FROM CIM SP. VOL. 15

885097

Lornex

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Abstract

The Lornex copper-molybdenum deposit is situated in the Highland Valley of British Columbia, 42 kilometers southeast of Ashcroft. This zoned, structurally controlled, porphyry deposit is entirely within Skeena Quartz Diorite. The host rock, a variety of the Bethlehem phase of the Upper Triassic Guichon Creek batholith, is intruded by a pre-mineral quartz porphyry dyke. The dyke trends northwesterly and is most prominent in the southern portion of the ore zone. The Lornex fault, a north-striking and west-dipping regional structure, is the northwestern boundary of the orebody and separates the host rock from younger, virtually barren Bethsaida Granodiorite west of the orebody.

The ore zone is approximately 1900 meters long and 500 meters wide, and geological interpretations suggest that the orebody plunges 30 to 40 degrees toward the northwest. Mineralization is fracture controlled and commonly occurs as fracture coatings or veins. The major sulphides, in order of abundance, are chalcopyrite, bornite, molybdenite and pyrite.

These sulphide minerals and hydrothermal alteration zones are distributed in a roughly concentric pattern. The bornite core is surrounded by a zone of chalcopyrite and molybdenite mineralization; pyrite is peripheral. Phyllic and pervasive argillic alterations occupy the ore zone and propylitic alteration occurs in the peripheral zone of pyrite and lower copper grades. Intensity of hydrothermal alteration increases with fracture density and sulphide content.

The Lornex orebody is considered to have formed at the intersection of regional structures. Tectonic stresses developed conjugate shears at this intersection which were subsequently mineralized by the injection of hydrothermal fluids. Reactivation of stresses caused rupture, displacement and tilting of the mineralized zone along the Lornex fault. Minor faulting and fracturing of the mineralized zone occurred after relaxation of major tectonic forces.

Location

THE LORNEX copper-molybdenum deposit is located in the interior plateau of British Columbia on the southern slope of the Highland Valley — Lat. 50° 27′ N, Long. 121° 03′ W, NTS 92I/6E. The original surface of the orebody is about 1550 meters above sea level. The property is 42 km by road southeast from Ashcroft and 72 km by road from Kamloops.

History

Copper mineralization was discovered in bulldozer trenches by Egil Lorentzen in 1964. Mr. Lorentzen formed Lornex Mining Corporation, and in 1965, under agreement with Lornex, Rio Tinto Canadian Exploration Limited began an investigation of the property. A program of geochemical, induced polarization, magnetometer and geological surveys was implemented. The IP survey outlined two zones where chargeabilities were in excess of twice mean background (i.e. chargeabilities in excess of 5 milliseconds). Subsequent diamond drilling of the anomalous zones returned encouraging copper grades. A total of 26,200 meters of surface diamond drilling and 27,000 meters of percussion drilling were completed by 1967. An underground bulk sampling program and a small open pit provided feed for a pilot mill at 90 tonnes per day. The mine was put into production in the spring of 1972 by Lornex Mining Corporation Limited, which is controlled by Rio Algom Mines Limited.

The developed orebody contained an estimated 266 million tonnes of mineable ore averaging 0.427 per cent copper and 0.014 per cent molybdenum at a cutoff grade of 0.26 per cent copper and a waste-to-ore ratio of 1.2:1. During the period from 1973 to 1974, an additional 20,700 meters of diamond drilling was completed. Drill-indicated reserves, within a single open pit, as of December 31, 1974, were estimated to be 425 million tonnes of proven ore grading 0.412 per cent copper and 0.014 per cent molybdenum at a 0.26 per cent copper cutoff grade and a 2:1 waste-to-ore ratio.

The mill was designed to process 34,500 tonnes of ore per day. Actual throughput, however, has been such that, for planning purposes, the mill capacity is now rated at 43,500 tonnes per day.

Regional Geology

The Lornex ore deposit occurs within the composite, concentrically zoned, Upper Triassic, Guichon Creek batholith (see McMillan, this volume).

The batholith, which is approximately 65 kilometers long and 30 kilometers wide, trends in a north-northwesterly direction. The batholith has been divided into four phases, which are compositionally and texturally distinguishable. From oldest to youngest, the phases are as follows.

1.) The Hybrid phase is peripheral and is generally a mafic-rich quartz diorite to diorite in composition.
2.) The Highland Valley phase consists of the Guichon and Chataway granodiorites.
3.) The Bethlehem phase is generally granodiorite, but the Skeena variety, the host rock for the orebody, is a medium- to coarse-grained quartz diorite.
4.) The central Bethsaida phase is coarse-grained granodiorite to quartz monzonite.

The batholith intrudes sedimentary and volcanic rocks of the Permian Cache Creek Group and Late Triassic Nicola Group.

Middle Jurassic sedimentary rocks and Cretaceous volcanic and sedimentary rocks unconformably overlie the batholith. The orebody and most of the batholith were mantled with a veneer of Pleistocene glacial deposits.

Structural zones transect the Guichon Creek batholith and are considered to be the result of regional tectonic stresses which created a series of block faults (Carr *et al.*, 1970). Predominant trends in the batholith are north, northwest and, to a lesser extent, east and northeast. According to McMillan, (pers. comm., 1974), the Lornex orebody is located in a horst bounded on the north by the Highland Valley fault and on the south by the Skuhun Creek fault. The horst is cut by the north-striking Lornex fault. This regional fault forms the contact between the Bethsaida and Bethlehem phases in the vicinity of the Lornex orebody and truncates mineralization in the ore zone. Cumulative movement on this west-dipping fault is apparently right lateral and reverse (McMillan, pers. comm., 1974).

Geology of the Ore Deposit

The Lornex copper-molybdenum deposit is approximately 1900 meters long, 500 meters wide and plunges northwesterly to a depth in excess of 750 meters (below 850 m A.S.L.). The ore deposit is mantled by 2 to 75 meters of overburden, which gradually thins eastward from a maximum depth in Award Creek Valley, the surface expression of the Lornex fault.

The orebody occurs within Skeena Quartz Diorite, a slightly porphyritic, medium- to coarse-grained rock (Fig. 1). It consists of quartz (20%), plagioclase (50%), orthoclase (10%), biotite (5-10%) and hornblende (5-10%), with accessory sphene, apatite, zircon and magnetite. Quartz occurs interstitially in subhedral grains that show undulatory extinction. Plagioclase is twinned and exhibits oscillatory zoning, with crystal cores of about An_{30-35}. Orthoclase is interstitial and perthitic. Biotite is subhedral to euhedral. Hornblende is irregular anhedral and commonly has a poikilitic texture.

A pre-mineral quartz porphyry dyke (Fig. 1), which is probably related to the Bethsaida phase (McMillan, pers. comm., 1974), trends northwesterly through the Highmont property and into the Lornex orebody.

Contacts of the dyke are indistinct because of silicification and sericitization of adjoining Skeena Quartz Diorite. The dyke is presumed to have intruded one of a series of structural zones parallel to Highland Valley (Bergey *et al.*, 1970). Quartz phenocrysts normally compose 20 to 25 per cent of the dyke and plagioclase phenocrysts occur locally. The grey aphanitic matrix is composed of 60 to 70 per cent plagioclase (An_{40}) and 10 per cent quartz.

AGES OF ROCK TYPES AND MINERALIZATION

All phases of the Guichon Creek batholith have been dated at 198 ± 8 m y (Northcote, 1969), however geologic evidence indicates that relative age decreases from the periphery to the core. Hydrothermal alteration products from the Lornex orebody were dated at 190 ± 4 m y (Jones *et al.*, 1974). This and geological evidence indicates that Lornex mineralization is slightly younger than the youngest intrusive phase of the batholith.

STRUCTURE

Mineralization at Lornex is controlled by fracture density and distribution. Mineralized and post-mineral fractures were formed during at least three periods of deformation. In order to facilitate the study of more than 11,000 structural measurements from the Lornex pit, a computerized stereo-plot program was utilized. This program plots poles to planes on a lower-hemisphere, equal-area net. As illustrated in Figure 3a, contoured plots of per cent density indicate three major attitudes for copper-molybdenum veins: N22°E/55°SE, N64°E/57°SE and N90°E/58°S. Certain of these veins are dominant in distinct zones of the orebody. The N22°E-striking veins are common in the northern zone, whereas the N90°E-striking veins are concentrated in the south and southeast zones. In the central and western zones there is an overlap of all three vein attitudes, which results in a greater

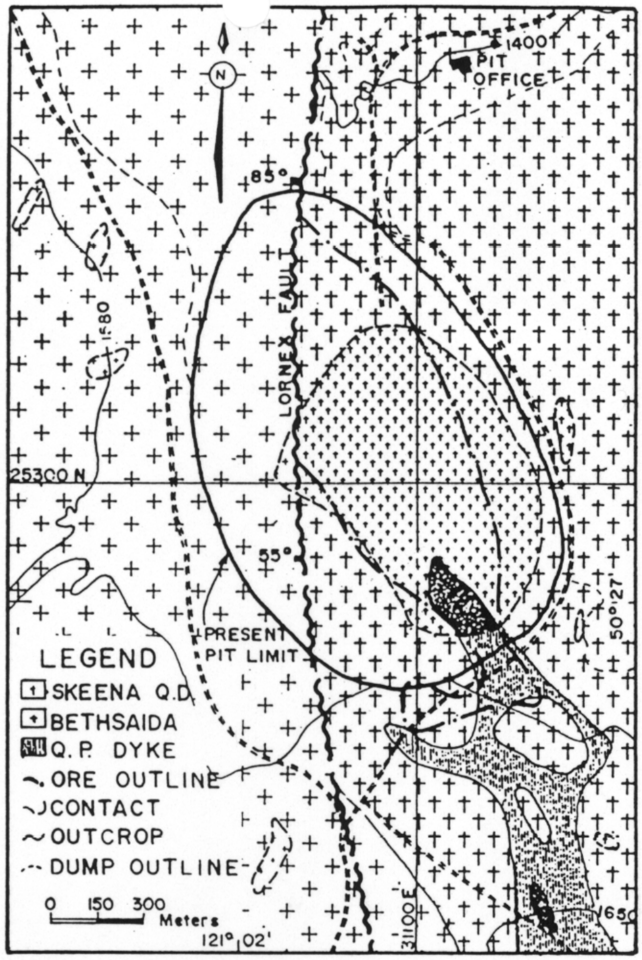

FIGURE 1 — General geology of the Lornex deposit.

concentration of veins and high copper grades (Fig. 2).

Two post-mineral fracture systems have been recognized in the open pit. One system of faults and fractures trends N86°W/52°S to N88°W/62°S and N21°E/46°SE to N32°E/54°SE (Fig. 3b and 3c), sub-parallel to the N22°E- and N90°E-striking copper-molybdenum veins. A second system which offsets the first has three dominant trends:

Fractures	Faults
1.) N68°W/69° S W	N63°W/57° S W
2.) N44°W/66° S W	
3.) N 8°W/68° W	N 8°W/64° W

Where faults cut vein mineralization, displacements are from 1 centimeter to 2 meters.

In summary, three distinct structural systems, one mineralized and two unmineralized, have been recognized in the orebody. They are, from oldest to youngest:

(1) mineralized fractures striking N22°E, N64°E and N90°E;

(2) post-mineral faults and fractures which strike N88° to 86°W and N21°E to N32°E;

(3) faults and fractures which strike N68° to 63°W, N44°W and N8°W.

The most prominent structural feature is the Lornex fault, illustrated in Figures 1 and 2a. It has been exposed by mining and intersected by diamond drill holes. The fault truncates the northwestern part of the ore deposit and juxtaposes Bethsaida Granodiorite and Skeena Quartz Diorite in the vicinity of the orebody.

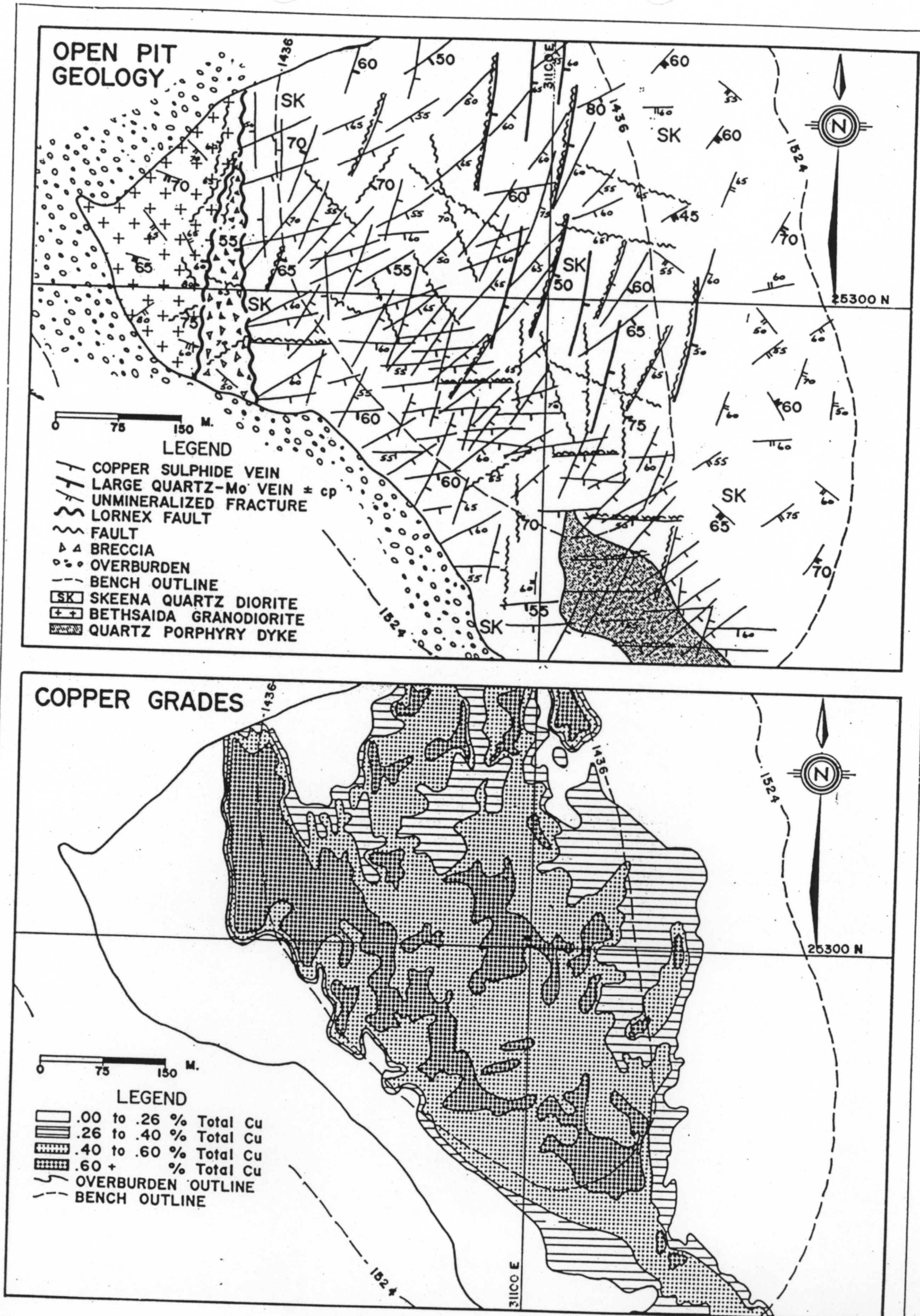

FIGURE 2 — Composite maps of 1436-m and 1524-m benches, illustrating: (a) structural geology and (b) copper-grade distributions.

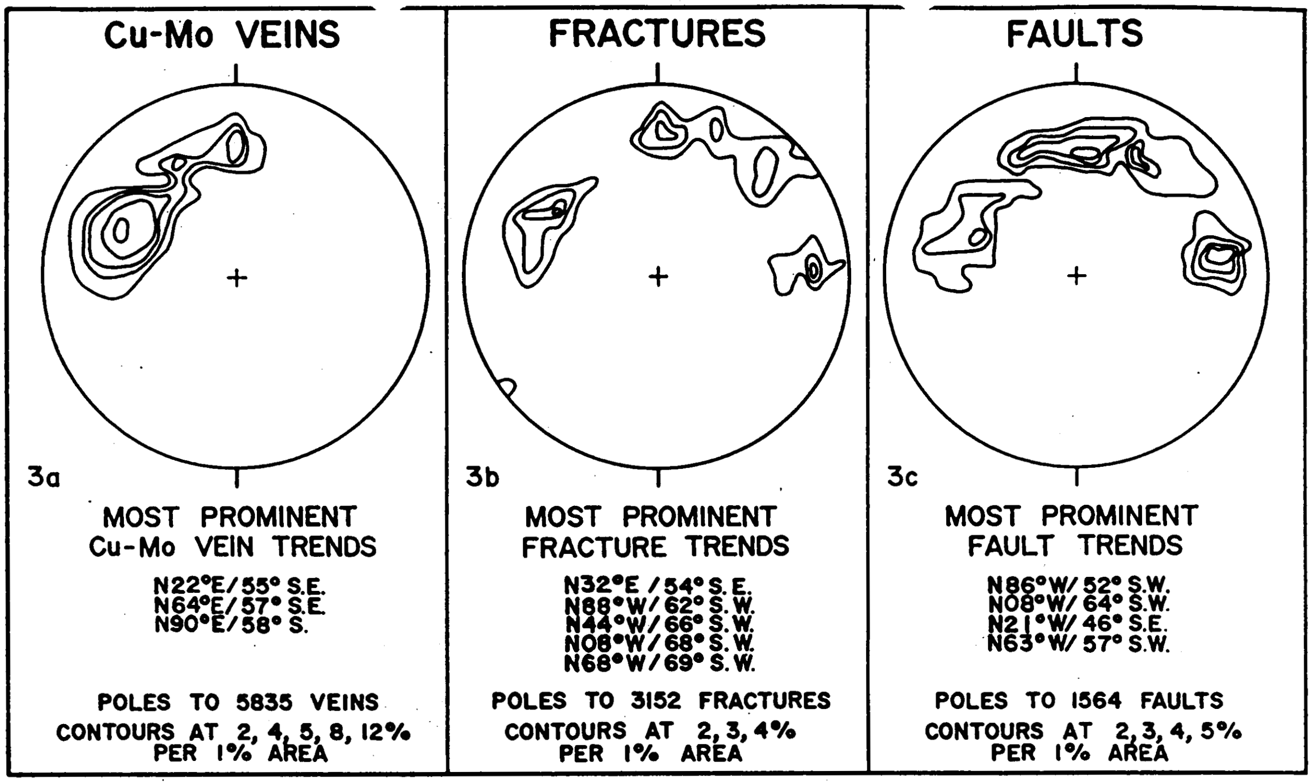

FIGURE 3 — Lower-hemisphere, equal-area stereographic projections of structures mapped in the open pit.

The fault strikes northerly and dips 55 to 85 degrees westward. In general, the dip is least in the south and steepens toward the north. Black gouge, which forms on the footwall of the fault zone, varies in thickness from 10 centimeters to 1½ meters. Mylonite, which forms discontinuous pods 1 to 50 meters wide in the hanging wall of the fault zone, has been exposed in the pit over a strike length of 75 meters.

MINERALIZATION

The predominant hypogene sulphide minerals, in order of abundance, are chalcopyrite, bornite, molybdenite and pyrite. Minor amounts of sphalerite, galena, tetrahedrite and pyrrhotite also occur. Total sulphide content averages 1 to 1.5 weight per cent in the ore zone, but gradually decreases from the central part of the orebody toward its periphery. Common gangue minerals include quartz, calcite, epidote, hematite, magnetite and gypsum.

Sulphide mineralization occurs primarily as fracture fillings with quartz and as fracture coatings. Only an estimated 5 per cent of the total bornite, chalcopyrite and pyrite mineralization occurs as disseminations or as partial replacements of mafic constituents of the host rock. Veins average 5 to 15 millimeters in width, but vary in width from a hairline to more than a meter. The larger veins, some of which have been mapped along strike lengths of over 200 meters, are commonly composed of quartz, molybdenite and chalcopyrite. Molybdenite may occur as rosettes in vuggy quartz veins, but normally occurs as thin laminae in banded quartz veins. Kimura and Drummond (1968) describe similar veins at Endako and suggest that repetitive pulses of mineralization occurred along these types of vein structures. Molybdenite veins more than a meter in width are prominent on the eastern side of the orebody (Fig. 2a). Post-ore faults are prevalent along these veins.

An erratic band of late-stage gypsum occurs at elevations below approximately 1100 meters (Fig. 7b). The gypsum is generally at a higher level on the fringe of the orebody and deeper in its center. Gypsum mineralization is post-ore and occurs in veins 5 to 10 millimeters thick.

Trace-element studies of the orebody, surrounding rocks and the Lornex fault zone indicate anomalous values of several elements. Anomalously high amounts of Zn, Ag and Bi and, according to Olade (1974), Pb, Mn, Hg, Cd and Ca exist in the Lornex fault where it truncates the orebody. Zinc values as high as 1200 ppm have been determined from analyses of Lornex fault gouge. Sphalerite and discontinuous pods of massive pyrite occur in the Lornex fault zone, but chalcopyrite, bornite and molybdenite have not been observed. Assays of over 70 ppm Bi in the fault are probably due to the presence of bismuthinite, which was identified by microprobe analyses of copper concentrate. The orebody is enriched in B, Ti and V, but anomalously low in Mn, Sn and Ba.

HYDROTHERMAL ALTERATION

X-ray diffraction (McMillan, pers. comm., 1974), megascopic and microscopic studies were conducted to classify intensities and types of hydrothermal alteration. Four types of alteration — potassic, phyllic, argillic and propylitic — which are related to quartz and sulphide mineralization have been recognized. A fifth type of alteration, silicification, is not detailed, because the zone of silicification appears to be related to the pre-mineral quartz porphyry dyke.

This dyke appears to be weakly affected by the other hydrothermal alterations, in contrast to the Skeena Quartz Diorite host, which was very susceptible.

Potassic Alteration

Potassic alteration is erratically distributed and no well-defined potassic zone exists at the levels explored in the Lornex orebody. The hydrothermal K-feldspar that does exist is found as veins that average approximately 5 millimeters in width.

Phyllic Alteration

Phyllic alteration in the orebody consists of quartz-sericite envelopes. A grey mixture of quartz and sericite commonly forms borders on quartz-copper sulphide and quartz-molybdenite veins within the argillic alteration zone (Fig. 10a & b). These envelopes, which commonly form sharp boundaries with pervasive moderate to intense argillic alteration, average approximately 3 centimeters in width.

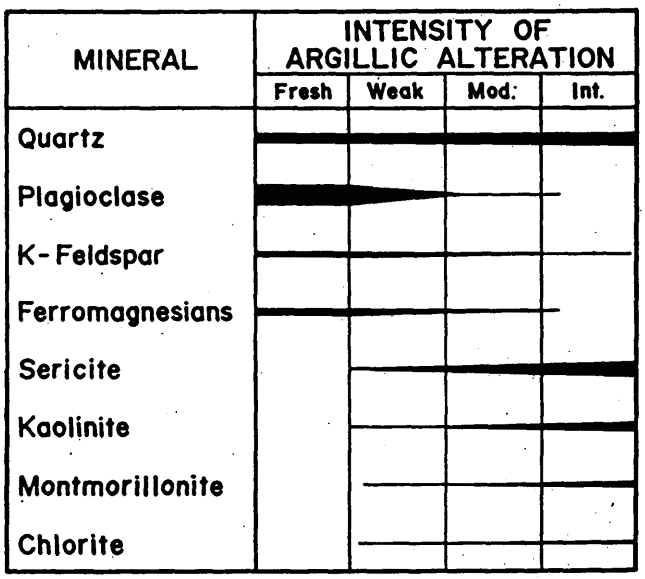

FIGURE 4—Abundance of minerals which define zones of varying intensity of argillic alteration.

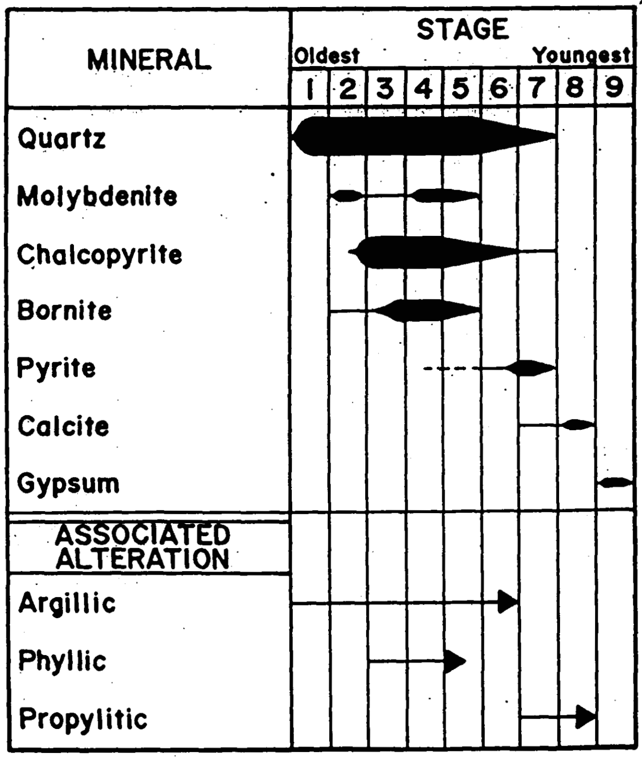

FIGURE 5—Paragenetic sequence and relative abundance of mineralization and related hydrothermal alteration.

Argillic Alteration

Argillic alteration, which is pervasive throughout the ore zone, is characterized by the presence of quartz, sericite, kaolinite, montmorillonite and chlorite. Sericite and kaolinite, with minor montmorillonite and chlorite, form pseudomorphs after plagioclase. The cores of the plagioclase crystals are more intensely altered than the rims, but in the intense stage of argillic alteration the entire plagioclase crystal is replaced by sericite and clays. Kaolinite, sericite and minor montmorillonite also replace orthoclase. In contrast to plagioclase, the alteration of these crystals progresses from the rim toward the core with increasing intensity of argillic alteration. Biotite and hornblende alter to chlorite and sericite. The pervasive argillic alteration of the Skeena Quartz Diorite has produced a cream or apple green coloured rock. In the cream varieties, kaolinite predominates over sericite, but in the apple green variety sericite predominates over kaolinite.

Classification of the intensity of argillic alteration is based on the degree of alteration of feldspars and mafic minerals. Figure 4 illustrates the variations in amounts of rock-forming and alteration minerals with increasing intensity of argillic alteration. Generally, total copper grades increase as the intensity of argillic alteration increases.

Propylitic Alteration

Propylitic alteration is also pervasive and is peripheral to the argillic alteration. The typical propylitic alteration assemblage consists of epidote (zoisite), chlorite and carbonates (calcite), with minor sericite and hematite. Epidote and calcite are most common as veins. Quartz and orthoclase are fresh, but plagioclase, which has a fresher appearance than in the argillic alteration zone, alters to calcite and epidote with minor amounts of sericite and chlorite. Mafic minerals alter to chlorite, calcite and sericite, with minor hematite and epidote.

PARAGENESIS AND ZONING

Relative ages of mineralization have been determined from crosscutting relationships, such as are illustrated in Figures 10a & b, polished-section exsolution features and vein zoning. The stages of mineralization and the related alteration types for each stage are illustrated in Figure 5. Quartz is ubiquitous in all but the two youngest stages of mineralization. Molybdenite occurs in stages 2 to 5, but is most abundant in stages 4 and 5.

Copper mineralization is generally confined to stages 3, 4 and 5. Pyrite mineralization is insignificant in the ore zone. It is probable that calcite veining associated with propylitic alteration is an alteration product rather than a late-stage product of hydrothermal fluid fractionation, but no definite relationship has been determined. The final stage of mineralization, gypsum, has no associated alteration. The concave line below the 1200-meter elevation on Figure 7b is the gypsum line.

Concentric horizontal (Fig. 6) and vertical (Fig. 7a and b) zonal distributions of principal sulphides and major hydrothermal alteration phases are evident at Lornex. Sulphide and alteration zones plunge northwesterly at 30 to 40 degrees and terminate abruptly against the footwall of the Lornex fault. Bottoms of

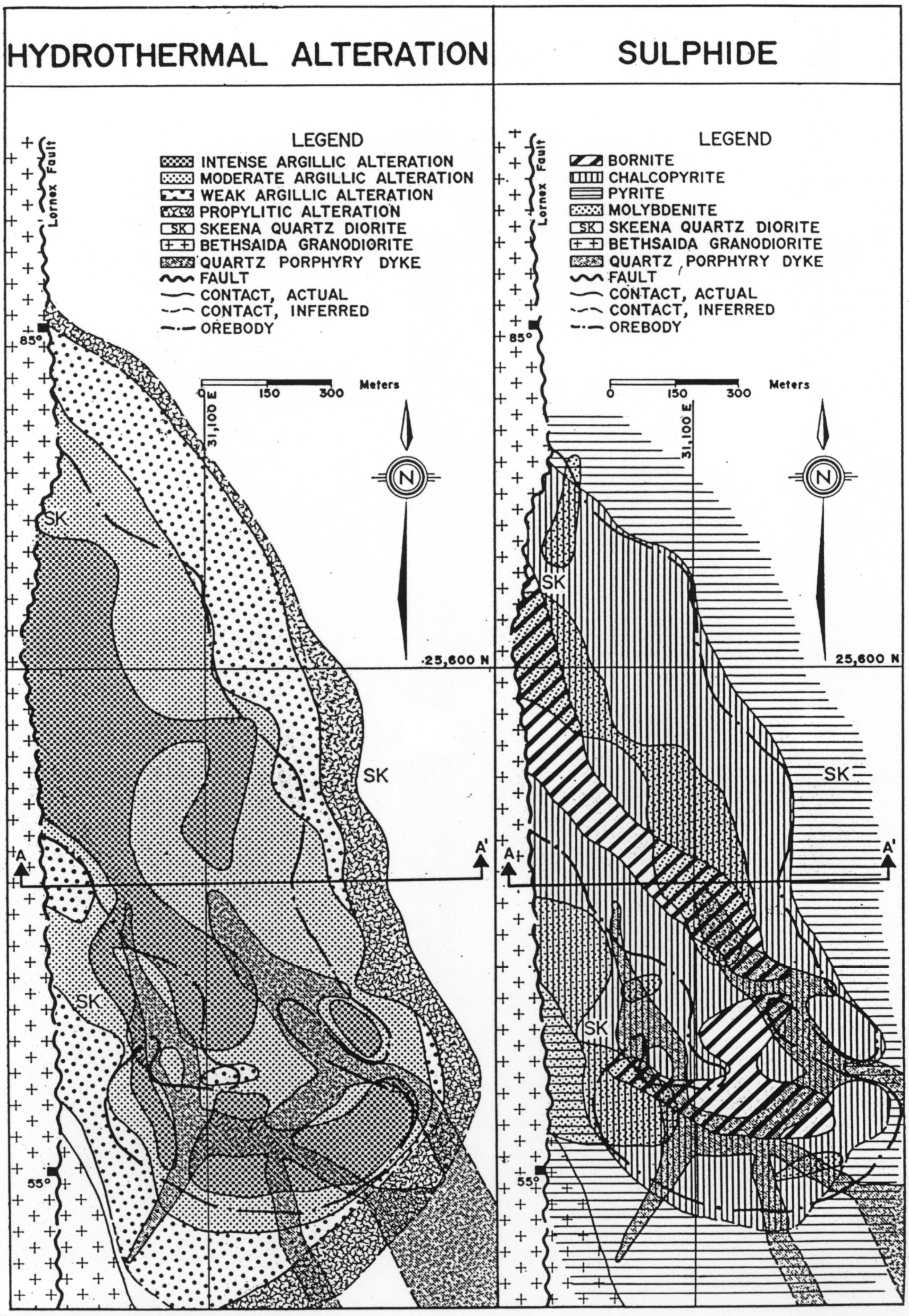

FIGURE 6 — Hydrothermal alteration and sulphide mineral zoning at the 1370 level.

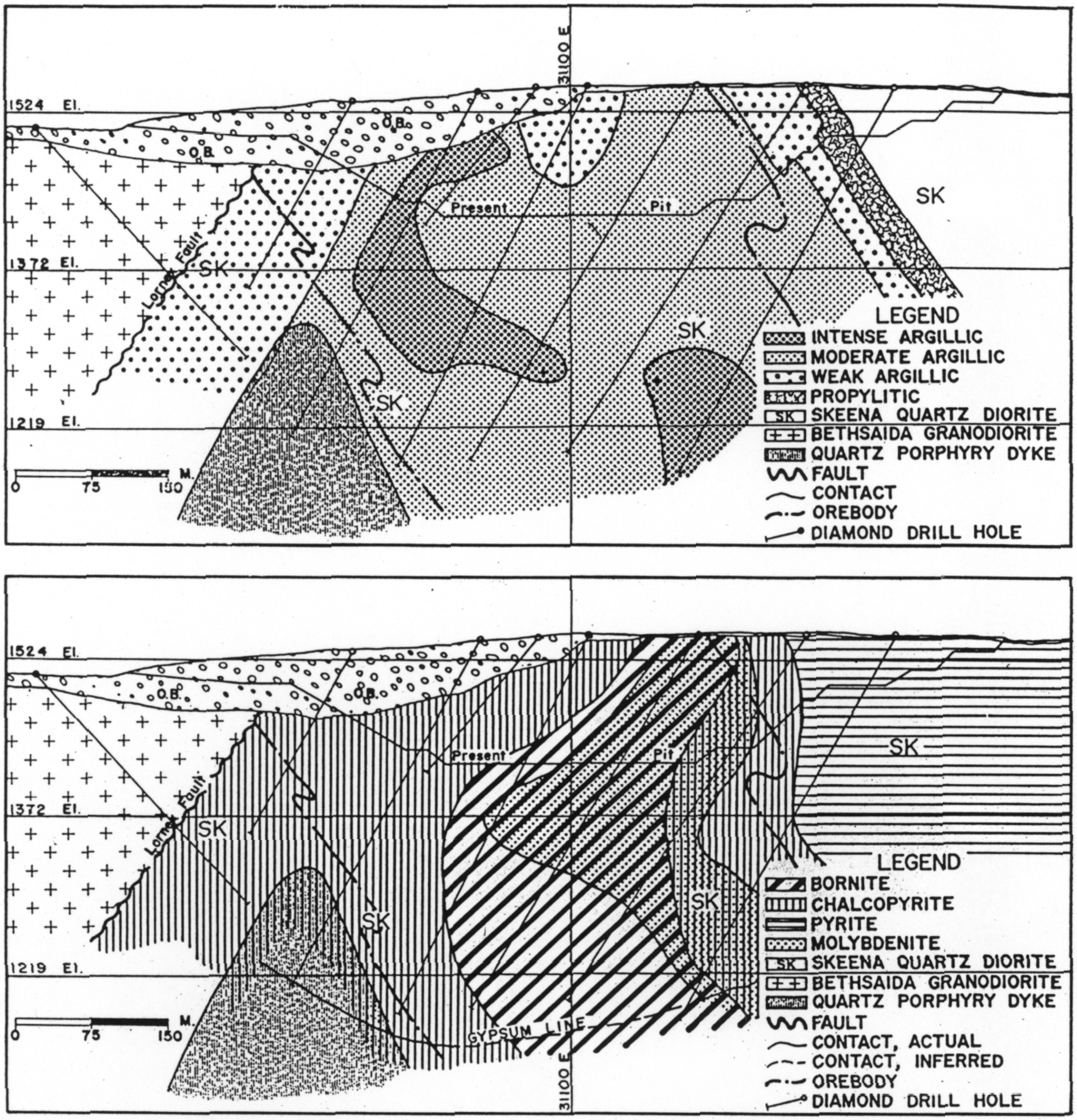

FIGURE 7 — Section A-A', looking north, showing: (a) zonation of hydrothermal alteration and (b) sulphide mineralization.

zones have been determined in the south-central portion of the orebody and have been interpreted in the northern part. The shallow depth of the zones in the south-central area coincides with the highest level of quartz porphyry dyke intrusion.

Weak hydrothermal alteration and the relatively low sulphide content in the dyke may be due in part to both the very fine grained nature of the dyke matrix and the halo of silicified rock surrounding the dyke, which may have impeded access of hydrothermal fluids to the dyke.

The sulphide zones illustrated in Figures 6 and 8 are defined as follows:

Bornite Zone: bornite $>$ chalcopyrite $>$ pyrite
Chalcopyrite Zone: chalcopyrite $>$ bornite $>$ pyrite
Pyrite Zone: More than 0.05% pyrite and total copper $\leq$ 0.26% Cu.
Molybdenite Zone: molybdenum $\geq$ 0.02% Mo.

Total sulphide content averages 1 to 1½ per cent in the bornite, chalcopyrite and molybdenite zones, but only ¼ to ½ per cent in the pyrite zone. According to Olade (1974), an increase in pH could cause the sulphide zonation, if the rate of decrease of copper, caused by deposition of copper sulphide, was less than the rate of decrease of H^+ activity caused by hydrothermal alteration.

The alteration maps (Figs. 6 and 7a) illustrate zones of pervasive argillic and propylitic alteration. The argillic alteration has been divided into three degrees of intensity, as defined in Figure 4. A marked zone of phyllic alteration is not shown on the maps, but generally coincides with zones of moderate to intense argillic alteration.

The following general statements regarding the mineral and alteration zoning of the orebody can be

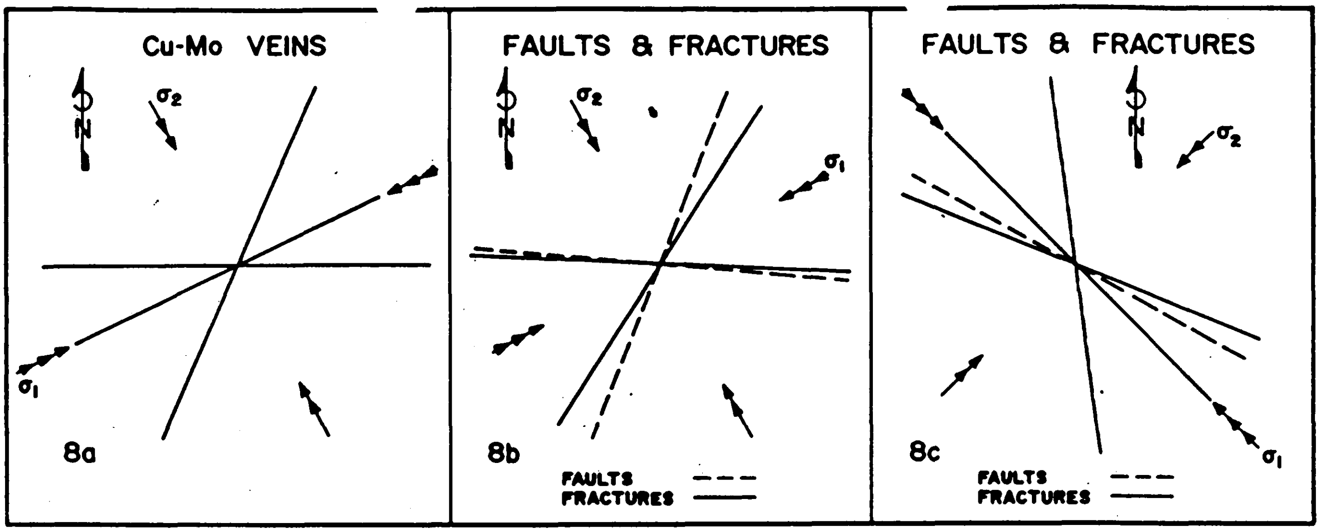

FIGURE 8 — Interpreted principal stress directions and structures developed during the three periods of deformation.

made.

(1) The principal sulphides form a concentric pattern, with bornite in the center, chalcopyrite outside bornite, and a molybdenite zone overlapping portions of the bornite and chalcopyrite zones. Pyrite forms a halo around the ore zone.

(2) Copper grades and total sulphide content decrease outward from the core of the orebody to its periphery.

(3) Sulphide and alteration zones are deep in the north and shallow in the southern portions of the orebody, indicating a 30- to 40-degree northwest plunge to the orebody.

(4) Zones of moderate to intense argillic alteration correspond to grades higher than 0.26 per cent copper and a total sulphide content greater than 1 per cent.

(5) The propylitic alteration zone which occurs on the margin of the orebody is associated with subeconomic copper grades, with the pyrite zone and with a total sulphide content of less than one-half of 1 per cent.

WEATHERING AND SUPERGENE CHARACTERISTICS

The oxide zone averages only 3 to 30 meters in thickness and contains only minor amounts of recoverable copper sulphides. It is thickest on the west side of the orebody and thins toward the east. The depth of the zone is irregular, apparently controlled by local fracture density. Malachite is the predominant copper mineral in the oxide cap, but azurite, cuprite, chalcocite, covellite and native copper are common. Limonite and pyrolusite are also abundant in this zone. No molybdenum oxide minerals have been identified. Enrichment in the oxide zone is not economically important, although a discontinuous layer of chalcocite, averaging about 5 to 10 centimeters thick, occurs at the oxide-sulphide interface.

Genesis of the Ore Deposit

The interpretation of the genesis of the orebody has been based on the following criteria.

(1) The age of 198 ± 8 m y for the batholith and 190 ± 4 m y for the mineralization.

(2) The intersection of the Lornex fault and the zones of weakness along which the quartz porphyry dyke intruded.

(3) Truncation of the Skeena Quartz Diorite and the ore zone by the Lornex fault.

(4) The interpreted right-lateral and reverse movement on the Lornex fault.

(5) Sulphide mineralization occurs primarily as fracture infillings.

(6) The N22°E/55°SE, N64°E/57°SE and N90°E/58°S orientations of copper-molybdenum veins.

(7) The density and spatial distribution of veins in the orebody.

(8) The presence and orientation of two post-mineral structural systems. Faults and fractures in the first set strike N26°E and N87°W. The youngest faults strike N65°N and N8°W; fractures strike N44°W.

(9) The relative ages of mineralization and related hydrothermal alteration.

(10) Hydrothermal alteration is weaker and sulphide content is less in the quartz porphyry dyke, relative to the Skeena Quartz Diorite.

(11) The concentric, zonal distribution of sulphides and hydrothermal alteration.

(12) The interpreted 30- to 40-degree northwest plunge of the ore deposit.

Emplacement of the Lower Jurassic Guichon Creek batholith into Permian and Triassic rocks of the Cache Creek and Nicola groups appears to have been controlled by major, deep-seated zones of weakness (Carr and McMillan, 1970).

The Lornex fault may be the rejuvenated supracrustal expression of one of these deep-seated structures. The quartz porphyry dyke, probably related to intrusion of the Bethsaida phase, was emplaced along a northwest-trending zone of weakness which intersects the Lornex fault.

Figure 9 illustrates the proposed genetic model of the orebody, as described below.

Pre-mineral tectonic stresses are thought to have formed a conjugate shear system at the intersection of the Lornex fault and the quartz porphyry dyke. Maximum principal stresses from the east-northeast and west-southwest produced the fracture pattern illustrated in Figure 8a. These shear fractures strike N22°E and N90°E, and extension fractures strike N64°E. Assuming that the principle stresses were vertical, fractures developed at this time would also be vertical.

Ore-bearing, hydrothermal fluids, which may have developed as a late-stage fractionation of the magma that formed the batholith, migrated along the fractures. The result was an epithermal ore deposit with a concentric zonal distribution of sulphide minerals and hydrothermal alteration (concentric rings in Fig. 9). The bornite-rich central core has associated phyllic and moderate to intense argillic alteration.

Successively outward is a chalcopyrite zone with phyllic and moderate to intense argillic alteration, and a peripheral zone of pyrite mineralization with associated weak argillic and propylitic alteration. A zone of high total sulphide content developed in the zone of most intense fracturing (stippled area on Fig. 9).

Following mineralization, it is thought that regional stresses, with maximum principal stresses from the east-northeast and west-southwest, produced further

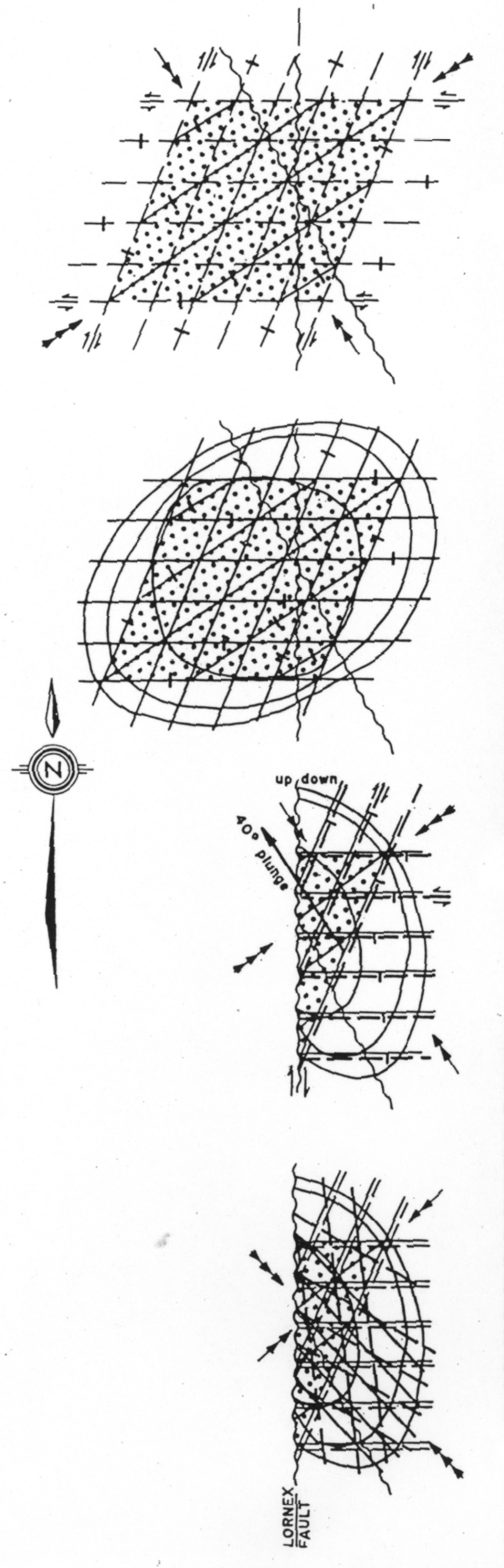

FIGURE 9 — Schematic plans illustrating the interpreted genesis of the orebody.

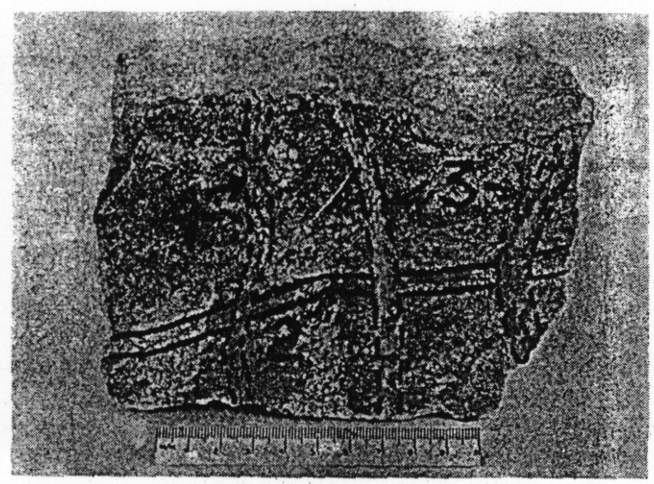

FIGURE 10a — A stage 2 quartz-molybdenite vein with associated argillic alteration is cut by stage 3 quartz-chalcopyrite-molybdenite veins with associated phyllic alteration and a stage 4 quartz-chalcopyrite-bornite vein with associated phyllic alteration.

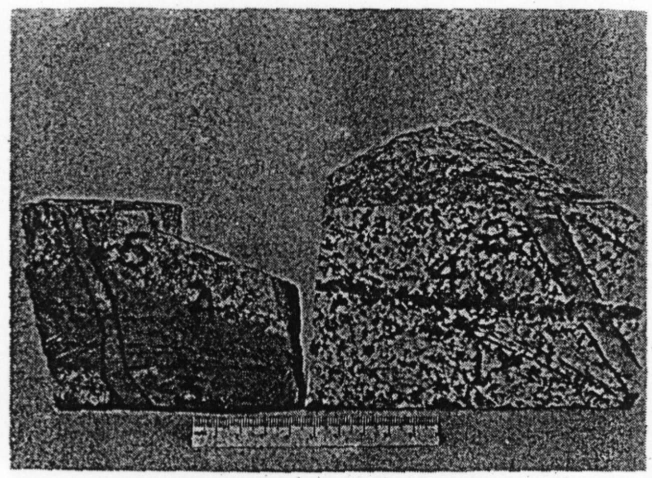

FIGURE 10b — **Left Sample** — A stage 3 quartz-chalcopyrite vein with associated phyllic alteration is cut by a stage 4 quartz-chalcopyrite-bornite vein with associated phyllic alteration. A stage 5 (or stage 6) vein composed of quartz-chalcopyrite with minor bornite and molybdenite and associated argillic alteration cuts the stage 3 and 4 mineralization. **Right Sample** — A stage 4 (or 3) quartz-chalcopyrite vein with minor bornite and associated phyllic alteration cuts argillic alteration associated with a barren, stage 1 quartz vein and a stage 2 quartz-chalcopyrite-molybdenite-bornite vein.

shearing subparallel to and along N[illegible]2°E- and N90°E-striking veins (Fig. 8b). It is probable that, during this period of deformation, apparent right-lateral displacement took place on the Lornex fault. Apparently, the Lornex orebody (the portion east of the fault) was tilted down in the north and relatively up in the south at this time. This 30- to 40-degree tilt is invoked to explain why mineralized fractures now dip in a southerly direction and why sulphide and alteration zones plunge northwesterly.

A late-stage deformation produced by maximum principal stresses, oriented from the northwest and southeast, developed a conjugate shear set (Fig. 8c). Conjugate shears are oriented N65°N and N8°W, and extension fractures strike N65°W. Displacements related to this period of deformation are generally minor.

Pleistocene glaciation and other geomorphological processes developed the present oxide cap and cover of glacial, fluvial and lacustrine sediments.

Acknowledgments

The authors thank Lornex Mining Corporation Limited for permission to publish this paper. J. D. Graham provided valuable assistance in the computer applications, R. Yorke-Hardy prepared the drawings and W. McBride did the photography. W. Marsh, C. D. Spence, R. V. Longe and other geologists associated with Rio Algom Mines Ltd. provided advice and suggestions on the manuscript. Acknowledgment is given to M. J. Skopos and other geologists previously associated with Lornex Mining Corporation Limited. J. Jambor of the Geological Survey of Canada supplied many of the thin sections for petrographic studies. Special thanks are given to W. J. McMillan of the B.C. Department of Mines and Petroleum Resources for advice and critical appraisal of the paper.

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