING

The Guichon batholith is a roughly oval body at least 24 miles long and up to 15 miles wide. Its long axis strikes 345^{o}. The batholith is bounded on the east and west by major north trending faults and according to Carr these faults delimit an up-faulted block of Cache Creek and Nicola rocks into which the batholith has been intruded. The rocks of the batholith are overlain by four later groups consisting largely of volcanics ranging in age from Middle Jurassic to Eocene. The age of the batholith is on geological evidence limited to the interval between early Upper Triassic and Middle Jurassic.

Isotopic ages on rocks of the batholith, 55 of which have now been published, show a remarkable concordance. The average for all of these ages is 196 million $\pm$ 8 M.Y. and the spread is from 184 to 206 M.Y. Most of these ages were done by the K/A method and the possibility of Argon loss has to be considered, however, six Rb/Sr ages from the Craigmont mine agree very closely, i.e. 200$\pm$ 2 M.Y. and this plus the lack of evidence of metamorphism which might have caused Argon loss shows that the ages are probably reliable. On the absolute time scale, this would place the time of consolidation of the Guichon rocks in the Upper Triassic.

The isotopic ages also show that there is no significant or systematic difference in age among the various phases of the intrusive, It would appear that all of the phases crystallized within a short interval and that multiple intrusion, if it did occur, must have been over a short period as well.

INTERNAL STRUCTURE OF THE BATHOLITH

The gross structural pattern in the batholith is shown, best by the distribution of intrusive phases. These phases are arranged in a concentric pattern around a central core of Bethsaida quartz monzonite. The Witches Brook phase displays cross-cutting relationships, but this rock type occurs only in dikes and relatively small irregular masses and since its distribution was probably controlled by local structure, it does not really disrupt the overall pattern.

The type and distribution of phases is shown on the accompanying figure. In all, there are seven distinct phases, two of which are subdivided into five varieties and a late porphyritic phase. There is no significant difference in the absolute ages of the phases, however, there is geological evidence that age increases from the core outward. The outer or hybrid phase, is the oldest and forms a shell up to five miles thick between the intruded rocks and the younger phases of the batholith. Its composition is generally quartz dioritic but this is variable and characteristically this phase contains partially assimilated blocks and fragments of the country rock. The contacts of the hybrid phase are generally gradational grading outward to Nicola or Cache Creek rocks and inward to the Guichon variety of the intrusive. The hybrid shell is much thicker on the western side of the batholith, i.e. 3 to 5 miles vs. ½ - 1 mile and this suggests that the whole batholith may have been tilted eastward by differential movement on the bounding faults.

The later phases are all granodiorites or quartz monzonites and distinction of them is based primarily on textural and mineralogical features and not on bulk compositional differences. There is, however, a decrease in specific gravity, i.e. from 2.80 to 2.64 from the hybrid to the Bethsaida phase that could reflect increasing differentiation. With the exception of the contaminated hybrid shell, the various phases are very similar and the differences among them probably resulted mostly from changing pressure and temperature conditions during intrusion.

Smaller structures within the batholith include faults, shears, breccia and shatter zones. Dikes and dike swarms, which are common, probably reflect another type of structure. The most common direction for linear structures is north-south and the majority of dikes follow this trend. The most notable of these structures is the Lornex fault which bisects the Bethsaida quartz monzonite. Faults and shear zones striking northeast are less common and a third set striking northwesterly, though not obvious, is important in localizing ore, e.g. Alwin, Valley Copper. Breccia zones such as those at Bethlehem, Trojan and on Gnawed Mountain may or may not be related to faulting, since the breccia types vary. However, the Trojan and Bethlehem breccias occur in areas where strong north-south faulting is common and a combination of suitable structural openings and access to volatile charged fluids is certainly suggested as a cause. Shatter zones much as those at Valley Copper, Krain and possibly Lornex occur within or adjacent to major faults and at least in the case of Valley Copper near the intersection of two major structures. The principal difference between the shatter zones and the breccias appears to be that in the shatter zones there was not sufficient space provided by stress release to permit the broken blocks to rotate.

MINERALIZATION IN THE BATHOLITH

Copper mineralization may occur anywhere in the batholith and in any of the various phases. The distribution of producing mines and better known prospects is shown in the accompanying figure. All of these lie close to a north-south line which bisects the batholith and the larger ones except for Craigmont are on or adjacent to a contact of the Bethlehem phase of the intrusive. This latter is suggestive of a genetic relationship with this phase, however, this is probably more apparent than real. All of these mines and prospects are structurally controlled and the mineralization in them is contained in open space fillings formed after the consolidation of the host rock. The significance of the Bethlehem phase and its contact is therefore limited to the influence each has had on the development of structures suitable for ore deposition. Similarly, the north-south zoning may reflect a concentration of deep seated north trending structures formed after differentiation had proceeded far enough to create a reservoir of copper bearing solutions. That this reservoir has been tapped by other structures is apparent from the wide distribution of copper within the batholith, however, structures large enough and continuous enough to contain sizeable orebodies appear at this time to be limited to the central zone.

The mineralization is quite similar from one mine or showing to another. Chalcopyrite is the most common copper mineral however, with the exception of Craigmont, the one producing mine (Bethlehem) and all of the potential producers contain bornite in amounts sufficient to determine the viability of the operation. Pyrite is a common associate of copper, but its amount varies considerably, e.g. at Bethlehem there is a heavy pyrite zone on the southwest side of the Jersey orebody while at Craigmont and Valley Copper pyrite is extremely scarce. The most common iron mineral in terms of occurrence is hematite. This mineral is ubiquitous in copper occurrences, but rarely does it occur in amounts greater than 3 percent, Craigmont being a notable exception. The widespread occurrence of hematite suggests that the mineralizinq solutions had a relatively high Eh such as might be expected in a highly aqeous environment. What effect this may have had in the partition of Fe, S and Cu is unknown, but in many deposits it appears that in the competion for sulphur, Cu was favoured over iron and perhaps the oxidation state influenced this. The source of sulphur has been the subject of two recent publications. Christmas, Baadsgaard, et al conclude from a study of S, C and O isotope ratios of Craigmont ore that the sulphur of the ore is of mantle origin and therefore from a deep source. M. P. Schau in a reply to this says that sulphur from assimilated Nicola basalts is just as likely a source since this sulphur would have mantle ratios too. As it now stands, the source of the sulphur is open to question, however the nature of the copper deposits and their relationship to deeply penetrating structures suggests that the copper and sulphur did come from some depth and could well be of mantle origin.

STRUCTURAL SYNTHESIS

The sequence of events leading to the discovery of the Valley Copper orebody started in 1964 with the formation of Valley Copper Mines Limited. This company, at that time, held various groups totalling 425 claims. Evaluation of these groups began immediately and during 1964, 1965, and 1966 various kinds of exploration programs were carried out on all of them. By 1966, a considerable amount of information had been gained from this work and this was used along with published data to produce a geological compilation of the batholith area. To supplement this, a study of aerial photographs was made and this was combined with the known geology to provide a structural interpretation.

The Lornex discovery in 1966 served to draw attention to the Lornex fault and at about the same time new aerial photographs of the area became available. These photographs clearly show the southern extension of this fault for some eight miles, along Skuhost Creek valley. The northern extension beyond Lornex is obscured by steep topography but clearly if the fault is string straight for eight miles, its northern extension should be as well. Thus projection of the fault north through Divide Lake seemed reasonable. Intersection with an inferred structure under Highland Valley was more conjectural for there was not then and there is not now any direct evidence of faulting under Highland Valley. In any case, however, the area adjacent to the conjectured intersection of two large fault structures was considered to provide a worthwhile exploration target.

Another possibility suggested by the location of the Lornex orebody in or adjacent to the Lornex fault was that the orebody might have a displaced portion somewhere along the west side of the fault. At that time, neither the sense nor amount of movement along the Lornex fault was known, however, the occurrence of copper mineralization on the Bethsaida claims suggested a relationship. If indeed the Lornex and Bethsaida mineralization were related, then right-hand movement of about 2 miles was indicated. Particularly suggestive of this was the low grade copper mineralization south of the Lornex orebody and in the southeastern part of the Bethsaida group as indicated by drilling in 1966. If these two areas of low grade mineralization were correlative, then the same spatial relationship could pertain on the Bethsaida group as did at Lornex. In this case, ore grade mineralization should be to the north or northeast.

This rather speculative interpretation needed further support and this was provided by the information compiled in 1966. This compilation in view of the possible importance of the Lornex fault was directed toward trying to find supporting evidence for the supposed right-hand movement of some 2 miles. It was found that the south contact of the Bethsaida quartz diorite had an apparent northward displacement on the west side of the Lornex fault. The amount of this displacement could not be measured accurately but was definitely of the same order as the distance between Lornex and the Bethsaida group.

This supporting evidence made the faulted offset hypothesis a good deal more tenable and suggested that the northeast quarter of the Bethsaida group would be a good exploration target. A second and supporting indicator was the possibility of a major fault intersection directly east of this same area under Divide Lake.

A number of factors have contributed to the discovery of the Valley Copper orebody. One of the most important of these was the realization early in the Valley Copper program that mineralization is always related to structure, particularly open space fillings. In the Guichon batholith there is little, if any, truly disseminated sulphides and with the exception of Craigmont, no replacement of host rock. Orebodies and showings, big or small, are invariably contained in breccias, shear zones, veins, shatter zones, etc. of obvious structural origin and the inference is clear that without the structurally prepared plumbing system there would be no mineralization. Also important is the distribution of copper mineralization within the batholith. Any of the major rock units may contain copper showings and in every case the mineralization is younger than the host rock. It thus becomes difficult to prove a genetic relationship to any rock unit and the importance of structure is further emphasized.

Thus the recognition of the possible significance of the Lornex fault and the Highland Valley fault zone was a very important element in the discovery of the Valley Copper orebody.

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Percussion drilling played a very important role in the discovery of Valley Copper and a few comments about the method follow.

In both 1967 and 1968, percussion drilling was done in the Bethsaida group. In both years, the purpose of this drilling was to test a broad area quickly and cheaply simply to see if copper mineralization was present. In each case, the percussion drill accomplished this purpose at about one-third the cost of diamond drilling.

Thus, for the same cost, three times as many holes can be drilled as with a diamond drill and herein lies the real virtue of the percussion drill. Most orebodies are irregular in shape and variable in grade. One hole drilled through an orebody may, because of geometry or grade distribution, miss the ore grade section completely. Even two or more holes may do the same. The obvious solution is to drill a lot of holes and often this may be uneconomic with a diamond drill, but less likely to be so with percussion drilling. However, the depth limitation of 300 feet poses restrictions for the percussion drill.

THE OREBODY

The Valley Copper orebody is roughly oval in plan with its long axis striking about 310°. Its long dimension is at least 4,500 feet and the shorter 3,000 feet. The deepest hole yet drilled in the orebody was still in ore at 2,340 feet. The tonnage potential easily qualifies it as the largest orebody yet found in Highland Valley and work is still proceeding to actually delimit the area of mineralization. Reserves are currently estimated to be of the order of 600,000 ton/vert. feet grading 0.46% Cu.

The geology of the orebody is quite simple for there is only one major rock type, the Bethsaida quartz monzonite. At least two types of porphyry dikes and a variety of Lamprophyre dike cut the orebody, but these are generally narrow and do not bulk large in the geological picture. The geology does not, therefore, offer much insight into the genesis of the ore and geological controls, e.g. contacts, do not appear to have been important in localizing ore.

Structure on the other hand appears to have been a dominating influence. Almost all of the rock in the orebody has been strongly sheared and fractured and there seems ample evidence that the mineralizing and altering solutions were introduced along a structurally prepared system of openings. Two steeply dipping structural directions predominate, 290° - 310° and 340 - 360°. It is along these directions that quartz veins, shears, faults and linear alteration zones are most commonly found. Other subsidiary systems occur and the pattern of quartz veining and fracturing may change across the orebody, however, the two dominant directions are always present. It is probably no coincidence that of the two dominant directions, one (290° - 310°) is parallel to the Highland Valley fault zone and the other (340 - 360°) is parallel to the Lornex fault. This also applies to the dike system. Both fault systems seem therefore to have had some influence on structural development. In addition, there is a set of flat quartz veins and shears which perhaps resulted from the interaction of the two fault systems.

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The alteration types associated with ore are of the classic kind occurring in porphyry copper deposits in other parts of the world. The most common alteration type is argillic which is pervasive throughout the deposit and appears to be early in the mineralizing sequence since it is cut by quartz veins, sericitic and potassic alteration. Argillic alteration is characterized by a chalky, slightly greenish appearnace of the feldspars and by the alteration of the biotite to a pale green mixture of chlorite and sericite. Potassic alteration is next in the sequence and this is marked by the development of potash feldspar. This type of alteration, though widespread, is generally restricted to zones fifty to one hundred feet wide. Mineralization associated with the potassic alteration tends to be largely chalcopyrite.

Sericitic alteration shows the closest relationship to copper mineralization and it may occur in two distinct ways. Copper-bearing quartz veins almost always carry a selvage of coarse sericite. These veins may as they narrow become fine stringers of sericite, granular quartz and copper sulphides, dominantly bornite. Alternatively, sericite and granular quartz may occur in irregular zones up to 20 feet wide impregnated with bornite and chalcopyrite. In general, when sericite is present, copper sulphides are as well.

Silicification is a prominent feature of.the orebody as shown by the great number of quartz veins and the presence of irregular siliceous patches. The amount of quartz observed is in excess of what might be expected from the remobilization of silica originally present in the fresh Bethsaida quartz monzonite and suggests that a good part of it must have been introduced with the mineralizing solutions. Several generations of quartz veins are present including a late barren type. This too might be construed as evidence supporting an epigenetic rather than syngenetic origin for the quartz. Propylitic alteration which commonly occurs on the periphery of porphyry copper deposits, is notable by its absence. Similarly, there is very little pyrite in the orebody and no evidence of a pyritic halo.

In summary, the Valley Copper orebody displays many of the characteristics ascribed to the better known porphyry copper deposits. The lack of a propylitic alteration zone and a pyrite halo probably reflect differences in fluid composition rather than in process and there seems to be little doubt in assigning the deposit to the prophyry copper class.

TESTING PROGRAM

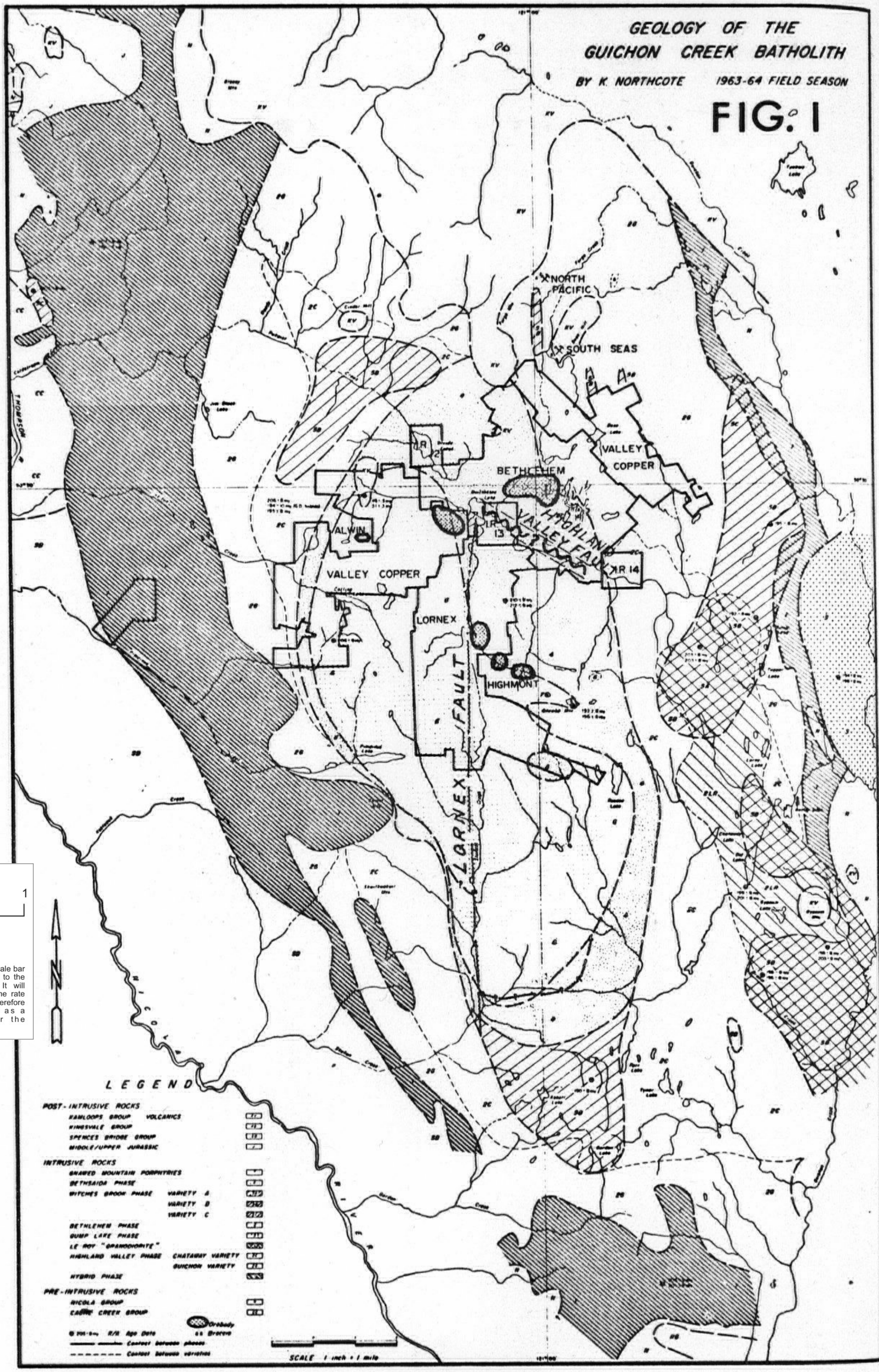
Since May of 1969, a comprehensive testing program has been under way. This program was designed to bulk sample the orebody and to fill in gaps with additional surface and underground drilling.

The underground testing has consisted of driving three inclined headings into the orebody and sampling on a round by round basis. The underground headings were driven at -20% using rubber tired diesel equipment and in plan these headings form an arrowhead pointing southwest. The total footage driven was 4100 feet and the ends of the declines are 500 feet below the portal.

The size of the opening driven was 14' x 11' with an arched back. Each round was mucked, crushed and sampled separately. In order to provide a comparison with diamond drilling, two holes were drilled ahead of the face and the core from these matched to the round lengths to provide three separate samples. This comparison sampling will be done over the entire length of the declines.

Surface diamond drilling has been going on almost continuously since August, 1968, and to date some 90,000 feet have been drilled, almost all of it N.Q. size. Underground drilling started in July, 1969, as soon as working places were available. This program on completion will total 36,000 feet, all B. Q. size.

The testing program is now completed and the information gained from it is currently being assessed. All of this information and the assessment of it will be incorporated into a feasibility study now in progress.


GEOLOGY OF THE GUICHON CREEK BATHOLITH
BY K. NORTHCOTE 1963-64 FIELD SEASON
FIG. 1
NORTH PACIFIC
SOUTH SEAS
VALLEY COPPER
BETHLEHEM
HIGHLAND VALLEY FAULT
IR 2
IR 13
IR 14
ALWIN
VALLEY COPPER
LORNEX
HIGHMONT
LORNEX FAULT
THOMPSON
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BRITISH COLUMBIA GEOLOGICAL SURVEY
LEGEND
POST-INTRUSIVE ROCKS
KAMLOOPS GROUP VOLCANICS
KINGSVALE GROUP
SPENCES BRIDGE GROUP
MIDDLE/UPPER JURASSIC
INTRUSIVE ROCKS
GNAWED MOUNTAIN PORPHYRIES
BETHSAIDA PHASE
WITCHES BROOK PHASE VARIETY A
VARIETY B
VARIETY C
BETHLEHEM PHASE
GUMP LAKE PHASE
LE ROY "GRANODIORITE"
HIGHLAND VALLEY PHASE CHATAWAY VARIETY
GUICHON VARIETY
HYBRID PHASE
PRE-INTRUSIVE ROCKS
NICOLA GROUP
CACHE CREEK GROUP
Orebody
Breccia
R/A Age Date
Contact between phases
Contact between varieties
SCALE 1 inch = 1 mile

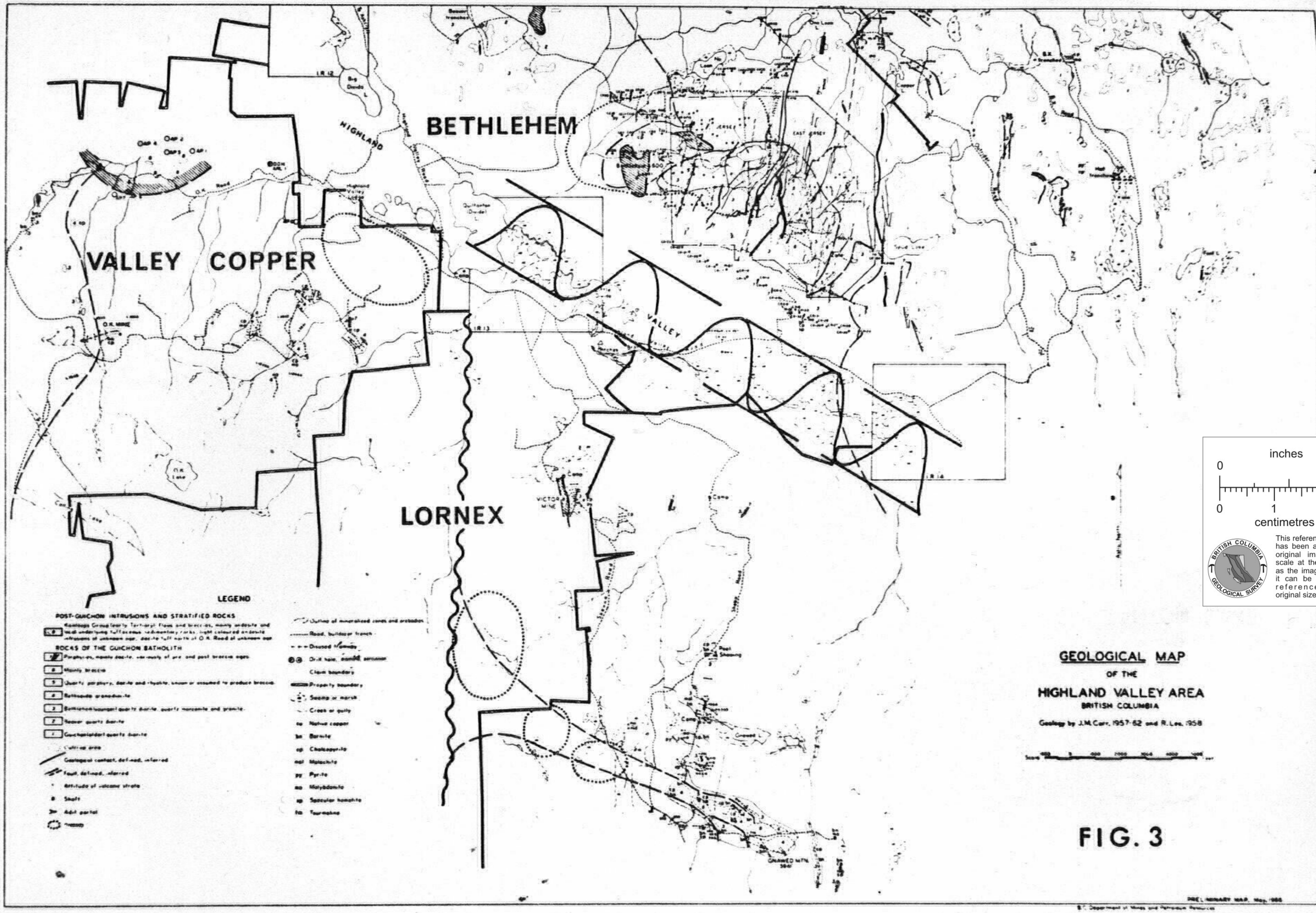
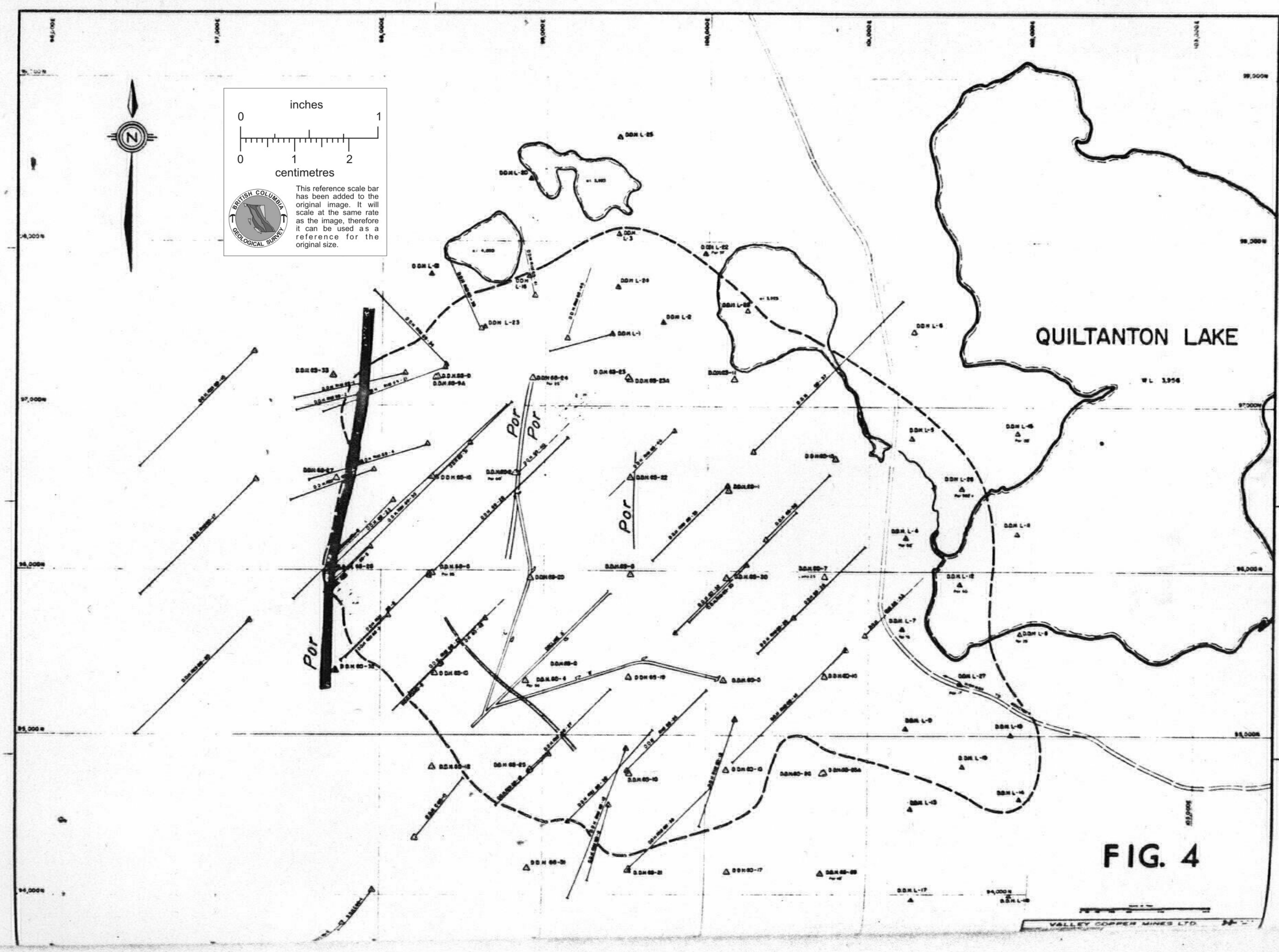

BETHLEHEM
VALLEY COPPER
LORNEX
HIGHLAND
VALLEY
LEGEND
POST-GUICHON INTRUSIONS AND STRATIFIED ROCKS
ROCKS OF THE GUICHON BATHOLITH
Mainly breccia
Geological contact, defined, inferred
Fault, defined, inferred
Attitude of volcanic strata
Shaft
Adit portal
Road, bulldozer trench
Claim boundary
Property boundary
Swamp or marsh
Creek or gully
Native copper
Bornite
Chalcopyrite
Malachite
Pyrite
Molybdenite
Specular hematite
Tourmaline
GEOLOGICAL MAP
OF THE
HIGHLAND VALLEY AREA
BRITISH COLUMBIA
Geology by J.M. Carr, 1957-62 and R. Lee, 1958
PRELIMINARY MAP, May, 1966
B.C. Department of Mines and Petroleum Resources

FIG. 3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BRITISH COLUMBIA GEOLOGICAL SURVEY
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VALLEY COPPER MINES LTD.

FIG. 4

THE GEOLOGICAL SETTING OF THE VALLEY COPPER OREBODY

BY: J. M. Allen and J. Richardson

GEOLOGICAL SETTING

INTERNAL STRUCTURE OF THE BATHOLITH

MINERALIZATION

STRUCTURAL SYNTHESIS

PERCUSSION DRILLING

THE OREBODY

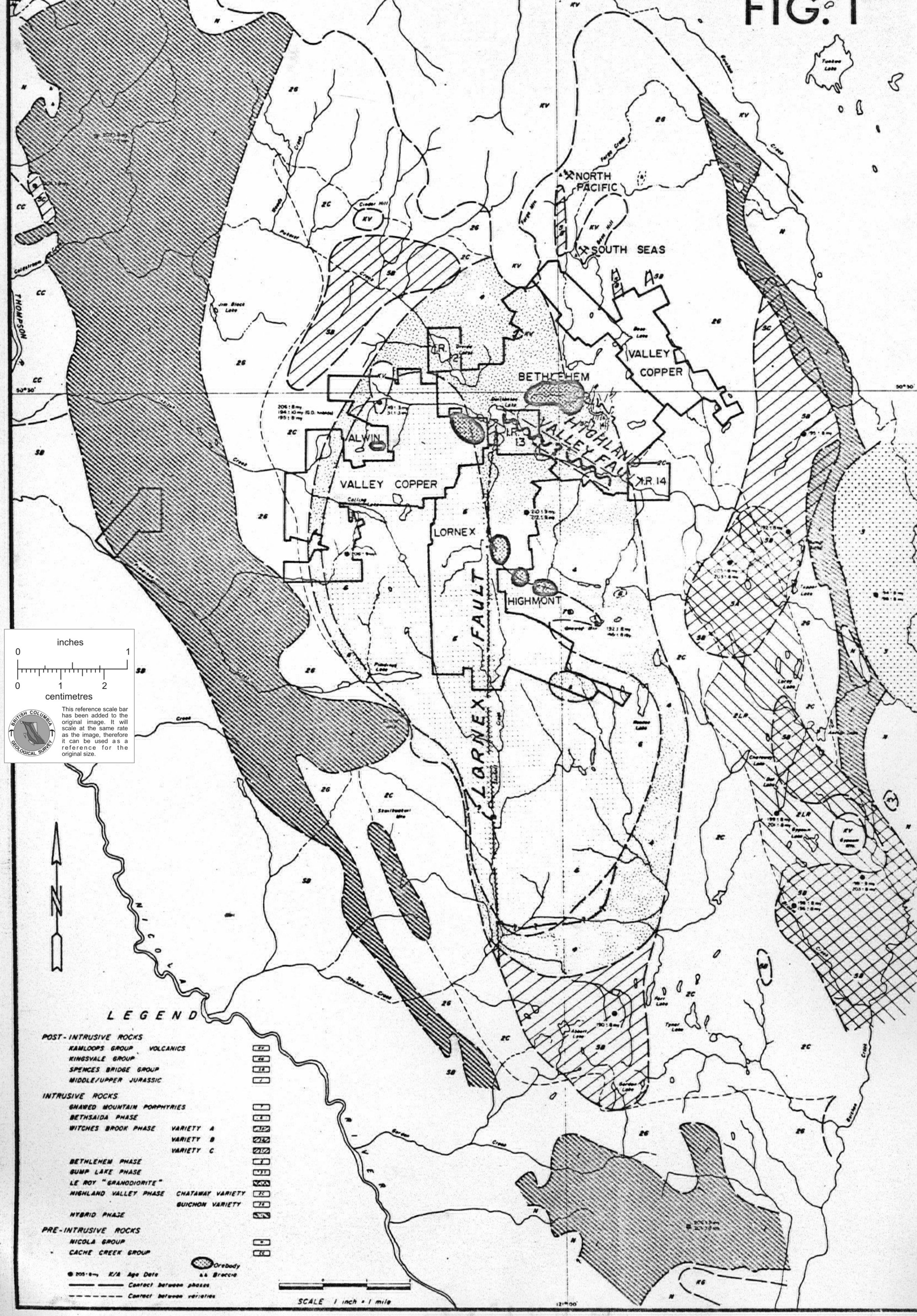
TESTING PROGRAM

Paper to be delivered at the C.I.M. Annual General Meeting, Toronto, 20 - 22 April, 1970 by Dr. J. M. Allen.

GEOLOGY OF THE GUICHON CREEK BATHOLITH

BY K. NORTHCOTE 1963-64 FIELD SEASON

FIG. I



THE GEOLOGY OF THE VALLEY COPPER OREBODY

During the past five years, the Highland Valley area of British Columbia has been the site of two major copper discoveries, Valley Copper and Lornex. A third discovery, Highmont, may also prove to be of major importance. Taken with the existing producers, Bethlehem and Craigmont, these potential orebodies suggest that the Highland Valley area may become one of the major copper areas of the world.

The location of the major discoveries, current producers and more promising showings is shown on the accompanying sketch (Fig. I). All of these are within or at the contact of the Guichon batholith, a concentrically zoned body of quartz diorite composition emplaced about 200 million years ago in Upper Triassic time. The deposits and showings discovered to date have many features in common and all are genetically linked to magmatic processes in the Guichon batholith. The purpose of this paper is to comment on the discovery of one of them, Valley Copper, and to describe what is presently known about the deposit.

GEOLOGICAL SETTING

The Guichon batholith is a roughly oval body at least 24 miles long and up to 15 miles wide. Its long axis strikes 345°. The batholith is bounded on the east and west by major north trending faults and according to Carr these faults delimit an up-faulted block of Cache Creek and Nicola rocks into which the batholith has been intruded. The rocks of the batholith are overlain by four later groups consisting largely of volcanics ranging in age from Middle Jurassic to Eocene. The age of the batholith is on geological evidence limited to the interval between early Upper Triassic to Middle Jurassic.

Isotopic ages on rocks of the batholith, 55 of which have now been published, show a remarkable concordance. The average for all of these ages is 196 million ± 8 M.Y. and the spread is from 184 to 206 M.Y. Most of these ages were done by the K/A method and the possibility of Argon loss has to be considered, however, six Rb/Sr ages from the Craigmont mine agree very closely, i.e. 200 ± 2 M.Y. and this plus the lack of evidence of metamorphism which might have caused Argon loss shows that the ages are probably reliable. On the absolute time scale, this would place the time of consolidation of the Guichon rocks in the Upper Triassic.

The isotopic ages also show that there is no significant or systematic difference in age among the various phases of the intrusive. It would appear that all of the phases crystallized within a short interval and that multiple intrusion, if it did occur, must have been over a short period as well.

INTERNAL STRUCTURE OF THE BATHOLITH

The gross structural pattern in the batholith is shown,best by the distribution of intrusive phases. These phases are arranged in a concentric pattern around a central core of Bethsaida quartz monzonite. The Witches Brook phase displays cross-cutting relationships, but this rock type occurs only in dikes and relatively small irregular masses and since its distribution was probably controlled by local structure, it does not really disrupt the overall pattern.

The type and distribution of phases is shown on the accompanying figure. In all, there are seven distinct phases, two of which are subdivided into five varieties and a late porphyritic phase. There is no significant difference in the absolute ages of the phases, however, there is geological evidence that age increases from the core outward. The outer or hybrid phase, is the oldest and forms a shell up to five miles thick between the intruded rocks and the younger phases of the batholith. Its composition is generally quartz dioritic but this is variable and characteristically this phase contains partially assimilated blocks and fragments of the country rock. The contacts of the hybrid phase are generally gradational grading outward to Nicola or Cache Creek rocks and inward to the Guichon variety of the intrusive. The hybrid shell is much thicker on the western side of the batholith, i.e. 3 to 5 miles vs. ½ - 1 mile and this suggests that the whole batholith may have been tilted eastward by differential movement on the bounding faults.

The later phases are all granodiorites or quartz monzonites and distinction of them is based primarily on textural and mineralogical features and not on bulk compositional differences. There is, however, a decrease in specific gravity, i.e. from 2.80 to 2.64 from the hybrid to the Bethsaida phase that could reflect increasing differentiation. With the exception of the contaminated hybrid shell, the various phases are very similar and the differences among them probably resulted mostly from changing pressure and temperature conditions during intrusion.

Smaller structures within the batholith include faults, shears, breccia and shatter zones. Dikes and dike swarms, which are common, probably reflect another type of structure. The most common direction for linear structures is north-south and the majority of dikes follow this trend. The most notable of these structures is the Lornex fault which bisects the Bethsaida quartz monzonite. Faults and shear zones striking northeast are less common and a third set striking northwesterly, though not obvious, is important in localizing ore, e.g. Alwin, Valley Copper. Breccia zones such as those at Bethlehem, Trojan and on Gnawed Mountain may or may not be related to faulting, since the breccia types vary. However, the Trojan and Bethlehem breccias occur in areas where strong north-south faulting is common and a combination of suitable structural openings and access to volatile charged fluids is certainly suggested as a cause. Shatter zones much as those at Valley Copper, Krain and possibly Lornex occur within or adjacent to major faults and at least in the case of Valley Copper near the intersection of two major structures. The principal difference between the shatter zones and the breccias appears to be that in the shatter zones there was not sufficient space provided by stress release to permit the broken blocks to rotate.

MINERALIZATION IN THE BATHOLITH

Copper mineralization may occur anywhere in the batholith and in any of the various phases. The distribution of producing mines and better known prospects is shown in the accompanying figure. All of these lie close to a north-south line which bisects the batholith and the larger ones except for Craigmont are on or adjacent to a contact of the Bethlehem phase of the intrusive. This latter is suggestive of a genetic relationship with this phase, however, this is probably more apparent than real. All of these mines and prospects are structurally controlled and the mineralization in them is contained in open space fillings formed after the consolidation of the host rock. The significance of the Bethlehem phase and its contact is therefore limited to the influence each has had on the development of structures suitable for ore deposition. Similarly, the north-south zoning may reflect a concentration of deep seated north trending structures formed after differentiation had proceeded far enough to create a reservoir of copper bearing solutions. That this reservoir has been tapped by other structures is apparent from the wide distribution of copper within the batholith, however, structures large enough and continuous enough to contain sizeable orebodies appear at this time to be limited to the central zone.

The mineralization is quite similar from one mine or showing to another. Chalcopyrite is the most common copper mineral however, with the exception of Craigmont, the one producing mine (Bethlehem) and all of the potential producers contain bornite in amounts sufficient to determine the viability of the operation. Pyrite is a common associate of copper, but its amount varies considerably, e. g. at Bethlehem there is a heavy pyrite zone on the southwest side of the Jersey orebody while at Craigmont and Valley Copper pyrite is extremely scarce. The most common iron mineral in terms of occurrence is hematite. This mineral is ubiquitous in copper occurrences, but rarely does it occur in amounts greater than 3 percent, Craigmont being a notable exception. The widespread occurrence of hematite suggests that the mineralizing solutions had a relatively high Eh such as might be expected in a highly aqueous environment. What effect this may have had in the partition of Fe, S and Cu is unknown, but in many deposits it appears that in the competion for sulphur, Cu was favoured over iron and perhaps the oxidation state influenced this.
The source of sulphur has been the subject of two recent publications. Christmas, Baadsgaard, et al conclude from a study of S, C and O isotope ratios of Craigmont ore that the sulphur of the ore is of mantle origin and therefore from a deep source. M. P. Schau in a reply to this says that sulphur from assimilated Nicola basalts is just as likely a source since this sulphur would have mantle ratios too. As it now stands, the source of the sulphur is open to question, however the nature of the copper deposits and their relationship to deeply penetrating structures suggests that the copper and sulphur did come from some depth and could well be of mantle origin.

STRUCTURAL SYNTHESIS

The sequence of events leading to the discovery of the Valley Copper orebody started in 1964 with the formation of Valley Copper Mines Ltd. This company, at that time, held various groups totalling 425 claims. Evaluation of these groups began immediately and during 1964, 1965, and 1966 various kinds of exploration programs were carried out on all of them. By 1966, a considerable amount of information had been gained from this work and this was used along with published data to produce a geological compilation of the batholith area. To supplement this, a study of aerial photographs was made and this was combined with the known geology to provide a structural interpretation.

The Lornex discovery in 1966 (? 1964) served to draw attention to the Lornex fault and at about the same time new aerial photographs of the area became available. These photographs clearly show the southern extension of this fault for some eight miles, along Skuhost Creek valley. The northern extension beyond Lornex is obscured by steep topography but clearly if the fault is string straight for eight miles, its northern extension should be as well. Thus projection of the fault north through Divide Lake seemed reasonable. Intersection with an inferred structure under Highland Valley was more conjectural for there was not then and there is not now any direct evidence of faulting under Highland Valley. In any case, however, the area adjacent to the conjectured intersection of two large fault structures was considered to provide a worthwhile exploration target.

Another possibility suggested by the location of the Lornex orebody in or adjacent to the Lornex fault was that the orebody might have a displaced portion somewhere along the west side of the fault. At that time, neither the sense nor amount of movement along the

Lornex fault was known, however, the occurrence of copper mineralization on the Bethsaida claims suggested a relationship. If indeed the Lornex and Bethsaida mineralization were related, then left-hand movement of about 2 miles was indicated. Particularly suggestive of this was the low grade copper mineralization south of the Lornex orebody and in the southeastern part of the Bethsaida group as indicated by drilling in 1966. If these two areas of low grade mineralization were correlative, then the same spatial relationship could pertain on the Bethsaida group as did at Lornex. In this case, ore grade mineralization should be to the north or northeast.

This rather speculative interpretation needed further support and this was provided by the information compiled in 1966. This compilation in view of the possible importance of the Lornex fault was directed toward trying to find supporting evidence for the supposed left-hand movement of some 2 miles. It was found that the south contact of the Bethsaida quartz diorite had an apparent northward displacement on the west side of the Lornex fault.

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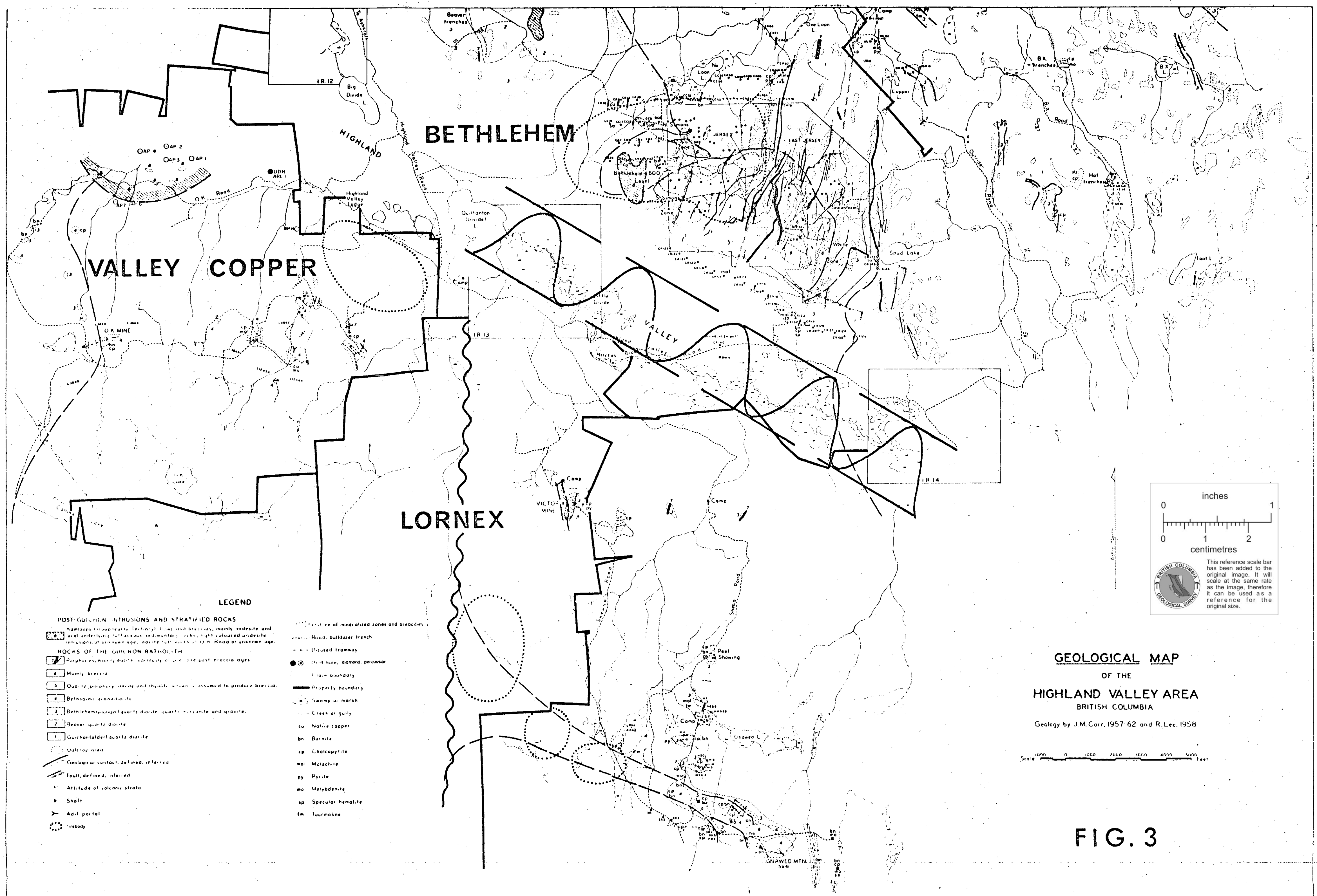

BETHLEHEM
VALLEY COPPER
LORNEX
HIGHLAND
VALLEY
O.K. Road
O.K. MINE
Highland Valley Lodge
Big Divide L.
I.R. 12
I.R. 13
I.R. 14
JERSEY
EAST JERSEY
Snowstorm
Spud Lake
VICTOR MINE
Peel Showing
GNAWED MTN.
LEGEND
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ROCKS OF THE GUICHON BATHOLITH
Mainly breccia
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Fault, defined, inferred
Attitude of volcanic strata
Shaft
Adit portal
Road, bulldozer trench
Disused tramway
Drill hole, diamond, percussion
Claim boundary
Property boundary
Swamp or marsh
Creek or gully
cu Native copper
bn Bornite
cp Chalcopyrite
mal Malachite
py Pyrite
mo Molybdenite
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GEOLOGICAL SURVEY
GEOLOGICAL MAP
OF THE
HIGHLAND VALLEY AREA
BRITISH COLUMBIA
Geology by J.M. Carr, 1957-62 and R. Lee, 1958

FIG. 3

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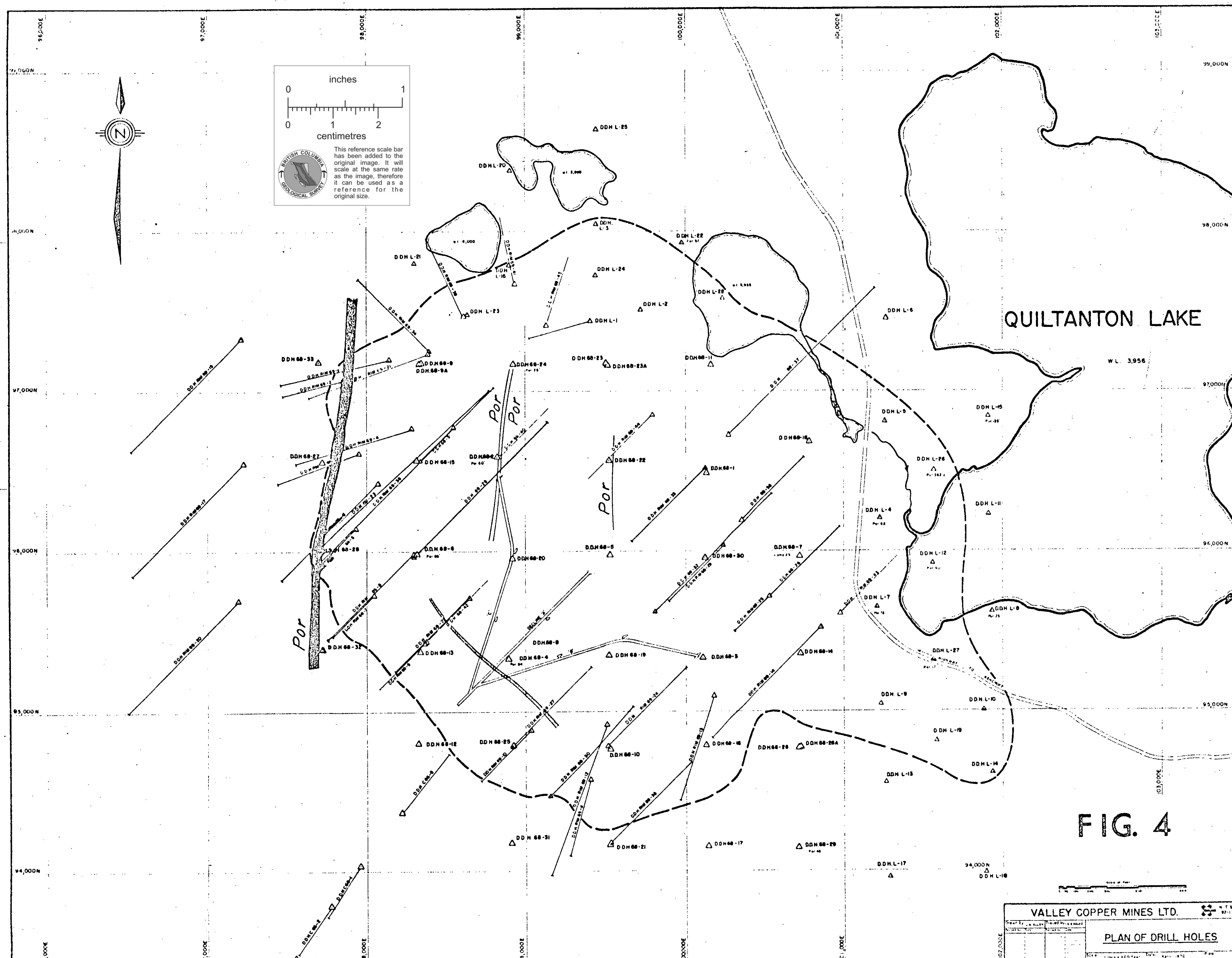

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DDH 68-6
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DDH 68-5
DDH 68-30
DDH 68-7
DDH L-7
DDH L-8
DDH 68-32
DDH 68-13
DDH 68-4
DDH 68-19
DDH 68-3
DDH 68-14
DDH L-27
DDH L-9
DDH L-10
DDH L-19
DDH 68-12
DDH 68-25
DDH 68-10
DDH 68-18
DDH 68-26
DDH 68-26A
DDH L-14
DDH L-13
DDH 68-31
DDH 68-21
DDH 68-17
DDH 68-29
DDH L-17
DDH L-18
96,000E
97,000E
98,000E
99,000E
100,000E
101,000E
102,000E
103,000E
99,000N
98,000N
97,000N
96,000N
95,000N
94,000N
FIG. 4
VALLEY COPPER MINES LTD.
PLAN OF DRILL HOLES

Potassic alteration is next in the sequence and this is marked by the development of potash feldspar. This type of alteration, though widespread, is generally restricted to zones fifty to one hundred feet wide. Mineralization associated with the potassic alteration tends to be largely chalcopyrite.

Sericitic alteration shows the closest relationship to copper mineralization and it may occur in two distinct ways. Copper-bearing quartz veins almost always carry a selvage of coarse sericite. These veins may as they narrow become fine stringers of sericite, granular quartz and copper sulphides, dominantly bornite. Alternatively, sericite and granular quartz may occur in irregular zones up to 20 feet wide impregnated with bornite and chalcopyrite. In general, when sericite is present, copper sulphides are as well.

Silicification is a prominent feature of the orebody as shown by the great number of quartz veins and the presence of irregular siliceous patches. The amount of quartz observed is in excess of what might be expected from the remobilization of silica originally present in the fresh Bethsaida quartz monzonite and suggests that a good part of it must have been introduced with the mineralizing solutions. Several generations of quartz veins are present including a late barren type. This too might be construed as evidence supporting an epigenetic rather than syngenetic origin for the quartz. Propylitic alteration which commonly occurs on the periphery of porphyry copper deposits, is notable by its absence. Similarly, there is very little pyrite in the orebody and no evidence of a pyritic halo.

In summary, the Valley Copper orebody displays many of the characteristics ascribed to the better known porphyry copper deposits. The lack of a propylitic alteration zone and a pyrite halo probably reflect differences in fluid composition rather than in process and there seems to be little doubt in assigning the dposit to the prophyry copper class.

TESTING PROGRAM

Since May of 1969, a comprehensive testing program has been under way. This program was designed to bulk sample the orebody and to fill in gaps with additional surface and underground drilling.

The underground testing has consisted of driving three inclined headings into the orebody and sampling on a round by round basis. The underground headings were driven at -20% using rubber tired diesel equipment and in plan these headings form an arrowhead pointing southwest. The total footage driven was 4100 feet and the ends of the declines are 500 feet below the portal.

The size of the opening driven was 14' x 11' with an arched back. Each round was mucked, crushed and sampled separately. In order to provide a comparison with diamond drilling, two holes were drilled ahead of the face and the core from these matched to the round lengths to provide three separate samples. This comparison sampling will be done over the entire length of the declines.

Surface diamond drilling has been going on almost continuously since August, 1968, and to date some 90,000 feet have been drilled, almost all of it N.Q. size. Underground drilling started in July, 1969, as soon as working places were available. This program on completion will total 36,000 feet, all B. Q. size.

The testing program is now virtually completed and the information gained from it is currently being assessed. All of this information and the assessment of it will be incorporated into a feasibility study now in progress.

JMAllen/nc
April 8, 1970

R E F E R E N C E S

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2. Christmas L., Baadsgaard H., Folinsbee R. E., Fritz P., Krouse H. R. and Sasaki A., (1969), Rb/Sr, S and O Isotopic Analyses indicating source and Date of Contact Metasomatic Copper Deposits, Craigmont, British Columbia, Canada, Economic Geology, Vol. 64, No. 5, P. 479 - 488.

3. Schau M. P., (1970): A criticism of Rb/Sr, S and O Isotopic Analyses indicating source and Date of Contact Metasomatic Copper Deposits, Craigmont, British Columbia, Canada Economic Geology, Vol. 65, #1, P. 62 - 63.

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Valley Copper - General Data

- 10 million shares issued, Cominco has 69.7% and spent roughly $1.5 million (George Cross Newsletter No. 40, 1970). I think they own considerably more than 69.7% now.

- Bethlehem owns rights to 20% of the orebody.

- Underground exploration roughly 3000', surface and underground drilling 60 000'.

- Reserves 600 000 Tons/vertical foot, grade 0.48% Cu (MoS_2 negligable). Ore carries minor silver values. (In the 1971 report, they announced reserves of 700 million tons).

- GCNL, 1975, No. 74 copper price of 80-85¢/lb was said to be needed to make the deposit economic (in 1975 dollars).

- To the end of 1976, Cominco has advanced the Company $11 million.

VALLEY COPPER DEPOSIT

M.J. OSATENKO

PROPERTY FILE

92ISW012(6E)

ABSTRACT

The Valley Copper porphyry deposit is located in the Highland Valley of B.C., about 370km northeast of Vancouver, B.C. Reserves are 790 million tonnes of 0.48 percent copper.

The rocks which host this deposit are mainly porphyritic Bethsaida phase granodiorites, the most central and youngest phase of the 198 m y old Guichon Creek batholith. Minor dyke phases include: pre-mineralization granodiorite and quartz diorite porphyries and aplite, syn-mineralization Tan felsite porphyry and post-mineralization lamprophyres.

Localization of the deposit is related to the formation of a zone of intense fracturing near the intersection of the northerly trending Lornex fault and the easterly trending Highland Valley fault. Predominant orientations of faults, fractures and quartz veinlets in the deposit are parallel to these two regional faults.

The alteration types recognized are: propylitic, pervasive sericitic and kaolinitic, vein sericitic, K-feldspathic, biotitic, silicic and post-mineralization veining (principally gypsum). K-feldspathic alteration is dominant in the central, deeper part of the deposit, where it is intimately associated with and enveloped by an extensive zone of moderate to strong vein sericitic and pervasive sericitic and kaolinitic alteration, which grades outward into a zone dominated by weak to moderate pervasive sericitic and kaolinitic alteration. This latter zone, in turn, grades outward into a zone with areas of weak to moderate propylitic alteration and areas with no hydrothermal alteration. A well developed silicic zone (in the form of barren quartz veinlets) occurs in the southeastern part of the deposit. Elsewhere quartz veinlets (principally mineralized but some barren) are only moderately developed within the deposit. The age of hydrothermal alteration, calculated by averaging several potassium-argon analyses of hydrothermal sericites, is 191 m y.

The sulfides present in the deposit are, in order of relative abundance: bornite, chalcopyrite, digenite, covellite, pyrite, pyrrhotite, molybdenite, sphalerite, galena and gudmundite (FeSbS). The greater part of the copper mineralization is associated with areas of abundant vein sericitic alteration and quartz veinlets. Bornite is the dominant sulfide in this sericitic association, whereas chalcopyrite is the dominant sulfide accompanying K-feldspathic alteration. Bornite/chalcopyrite ratios show highest values in the central part of the deposit, where they exceed 3 to 1 and decrease away from the core to the fringes of the deposit where chalcopyrite predominates. The deposit has a weakly developed pyrite halo.

Geochemical patterns related to hydrothermal alteration show a decrease in CaO, Na_2O, MgO, Sr, Ba and Mn and a corresponding increase in K_2O, SiO_2, Rb and TiO_2 from the periphery to the centre of the deposit. Patterns related to mineralization show that the deposit (as defined by copper values exceeding 0.30 percent) is roughly oval in plan, with a broad halo of lower copper grades around it. Molybdenum and zinc form annular, geochemically enriched zones around the deposit.

Sericite stabilities and fluid inclusion compositions as well as sulfur, oxygen and hydrogen isotopic data, suggest both that sulfur in the sulfides is of sub-crustal or magmatic derivation and that the deposit was formed at a shallow depth from saline, hydrothermal fluids. The fluids had the following range in characteristics during the alteration sequence:

$$T = 260 \text{ to } 480^{\circ}C$$

$$pH = 1.7 \text{ to greater than } 4.0$$

$$-\log fS_2 = 1.5 \text{ to } 4.5$$

$$-\log fO_2 = 21.6 \text{ to } 23.4$$

The main period of copper mineralization occurred at about $400^{\circ}C$ from a solution of about pH 2.2 to 3.1 which exhibited -log fugacities of oxygen and sulfur of 21.8 to 23.0 and 1.8 to 2.7 respectively. The controlling factor in the deposition of sulfides was apparently an increase in the sulfide ion concentration. Mixing of magmatic water and seawater probably occurred throughout the various stages of hydrothermal alteration and is estimated to be about 25 percent SMOW (Standard Mean Ocean Water) during the main period of mineralization.

GENETIC SYNTHESIS

The copper-rich magma of the Guichon Creek batholith was probably derived from a subcrustal source with the ore metals and hydrothermal fluids probably derived from it by processes of differentiation. It is likely, however, that seawater was contributed to the magmatic hydrothermal system.

The purpose of this part of the paper is to summarize the sequence of major events leading to formation of the Valley Copper deposit. They are believed to have been as follows:

1. The Bethsaida granodiorite was intruded in Upper Triassic time about 198 ± 8 m y ago.

2. Movement on the Lornex and Highland Valley faults initiated a zone of intense fracturing in Bethsaida granodiorite near the fault intersection.

3. Pre-mineralization aplite, granodiorite and quartz diorite porphyry dykes were injected along northerly and easterly trends.

4. Hot, saline fluids moved upward in the zone of fracturing and mixed with downward percolating seawater to produce a fluid with a temperature of about 260°C, pH about 1.7 and -log fS_2 of about 4.5. This fluid reacted with and leached Na_2O and CaO while adding K_2O and H_2O to the wall rocks. This stage of alteration produced extensive pervasive sericitic and kaolinitic alteration with associated trace amounts of pyrite and chalcopyrite.

5. A continued influx of magmatic hydrothermal fluids and seawater gave rise to a hydrothermal fluid with a temperature about 400°C, slightly higher pH of 2.2 to 3.1, and a lower -log fS_2 of 1.8 to 2.7. These fluids reopened many of the access channelways used by previous hydrothermal fluids and produced vein sericitic alteration. Deposition of main stage copper mineralization occurred during this stage, probably as the result of increased sulfur ion concentration.

   Tan felsite dykes, of syn-mineralization age, were also intruded at this time.

6. In the main part of the deposit a further influx of fluids again reopened the old channelways and formed quartz veinlets containing vugs lined by or filled with bornite and chalcopyrite.

7. Continued fracturing of the rock mass occurred along with formation of quartz veinlets with disseminations and envelopes of secondary K-feldspar. The pH of the hydrothermal fluid at this stage probably continued to increase to about 4.0 while -log fS_2 probably increased slightly to about 3.5. Mineralization of this stage was limited to minor amounts of chalcopyrite, probably as a result of further decreased sulfur fugacity. Chemically, this stage is characterized by a pronounced increase of K_2O and SiO_2 and a marked decrease of H_2O, relative to zones with pervasive and vein sericitic alteration.

8. Further fracturing occurred followed by deposition of essentially barren quartz veinlets from hydrothermal fluids of still further increased pH and -log fS_2.

9. In close spatial association with previously formed secondary K-feldspar fractures were re-opened and gypsum deposited. The hydrothermal solutions were rich in sea-water sulfate.

10. Lamprophyre dykes were intruded about 132 $\pm$ 3 m y ago.

11. During subsequent uplift and erosion the overlying rocks and the upper part of the deposit were removed and an oxidized zone and weak supergene blanket developed. Glaciation followed by glaciofluvial deposition and continued erosion produced the present day surface.

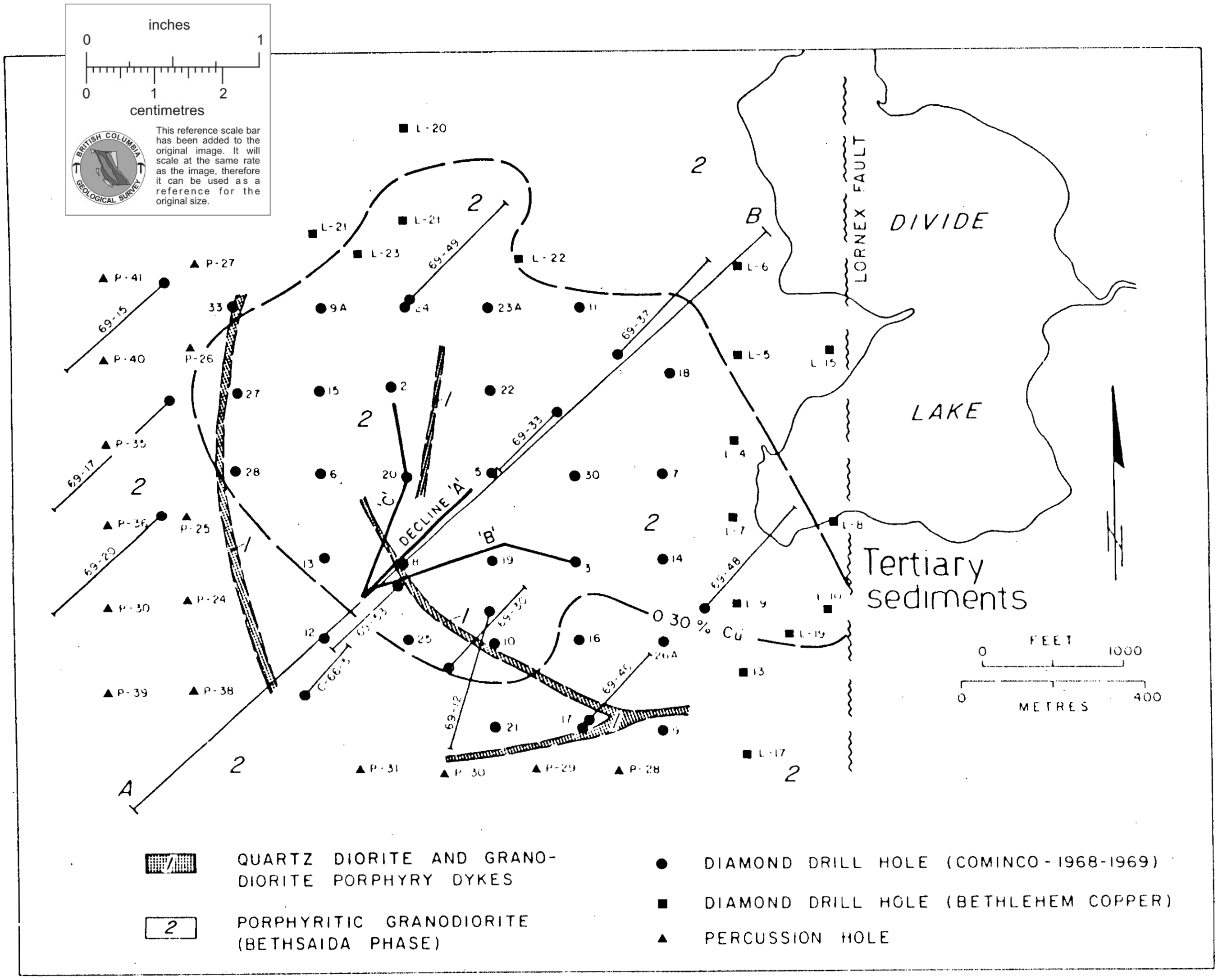

Figure 1. Geology of the Valley Copper deposit, showing distribution of drill holes studies, location of underground workings and location of vertical section A-B.

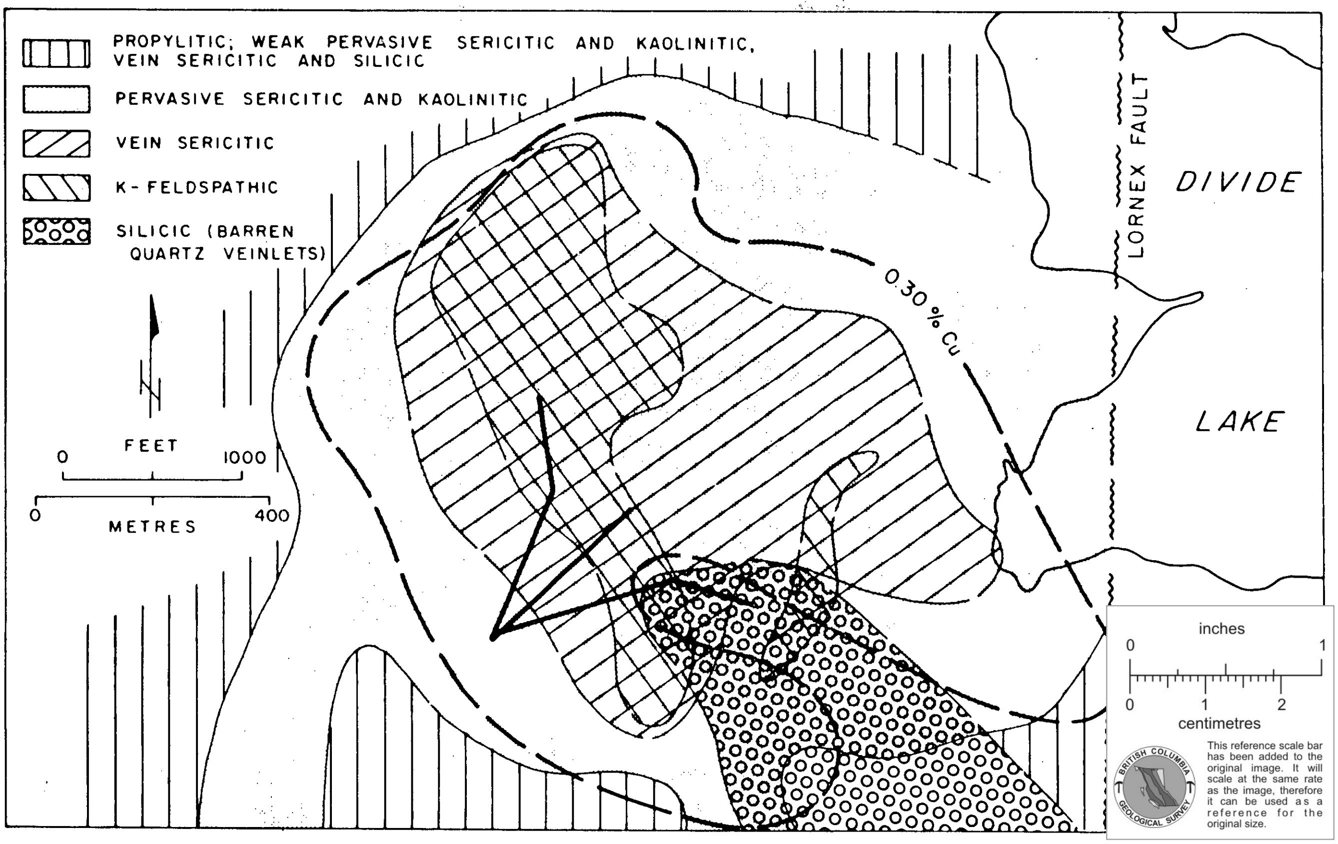

Figure 2. Map of dominant alteration types on the 1097m level.

59. DISTRIBUTION AND ORIGIN OF THE "GYPSUM LINE" IN THE VALLEY COPPER PORPHYRY DEPOSIT, HIGHLAND VALLEY, BRITISH COLUMBIA

Project 700041

J.L. Jambor[1] and W.J. McMillan[2]
Regional and Economic Geology Division

Introduction

Gypsum and anhydrite have been reported to occur in several porphyry copper deposits in the United States (Meyer, 1965; Lowell, 1968; Sheppard and Taylor, 1974; Phillips *et al.*, 1974; Corn, 1975), in Puerto Rico (Cox *et al.*, 1973), in Chile (Howell and Molloy, 1960; Sillitoe, 1973), in the Philippines (Bryner, 1969), and in Canada (e.g., Barr, 1966; Carson and Jambor, 1974). Occurrences of anhydrite seem to be much more common than those of gypsum, and where mention is made of either mineral, the association seems to be most commonly with the zone of potassic alteration in porphyry deposits. In the compilation by Lowell and Guilbert (1970), anhydrite appears only in the "Inner Zone" of hydrothermal alteration at one deposit, and in the "Innermost Zone" at eight deposits. Although the mineral has not been found in the outer zones of alteration, detailed studies of the El Salvador (Chile) orebody by Gustafson and Hunt (1975) have shown that the sulphate zone overlaps several of the major hydrothermal alteration zones.

To the writers' knowledge, the distribution of sulphates in porphyry deposits has not been studied in detail except at El Salvador. This paper presents the results of a study of gypsum distribution in the Valley Copper porphyry deposit, Highland Valley, British Columbia. The deposit is about 55 km southwest of Kamloops and is entirely in Bethsaida quartz monzonite of the Triassic Guichon Creek batholith. Reserves in the deposit are approximately 850 million tons grading 0.48 per cent copper to a depth of 1450 feet. The largest part of the copper zone is in Valley Copper proper, which is controlled by Cominco Ltd., but part extends into claims held by Bethlehem Copper Corporation (Fig. 59.1). Bethlehem has named its part of the deposit the Lake Zone. No date has been set for bringing the Valley Copper deposit into production.

Gypsum at Valley Copper

Although gypsum in porphyry deposits of the Highland Valley was recognized several years earlier, the spatial distribution of the mineral was first published by McMillan (1971). In two vertical cross-sections through the Valley Copper deposit, McMillan demonstrated that the initial appearance of gypsum down the drillholes is not erratic but occurs at a fairly constant topographic elevation that can be projected form hole to hole to form a "gypsum line". Below this "line" gypsum is common. Subsequently, J.L. Jambor logged all the drillholes in the Cominco part of the deposit in order to define more precisely the distribution of gypsum both in the copper zone and peripheral to it. Drill core from the Lake Zone was sampled, but the L-series holes (Bethlehem Copper) were not logged. Therefore, the vertical distribution of gypsum in L-holes is based on laboratory samples and is not accurate.

Recently, Jones (1975) established the position of the gypsum line in the deposit in 12 surface drillholes not logged by McMillan (1971). These independently determined results are generally in excellent agreement with the more extensive data reported here.

Description of Sulphates

Most gypsum is white to orange and fibrous, but plates up to 5 mm long are present locally. The principal occurrence is in veinlets from less than 1 mm to about 5 mm thick. The maximum width is 8 cm (Jones, 1975), but veinlets more than 1 cm wide are rare. Veinlet abundances are variable, but several occurrences per foot are common in some drillholes. The veinlets extend at least 2500 feet below surface, but the general impression is that widths decrease near the bottoms of the deepest holes. Gypsum veinlets cut all hydrothermal alteration types, and all quartz and sulphide-bearing veinlets in the deposit.

In addition to its presence as veinlets, gypsum also occurs as patches disseminated in potassic-altered rocks and is present in minor amounts as interstitial grains in both mineralized quartz and K-feldspar-quartz veins. No gypsum has been found near the surface of the deposit, and its distribution is not related to the oxidation zone which is only locally developed and rarely more than 50 m deep.

Anhydrite is common as microscopic grains associated with K-feldspar and sericite in rocks which have intense potassic-alteration but no significant argillic alteration. Rare megascopic anhydrite grains are pale purple and have been noted in masses up to 2 by 2 cm. Although anhydrite veinlets have not been observed, Jones (1975) reported that anhydrite is present in gypsum from moderately argillized rock, and in sulphide-bearing quartz and quartz-sericite veins. According to Jones, virtually all the anhydrite is below the 3400-foot level.

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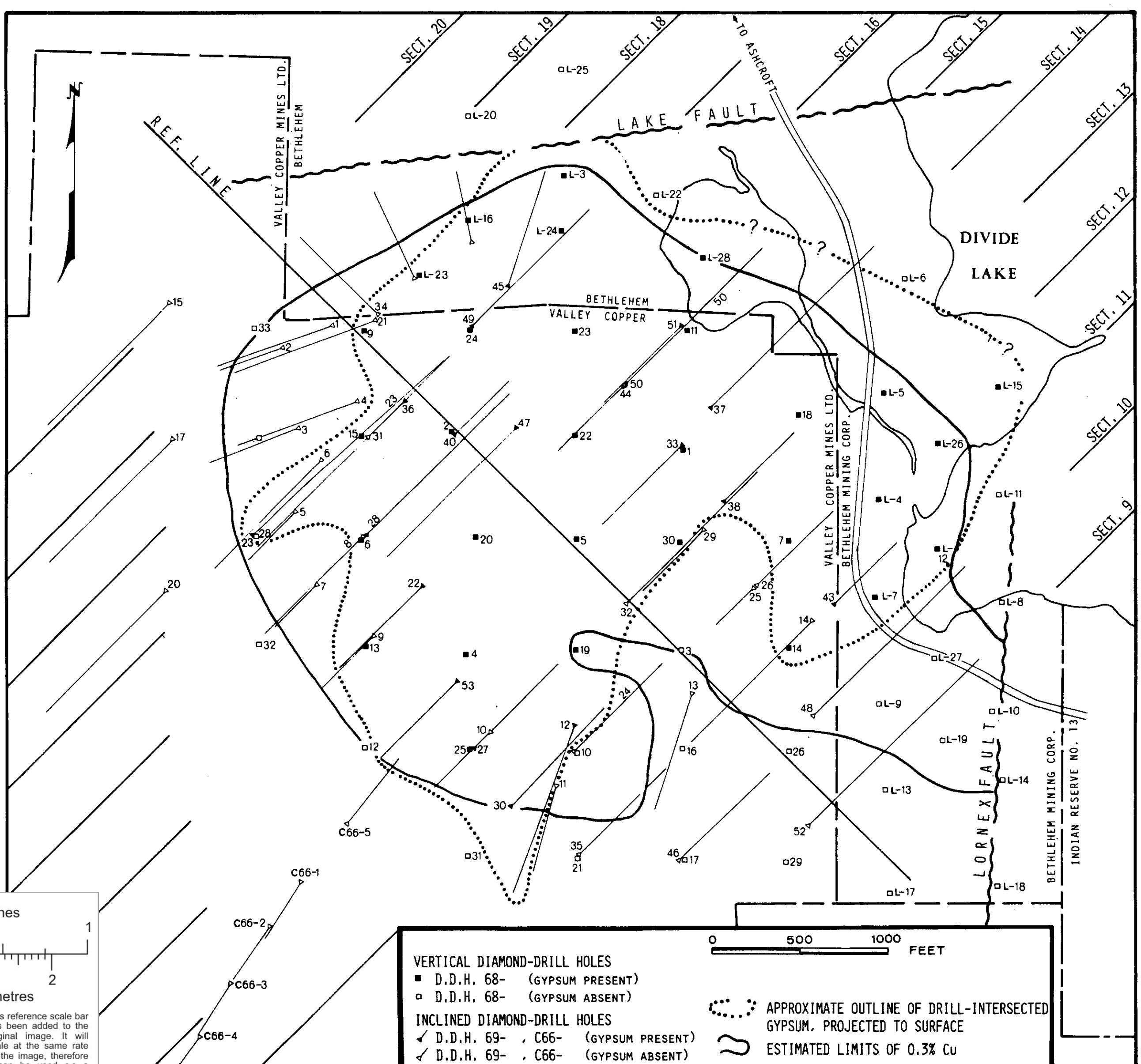
Copper Zone and Gypsum Line

The gypsum line and the copper zone at Valley Copper are shown in plan in Figure 59.1. The position of the 0.3 per cent copper isopleth for the Lake Zone is based on assay data for several of the earliest drill-holes (Bethlehem Copper Corporation, 1968, 1969; Northern Miner, Nov. 21, 1968, Dec. 19, 1968), but information is not available for most later drillholes, and thus the isopleth for part of the Lake Zone is partly interpreted. The copper zone on the remainder of the Valley Copper deposit is better defined because it is based on assay data for 40 percussion drillholes and 19 diamond-drill holes (Allen, 1969).

Almost all the approximately 90 000 feet of core from surface drilling on the Cominco portion of the deposit was logged for information about mineralization-alteration zoning, and the position of the gypsum line. However, core from only a few holes in the Lake Zone was logged and the position of the gypsum line in this area is approximate because it is based primarily on data from core samples selected for laboratory study.

Core logs and assay data indicate that the copper zone is roughly elliptical in plan (Fig. 59.1), but the eastern part of the deposit is narrow and truncated by the Lornex fault. The pronounced inward deflection of the 0.3 per cent copper isopleth in the southeastern part of the deposit reflects the presence of a stockwork



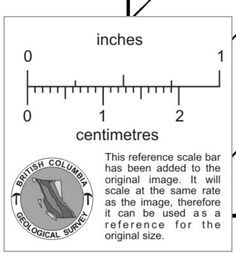


Figure 59.1. Distribution of gypsum in surface diamond-drill holes in the Valley Copper porphyry copper deposit.

of late-stage, barren quartz veins and associated silicification. The most intensely veined and silicified part of this zone forms an elongate dome which extends from the Lornex fault toward the core of the deposit. Rocks within the dome commonly consist of up to 50 per cent barren quartz. The contacts of the dome are gradational. The highest grade part of the copper zone (> 0.5 per cent copper) is centrally located in the deposit and is wrapped around the northwestern part of the quartz-rich dome.

The three-dimensional shape of the copper zone is not precisely known. However, near the Lornex fault (Section 9, Fig. 59.1), the copper zone appears to have a steep or vertical dip whereas the western side of the deposit dips inward at a moderate angle.

In plan, the drill-intersected gypsum line conforms fairly closely with the copper zone. Cross-sections of the deposit (Fig. 59.2) show that the gypsum line has the following features:

1. At the southeastern end of the deposit, gypsum is absent in Sections 9 and 10 and comprises only a thin band in Section 11 in diamond drill holes 68-14 (Fig. 59.2). Gypsum-bearing samples in holes L-7 and L-12, which are southeast of the section, are approximately 250 feet lower. Because the holes were not logged in detail it is not certain whether the gypsum line is almost horizontal, is offset by faulting between holes 68-14 and L-12, or plunges steeply southeastward.
2. The gypsum zone broadens and thickens northward. The elevation of the top of the gypsum line rises from about 3200 feet in Section 11 to 3500 feet in Section 12, beyond which its elevation remains fairly constant to Section 17. Gypsum in this extensive central area of the deposit persists to the bottoms of the deepest drillholes.
3. In Section 17, the elevation of the gypsum line southwest of the reference line decreases to about 3100 feet elevation, and in Section 18 the gypsum zone pinches out to the southwest.

Relationship to Hydrothermal Alteration

Hydrothermal alteration at Valley Copper has been described by McMillan (1971), Jones (1975), and in less detail by several others. Additional studies by J.L. Jambor are still in progress, but some generalizations with respect to gypsum and hydrothermal alteration can be made.

The copper zone at Valley Copper is roughly centrally located within a zone of potassic alteration, the outer limits of which are marked by the disappearance of hydrothermal biotite. In the core of the deposit, K-feldspar is abundant and at depth the potassic assemblage is K-feldspar-sericite-biotite-anhydrite. Within the copper zone, argillic alteration is locally extremely intense to the point where large masses of rock in the deposit are cream coloured and chalky in appearance; in such material the feldspars are largely obliterated, and primary and hydrothermal biotite commonly is completely replaced, though sericite and quartz are not visibly affected. Areas in which intense argillic alteration of this type predominate are shown in several cross-sections (Fig. 59.2). Such areas are not laterally continuous across ~~outside~~ the copper zone and are rare outside it. Significantly, these intense argillic zones decrease with depth; the change is seen best in Sections 16 and 17 (Fig. 59.2) because this area is distant from the zone of late-stage silicification. These sections show a downward change from intense argillic to potassic alteration at depth. Within the deep core of the deposit, pink K-feldspar is a conspicuous megascopic constituent, sericite is coarse but not demarcated as well-defined selvages, and sharply-bounded discrete quartz veins are rare. In the potassic zone peripheral to the K-feldspar-rich core, hydrothermal biotite predominates and relatively linear quartz-poor sericitic veinlets occur. These veinlets clearly cut the pervasively biotized rock.

The so-called transition zone (Section 16 and 17) consists largely of the K-feldspar-rich potassic assemblage, but contains minor zones of argillic alteration. Below the lower boundary of this transition zone, pervasive argillic alteration is negligible. Rare argillized sections of core, which are not demonstrably related to faults, show that the clay alteration has been superimposed on the gross pattern of potassic alteration. This trend is also evident throughout the deposit because vestiges of potassic alteration are locally perserved in the upper argillic zone.

The distribution of hydrothermal alteration assemblages and gypsum show a clear spatial relationship. Intense argillization and gypsum veining are generally antithetic whereas gypsum and "deep" K-feldspar-rich potassic zones are sympathetic. There are indications that the gypsum zone deepens and pinches out at the periphery of the copper zone, and this too is correlative with the decline in overall intensity of potassic alteration.

Origin of the Gypsum Line

A hypogene origin is accepted for the Valley Copper sulphate zone. The top of the zone is a gently undulating surface below which primary anhydrite is present. A similar sulphate distribution also appears to be present in the porphyry deposit at El Salvador, Chile. Because of the presence of tiny relict grains of anhydrite preserved in quartz, Gustafson and Hunt (1975) concluded that the original sulphate zone at El Salvador probably extended at least several hundred feet above its present level. Although sulphates have not been noted above the gypsum line at Valley Copper, the studies to date have not been sufficiently detailed to exclude their presence. The microscopical studies, however, do indicate that some disseminated interstitial anhydrite has been partly hydrated to gypsum, and that disseminated gypsum increases at the expense of anhydrite near the gypsum line.

The interpretation of the origin of the gypsum distribution is inextricably related to the interpretation

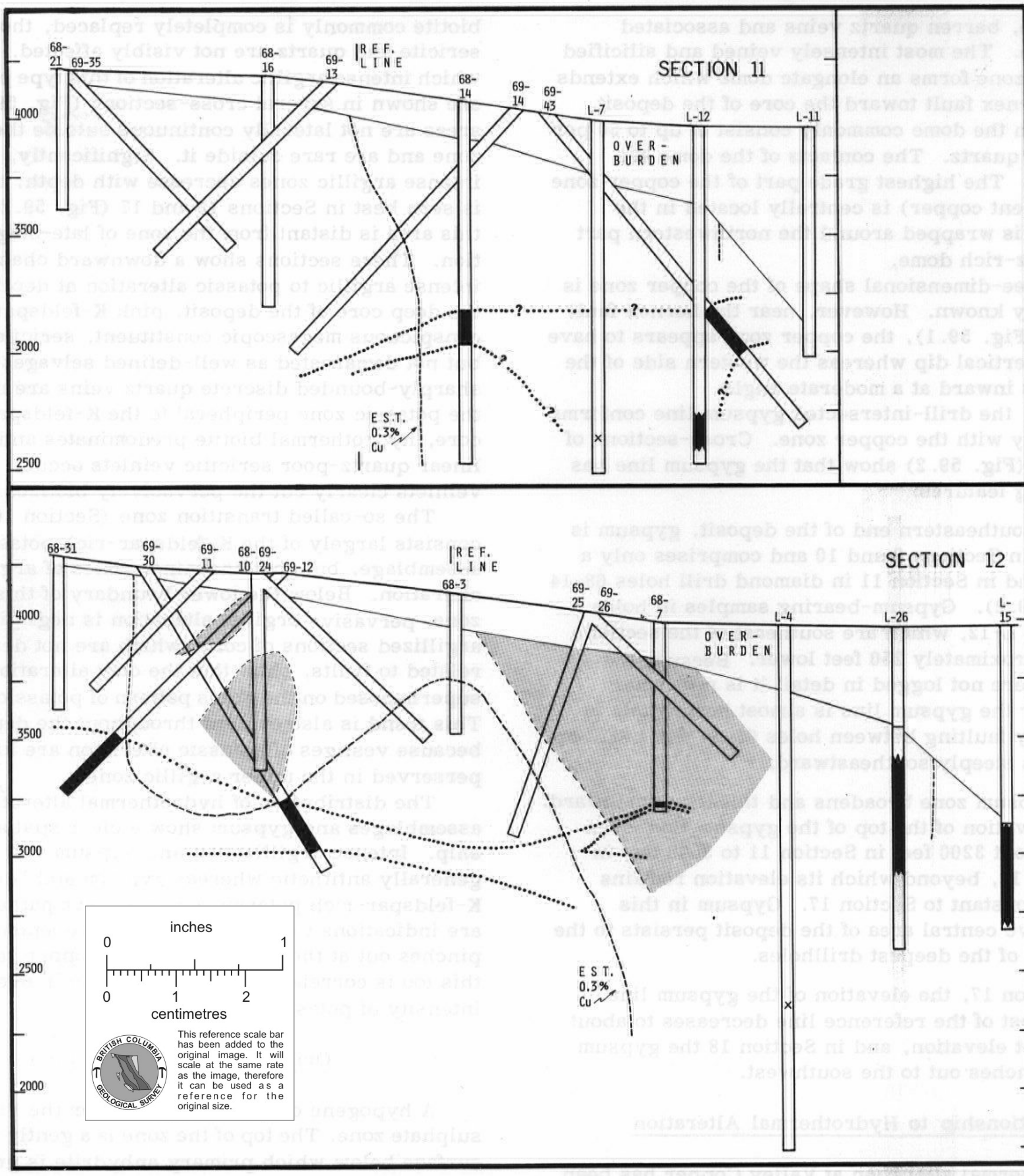


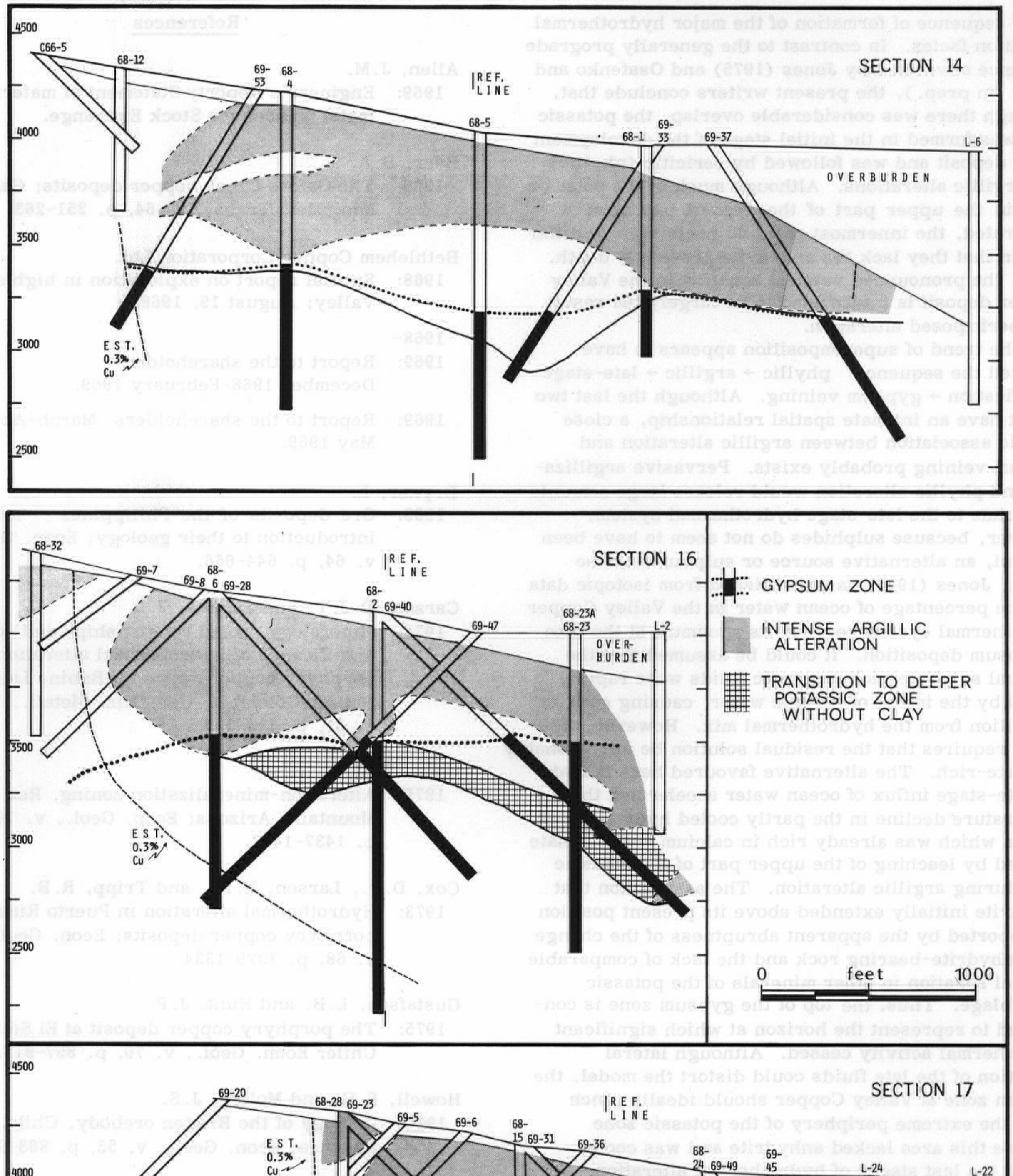
Figure 59.2. Vertical cross-sections of the Valley Copper deposit. Horizontal and vertical scales are identical in all sections. Section lines are shown in Figure 59.1.

Section 11: gypsum zone is shown in solid black; limits of the zone in hole L-12 are not known, and the single occurrence in hole L-7 is designated by an X. Only local, intense argillic alteration is present in the section.

Section 12: argillic alteration, designated by shaded pattern, is more intense in the area on the right side of the diagram than on the left. Strong K-feldspar alteration is not present in sections 11 or 12.

Section 14: (opposite) solid line beneath the area of intense argillic alteration marks the upper limit of the potassic zone in which only local, minor argillic alteration is present. Moderate K-feldspar alteration occurs between D.D.H. 68-4 and D.D.H. 68-1. The alteration down D.D.H. 68-5 is from intense argillic at the top, through a transition zone in which numerous, discontinuous argillic zones are present in a K-feldspar-bearing potassic zone, and to a deep potassic zone in which argillization is quantitatively insignificant.

Section 16, 17: (opposite) argillic alteration is weaker on the extreme left sides of the diagrams than on the right. Moderate K-feldspar alteration noted in section 14 is continuous to section 16 and declines substantially by section 17. Gypsum in section 18 (not shown) is absent to the left of the reference line.


SECTION 14
4500
4000
3500
3000
2500
C66-5
68-12
69-53
68-4
REF. LINE
68-5
68-1
69-33
69-37
L-6
OVERBURDEN
EST. 0.3% Cu
SECTION 16
68-32
69-7
69-8
68-6
69-28
68-2
69-40
69-47
68-23A
68-23
L-2
OVER-BURDEN
EST. 0.3% Cu
GYPSUM ZONE
INTENSE ARGILLIC ALTERATION
TRANSITION TO DEEPER POTASSIC ZONE WITHOUT CLAY
0 feet 1000
SECTION 17
69-20
68-28
69-23
69-5
69-6
68-15
69-31
69-36
68-24
69-49
69-45
L-24
L-22
OVER-BURDEN
EST. 0.3% Cu
inches
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BRITISH COLUMBIA GEOLOGICAL SURVEY

of the sequence of formation of the major hydrothermal alteration facies. In contrast to the generally prograde sequence advocated by Jones (1975) and Osatenko and Jones (in prep.), the present writers conclude that, although there was considerable overlap, the potassic zone was formed in the initial stage of the development of the deposit and was followed by sericitic (phyllic) and argillic alterations. Although much of the potassic zone in the upper part of the deposit has been obliterated, the innermost residual parts seem to differ only in that they lack the anhydrite present at depth. Thus, the pronounced vertical zonation in the Valley Copper deposit is interpreted to be largely the result of superimposed alteration.

The trend of superimposition appears to have followed the sequence: phyllic → argillic → late-stage silicification → gypsum veining. Although the last two do not have an intimate spatial relationship, a close genetic association between argillic alteration and gypsum veining probably exists. Pervasive argillization and phyllic alteration would release large amounts of calcium to the late-stage hydrothermal system; however, because sulphides do not seem to have been affected, an alternative source or sulphur must be found. Jones (1975) has established from isotopic data that the percentage of ocean water in the Valley Copper hydrothermal system reached its maximum at the time of gypsum deposition. It could be assumed that the residual sulphate-rich magmatic fluids were rapidly cooled by the influx of oceanic water, causing gypsum deposition from the hydrothermal mix. However, this model requires that the residual solution be unreasonably sulphate-rich. The alternative favoured here is that the late-stage influx of ocean water accelerated the temperature decline in the partly cooled hydrothermal system which was already rich in calcium and sulphate derived by leaching of the upper part of the potassic zone during argillic alteration. The assumption that anhydrite initially extended above its present position is supported by the apparent abruptness of the change into anhydrite-bearing rock and the lack of comparable vertical zonation in other minerals of the potassic assemblage. Thus, the top of the gypsum zone is considered to represent the horizon at which significant hydrothermal activity ceased. Although lateral migration of the late fluids could distort the model, the gypsum zone at Valley Copper should ideally pinch out at the extreme periphery of the potassic zone because this area lacked anhydrite and was cooler during the last stages of hydrothermal alteration.

Acknowledgments

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C/M at 70
Pantelyev

VALLEY COPPER

A CASE HISTORY

PROPERTY FILE

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By

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During the past five years, the Highland Valley area of British Columbia has been the site of two major copper discoveries, Valley Copper and Lornex. A third discovery, Highmont, may also prove to be of major importance. Taken with the existing producers, Bethlehem and Craigmont, these potential orebodies suggest that the Highland Valley area may become one of the major copper areas of the world.

The location of the major discoveries, current producers and more promising showings is shown on the accompanying sketch (Fig. 1). All of these are within or at the contact of the Guichon batholith, a concentrically zoned body of quartz diorite composition emplaced about 200 million years ago in Upper Triassic time. The deposits and showings discovered to date have many features in common and all are genetically linked to magmatic processes in the Guichon batholith. The purpose of this paper is to comment on the discovery of one of them, Valley Copper, and to describe what is presently known about the deposit.

GEOLOGICAL SETTING

The Guichon batholith is a roughly oval body at least 24 miles long and up to 15 miles wide. Its long axis strikes 345°. The batholith is bounded on the east and west by major north trending faults and according to Carr these faults delimit an up-faulted block of Cache Creek and Nicola rocks into which the batholith has been intruded. The rocks of the batholith are overlain by four later groups consisting largely of volcanics ranging in age from Middle Jurassic to Eocene. The age of the batholith is on geological evidence limited to the interval between early Upper Triassic and Middle Jurassic.

Isotopic ages on rocks of the batholith, 55 of which have now been published, show a remarkable concordance. The average for all of these ages is 196 million $\pm$ 8 M.Y. and the spread is from 184 to 206 M.Y. Most of these ages were done by the K/A method and the possibility of Argon loss has to be considered, however, six Rb/Sr ages from the Craigmont mine agree very closely, i.e. 200$\pm$ 2 M.Y. and this plus the lack of evidence of metamorphism which might have caused Argon loss shows that the ages are probably reliable. On the absolute time scale, this would place the time of consolidation of the Guichon rocks in the Upper Triassic.

The isotopic ages also show that there is no significant or systematic difference in age among the various phases of the intrusive, It would appear that all of the phases crystallized within a short interval and that multiple intrusion, if it did occur, must have been over a short period as well.

INTERNAL STRUCTURE OF THE BATHOLITH

The gross structural pattern in the batholith is shown, best by the distribution of intrusive phases. These phases are arranged in a concentric pattern around a central core of Bethsaida quartz monzonite. The Witches Brook phase displays cross-cutting relationships, but this rock type occurs only in dikes and relatively small irregular masses and since its distribution was probably controlled by local structure, it does not really disrupt the overall pattern.

The type and distribution of phases is shown on the accompanying figure. In all, there are seven distinct phases, two of which are subdivided into five varieties and a late porphyritic phase. There is no significant difference in the absolute ages of the phases, however, there is geological evidence that age increases from the core outward. The outer or hybrid phase, is the oldest and forms a shell up to five miles thick between the intruded rocks and the younger phases of the batholith. Its composition is generally quartz dioritic but this is variable and characteristically this phase contains partially assimilated blocks and fragments of the country rock. The contacts of the hybrid phase are generally gradational grading outward to Nicola or Cache Creek rocks and inward to the Guichon variety of the intrusive. The hybrid shell is much thicker on the western side of the batholith, i.e. 3 to 5 miles vs. ½ - 1 mile and this suggests that the whole batholith may have been tilted eastward by differential movement on the bounding faults.

The later phases are all granodiorites or quartz monzonites and distinction of them is based primarily on textural and mineralogical features and not on bulk compositional differences. There is, however, a decrease in specific gravity, i.e. from 2.80 to 2.64 from the hybrid to the Bethsaida phase that could reflect increasing differentiation. With the exception of the contaminated hybrid shell, the various phases are very similar and the differences among them probably resulted mostly from changing pressure and temperature conditions during intrusion.

Smaller structures within the batholith include faults, shears, breccia and shatter zones. Dikes and dike swarms, which are common, probably reflect another type of structure. The most common direction for linear structures is north-south and the majority of dikes follow this trend. The most notable of these structures is the Lornex fault which bisects the Bethsaida quartz monzonite. Faults and shear zones striking northeast are less common and a third set striking northwesterly, though not obvious, is important in localizing ore, e.g. Alwin, Valley Copper. Breccia zones such as those at Bethlehem, Trojan and on Gnawed Mountain may or may not be related to faulting, since the breccia types vary. However, the Trojan and Bethlehem breccias occur in areas where strong north-south faulting is common and a combination of suitable structural openings and access to volatile charged fluids is certainly suggested as a cause. Shatter zones much as those at Valley Copper, Krain and possibly Lornex occur within or adjacent to major faults and at least in the case of Valley Copper near the intersection of two major structures. The principal difference between the shatter zones and the breccias appears to be that in the shatter zones there was not sufficient space provided by stress release to permit the broken blocks to rotate.

MINERALIZATION IN THE BATHOLITH

Copper mineralization may occur anywhere in the batholith and in any of the various phases. The distribution of producing mines and better known prospects is shown in the accompanying figure. All of these lie close to a north-south line which bisects the batholith and the larger ones except for Craigmont are on or adjacent to a contact of the Bethlehem phase of the intrusive. This latter is suggestive of a genetic relationship with this phase, however, this is probably more apparent than real. All of these mines and prospects are structurally controlled and the mineralization in them is contained in open space fillings formed after the consolidation of the host rock. The significance of the Bethlehem phase and its contact is therefore limited to the influence each has had on the development of structures suitable for ore deposition. Similarly, the north-south zoning may reflect a concentration of deep seated north trending structures formed after differentiation had proceeded far enough to create a reservoir of copper bearing solutions. That this reservoir has been tapped by other structures is apparent from the wide distribution of copper within the batholith, however, structures large enough and continuous enough to contain sizeable orebodies appear at this time to be limited to the central zone.

The mineralization is quite similar from one mine or showing to another. Chalcopyrite is the most common copper mineral however, with the exception of Craigmont, the one producing mine (Bethlehem) and all of the potential producers contain bornite in amounts sufficient to determine the viability of the operation. Pyrite is a common associate of copper, but its amount varies considerably, e.g. at Bethlehem there is a heavy pyrite zone on the southwest side of the Jersey orebody while at Craigmont and Valley Copper pyrite is extremely scarce. The most common iron mineral in terms of occurrence is hematite. This mineral is ubiquitous in copper occurrences, but rarely does it occur in amounts greater than 3 percent, Craigmont being a notable exception. The widespread occurrence of hematite suggests that the mineralizing solutions had a relatively high Eh such as might be expected in a highly aqeous environment. What effect this may have had in the partition of Fe, S and Cu is unknown, but in many deposits it appears that in the competion for sulphur, Cu was favoured over iron and perhaps the oxidation state influenced this. The source of sulphur has been the subject of two recent publications. Christmas, Baadsgaard, et al conclude from a study of S, C and O isotope ratios of Craigmont ore that the sulphur of the ore is of mantle origin and therefore from a deep source. M. P. Schau in a reply to this says that sulphur from assimilated Nicola basalts is just as likely a source since this sulphur would have mantle ratios too. As it now stands, the source of the sulphur is open to question, however the nature of the copper deposits and their relationship to deeply penetrating structures suggests that the copper and sulphur did come from some depth and could well be of mantle origin.

STRUCTURAL SYNTHESIS

The sequence of events leading to the discovery of the Valley Copper orebody started in 1964 with the formation of Valley Copper Mines Limited. This company, at that time, held various groups totalling 425 claims. Evaluation of these groups began immediately and during 1964, 1965, and 1966 various kinds of exploration programs were carried out on all of them. By 1966, a considerable amount of information had been gained from this work and this was used along with published data to produce a geological compilation of the batholith area. To supplement this, a study of aerial photographs was made and this was combined with the known geology to provide a structural interpretation.

The Lornex discovery in 1966 served to draw attention to the Lornex fault and at about the same time new aerial photographs of the area became available. These photographs clearly show the southern extension of this fault for some eight miles, along Skuhost Creek valley. The northern extension beyond Lornex is obscured by steep topography but clearly if the fault is string straight for eight miles, its northern extension should be as well. Thus projection of the fault north through Divide Lake seemed reasonable. Intersection with an inferred structure under Highland Valley was more conjectural for there was not then and there is not now any direct evidence of faulting under Highland Valley. In any case, however, the area adjacent to the conjectured intersection of two large fault structures was considered to provide a worthwhile exploration target.

Another possibility suggested by the location of the Lornex orebody in or adjacent to the Lornex fault was that the orebody might have a displaced portion somewhere along the west side of the fault. At that time, neither the sense nor amount of movement along the Lornex fault was known, however, the occurrence of copper mineralization on the Bethsaida claims suggested a relationship. If indeed the Lornex and Bethsaida mineralization were related, then right-hand movement of about 2 miles was indicated. Particularly suggestive of this was the low grade copper mineralization south of the Lornex orebody and in the southeastern part of the Bethsaida group as indicated by drilling in 1966. If these two areas of low grade mineralization were correlative, then the same spatial relationship could pertain on the Bethsaida group as did at Lornex. In this case, ore grade mineralization should be to the north or northeast.

This rather speculative interpretation needed further support and this was provided by the information compiled in 1966. This compilation in view of the possible importance of the Lornex fault was directed toward trying to find supporting evidence for the supposed right-hand movement of some 2 miles. It was found that the south contact of the Bethsaida quartz diorite had an apparent northward displacement on the west side of the Lornex fault. The amount of this displacement could not be measured accurately but was definitely of the same order as the distance between Lornex and the Bethsaida group.

This supporting evidence made the faulted offset hypothesis a good deal more tenable and suggested that the northeast quarter of the Bethsaida group would be a good exploration target. A second and supporting indicator was the possibility of a major fault intersection directly east of this same area under Divide Lake.

A number of factors have contributed to the discovery of the Valley Copper orebody. One of the most important of these was the realization early in the Valley Copper program that mineralization is always related to structure, particularly open space fillings. In the Guichon batholith there is little, if any, truly disseminated sulphides and with the exception of Craigmont, no replacement of host rock. Orebodies and showings, big or small, are invariably contained in breccias, shear zones, veins, shatter zones, etc. of obvious structural origin and the inference is clear that without the structurally prepared plumbing system there would be no mineralization. Also important is the distribution of copper mineralization within the batholith. Any of the major rock units may contain copper showings and in every case the mineralization is younger than the host rock. It thus becomes difficult to prove a genetic relationship to any rock unit and the importance of structure is further emphasized.

Thus the recognition of the possible significance of the Lornex fault and the Highland Valley fault zone was a very important element in the discovery of the Valley Copper orebody.

PERCUSSION DRILLING

Percussion drilling played a very important role in the discovery of Valley Copper and a few comments about the method follow.

In both 1967 and 1968, percussion drilling was done in the Bethsaida group. In both years, the purpose of this drilling was to test a broad area quickly and cheaply simply to see if copper mineralization was present. In each case, the percussion drill accomplished this purpose at about one-third the cost of diamond drilling.

Thus, for the same cost, three times as many holes can be drilled as with a diamond drill and herein lies the real virtue of the percussion drill. Most orebodies are irregular in shape and variable in grade. One hole drilled through an orebody may, because of geometry or grade distribution, miss the ore grade section completely. Even two or more holes may do the same. The obvious solution is to drill a lot of holes and often this may be uneconomic with a diamond drill, but less likely to be so with percussion drilling. However, the depth limitation of 300 feet poses restrictions for the percussion drill.

THE OREBODY

The Valley Copper orebody is roughly oval in plan with its long axis striking about 310°. Its long dimension is at least 4,500 feet and the shorter 3,000 feet. The deepest hole yet drilled in the orebody was still in ore at 2,340 feet. The tonnage potential easily qualifies it as the largest orebody yet found in Highland Valley and work is still proceeding to actually delimit the area of mineralization. Reserves are currently estimated to be of the order of 600,000 ton/vert. feet grading 0.46% Cu.

The geology of the orebody is quite simple for there is only one major rock type, the Bethsaida quartz monzonite. At least two types of porphyry dikes and a variety of Lamprophyre dike cut the orebody, but these are generally narrow and do not bulk large in the geological picture. The geology does not, therefore, offer much insight into the genesis of the ore and geological controls, e.g. contacts, do not appear to have been important in localizing ore.

Structure on the other hand appears to have been a dominating influence. Almost all of the rock in the orebody has been strongly sheared and fractured and there seems ample evidence that the mineralizing and altering solutions were introduced along a structurally prepared system of openings. Two steeply dipping structural directions predominate, 290° - 310° and 340 - 360°. It is along these directions that quartz veins, shears, faults and linear alteration zones are most commonly found. Other subsidiary systems occur and the pattern of quartz veining and fracturing may change across the orebody, however, the two dominant directions are always present. It is probably no coincidence that of the two dominant directions, one (290° - 310°) is parallel to the Highland Valley fault zone and the other (340 - 360°) is parallel to the Lornex fault. This also applies to the dike system. Both fault systems seem therefore to have had some influence on structural development. In addition, there is a set of flat quartz veins and shears which perhaps resulted from the interaction of the two fault systems.

The ore mineralogy is relatively simple. Two copper sulphides, bornite and chalcopyrite, are present and molybdenite, though ubiquitous, is scarce. Hematite in amounts to 2% is the most common iron mineral, magnetite occurs in rare small patches and pyrite at less than .5% of total sulphide is remarkable for its scarcity. The relative proportions of bornite and chalcopyrite vary within the orebody, but generally bornite predominates in a ratio of about two to one.

The alteration types associated with ore are of the classic kind occurring in porphyry copper deposits in other parts of the world. The most common alteration type is argillic which is pervasive throughout the deposit and appears to be early in the mineralizing sequence since it is cut by quartz veins, sericitic and potassic alteration. Argillic alteration is characterized by a chalky, slightly greenish appearnace of the feldspars and by the alteration of the biotite to a pale green mixture of chlorite and sericite. Potassic alteration is next in the sequence and this is marked by the development of potash feldspar. This type of alteration, though widespread, is generally restricted to zones fifty to one hundred feet wide. Mineralization associated with the potassic alteration tends to be largely chalcopyrite.

Sericitic alteration shows the closest relationship to copper mineralization and it may occur in two distinct ways. Copper-bearing quartz veins almost always carry a selvage of coarse sericite. These veins may as they narrow become fine stringers of sericite, granular quartz and copper sulphides, dominantly bornite. Alternatively, sericite and granular quartz may occur in irregular zones up to 20 feet wide impregnated with bornite and chalcopyrite. In general, when sericite is present, copper sulphides are as well.

Silicification is a prominent feature of the orebody as shown by the great number of quartz veins and the presence of irregular siliceous patches. The amount of quartz observed is in excess of what might be expected from the remobilization of silica originally present in the fresh Bethsaida quartz monzonite and suggests that a good part of it must have been introduced with the mineralizing solutions. Several generations of quartz veins are present including a late barren type. This too might be construed as evidence supporting an epigenetic rather than syngenetic origin for the quartz. Propylitic alteration which commonly occurs on the periphery of porphyry copper deposits, is notable by its absence. Similarly, there is very little pyrite in the orebody and no evidence of a pyritic halo.

In summary, the Valley Copper orebody displays many of the characteristics ascribed to the better known porphyry copper deposits. The lack of a propylitic alteration zone and a pyrite halo probably reflect differences in fluid composition rather than in process and there seems to be little doubt in assigning the deposit to the prophyry copper class.

TESTING PROGRAM

Since May of 1969, a comprehensive testing program has been under way. This program was designed to bulk sample the orebody and to fill in gaps with additional surface and underground drilling.

The underground testing has consisted of driving three inclined headings into the orebody and sampling on a round by round basis. The underground headings were driven at -20% using rubber tired diesel equipment and in plan these headings form an arrowhead pointing southwest. The total footage driven was 4100 feet and the ends of the declines are 500 feet below the portal.

The size of the opening driven was 14' x 11' with an arched back. Each round was mucked, crushed and sampled separately. In order to provide a comparison with diamond drilling, two holes were drilled ahead of the face and the core from these matched to the round lengths to provide three separate samples. This comparison sampling will be done over the entire length of the declines.

Surface diamond drilling has been going on almost continuously since August, 1968, and to date some 90,000 feet have been drilled, almost all of it N.Q. size. Underground drilling started in July, 1969, as soon as working places were available. This program on completion will total 36,000 feet, all B. Q. size.

The testing program is now completed and the information gained from it is currently being assessed. All of this information and the assessment of it will be incorporated into a feasibility study now in progress.

Pontlyon

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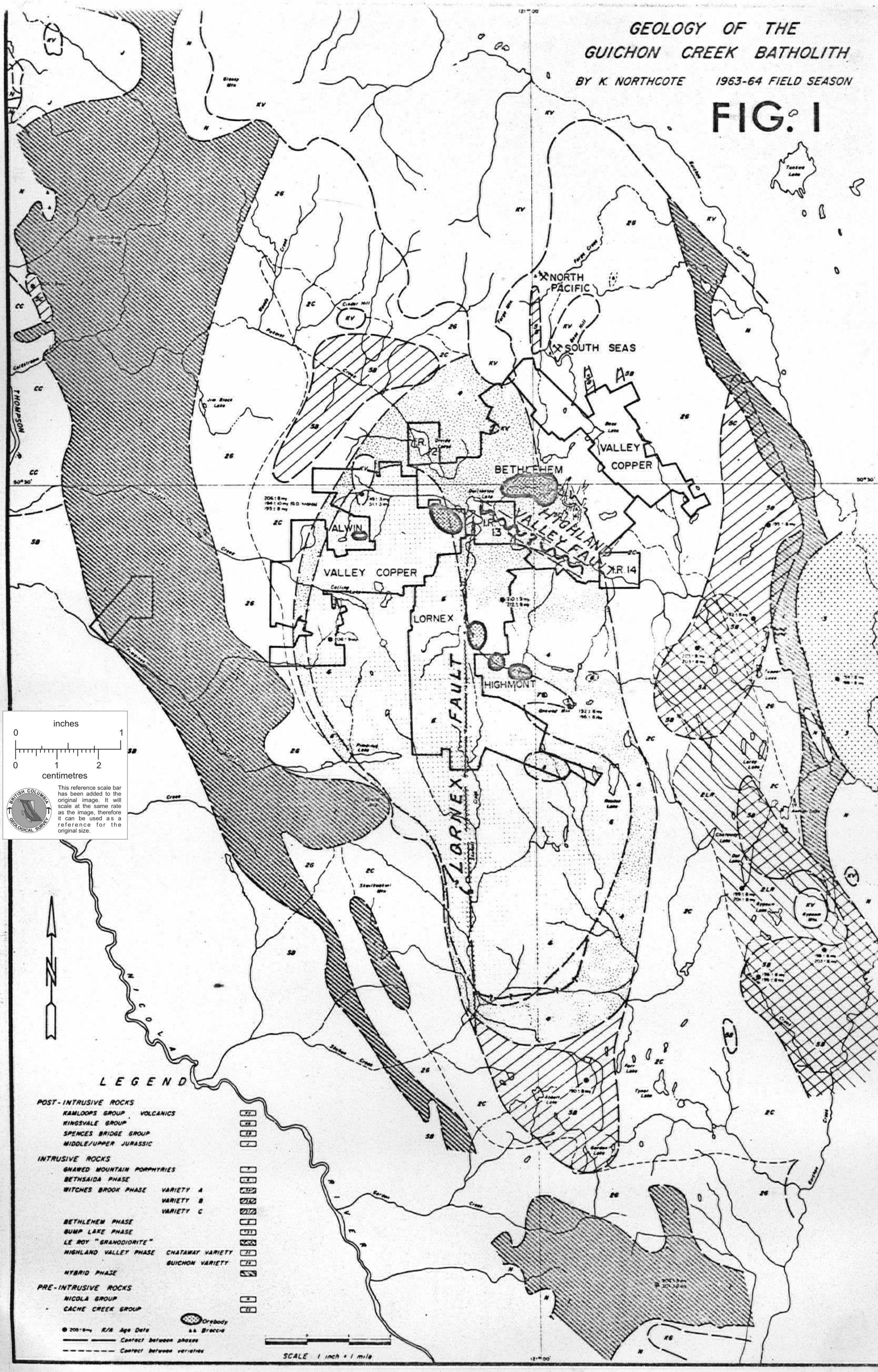
PROPERTY FILE

THE GEOLOGICAL SETTING OF THE VALLEY COPPER OREBODY

BY: J. M. Allen and J. Richardson

Paper to be delivered at the C.I.M. Annual General Meeting, Toronto, 20 - 22 April, 1970 by Dr. J. M. Allen.

VALLEY COPPER


GEOLOGY OF THE
GUICHON CREEK BATHOLITH
BY K. NORTHCOTE 1963-64 FIELD SEASON
FIG. I
NORTH PACIFIC
SOUTH SEAS
VALLEY COPPER
BETHLEHEM
I.R. 12
I.R. 13
I.R. 14
ALWIN
VALLEY COPPER
HIGHLAND VALLEY FAULT
LORNEX
HIGHMONT
LORNEX FAULT
THOMPSON
NICOLA RIVER
LEGEND
POST-INTRUSIVE ROCKS
KAMLOOPS GROUP VOLCANICS
KINGSVALE GROUP
SPENCES BRIDGE GROUP
MIDDLE/UPPER JURASSIC
INTRUSIVE ROCKS
GNAWED MOUNTAIN PORPHYRIES
BETHSAIDA PHASE
WITCHES BROOK PHASE VARIETY A
VARIETY B
VARIETY C
BETHLEHEM PHASE
GUMP LAKE PHASE
LE ROY "GRANODIORITE"
HIGHLAND VALLEY PHASE CHATAWAY VARIETY
GUICHON VARIETY
HYBRID PHASE
PRE-INTRUSIVE ROCKS
NICOLA GROUP
CACHE CREEK GROUP
Orebody
Breccia
K/A Age Date
Contact between phases
Contact between varieties
SCALE 1 inch = 1 mile
inches
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centimetres
This reference scale bar has been added to the original image. It will scale at the same rate as the image, therefore it can be used as a reference for the original size.
BRITISH COLUMBIA GEOLOGICAL SURVEY

THE GEOLOGY OF THE VALLEY COPPER OREBODY

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Smaller structures within the batholith include faults, shears, breccia and shatter zones. Dikes and dike swarms, which are common, probably reflect another type of structure. The most common direction for linear structures is north-south and the majority of dikes follow this trend. The most notable of these structures is the Lornex fault which bisects the Bethsaida quartz monzonite. Faults and shear zones striking northeast are less common and a third set striking northwesterly, though not obvious, is important in localizing ore, e.g. Alwin, Valley Copper. Breccia zones such as those at Bethlehem, Trojan and on Gnawed Mountain may or may not be related to faulting, since the breccia types vary. However, the Trojan and Bethlehem breccias occur in areas where strong north-south faulting is common and a combination of suitable structural openings and access to volatile charged fluids is certainly suggested as a cause. Shatter zones much as those at Valley Copper, Krain and possibly Lornex occur within or adjacent to major faults and at least in the case of Valley Copper near the intersection of two major structures. The principal difference between the shatter zones and the breccias appears to be that in the shatter zones there was not sufficient space provided by stress release to permit the broken blocks to rotate.

MINERALIZATION IN THE BATHOLITH

Copper mineralization may occur anywhere in the batholith and in any of the various phases. The distribution of producing mines and better known prospects is shown in the accompanying figure. All of these lie close to a north-south line which bisects the batholith and the larger ones except for Craigmont are on or adjacent to a contact of the Bethlehem phase of the intrusive. This latter is suggestive of a genetic relationship with this phase, however, this is probably more apparent than real. All of these mines and prospects are structurally controlled and the mineralization in them is contained in open space fillings formed after the consolidation of the host rock. The significance of the Bethlehem phase and its contact is therefore limited to the influence each has had on the development of structures suitable for ore deposition. Similarly, the north-south zoning may reflect a concentration of deep seated north trending structures formed after differentiation had proceeded far enough to create a reservoir of copper bearing solutions. That this reservoir has been tapped by other structures is apparent from the wide distribution of copper within the batholith, however, structures large enough and continuous enough to contain sizeable orebodies appear at this time to be limited to the central zone.

The mineralization is quite similar from one mine or showing to another. Chalcopyrite is the most common copper mineral however, with the exception of Craigmont, the one producing mine (Bethlehem) and all of the potential producers contain bornite in amounts sufficient to determine the viability of the operation. Pyrite is a common associate of copper, but its amount varies considerably, e. g. at Bethlehem there is a heavy pyrite zone on the southwest side of the Jersey orebody while at Craigmont and Valley Copper pyrite is extremely scarce. The most common iron mineral in terms of occurrence is hematite. This mineral is ubiquitous in copper occurrences, but rarely does it occur in amounts greater than 3 percent, Craigmont being a notable exception. The widespread occurrence of hematite suggests that the mineralizing solutions had a relatively high Eh such as might be expected in a highly aqueous environment. What effect this may have had in the partition of Fe, S and Cu is unknown, but in many deposits it appears that in the competion for sulphur, Cu was favoured over iron and perhaps the oxidation state influenced this.

The source of sulphur has been the subject of two recent publications. Christmas, Baadsgaard, et al conclude from a study of S, C and O isotope ratios of Craigmont ore that the sulphur of the ore is of mantle origin and therefore from a deep source. M. P. Schau in a reply to this says that sulphur from assimilated Nicola basalts is just as likely a source since this sulphur would have mantle ratios too. As it now stands, the source of the sulphur is open to question, however the nature of the copper deposits and their relationship to deeply penetrating structures suggests that the copper and sulphur did come from some depth and could well be of mantle origin.

STRUCTURAL SYNTHESIS

The sequence of events leading to the discovery of the Valley Copper orebody started in 1964 with the formation of Valley Copper Mines Ltd. This company, at that time, held various groups totalling 425 claims. Evaluation of these groups began immediately and during 1964, 1965, and 1966 various kinds of exploration programs were carried out on all of them. By 1966, a considerable amount of information had been gained from this work and this was used along with published data to produce a geological compilation of the batholith area. To supplement this, a study of aerial photographs was made and this was combined with the known geology to provide a structural interpretation.

The Lornex discovery in 1966 served to draw attention to the Lornex fault and at about the same time new aerial photographs of the area became available. These photographs clearly show the southern extension of this fault for some eight miles, along Skuhost Creek valley. The northern extension beyond Lornex is obscured by steep topography but clearly if the fault is string straight for eight miles, its northern extension should be as well. Thus projection of the fault north through Divide Lake seemed reasonable. Intersection with an inferred structure under Highland Valley was more conjectural for there was not then and there is not now any direct evidence of faulting under Highland Valley. In any case, however, the area adjacent to the conjectured intersection of two large fault structures was considered to provide a worthwhile exploration target.

Another possibility suggested by the location of the Lornex orebody in or adjacent to the Lornex fault was that the orebody might have a displaced portion somewhere along the west side of the fault. At that time, neither the sense nor amount of movement along the

Lornex fault was known, however, the occurrence of copper mineralization on the Bethsaida claims suggested a relationship. If indeed the Lornex and Bethsaida mineralization were related, then left-hand movement of about 2 miles was indicated. Particularly suggestive of this was the low grade copper mineralization south of the Lornex orebody and in the southeastern part of the Bethsaida group as indicated by drilling in 1966. If these two areas of low grade mineralization were correlative, then the same spatial relationship could pertain on the Bethsaida group as did at Lornex. In this case, ore grade mineralization should be to the north or northeast.

This rather speculative interpretation needed further support and this was provided by the information compiled in 1966. This compilation in view of the possible importance of the Lornex fault was directed toward trying to find supporting evidence for the supposed left-hand movement of some 2 miles. It was found that the south contact of the Bethsaida quartz diorite had an apparent northward displacement on the west side of the Lornex fault. The amount of this displacement could not be measured accurately but was definitely of the same order as the distance between Lornex and the Bethsaida group.

This supporting evidence made the faulted offset hypothesis a good deal more tenable and suggested that the northeast quarter of the Bethsaida group would be a good exploration target. A second and supporting indicator was the possibility of a major fault intersection directly east of this same area under Divide Lake.

A number of factors have contributed to the discovery of the Valley Copper orebody. One of the most important of these was the realization early in the Valley Copper program that mineralization is always related to structure, particularly open space fillings. In the Guichon batholith there is little, if any, truly disseminated sulphides and with the exception of Craigmont, no replacement of host rock. Orebodies and showings, big or small, are invariably contained in breccias, shear zones, veins, shatter zones, etc. of obvious structural origin and the inference is clear that without the structurally prepared plumbing system there would be no mineralization. Also important is the distribution of copper mineralization within the batholith. Any of the major rock units may contain copper showings and in every case the mineralization is younger than the host rock. It thus becomes difficult to prove a genetic relationship to any rock unit and the importance of structure is further emphasized.

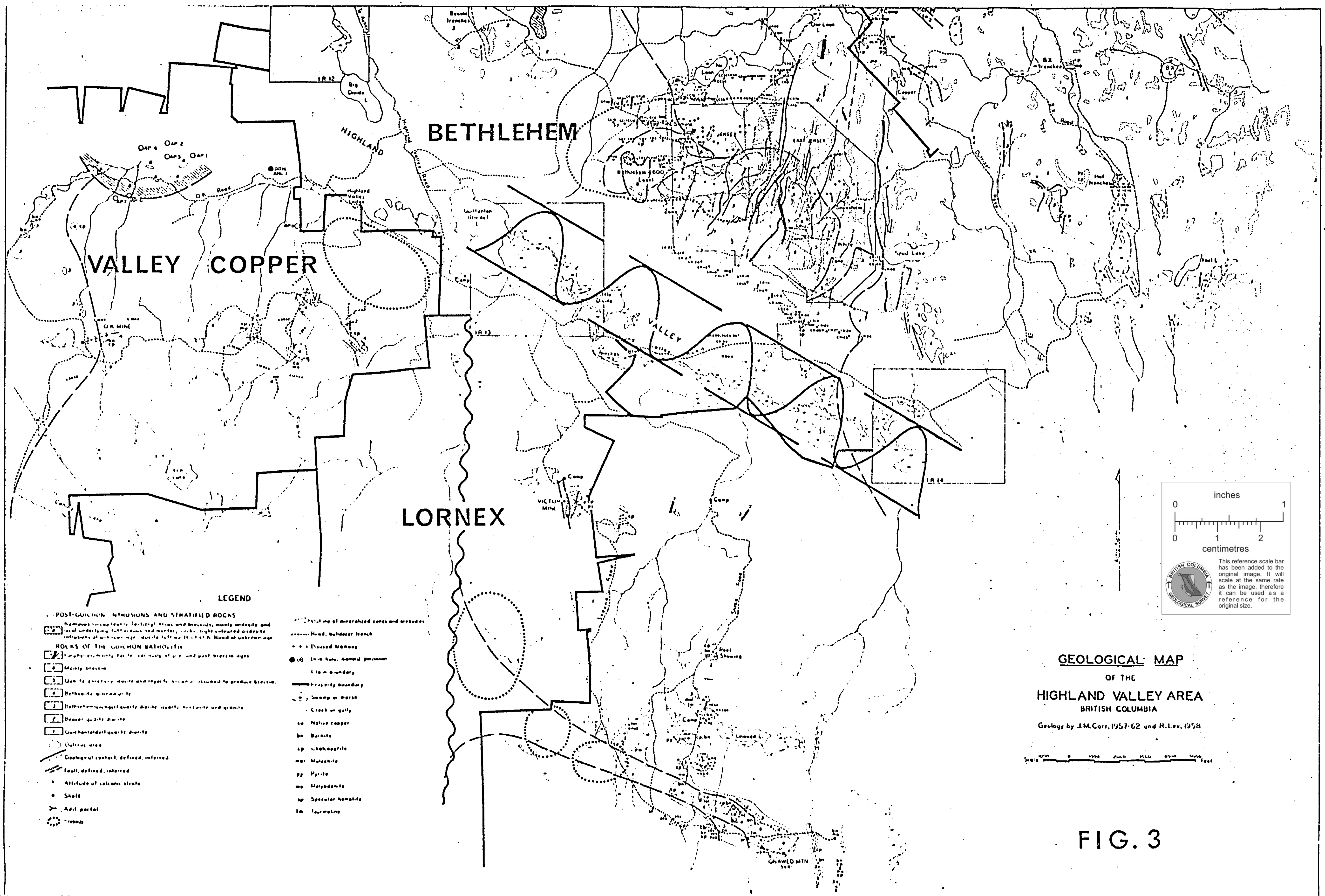
Thus the recognition of the possible significance of the Lornex fault and the Highland Valley fault zone was a very important element in the discovery of the Valley Copper orebody.

PERCUSSION DRILLING

Percussion drilling played a very important role in the discovery of Valley Copper and a few comments about the method follow.

In both 1967 and 1968, percussion drilling was done in the Bethsaida group. In both years, the purpose of this drilling was to test a broad area quickly and cheaply simply to see if copper mineralization was present. In each case, the percussion drill accomplished this purpose at about one-third the cost of diamond drilling.

Thus, for the same cost, three times as many holes can be drilled as with a diamond drill and herein lies the real virtue of the percussion drill. Most orebodies are irregular in shape and variable in grade. One hole drilled through an orebody may, because of geometry or grade distribution, miss the ore grade



GEOLOGICAL MAP OF THE HIGHLAND VALLEY AREA
BRITISH COLUMBIA
Geology by J.M. Carr, 1957-62 and R. Lee, 1958

FIG. 3

section completely. Even two or more holes may do the same. The obvious solution is to drill a lot of holes and often this may be uneconomic with a diamond drill, but less likely to be so with percussion drilling. However, the depth limitation of 300 feet poses restrictions for the percussion drill.

THE OREBODY

The Valley Copper orebody is roughly oval in plan with its long axis striking about 310°. Its long dimension is at least 4,500 feet and the shorter 3,000 feet. The deepest hole yet drilled in the orebody was still in ore at 2,340 feet. The tonnage potential easily qualifies it as the largest orebody yet found in Highland Valley and work is still proceeding to actually delimit the area of mineralization.

The geology of the orebody is quite simple for there is only one major rock type, the Bethsaida quartz monzonite. At least two typesof porphyry dikes and a variety of Lamprophyre dike cut the orebody, but these are generally narrow and do not bulk large in the geological picture. The geology does not, therefore, offer much insight into the genesis of the ore and geological controls, e. g. contacts, do not appear to have been important in localizing ore.

Structure on the other hand appears to have been a dominating influence. Almost all of the rock in the orebody has been strongly sheared and fractured and there seems ample evidence that the mineralizing and altering solutions were introduced along a structurally prepared system of openings. Two steeply dipping structural directions predominate, 290 - 310° and 340 - 360°.

It is along these directions that quartz veins, shears, faults and linear alteration zones are most commonly found. Other subsidiary systems occur and the patternof quartz veining and fracturing may change across the orebody, however, the two dominant directions are always present. It is probably no coincidence that of the two dominant directions, one (290° - 310°) is parallel to the Highland Valley fault zone and the other (340 - 360°) is parallel to the Lornex fault. This also applies to the dike system. Both fault systems seem therefore to have had some influence on structural development. In addition, there is a set of flat quartz veins and shears which perhaps resulted from the interaction of the two fault systems.

The ore mineralogy is relatively simple. Two copper sulphides, bornite and chlcopyrite, are present and molybdenite, though ubiquitous, is scarce. Hematite in amounts to 2% is the most common iron mineral, magnetite occurs in rare small patches and pyrite at less than .5% is remarkable for its scarcity. The relative proportions of bornite and chalcopyrite vary within the orebody, but generally bornite predominates in a ratio of about two to one.

The alteration types associated with ore are of the classic kind occurring in prophyry copper deposits in other parts of the world. The most common alteration type is argillic which is pervasive throughout the deposit and appears to be early in the mineralizing sequence since it is cut by quartz veins, sericitic and potassic alteration. Argillic alteration is characterized by a chalky, slightly greenish appearance of the feldspars and by the alteration of the biotite to a pale green mixture of chlorite and sericite.

Potassic alteration is next in the sequence and this is marked by the development of potash feldspar. This type of alteration, though widespread, is generally restricted to zones fifty to one hundred feet wide. Mineralization associated with the potassic alteration tends to be largely chalcopyrite.

Sericitic alteration shows the closest relationship to copper mineralization and it may occur in two distinct ways. Copper-bearing quartz veins almost always carry a selvage of coarse sericite. These veins may as they narrow become fine stringers of sericite, granular quartz and copper sulphides, dominantly bornite. Alternatively, sericite and granular quartz may occur in irregular zones up to 20 feet wide impregnated with bornite and chalcopyrite. In general, when sericite is present, copper sulphides are as well.

Silicification is a prominent feature of the orebody as shown by the great number of quartz veins and the presence of irregular siliceous patches. The amount of quartz observed is in excess of what might be expected from the remobilization of silica originally present in the fresh Bethsaida quartz monzonite and suggests that a good part of it must have been introduced with the mineralizing solutions. Several generations of quartz veins are present including a late barren type. This too might be construed as evidence supporting an epigenetic rather than syngenetic origin for the quartz. Propylitic alteration which commonly occurs on the periphery of porphyry copper deposits, is notable by its absence. Similarly, there is very little pyrite in the orebody and no evidence of a pyritic halo.

In summary, the Valley Copper orebody displays many of the characteristics ascribed to the better known porphyry copper deposits. The lack of a propylitic alteration zone and a pyrite halo probably reflect differences in fluid composition rather than in process and there seems to be little doubt in assigning the dposit to the prophyry copper class.

TESTING PROGRAM

Since May of 1969, a comprehensive testing program has been under way. This program was designed to bulk sample the orebody and to fill in gaps with additional surface and underground drilling.

The underground testing has consisted of driving three inclined headings into the orebody and sampling on a round by round basis. The underground headings were driven at -20% using rubber tired diesel equipment and in plan these headings form an arrowhead pointing southwest. The total footage driven was 4100 feet and the ends of the declines are 500 feet below the portal.

The size of the opening driven was 14' x 11' with an arched back. Each round was mucked, crushed and sampled separately. In order to provide a comparison with diamond drilling, two holes were drilled ahead of the face and the core from these matched to the round lengths to provide three separate samples. This comparison sampling will be done over the entire length of the declines.

Surface diamond drilling has been going on almost continuously since August, 1968, and to date some 90,000 feet have been drilled, almost all of it N.Q. size. Underground drilling started in July, 1969, as soon as working places were available. This program on completion will total 36,000 feet, all B. Q. size.

The testing program is now virtually completed and the information gained from it is currently being assessed. All of this information and the assessment of it will be incorporated into a feasibility study now in progress.

JMAllen/nc
April 8, 1970

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