# The Eaglehead porphyry copper prospect, northern British Columbia

R.M. BRITTEN
Homestake Canada Inc., Vancouver, British Columbia

J.M. MARR
Agate Bay Resources Ltd., Vancouver, British Columbia

## ABSTRACT

*Strongly structurally-controlled, intrusion-hosted, porphyry copper mineralization of the Eaglehead prospect is located in the Cassiar Mountains on the southwest margin of the Eaglehead Pluton, about 48 km east of Dease Lake in northern British Columbia. This northwest-trending pluton is fault-bounded to the north against Devonian or older marine sedimentary rocks and Upper Triassic volcanic rocks of the Kutcho Formation. Sedimentary and volcanic rocks of the Kutcho and the Lower Jurassic Inklin formations are in fault contact with the pluton to the south.*

*Elongate, multiphase, soda-rich, calc-alkaline intrusions of Early Jurassic age, at the southwest margin of the Eaglehead Pluton, host the mineralization. They vary from marginal hornblende granodiorite to biotite granodiorite toward central regions of mineralized zones and were probably emplaced at about 186 Ma.*

*Strike-slip tectonics probably controlled mineralizing events and also caused postmineral fault disruption. Late magmatic and early alteration and mineralization involved pervasive K-feldspar-dominant assemblages and minor quartz, chalcopyrite, and bornite fracture-controlled mineralization. They were overprinted by main stage copper sulphide-enriched chloritic and sericitic assemblages in progressively outer zones.*

*Biotite granodiorite, the major host to mineralization, is thought to be the source of both metals and fluids. Early high temperature, highly saline fluids caused pervasive K-feldspar alteration of the cupola and margins of the progenitor as well as adjacent host rocks. Breaching of the outer carapace and a probable change from lithostatic to hydrostatic pressures were triggered by renewed structural disruption which ultimately controlled the elongate geometry of the mineralized zones. Cooling and dilution of hot, metal-charged, K-rich saline fluids by the influx of meteoric waters were key precipitation mechanisms of copper sulphides in the sericitic and chloritic alteration zones.*

*Postmineral tilting and erosion have exposed a cross-section of alteration/mineralization from inner bornite-rich K-feldspar alteration and mineralization in the Bornite zone in the southeast to chalcopyrite-pyrite rich sericitic assemblages in the Camp zone at the northwest end of the property.*

## Introduction

The Eaglehead porphyry copper prospect lies in the Liard Mining Division, approximately 48 km east of Dease Lake in northern British Columbia. The property is 6 km southeast of Eaglehead Lake. The claims are on NTS map sheets 104 I/6E and 104 I/11E at approximately 58°30′ N latitude and 129°10′W longitude.

Access is by helicopter from Dease Lake or Eaglehead Lake which is the closest fixed-wing drop-off point for supplies and materials. A bulldozer track from Dease Lake along the Turnagain River passes within 12 km of the claims and could probably be used to service the property in winter or early spring.

The Eaglehead property is in the Stikine Ranges of the Cassiar Mountains which are characterized by variably shaped ridges separated by wide drift-filled valleys. The mineralized zones at Eaglehead lie in one such broad northwesterly-trending valley at an elevation of about 1500 m. The well-rounded flanking mountain range to the north of the valley reaches elevations of 1800 m and is underlain by the Eaglehead Pluton. Rugged cirques and sharp ridges on the southern margin of the valley provide excellent exposures of volcanic and sedimentary rocks.

Lower slopes in the valley of Eaglehead Creek are covered by talus, buckbrush, and scrub alpine spruce or balsam. The valley floor is extensively covered by glacial drift, including kames, kettles and eskers which are evidence of the ablation of thin, stagnant glacier ice. All of the significant mineralized zones are drift-covered and the character of the mineralization can only be seen in creek exposures at the northwest end of the mineralized area.

## History

In 1963, Kennco Explorations Ltd. discovered mineralized granitic float near Eaglehead Lake during follow-up of regional silt geochemical anomalies. Until 1965, it carried out silt and soil geochemical surveys, geological mapping, trenching and an I.P. survey, followed by four short diamond drill holes in the Camp and Pass zone areas. The property was allowed to lapse in 1970.

Imperial Oil Limited optioned the property from Spartan Explorations Ltd. in 1971. In the years up to 1976, it expanded the geological, geophysical and geochemical surveys and drilled a total of 30 holes (5607 m) in the Camp, Pass and the newly-discovered Bornite zones. Zones further to the southeast, such as the East zone, were also discovered at this time.

From 1979 to 1981, Nuspar Resources Limited, formerly Spartan Explorations Ltd., resumed work on the property and drilled 25 holes, in addition to further geological, geochemical and geophysical surveys. At that time, Caulfield (1982) completed a B.Sc. thesis on the alteration and mineralization of the property.

Esso Minerals Canada Limited, formerly Imperial Oil, reassumed control of the property in 1982, re-evaluated previous results and explored the mineral potential in the Bornite zone and off the southeast end of the known mineralized trend. Since 1982, there has been no further significant work done on the property.

Regional mapping by the Geological Survey of Canada (Gabrielse, 1978; Gabrielse and Dodds, 1982) and an M.Sc. research project (Thorstad, 1984) culminated in a joint publication of this work by Thorstad and Gabrielse in 1986.

The property is currently owned by Homestake Canada Inc.; Nuspar Resources Limited retains an undefined 10% interest.

## Exploration Techniques

Regional stream sediment geochemistry was the key tool that resulted in the earliest recognition of mineralization in the Eagle-

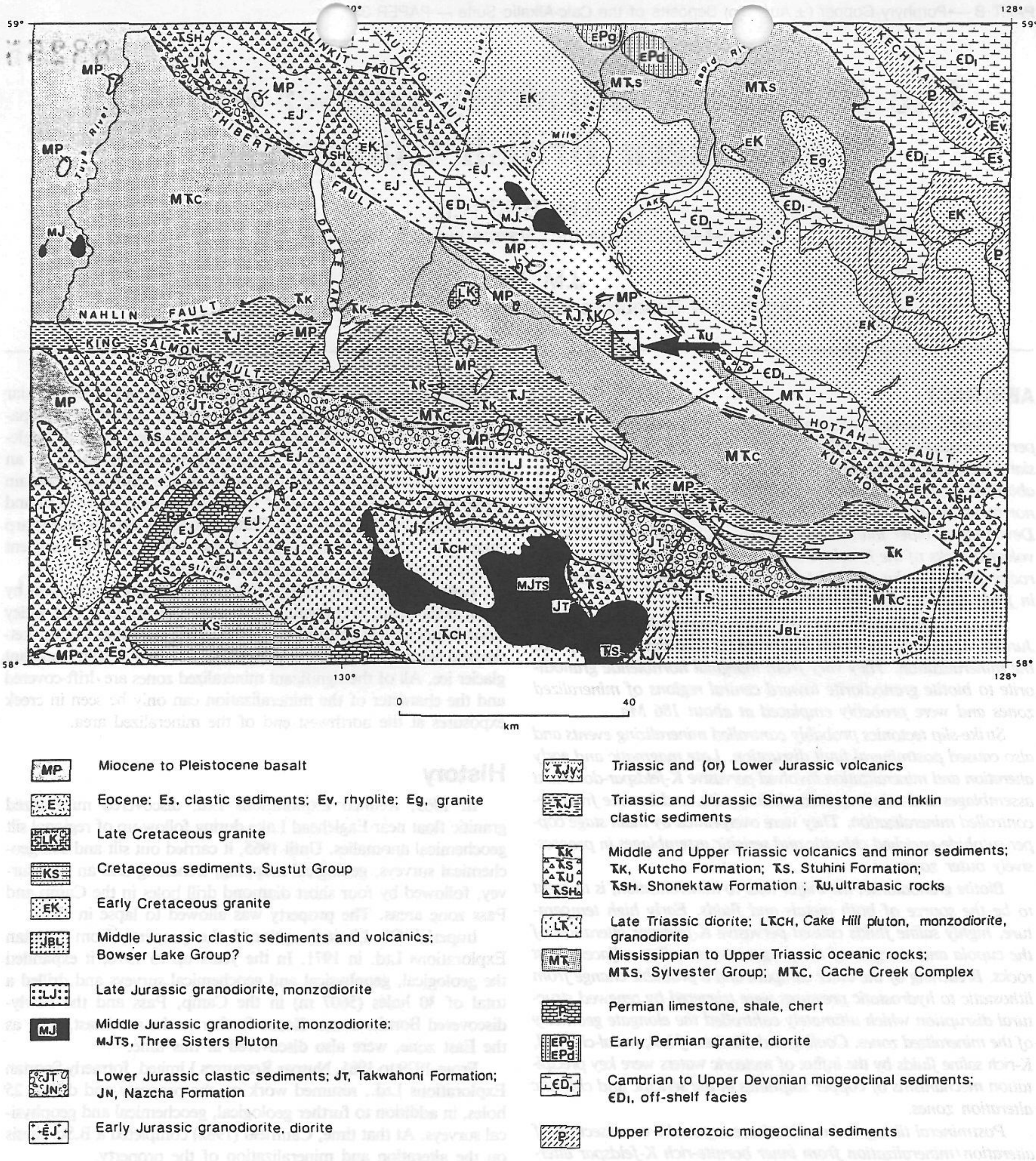


**FIGURE 1. Location and regional geological setting of the Eaglehead porphyry copper prospect, northern British Columbia (modified after Gabrielse and Thorstad, 1986).**

head Lake area. Analysis of the – 80 mesh fraction of active stream sediments defined copper anomalies in several drainages. More detailed stream silt geochemistry, prospecting and rock sampling led to the discovery of fracture-controlled copper mineralization in the upper part of Eaglehead Creek and the acquisition of the ground by Kennco Explorations Ltd. Grid-controlled follow-up, using B-horizon soil geochemistry and Time-Domain I.P., provided more specific targets for diamond drilling. Mapping and rock sampling were important only in downstream creek exposures northwest of the Camp zone because all of the main mineralized zones are concealed by 5 m to 15 m of glacial overburden.

## Regional Geology

The Eaglehead property is in the Cry Lake map sheet near the junction of the Intermontane Belt and the Omineca Belt (Monger et al., 1972). In terms of regional terranes, which are defined as distinct zones of related rock assemblages within the Belts (Coney et al., 1980, Monger and Berg, 1984), the Eaglehead property lies at the southern margin of Quesnellia close to its fault-bounded contact with the Cache Creek terrane to the southwest (Gabrielse, 1994).

The Cache Creek terrane consists of a distinctive Upper Paleozoic oceanic assemblage which is structurally transposed over a Mesozoic island arc sequence to the south termed the King Salmon

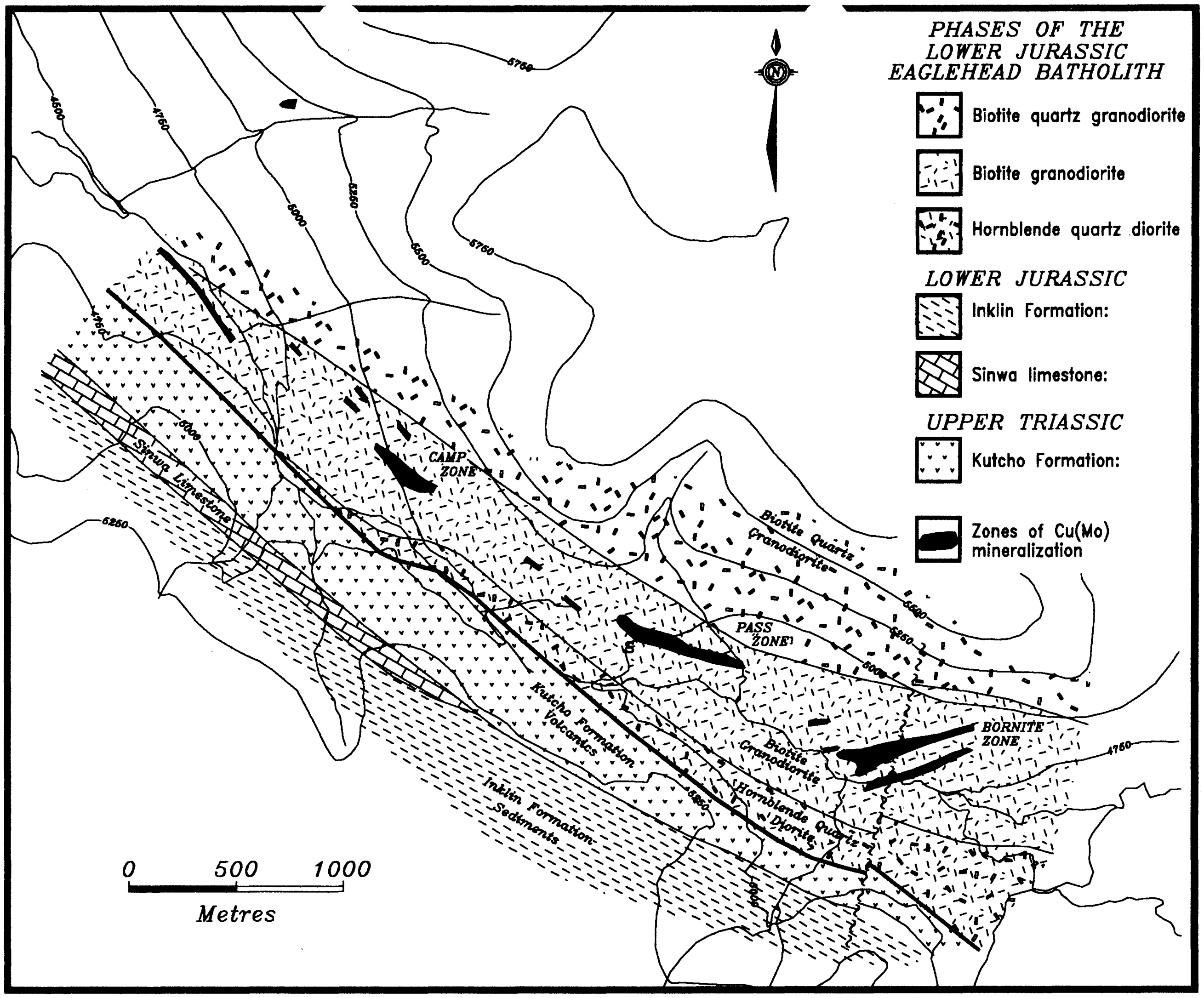


**FIGURE 2. Geological map of the Eaglehead property showing the location and trends of the main zones of mineralization.**

Assemblage. Quesnellia in the Cry Lake area is a narrow, complex zone, largely made up of Mesozoic intrusive rocks. It is flanked to the north by the Paleozoic sedimentary succession of Ancestral North America.

The Eaglehead porphyry mineralization lies at the southeastern margin of the Early Jurassic Eaglehead Pluton, near its contact with a sliver of Upper Triassic volcanic and sedimentary rocks (Fig. 1). On the basis of strong lithologic similarities with the sequence that hosts the Kutcho Creek volcanogenic massive sulphide deposit to the east-southeast, these Upper Triassic volcanic and sedimentary rocks have been correlated with the Kutcho Formation and the Inklin Formation of the King Salmon Assemblage (J.M. Marr, unpub., 1975; Thorstad, 1984). Although they could represent an island arc sequence constructed on oceanic assemblages of the Cache Creek Group, they could equally be a part of Quesnellia or a separate terrane that has been structurally juxtaposed with slivers of the Cache Creek terrane.

In the Eaglehead area, the Eaglehead Pluton and Kutcho Formation rocks lie within a wedge-shaped area bounded by two regional faults (Gabrielse, 1994). The Kutcho Fault to the north is a well-defined linear feature that exhibits in the order of tens of kilometres of dextral movement. The Thibert Fault to the south (Gabrielse and Dodds, 1982) is a high-angle structure which separates the Kutcho Formation rocks on the property from the Cache Creek Group immediately to the south. There may also be a strong southward directed thrust component on these faults.

## Property Geology

Mineralization at the Eaglehead prospect lies within the marginal granodiorite phases of the Early Jurassic Eaglehead Pluton (Fig. 2). Southwest of the pluton upright volcaniclastic units of the Kutcho Formation dip steeply southwest and probably represent a volcanic-sedimentary transition. The oldest units, near the intrusive contact, are a sparsely distributed and complex sequence of chlorite schists which probably represent metamorphosed volcanic rocks of intermediate composition. They are overlain to the south by a thick succession of feldspathic arenites and local volcanic conglomerate which grades upward into thin beds of greywacke and siltstone. A distinctive blue-grey carbonate member, up to 100 m thick, is probably the equivalent of the Sinwa Formation to the south as described by Monger and Thorstad (1978). It marks the top of the Kutcho Formation and is succeeded by an interbedded sequence of siltstones, graphitic argillites and greywackes assigned to the Inklin Formation.

There are three major phases of the Eaglehead Pluton on the property, although only one is significantly mineralized. A narrow zone of hornblende quartz diorite is the outermost phase of the pluton and separates the mineralized zones from Kutcho Formation rocks to the south (Fig. 2). It ranges in texture from medium-grained, crowded porphyritic to near holocrystalline and equigranular. Where the unit is least altered, hornblende, quartz and plagioclase are major phenocryst phases whereas quartz and minor K-feldspar are interstitial components.

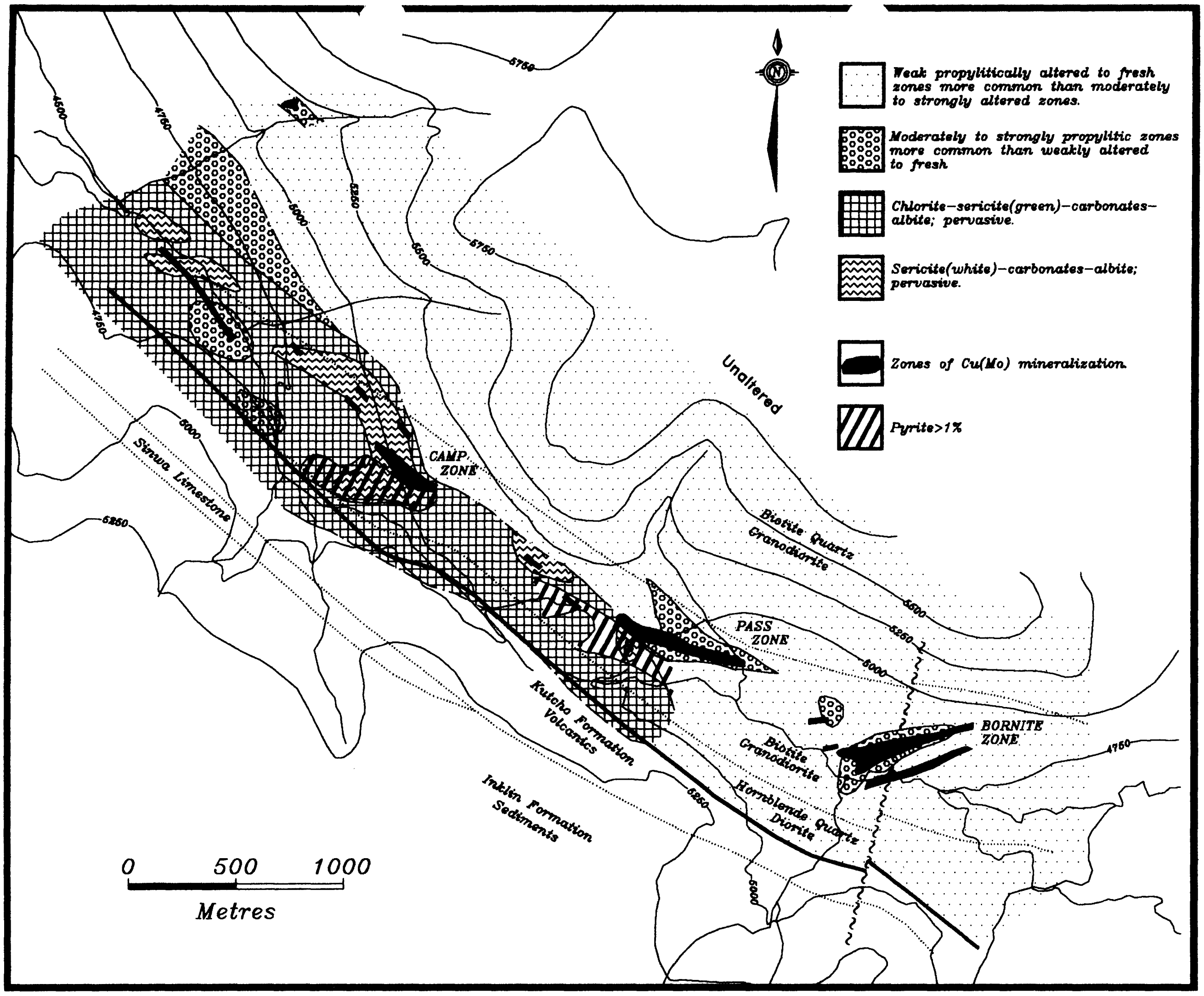


**FIGURE 3. Alteration and mineralization zonation patterns at the Eaglehead property.**

The hornblende quartz diorite is flanked to the north by a dike-like unit of biotite granodiorite, trending northwesterly and about 500 m wide. Mineralized zones occur mainly in this middle intrusive phase.

The biotite granodiorite exhibits similar textural features to the hornblende quartz diorite. Biotite content increases at the expense of hornblende and overall ferromagnesian content decreases from about 20% to 10%. Contacts between the two units are probably gradational as indicated by coexisting biotite and hornblende, although widespread alteration within the unit has obscured the nature of the contacts.

Biotite quartz granodiorite, the third phase, occurs northeast of the main zones of mineralization. Distinctive seriate quartz and less common oligoclase phenocrysts range up to 5 mm in size. Larger corroded quartz phenocrysts, up to 1 cm, and rare K-feldspar phenocrysts are found toward the core of the pluton to the north, as grain size increases and as the intrusion changes to a quartz monzonite composition. Primary biotite and prominent well disseminated magnetite grains are also typical of this unit. A K-Ar age determination on biotite, using updated time constants, gave an age of 186 ± 7 Ma (D. Oddy and M. Morrice, unpubl., 1972).

Caulfield (1982) indicated that all three intrusive phases are soda-rich and calc-alkaline, based on the chemistry of a limited number of samples. He postulated that the two innermost phases probably reflect a normal differentiation sequence whereas assimilated basalts of the Kutcho Formation contaminated the composition of the outer, mafic rich border phase. Caulfield's data also showed $K_2O$ increases from the border phase inward, in contrast to a slight decrease in Na in this direction.

Three types of dikes occur on the property. Quartz feldspar porphyritic and hornblende feldspar porphyritic dikes occur in the immediate area of the mineralized zones where they have been intersected by numerous drill holes. Both post-date biotite granodiorite and are postmineral. The third type are moderately west-northwest dipping, dark green diabase dikes. They cut all intrusive phases and are probably late stage mineralization in age. Where unaltered, these dikes are of andesitic to trachyandesitic composition but, near mineralized zones, overprinting propylitic alteration may obscure original compositions.

## Mineralized Zones

From northwest to southeast three main mineralized zones, the Camp, Pass and Bornite zones, occur in a linear array within the Eaglehead valley over a strike length of about 3 km (Fig. 2). They lie within a broader zone of variable alteration, which is primarily restricted to the biotite granodiorite and measures 7 km long and half a kilometre wide.

The early discovered, vertically dipping Camp zone is approximately 400 m long and consists of erratic high copper values restricted to narrow, well mineralized structures within a zone ranging up to 30 m wide. The northwest trending Pass zone, 1.5 km to the southeast, is 700 m long, 30 m wide and consists of pinch and swell *en echelon* structures which extend to 245 m in depth. The Bornite zone, near the height of land to the southeast, measures about 500 m in length, ranges between 50 m to 100 m in width and extends, at a 60° to 75° southerly dip, to 300 m in depth.

Largely fracture-controlled copper sulphides and more pervasive silicate alteration assemblages systematically vary from the Camp to the Bornite zones. In the northwest, chalcopyrite-pyrite-molybdenite in quartz veins and fractures are commonly enveloped by K-silicate or sericitic alteration assemblages and are fringed, particularly to the southwest, by broad pervasive sericitic alteration containing abundant disseminated pyrite (Fig. 3). Toward the southeast, in the Bornite zone, fractures filled with bornite, chalcopyrite and molybdenite are enveloped by K-feldspar-sericite-chlorite alteration and are surrounded by propylitic alteration beyond the zone of mineralization.

A contrasting style of mineralization, east of the Bornite zone, consists of massive chalcopyrite and minor bornite in a quartz vein system that assayed 7.13% Cu over a 6.3 m drill intersection.

Relatively well-defined major trends to mineralization range from 126° in the Camp zone, at the northwest end, to 108° and 072° in the central Pass and southeastern Bornite zones, respectively (Fig. 3). Resource estimates increase toward the southeast from the Camp to the Bornite zones. In contrast, mineralization in both the Bornite and Pass zones appears to plunge to the east and bottom out with depth.

## Alteration and Mineralization

Alteration varies from early K-feldspar-rich to overprinting chloritic and sericitic assemblages, both within and peripheral to the mineralized zones. These are typically surrounded by propylitic alteration (Fig. 3).

### K-feldspar-Sericite

Alteration within the Bornite and, less frequently, the Pass zones is dominated by K-feldspar-sericite assemblages commonly containing albite, chlorite, carbonates or minor epidote or clay alteration. These assemblages are typically fine-grained, pervasive and generally texturally destructive. Magnetite or hematite and trace rutile are common accessories.

K-feldspar found in aplite, pegmatite and narrow, essentially monomineralic fracture fillings throughout the property, and the K-feldspar rich matrix of the biotite quartz granodiorite north of the Camp zone are of late magmatic, premineral origin and are not a product of alteration.

### Propylitic

Areas peripheral to K-feldspar-sericite alteration in the Bornite zone and sericitic alteration in the Camp and Pass zones are altered to propylitic assemblages consisting of sericite, chlorite, calcite, epidote, albite and lesser biotite and K-feldspar. Secondary phlogopitic biotite is most commonly found in the propylitic assemblages of the Bornite zone where it replaces hornblende, matrix material and, less commonly, the rims of primary biotite. Primary disseminated magnetite is commonly partially oxidized to hematite. Rutile is rare but widespread; whereas, except for chalcopyrite, copper sulphides are sparse. Propylitic alteration can be asymmetric; it is at its widest and most intense on the north side of the Pass zone.

Propylitic alteration occurs in multiple episodes of fracture-controlled, cream-coloured assemblages which overprint granodiorite in bands 1 m to 10 m wide. These bands increase in abundance toward mineralized zones where they coalesce into a distinct zone of moderate to strong propylitic alteration. They decrease into narrow bands at the outer contact of K-feldspar-sericitic assemblages which commonly mark the outer boundary of the main mineralized zones. Intervening, weakly altered or relatively fresh granodiorite, between patches of propylitic alteration, locally exhibits incipient chloritization of primary biotites. Otherwise, intrusive textures are distinct except where relatively sparse, 1 cm to 10 cm wide alteration selvages to thin fractures obscure textures. Weak propylitic alteration is the most peripheral expression of the mineralization at Eaglehead (Fig. 3) and represents the most distal exploration guide to this type of intrusion-hosted porphyry copper mineralization.

### Chlorite-Sericite

Chlorite-sericite alteration is most common in the Camp zone area; it decreases in areal extent toward the Pass zone and is patchy in the Bornite zone. Conversion of all mafic minerals and some matrix components to grey sericite-chlorite is the key feature of this alteration. Feldspars are altered to light-green sericite, albite, quartz and carbonates. Disseminated pyrite is widespread, along with lesser amounts of magnetite, hematite, chalcopyrite and trace rutile. The common association of chlorite with chalcopyrite and bornite in fractures within the mineralized zones and sericite-quartz altered fragments cemented by a chlorite-rich matrix in the Pass zone, suggests that the distinction between chlorite-sericite and purely sericitic alteration is warranted.

### Sericitic

Pervasive, very fine-grained, white to buff-coloured, and less common pale green sericitic alteration is present over wide areas within and northwest of the Camp zone as well as at the southwest margin of the Pass zone. It has a blanket-like geometry with lobes of alteration which extend down along zones of pre-alteration structural weakness such as northwest-trending fault zones. In addition to sericite, quartz and pyrite, carbonates (mainly calcite but also dolomite and siderite) are the main alteration minerals. Carbonates partially pseudomorph feldspars, replace mafic sites and occur along grain boundaries and in veins. Sericitic alteration is typically feldspar-destructive although albite, of probable secondary origin, is locally abundant. Neither carbonate nor albite are commonly found in sericitic alteration assemblages of typical porphyry copper deposits.

## Vein Paragenesis and Structure

Lack of rock exposure in areas of mineralization precludes detailed evaluation of vein paragenesis or structural attitudes of veins. Outcrop to the northwest of the Camp zone provided the most useful structural information. The relative timing of episodes, particularly mineralized veins, was established mainly from the examination of drill core in the area of the main mineralized zones. Paragenetic relationships are best preserved at the inner margin of the propylitic alteration zone which fringes the Bornite zone.

Ten main fracture filling events have been recognized at Eaglehead. Narrow, widespread, early planar fractures, healed by K-feldspar and lesser quartz, together with pervasive groundmass K-feldspar are thought to reflect late magmatic processes. The veins commonly trend from 060° to 130° and dip steeply to the north. In the Bornite and Pass zones some K-feldspar veins contain chalcopyrite, bornite or other minerals and are commonly enveloped by K-feldspar rich selvages. They cut the planar K-feldspar quartz veins and represent the earliest mineralizing event.

The main period of alteration and mineralization is dominated by quartz-chalcopyrite veins, stringers and stockworks, which are generally surrounded by quartz-sericite selvages. Chlorite-quartz stringers containing chalcopyrite and bornite are a late mineralizing episode. Two mineralized vein sets are exposed northwest of the Camp zone. Early thick quartz-chalcopyrite veins with relatively thin sericitic selvages dip 80° toward 135°; these are truncated by thin chalcopyrite-quartz veins with wide sericite selvages that dip 60° to 80° toward 040°. A prominent post-alteration shear foliation, noted in envelopes to veins and zones of pervasive sericitic or chloritic alteration, generally strikes northwest to west and dips 50° to 90° northeast.

Epidote-rich veins are most common ' 'nging propylitic areas although minor epidote occurs througho the Bornite zone.

Fluid inclusions, noted in polished thin sections of veins, typically contain between 60% and 90% fluid, the remainder normally being gas, although both sylvite and halite daughter products are locally common. Gas-rich inclusions are rare.

## Genesis

Mesozoic volcanic and sedimentary rocks of the Kutcho and Inklin formations were intruded by granodiorite of the Eaglehead Pluton along a northwest-trending belt. Hornblende granodiorite, the marginal phase of the pluton, probably assimilated significant amounts of the Kutcho Formation volcanic rocks of basic to intermediate composition. Inner portions of the pluton are dominated by biotite quartz granodiorite which was emplaced at about 186 Ma. The dike-like medium-grained biotite granodiorite which lies between the hornblende diorite and coarser biotite quartz granodiorite in the core of the pluton hosts all of the mineralized zones. It roughly coincides with the bulk of the property-scale alteration and is unlikely to be older than 186 Ma. Biotite granodiorite is thought to be the progenitor to mineralization at Eaglehead.

Strike-slip movement near the intrusive contact probably controlled some of the intrusive and mineralizing events and, based on the orientation of mineralized zones and fracture patterns, also caused postmineral fault disruption. Spatial and temporal relations, particularly in the Bornite zone, indicate late magmatic-early alteration and mineralization involved K-feldspar rich assemblages and probably quartz, chalcopyrite, and bornite fracture-controlled mineralization. These early events were overprinted by chloritic and sericitic assemblages enriched in copper sulphides in both the Camp and Pass zones at the northwest end of the hydrothermal system. Cross-cutting quartz-chalcopyrite fractures of several generations, enclosed by sericitic or chloritic alteration selvages, are indicative of an episodic and perhaps prolonged series of hydrothermal events.

Early high-temperature, highly saline fluids caused pervasive K-feldspar alteration of both the cupola and margins of the progenitor as well as adjacent host rocks. Breaching of the outer carapace and a change from lithostatic to hydrostatic pressures were triggered by renewed structural disruption which ultimately controlled the elongate geometry of the mineralized zones. Cooling and dilution of hot, metal-charged, K-rich saline fluids due to the influx of meteoric waters are thought to be key precipitation mechanisms of copper sulphides in the sericitic and chloritic alteration zones.

Postmineral tilting and erosion have exposed a cross-section of alteration and mineralization from inner bornite-rich, K-feldspar assemblages at the southeast end to chalcopyrite-pyrite-rich sericitic assemblages at the northwest end of the property.

## Economics

Various operators from 1972 to 1982 estimated tonnage and grades, as the individual zones were discovered. Geological resources for the Camp and Pass zones (Fig. 2) are 2.72 million tonnes grading 0.45% Cu and 11.8 million tonnes grading 0.52% Cu, respectively (J.M. Marr, unpub., 1973). The Bornite zone, 1 km to the southeast, was shown to have in excess of 16 million tonnes of 0.65% Cu equivalent, using molybdenum credits (Everett, unpub., 1982). These resources are presently considered subeconomic.

## Discussion

Porphyry copper mineralization at Eaglehead is distinctive relative to other intrusion-hosted systems in British Columbia and elsewhere because of the extensive control structural events played in causing the elongate geometry of the mineralized zones. The location of these narrow and relatively small tonnage zones in a broad valley bottom would result in a high stripping ratio for open-pit mining and downgrades the likelihood of mine development, given the lack of infrastructure in the area.

The presence of bulk-mineable porphyry copper mineralization of significant grade immediately peripheral to the known zones is not likely. However, a 7.1% Cu assay over a 6.3 m intersection in a drill hole to the east of the Bornite zone indicates potential for smaller tonnage vein-type deposits. Similar high-grade veins occur in peripheral areas to the Highland Valley Copper mine in southern British Columbia, one of the world's largest, intrusion-hosted porphyry copper deposits.

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