 884181 EXPO Tom Schmitt

The Hushamu porphyry copper-gold deposit, northern Vancouver Island, British Columbia

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ABSTRACT

The Expo property is located on northern Vancouver Island approximately 360 km northwest of Vancouver, British Columbia, Canada. The Hushamu deposit is located at 50° 40′ 30″ North latitude, 127° 51′ 30″ West longitude and is central to the 542 contiguous mineral claims which make up the 15 000 hectare Expo property. The deposit is 26 km west-northwest of the Island Copper mine, one of British Columbia's five major porphyry Cu-Au-Mo deposits.

The Hushamu gold-copper deposit was discovered in 1967. The mineralization is predominantly hosted within silicified and chloritized volcanic flows and tuffs adjacent to quartz diorite and feldspar porphyry intrusions. Within the mineralized zone sulphide minerals occur mainly as disseminated chalcopyrite and pyrite within the volcanic rocks and also in quartz vein stockworks associated with magnetite. The mineralized zone is generally overlain by 30 m to 200 m of silica and silica-kaolinite-pyrophyllite altered rock at McIntosh Mountain.

Certain geological features including the gold-rich nature of the porphyry copper mineralization, the telescoped environment with preserved argillic caps of epithermal affinities, the association with porphyry stocks of intermediate composition, and the abundance of hypogene iron oxides (magnetite) can be compared with the gold-rich porphyry copper deposits of the Philippines and the gold-only porphyry systems of northern Chile.

The Hushamu porphyry copper deposit currently has a combined geological "probable" and "possible" drill indicated resource of 283.7 million tonnes estimated to grade 0.28% Cu, 342 ppb gold, and 0.009% Mo, at a 0.20% Cu cutoff. Within this resource there are an estimated 173.3 million mineable tonnes of the same average grade and copper cutoff.

A detailed statistical evaluation of copper, gold and molybdenum was used along with an updated geological model to guide open pit optimization using a net smelter return (NSR) formula. The statistical analyses provided confidence limits to the drill hole data. The NSR model allowed detailed modelling of the two product (copper-gold) nature of the deposit. The Hushamu deposit is currently regarded as a potential supply source for the existing Island Copper concentrator which is located 26 km to the east. A prefeasibility study completed in March 1993 provided a positive operating scenario and proposed that the ore be transported by conveyor to the Island Copper site.

Introduction

The Expo property which contains the Hushamu deposit is located on northern Vancouver Island, approximately 360 km northwest of Vancouver and 25 km west of Port Hardy, British Columbia, Canada (Fig. 1). This large claim group covers approximately 15 000 hectares, mainly within topographic map 92l/12, and extends over 20 km of ground immediately north, and parallel to, the west end of Holberg Inlet. The Hushamu deposit is located at 50° 40′30″' North latitude, 127° 51′ 30″ West longitude in the centre of the Expo property's 542 contiguous mineral claims. All areas of the property can be reached by well maintained logging roads and forest tracks from Port Hardy.

The Expo property is characterized by many low, northwesterly to westerly trending hills and ridges bounded by narrow deeply incised valleys with steep slopes. Elevations range from sea level to over 600 m. Within the claim block ridge tops are commonly about 300 m above valley floors. The Hushamu deposit is located within a currently active logging area; consequently forest cover varies from mature stands of fir, hemlock, spruce and cedar to dense second growth, or to open clearcut areas of recent logging. The ridge tops are fairly open with only stunted evergreens. Rock exposure is abundant in the areas of steep relief and on the higher ridges; however, thick humus development on the forested slopes and scattered residual glacial gravels on the valley floors restrict geological mapping in these areas (Fig. 3).

History

In 1963, the British Columbia Department of Mines published the results of a recently completed aeromagnetic survey covering the northern end of Vancouver Island (BCDM/GSC, 1963). The survey showed a northwesterly trending belt of magnetic highs on the north side of Holberg Inlet. Since magnetite-bearing deposits were of interest at this time, considerable exploration activity was generated examining all the magnetic anomalies in the area.

The Expo claims were staked in 1966 by the Utah Construction and Mining Company following the discovery of the Island Copper deposit to the east. This deposit was found within one of the magnetic anomalies in the belt north of Holberg Inlet (Perello et al., this volume). During the height of the exploration activity, Utah controlled most of the ground extending along the north shore from the east end of Rupert Inlet to the west end of Holberg Inlet.

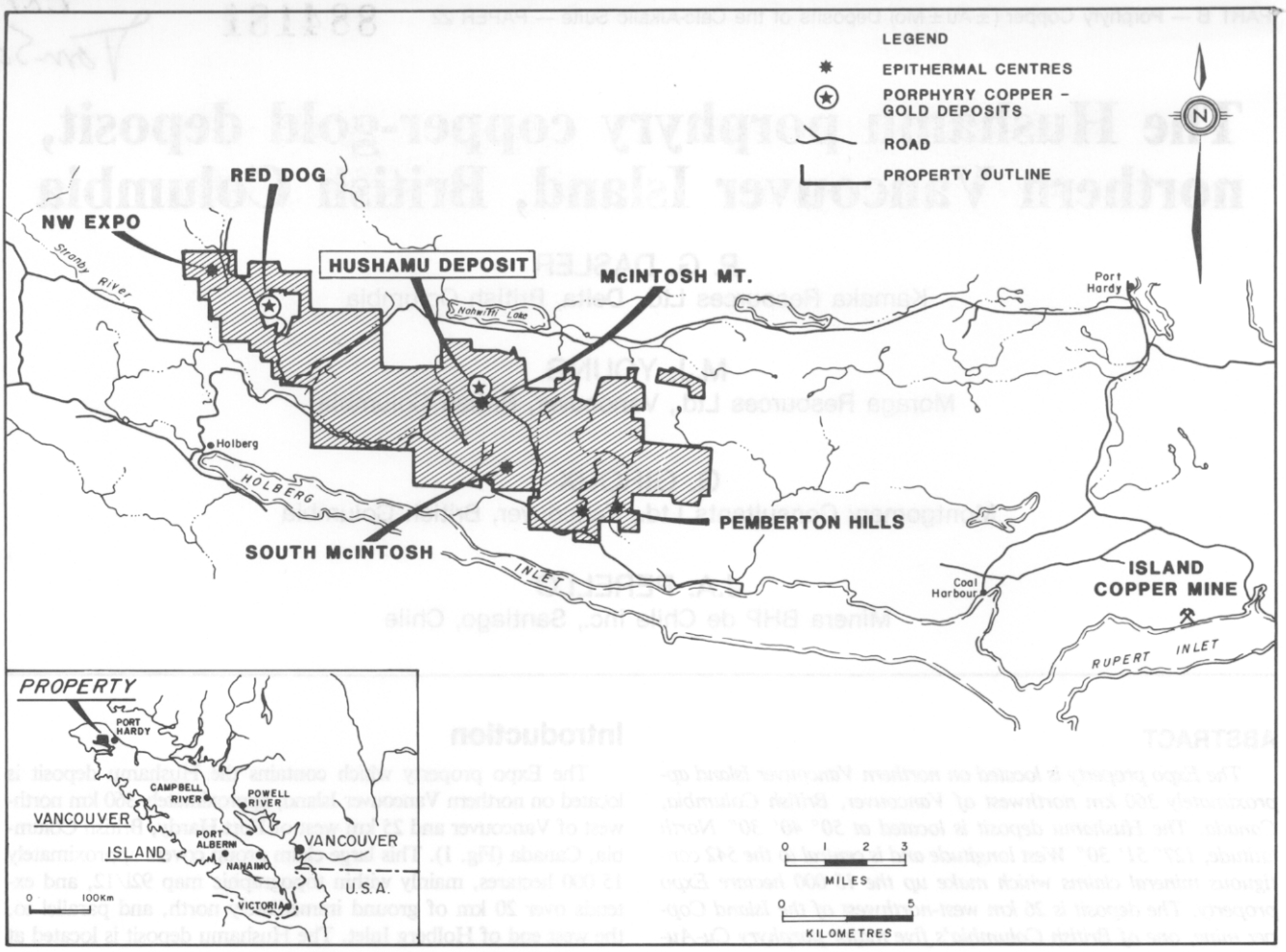


FIGURE. 1. Location of Expo property and other porphyry deposits in the Bonanza Group trend, northern Vancouver Island.

Their properties included the large block of claims covering the Island Copper deposit, as well as the favourable geology on trend to the northwest (most of the present Expo property). The Expo property was extensively mapped at 1:2400 scale between 1967 and 1975, but received only limited exploration from then until 1988.

Utah's exploration work on the Expo claims resulted in the discovery of a large area of low-grade copper-molybdenum mineralization in the valley on the north side of McIntosh Mountain. This occurrence was named the "Hushamu Zone", after the name of a nearby lake. Reconnaissance geochemical sampling north and west of the limonitic outcrops on McIntosh Mountain identified moderate copper anomalies in the soils. Further geochemical sampling, geophysical surveying and diamond drilling outlined copper mineralization surrounding intrusive rocks, similar to the Island Copper occurrence. The zone was estimated at that time to contain 52.9 million mineable tonnes grading 0.32% Cu, 0.008% MoS_2 and 413 ppb Au with a stripping ratio of 2.21:1 (Utah Mines Ltd., unpub., 1975).

In 1980, Utah reactivated the Expo project to look at the gold potential of the McIntosh Mountain alteration system. Multiple phases of intensely silicified breccia had previously been mapped at Expo. Subsequent recognition of similar zones in the Pemberton Hills area 5 km east of Hushamu led to a search from 1980-1984 for gold deposits of the Pueblo Viejo (Kesler et al., 1981) advanced argillic type by Utah Mines' geologists.

The enhanced copper and gold values prompted the drilling of two holes, EC-154 and EC-155. Both of these returned significant gold and copper mineralization, but were not followed up by Utah as they are over 1000 m south of the original 52.9 million tonne ore reserve, and did not conform to the style of the Hushamu occurrence in the valley.

Moraga Resources Ltd. optioned the property from BHP-Utah Mines Ltd. in 1987 and has since completed several phases of geophysical and geochemical surveys and diamond drill exploration on Hushamu and surrounding exploration targets. The drilling programs at Hushamu were the centre of most attention because of the recent discovery of copper and gold reserves south of the original reserve block. The current reserves within the preliminary pit at Hushamu are 173.3 million tonnes grading 0.28% Cu, 342 ppb Au and 0.009% Mo. The stripping ratio of the zone is 2.2:1. (D.G. Graham, unpub., 1993). The property is to be further developed as a joint venture between BHP Minerals Canada Ltd. (55%) and Moraga Resources Ltd. (45%).

Applied Exploration Techniques

The Hushamu deposit was initially indicated by the government airborne magnetics survey. This identified a belt of magnetite-rich Bonanza Group volcanic rocks, with numerous magnetic highs, trending northwest from the Island Copper discovery. The interpretive work by Utah's staff was followed by reconnaissance silt sampling, and eventually an extensive grid-controlled soil sampling and geological mapping program. The first drilling at Hushamu tested the strongest copper geochemical highs within the magnetic highs. A regular 122 m (400 foot) north-south oriented drill grid was established following the identification of a volcanic-hosted porphyry copper occurrence interpreted to be similar to that at Island Copper.

During the early copper exploration at Hushamu (1968-1972), only two holes were completed along the McIntosh Mountain ridge top. During the 1980-1984 evaluation of the gold potential of the

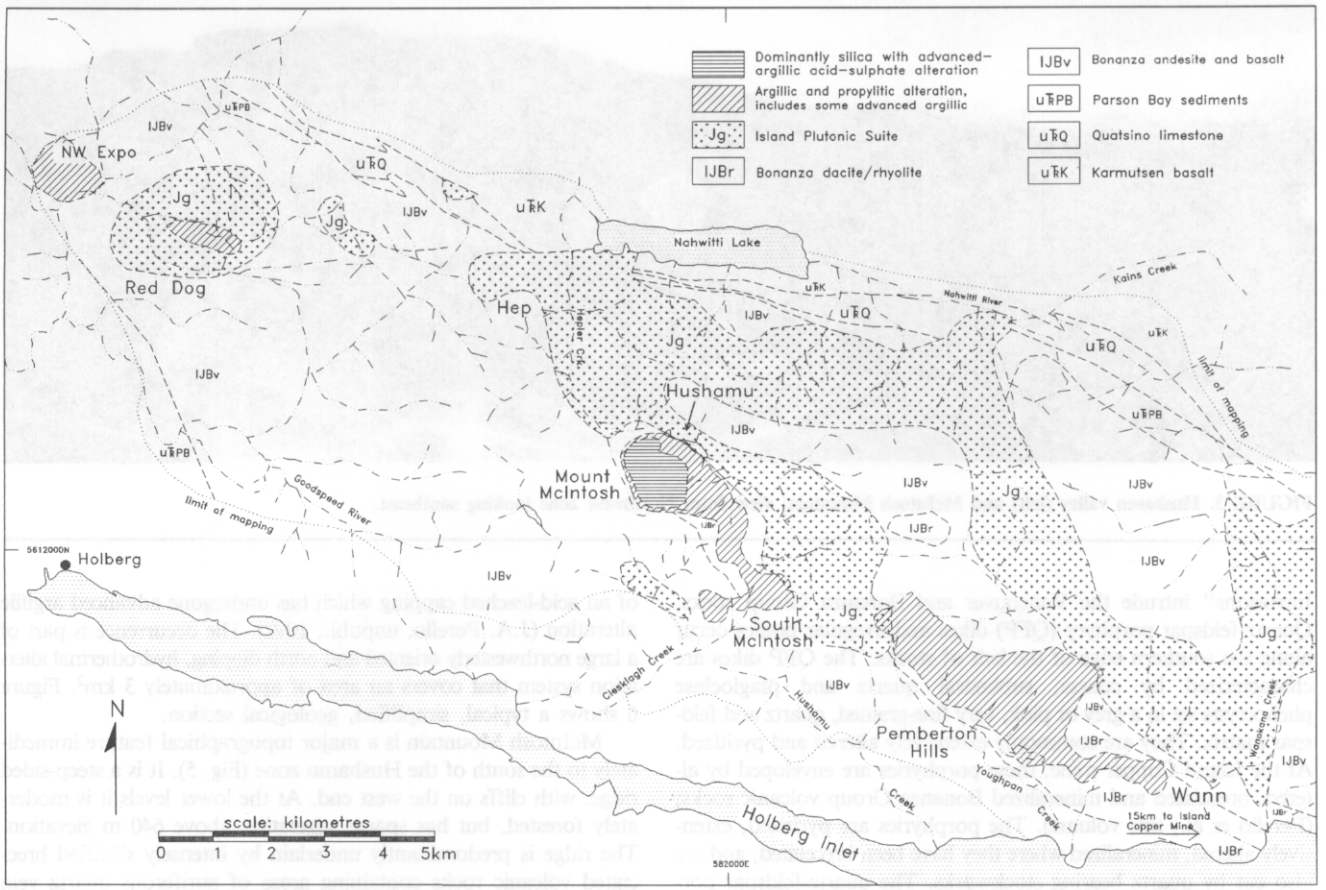


FIGURE 2. Generalized geological map units, after Nixon et al. (1994).

area, one of the early holes, EC-86, revealed two zones that averaged 450 ppb gold over the two intervals between 73 m to 107 m and 146 m to 186 m. Copper mineralization in this hole is significant between 155 m to 192 m with 0.28% Cu, 530 ppb Au, and 0.012% Mo. The second hole, EC-88, had 79 m of anomalous copper (0.09% Cu) in the bottom half of the hole, with intermittent gold to 850 ppb.

Rock geochemistry along the ridge at McIntosh Mountain also revealed anomalous gold zones related to the residual silica in the hydrothermally acid leached breccias. Channel samples taken over approximate 3 m widths returned a range of clustered values from 20 ppb to 400 ppb gold. Enhanced copper, molybdenum, arsenic and antimony are associated with anomalous gold over an outcrop length of 300 m. Gold analyses of surface chip samples range up to 1820 ppb. To the east of these exposures there are only scattered outcroppings because of the forest cover and the area is not adequately explored.

Exploration by Moraga Resources Ltd. commenced in late November of 1987. Moraga's work has included regional mapping with road cut sampling and follow-up grid soil sampling, computer modelling of the 1963 airborne geophysical data, and 13 405 m of drilling to April 1994. In addition, archived soil sample rejects were recovered from storage and analyzed for gold, arsenic, selenium, tellurium, bismuth and antimony. These samples had previously been analyzed for only copper, and selectively zinc and molybdenum.

The follow-up work, beginning in 1988, has also shown a strong gold-in-soil geochemical anomaly in the area of McIntosh Mountain. This was first identified from the analyses of the soil sample rejects which had been archived by Utah in 1969, and confirmed by recent follow-up surveys. The gold anomaly (from 20 ppb to 900 ppb Au) is quite distinct, and is in large part separate from the copper anomaly to the north (Fig. 4). The copper anomaly in the valley is defined by the 100 ppm copper contour and trends further to the northwest than the gold anomaly. This copper anomaly is four times the background value determined from orientation surveys (Young, 1969). There is strong correlation between the 100 ppm copper in soil and the 2100 gamma magnetics anomalies (Fig. 4). Outside the Hushamu zone, other copper anomalies also have a close relationship with zones marked by linear magnetic highs.

Regional Geology

Vancouver Island north of Holberg and Rupert Inlets is underlain by rocks of the Vancouver and Bonanza Groups (Nixon et al., 1993). These rocks range in age from Upper Triassic to Middle Jurassic. They are intruded by dikes and stocks of Jurassic and Tertiary age, and overlain by Cretaceous and Tertiary sedimentary rocks. There is a pronounced northwest regional trend to all the major lithologic units (Nixon et al., 1994). Figure 2 details the geology of the area north of Holberg Inlet.

The Vancouver Group is described as follows (from bottom to top):

(a) Basal Sediment - Sill Unit: The so-called "Daonella" beds Middle Triassic;
(b) Karmutsen Formation: Basaltic flows and tuffs; Upper Triassic;
(c) Quatsino Formation: Limestone; Upper Triassic;
(d) Parson Bay Formation: Fine ash tuffs and sediments; Upper Triassic.

The Bonanza Group consists of (from bottom to top):

(a) Harbledown Formation: Sediments; Lower Jurassic;
(b) Bonanza Group: Andesitic ash tuff, and flows; Lower Jurassic.

The Bonanza Group hosts the majority of the copper occurrences in the district with the large porphyry copper systems appearing in the lower part of the volcanic succession. Large diorite-quartz diorite stocks of the Island Plutonic suite or "Island

FIGURE 3. Hushamu valley (left) and McIntosh Mountain, view from Northwest zone looking southeast.

Intrusions" intrude the Vancouver and Bonanza Group rocks. Quartz-feldspar porphyry (QFP) dikes and irregular bodies occur along the southern edge of the belt of stocks. The QFP dikes are characterized by coarse, subhedral quartz and plagioclase phenocrysts set in a grey or pink, very fine-grained, quartz and feldspar matrix. They are commonly extensively altered and pyritized. At the Island Copper mine, these porphyries are enveloped by altered, brecciated and mineralized Bonanza Group volcanic rocks; (Perello et al., this volume). The porphyries are pyritized, extensively altered, mineralized where they have been brecciated, and are also cut by quartz bearing stockworks. The quartz-feldspar porphyries are thought to be differentiates of Middle Jurassic felsic intrusive rocks of the Island Intrusions (Muller et al., 1974). Cretaceous sedimentary rocks locally overly the Bonanza Group volcanic rocks; they have been variably referred to as the Longarm Formation (Kyuquot Group), Queen Charlotte Group, or Coal Harbour Group.

The most significant of the regional fault systems trends west to northwest following Rupert and Holberg Inlets. Near the west end of Holberg Inlet this fault splits, with the main branch following Holberg Inlet, and the other branch passing through the west side of the Stranby River valley. Another northwesterly to westerly fault system passes through William Lake, in the valley south of the Stranby River, and still another smaller system passes through Nahwitti Lake.

Northeasterly trending faults comprise a subordinate fault system. In some cases, apparent lateral displacement in the order of several hundred metres can be measured on certain horizons. The airborne magnetometer data clearly show the major west-northwest trending breaks and the secondary conjugate sets of northeast faults. The intersections of these conjugate fault zones appear to coincide directly with the copper-gold occurrences at Hushamu, Hep, Red Dog, and the Island Copper orebody.

Geology of the Hushamu Zone

Geochemical soil sampling in 1967-1968 defined a large northwest-trending copper anomaly lying immediately to the south of a series of linear magnetic anomalies which occupy the Hushamu valley (Fig. 4). These anomalies are close to the spectacular limonitic zone on the north side of McIntosh Mountain. One hundred and sixteen diamond drill holes totalling 24 785.31 m have been completed in and around the zone to April 1994 (Fig. 5).

The Hushamu copper-gold deposit was initially thought to underly part of the valley floor north of McIntosh Mountain, and part of the adjacent hillsides. Additional copper-gold mineralization has been identified south of the valley, under the limonitic zones, during subsequent exploration. The gossans are now seen to be part of an acid-leached capping which has undergone advanced argillic alteration (J.A. Perello, unpubl., 1992). The occurrence is part of a large northwesterly oriented and north dipping, hydrothermal alteration system that covers an area of approximately 3 km^2. Figure 6 shows a typical, simplified, geological section.

McIntosh Mountain is a major topographical feature immediately to the south of the Hushamu zone (Fig. 5). It is a steep-sided ridge, with cliffs on the west end. At the lower levels it is moderately forested, but has sparse vegetation above 640 m elevation. The ridge is predominantly underlain by intensely silicified brecciated volcanic rocks containing areas of auriferous quartz vein stockworking. Pyritic gossans are visible as east-west trending zones on the southwest and northeast sides of the ridge. McIntosh ridge is truncated to the west by Hepler Creek.

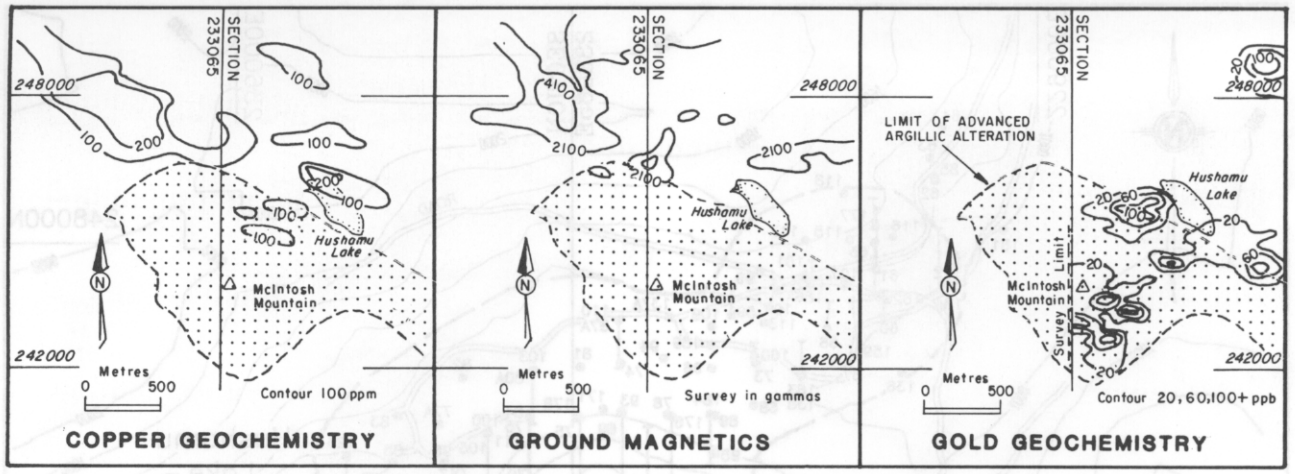
Drill holes EC-173, 174, 175, 179, 180-182, and 190-192 (Fig. 5) intersected chlorite-magnetite altered Bonanza Group tuff under the silica-kaolinite-pyrophyllite cap which forms McIntosh Mountain. This underlying tuff unit and portions of the cap rock host ore grade copper-gold mineralization contiguous to the copper occurrence in the valley. These zones have contributed to the bulk of the recently increased ore reserves, and have raised the gold content of the reserves.

A wide step-out hole (EC-192) 1000 m southeast of the main zone also intersected anomalous (0.2%) copper from 107 m to 250 m depth. The ground magnetic information suggest that a quartz feldspar porphyry dike system trends southeast from the Hushamu zone into this area. Two recent holes (EC-202 and EC-207) between the main zone and EC-192 have confirmed the presence of extensive copper-gold mineralization in Bonanza Group volcanic rocks adjacent to a quartz-feldspar porphyry intrusive within 75 m of the surface. EC-202 intersected 256 m grading 0.245% Cu and 308 ppb Au.

Deposit Model

The detailed understanding of the Hushamu zone geology was developed from the study of the drillcore. Only the intensely silicified upper zones of the hydrothermal alteration system are exposed along the ridge crests and in the deeply incised drainages in areas of rugged relief. The valley floor is covered by overburden. Extensive logging and associated road building over the past two years have provided only two new exposures of the lower part of the copper occurrence to add to the geology, however, the road building to the south and east indicates the large size of the pyrite alteration halo.

The mineralized area is underlain by Bonanza Group andesitic volcanic flows and volcaniclastic rocks that are intruded by a stock of medium-grained diorite or quartz diorite, and feldspar-phyric



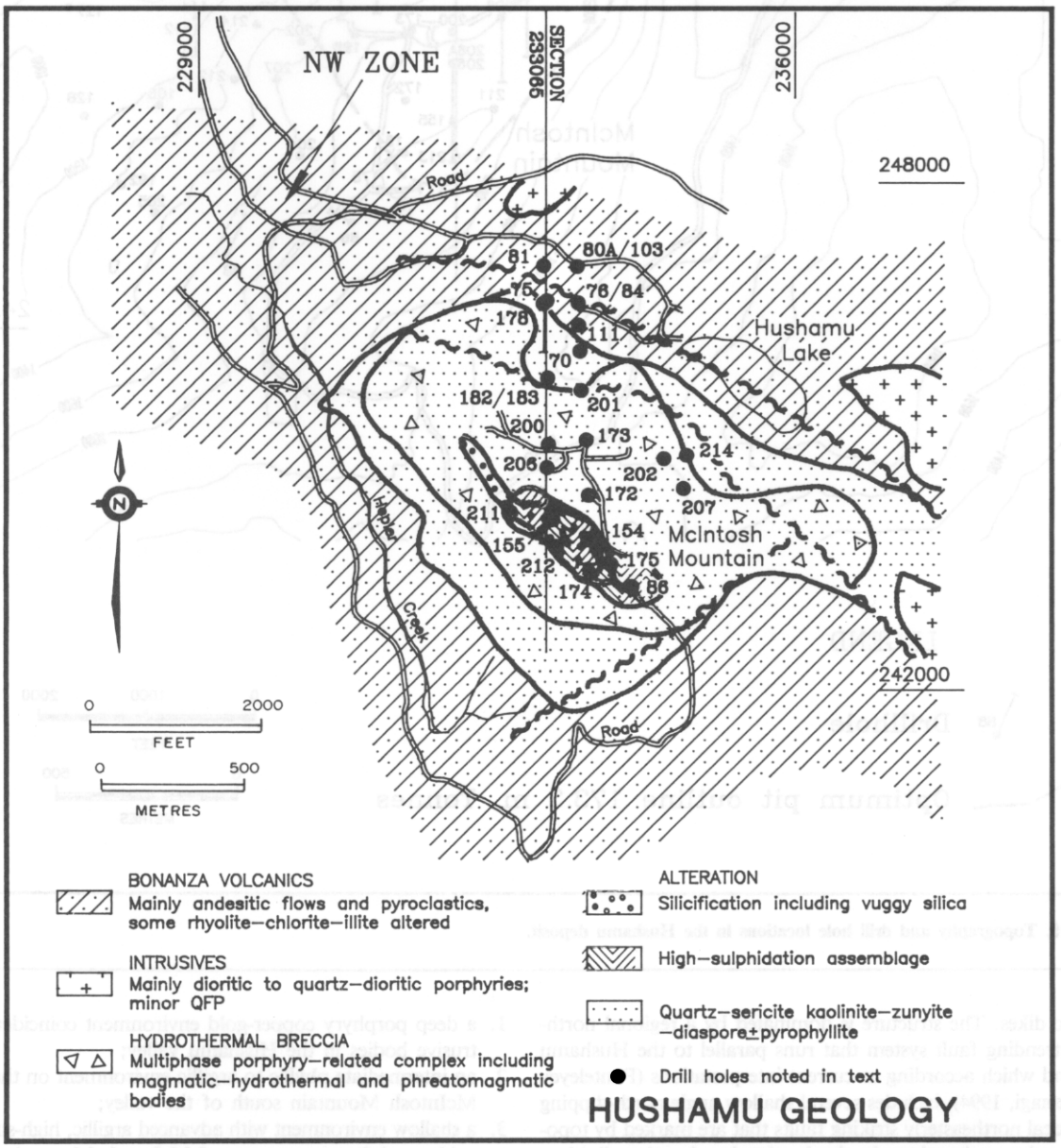


FIGURE 4. Simplified geological plan of Hushamu-McIntosh zone showing breccia complex and alteration. Inserts show extent of copper-gold geochemistry and ground magnetics anomalies.

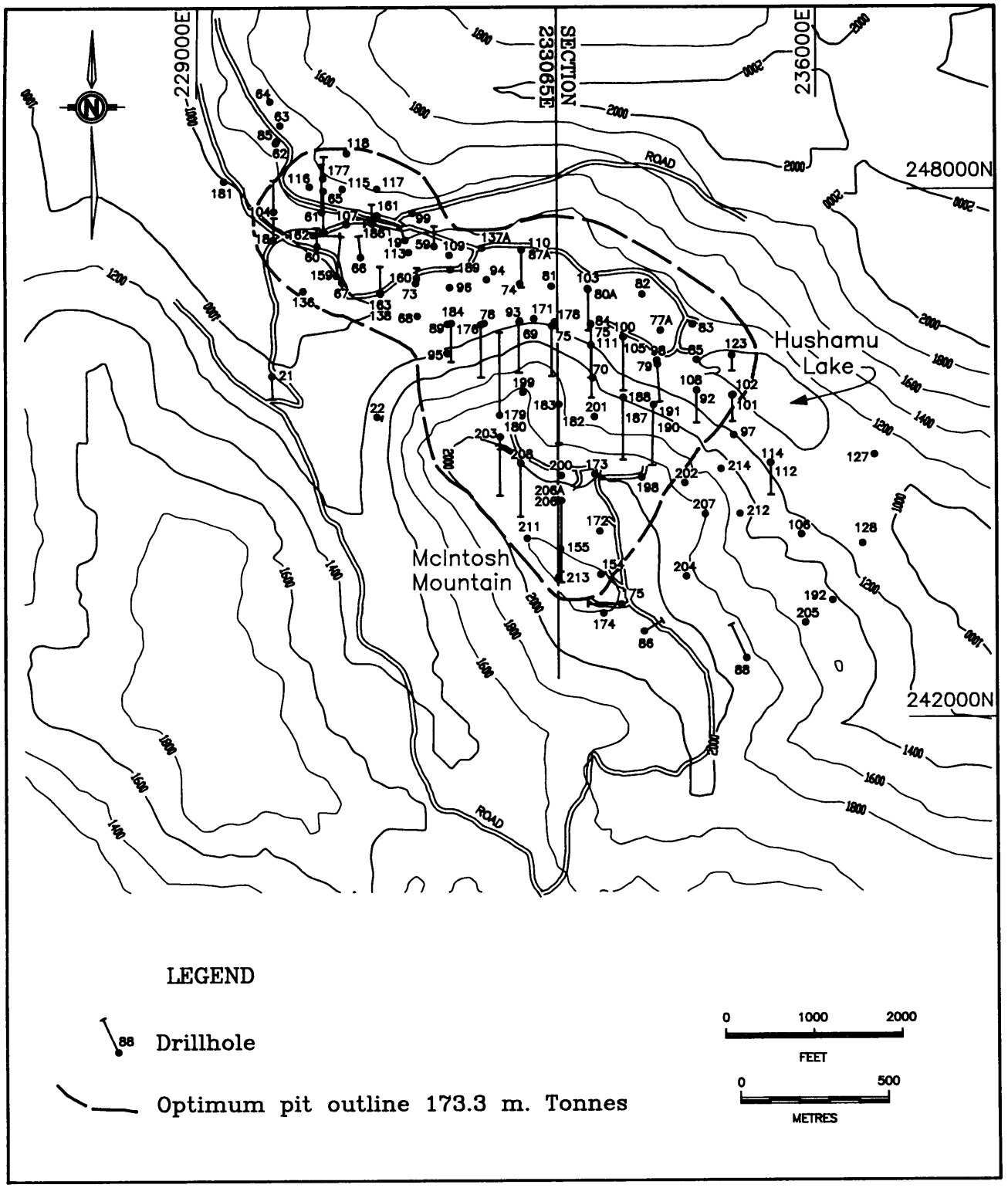


FIGURE 5. Topography and drill hole locations in the Hushamu deposit.

and felsic dikes. The structure is dominated by a regional northwesterly trending fault system that runs parallel to the Hushamu valley, and which according to current interpretations (Panteleyev and Koyanagi, 1994), includes several shallow angle north-dipping faults. Local northeasterly striking faults that are marked by topographic breaks are thought to be closely related to the mineralization.

The Hushamu-McIntosh porphyry copper-gold system appears to be a telescoped and tilted hydrothermal system (Figs. 6 and 7). The key elements which characterize the mineralized system are as follows (J.A. Perello, unpubl., 1992):

1. a deep porphyry copper-gold environment coincident with intrusive bodies in the Hushamu valley;
2. an intermediate phyllic to argillic environment on the slopes of McIntosh Mountain south of the valley;
3. a shallow environment with advanced argillic, high-sulphidation epithermal features on top of McIntosh Mountain.

The porphyry copper-gold mineralization at Hushamu is characterized by multiple stage quartz-magnetite-chalcopyrite-pyrite stockworks hosted by feldspar porphyry (FP) and feldspar-quartz porphyries (FQP) and the andesitic volcanic rocks. Disseminated

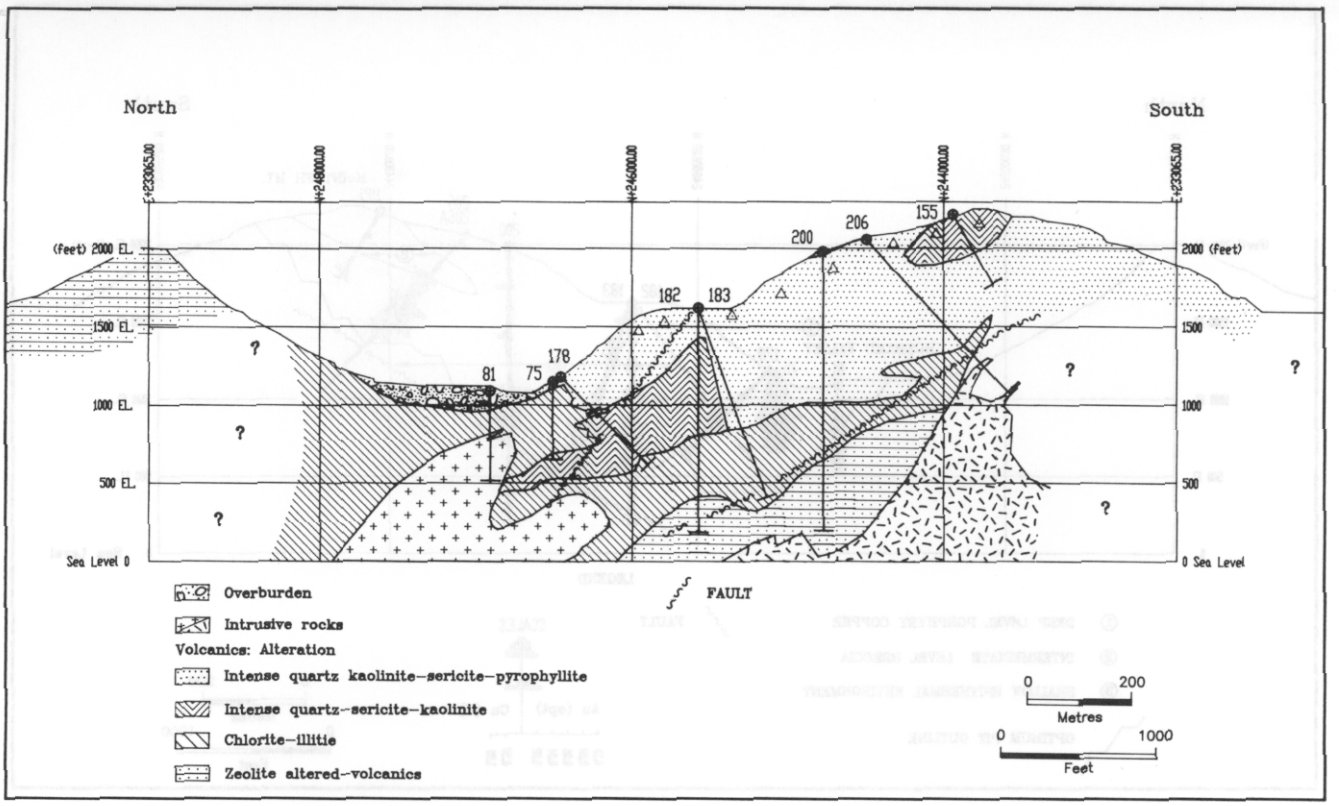


FIGURE 6. Section 233065 showing simplified geology, alteration and drillholes at Hushamu-McIntosh.

and hairline fracture-controlled copper mineralization also occurs. Early and widespread alteration is dominated by chlorite together with minor amounts of albitic feldspar and illitic clays with local remnants of earlier biotite-bearing K-silicate alteration assemblages. The chlorite-altered area is locally cross-cut and overprinted by structurally controlled phyllic alteration dominated by quartz and sericite, with some clays and trace rutile. The phyllic alteration is associated with vein, hairline-veinlet and disseminated pyrite and minor chalcopyrite.

The intermediate levels of the porphyry system are associated with a large, multiple-stage hydrothermal breccia complex which dominates the landscape and geology of McIntosh Mountain. This complex, which includes mineralized volcanic breccia units, magmatic-hydrothermal and phreatomagmatic breccia types, displays an incipient zonation outward from the intrusive centre. Fragments of feldspar porphyry and feldspar-quartz porphyry are dominant in the vicinity overlying the main dioritic intrusion, whereas andesite clasts prevail away from this intrusive centre in the contact area with propylitic volcanic wallrocks. Alteration in the breccias is characterized by abundant quartz, kaolinite, zunyite, diaspore, and minor pyrophyllite, all characteristic components of high temperature advanced argillic alteration assemblages. Where alteration is most intense, the rocks acquire a characteristic "mottled" texture with irregular grey to buff or pink-coloured masses or patches of kaolinite, zunyite, dickite, and diaspore in a fine-grained siliceous cement.

The breccia complex is clearly intramineral in age for it contains abundant mineralized fragments of various lithologies and, it is crosscut in turn by high-level, structurally-controlled, quartz-veined, moderately mineralized FP bodies, pyrite-rich, phreatomagmatic (and phreatic?) pebble breccia dikes and late rhyolite dikes. These breccia bodies are found near the top of McIntosh Mountain and are intersected in diamond holes EC211,212, 154, 174, and 175 on top of McIntosh Mountain. Copper and gold mineralization within this breccia complex consists of, in order of abundance, covellite, bornite, chalcocite, chalcopyrite and minor enargite. This high sulphidation assemblage is typical of those found associated with advanced argillic alteration high in porphyry copper systems elsewhere (e.g. in The Philippines and Chile). Pyrite is the most common sulphide mineral present in this zone, averaging between five and eight volume per cent. Locally, the pyrite content may be as high as 30 % particularly where it occurs as a cement in late-stage hydrothermal breccias and as relatively narrow massive veins.

Part of the copper mineralization intersected in some holes at Mount McIntosh (e.g. EC-206) appears to be part of a weakly-developed chalcocite-covellite supergene "blanket" since chalcocite and/or covellite coatings on pyrite and bornite are commonly observed. Enargite has been also observed to be partly to totally replaced by chalcocite and/or covellite.

The uppermost part of the Hushamu-McIntosh mineralization is observed on the top of McIntosh Mountain where a northwesterly-trending silica zone ("ledge"), containing intensely silicified hydrothermal breccias and vuggy silica rock, cross-cuts quartz-stockworks and porphyry-style mineralization (e.g. holes EC-154 and 155). Lithologies at the top of MacIntosh Mountain are considered by Nixon et al. (1994) to represent a rhyolite flow-dome complex. Alteration minerals include abundant kaolinite, zunyite, and diaspore and, most importantly, vuggy silica rock. The presence of the latter reveals that the ledge formed in a high sulphidation epithermal environment under extreme acidic conditions. The acidic magmatic volatiles are believed to be derived from the underlying cooling Hushamu porphyry system. This epithermal alteration transition is within 350 m vertically above the porphyry deposit in the valley (Fig. 7), hence the description of the system as "telescoped". Structural compression of the mineralized zones by post-ore, northward-dipping normal faults is considered likely (Panteleyev and Koyanagi, 1994).

Whole-rock geochemistry for holes EC-154, 155 and by Panteleyev and Koyanagi (1993) shows that vuggy silica rock is nearly depleted in all major elements except SiO_2 (up to 96%), Fe_2O_3 (up to 10.6%), and TiO_2 (up to 2.8%) and further supports the extreme base-leaching conditions associated with ledge formation at

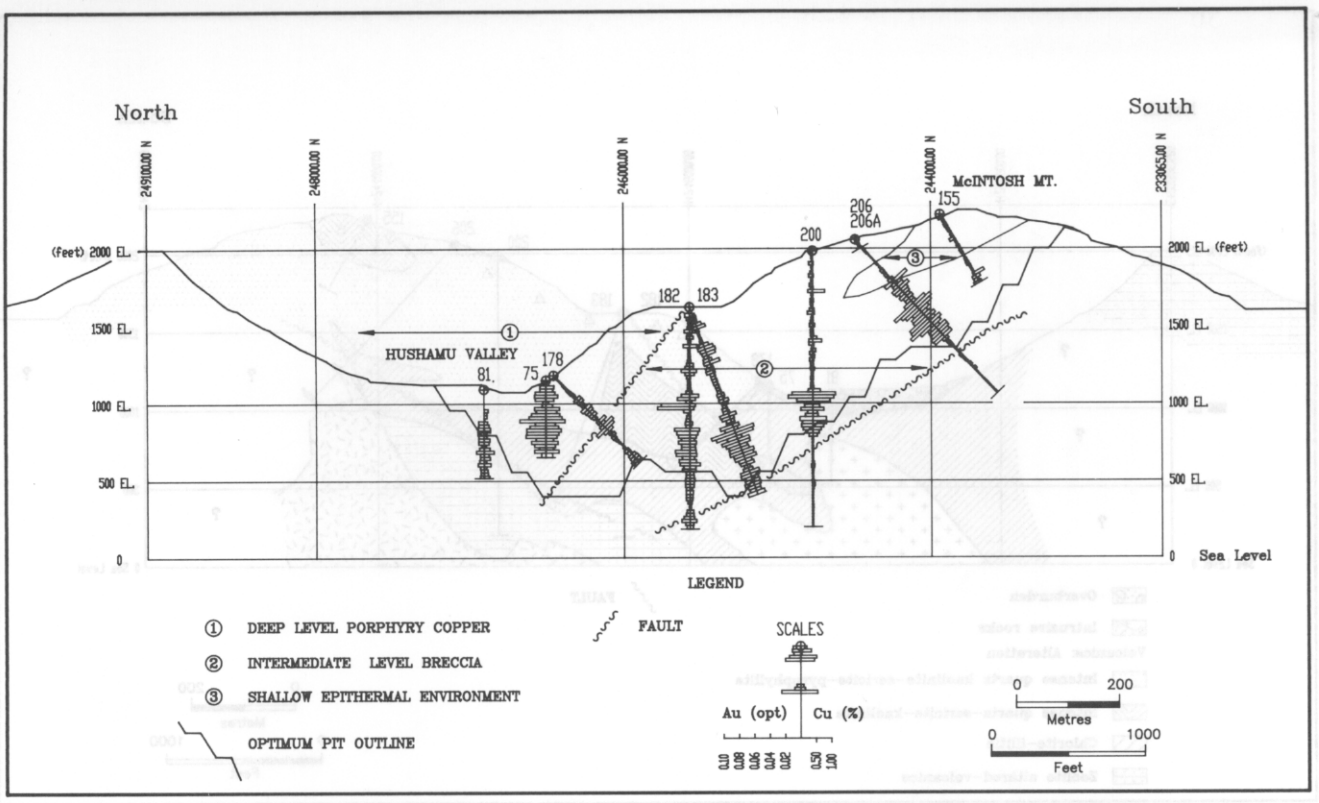


FIGURE 7. Section 233065 showing copper and gold distribution, design pit limits (173.3 million tonnes), and varying mineralization styles at Hushamu-McIntosh.

McIntosh Mountain. Similarly, trace element geochemistry shows that vuggy silica rock is, in general, devoid of any significant copper, gold, or molybdenum mineralization unless it contains mineralized clasts with older quartz stockworks or veins.

Recent age dating (Panteleyev and Koyanagi, 1994), indicate (K-Ar, Ar-Ar) ages of 172 Ma for the Hushamu stock hornblende and 171 Ma for the Hushamu sericite alteration. These dates indicate a Middle Jurassic mineralizing event.

Ore Reserves

A detailed re-evaluation of the geology of the Hushamu zone was completed in December 1992. The ensuing model was used to control a statistical evaluation of the copper and gold occurrence for use in a series of economic pit designs. The statistical evaluations were carried out by Montgomery Consultants Ltd. (G.H. Giroux, unpubl., 1993), and the pit optimization was performed by Steffen, Robertson and Kirsten Ltd., (D. Charbonneau, unpubl., 1993).

The grade model guided the pit optimization. The attention given to the geostatistical evaluation provided very significant benefits to the economics of the proposed pits. Figure 8 details the distribution of copper mineralized rock within the Hushamu zone by bench level, and includes the value of the contained gold (converted to a net smelter return). The figures show that the gold content is close to 50% of the value of the mineral in any particular block. The distribution of gold and its relationship to the copper is critical to the viability of the project. The average grade of 0.28% Cu is not viable in the foreseeable future without the gold contribution.

Geostatistical Evaluation

In the geostatistical study the Hushamu hole data were subdivided on the basis of geology into five rock types: siliceous pyrophyllite breccia, siliceous breccia, altered andesite, intrusive and relatively unaltered andesite. Simple statistical analysis showed that the distribution of copper and gold within rock types is unique. (Note that the deposit parameters are still defined in imperial units, to conform with earlier work).

Assay data of composites samples 20 feet in length, were formed from hole data. These honoured geological boundaries, i.e. andesite composites, only contained hole data coded as andesite. Again simple statistical analysis within each of the five rock types showed copper and gold distributions to be unique for the composite data. A study of copper-gold correlation showed poor agreement in the area of economic cutoffs. Samples with copper grades of 0.30%, for example, sometimes individually had gold grades anywhere from 0.001 oz/ton to 0.02 oz/ton (34 ppb to 680 ppb Au).

Semi-variograms for each variable were produced for each of five rock types. With the exception of altered andesites and basalts all were isotropic. For copper within the andesite unit a geometric anisotropy was indicated with a maximum horizontal range of 600 feet along the 045° azimuth. The range of maximum continuity in the vertical plane was 300 feet dipping 045° at 060° azimuth. An identical pattern was obtained for gold with ranges 700 feet in the horizontal plane and 300 feet plunging 60° N at 045° azimuth.

The geological block model was used to control the interpolation process. A total of 503 580 blocks 100 by 100 by 40 feet in dimension were coded with topographic and geological information. Kriging was used to interpolate a grade into each block coded as one of the five rock types. A total of 46 515 blocks were estimated. Results for the geological in situ resource at several copper cutoffs are shown in Table 1 (after G.H. Giroux, unpubl., 1993).

In order to produce a block model suitable for input into an open pit optimization routine a single value was needed for each block. As a result a net smelter return (NSR) value was calculated in Canadian dollars for each block. This NSR value was based on metal prices, exchange rate, smelter and treatment costs and varying recoveries for copper and gold based on grades.

The computer optimized open pit was designed for the Hushamu zone mineralization during March 1993. The data for the pit were

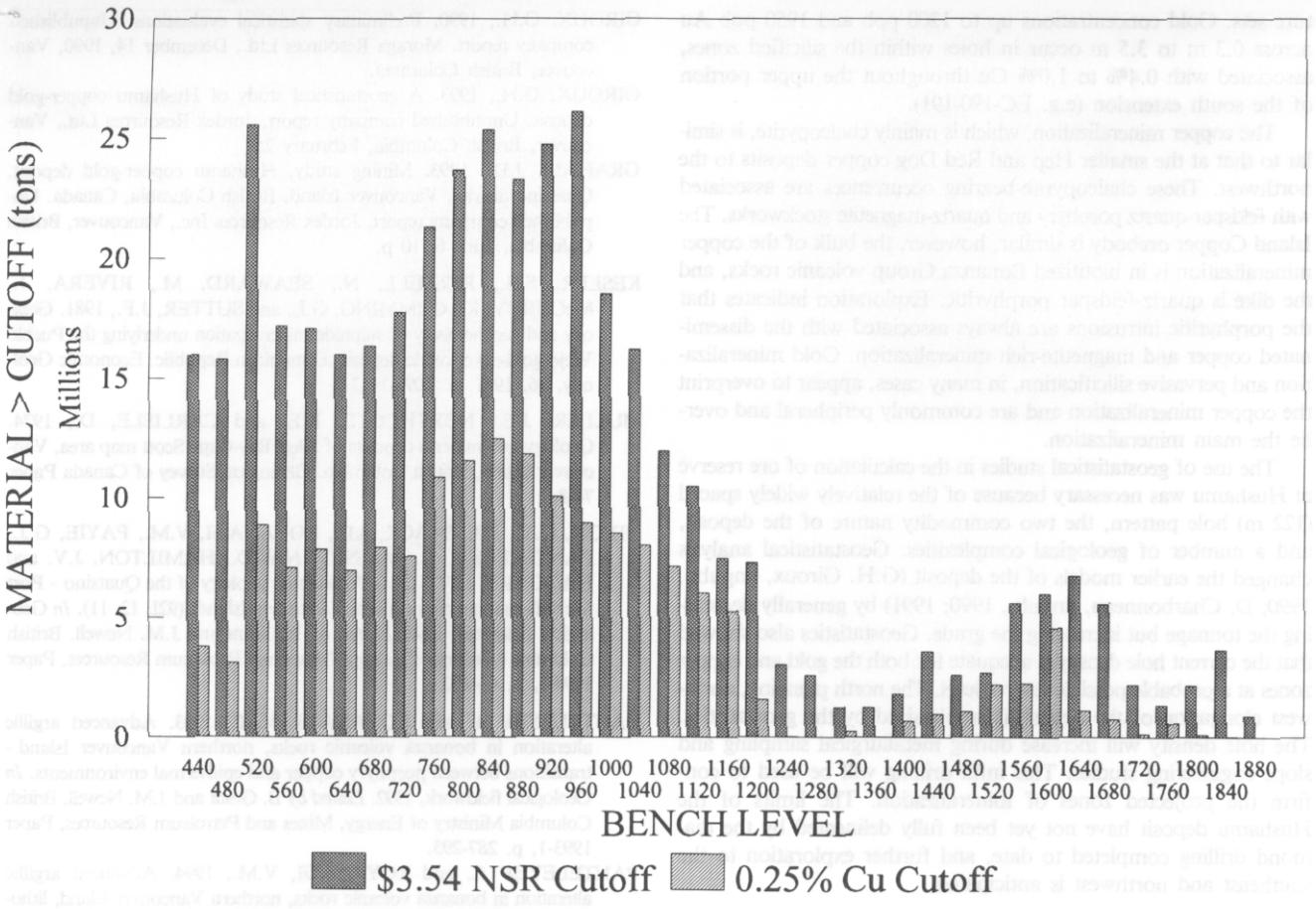


FIGURE 8. Geological reserves of Hushamu deposit showing tonnage by bench utilizing either a 0.25% Cu cutoff or a $3.54 NSR cutoff (includes both copper and gold values and variable recoveries related to drill sample grade).

obtained from the file of total drillholes, the geological model and the statistical studies and NSR calculations by G.H. Giroux, (unpub., 1993). The pit outline was engineered by Steffen, Robertson Kirsten Ltd. of Vancouver using the Gemcom Services Inc. PC-Mine software, and the Whittle 4D optimization program. This optimization was used to design the working pit outline including ramps (D. G. Graham, unpub., 1993).

The core of the zone has been determined as hosting a "possible-probable" mineable reserve of 173.3 million tonnes (190.2 million tons) with an average copper grade of 0.272% Cu; 342 ppb Au (0.010 opt Au); and 0.009% Mo. This deposit has a strip ratio of 2.2:1 based upon a NSR cutoff of $3.32, excluding molybdenum and rhenium.

Discussion and Conclusions

The Hushamu gold-copper deposit is predominantly hosted within silicified and chloritized volcanic flows and tuffs adjacent to quartz diorite and feldspar porphyry intrusions. Within the mineralized zone sulphide minerals occur mainly as disseminated chalcopyrite and pyrite within the volcanic rocks and also in quartz vein stockworks associated with magnetite. The mineralized zone is generally overlain by 30 m to 200 m of silica and silica-kaolinite-pyrophyllite altered rock at McIntosh Mountain.

On average approximately 50% of the gold is closely associated with the copper. The most consistent gold values are from holes within the chlorite-magnetite alteration zone. These are generally 340 ppb to 445 ppb gold associated with copper grades of 0.30% to 0.35%. There is a noticeable diminished gold grade with depth within the main zone. The northwest portion of the zone, however, generally has similar copper and gold grades to the deeper levels of the main zone (100 ppb to 230 ppb Au with 0.27 % to 0.35% Cu). This variation can be explained by block faulting. Gold also occurs in discrete siliceous alteration zones within late stage frac-

TABLE 1. Hushamu deposit geological reserves

			Average grade above cutoff		
Description	**Cu Cutoff (%)**	**Tons > Cutoff**	**Cu (%)**	**Au (oz/ton)**	**Mo (%)**
Probable resource	0.20	255 200 000	0.275	0.009	0.008
Possible resource	0.20	57 400 000	0.279	0.011	0.014
Total resource	0.20	312 600 000	0.276	0.010	0.009
Probable resource	0.25	135 500 000	0.320	0.011	0.009
Possible resource	0.25	34 800 000	0.317	0.013	0.014
Total resource	0.25	170 300 000	0.320	0.011	0.010
Probable resource	0.30	70 600 000	0.366	0.012	0.009
Possible resource	0.30	19 700 000	0.352	0.014	0.016
Total resource	0.30	90 300 000	0.363	0.013	0.010

ture sets. Gold concentrations up to 1200 ppb and 1950 ppb Au across 0.3 m to 3.5 m occur in holes within the silicified zones, associated with 0.4% to 1.0% Cu throughout the upper portion of the south extension (e.g. EC-190-191).

The copper mineralization, which is mainly chalcopyrite, is similar to that at the smaller Hep and Red Dog copper deposits to the northwest. These chalcopyrite-bearing occurrences are associated with feldspar-quartz porphyry and quartz-magnetite stockworks. The Island Copper orebody is similar, however, the bulk of the copper mineralization is in biotitized Bonanza Group volcanic rocks, and the dike is quartz-feldspar porphyritic. Exploration indicates that the porphyritic intrusions are always associated with the disseminated copper and magnetite-rich mineralization. Gold mineralization and pervasive silicification, in many cases, appear to overprint the copper mineralization and are commonly peripheral and overlie the main mineralization.

The use of geostatistical studies in the calculation of ore reserve at Hushamu was necessary because of the relatively widely spaced (122 m) hole pattern, the two commodity nature of the deposit, and a number of geological complexities. Geostatistical analysis changed the earlier models of the deposit (G.H. Giroux, unpubl., 1990; D. Charbonneau, unpub., 1990; 1991) by generally decreasing the tonnage but increasing the grade. Geostatistics also showed that the current hole density is adequate for both the gold and copper zones at a probable-possible reserve level. The north plunging, northwest elongation of the deposit is emphasized by the geostatistics. The hole density will increase during metallurgical sampling and slope engineering studies. This infill drilling will be used to confirm the projected zones of mineralization. The limits of the Hushamu deposit have not yet been fully delineated by the diamond drilling completed to date, and further exploration to the southeast and northwest is anticipated.

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REFERENCES

BCDM/GSC, 1963. Aeromagnetic Map Series. Geological Survey of Canada, Geophysics Papers and Maps, 1733-1738, September, 1962.

CHARBONNEAU, D.J., 1990. Open pit optimization and mineable reserves. Steffen Robertson Kirsten (B.C.) Ltd. Unpublished company report, Moraga Resouces Ltd., Vancouver, British Columbia, December 18, 1990, 9 p.

CHARBONNEAU, D.J., 1991. Open pit optimization and mineable reserves. Steffen Robertson Kirsten, (B.C.) Ltd. Unpublished company report, Moraga Resources Ltd., Vancouver, British Columbia, January 16, 1991, 9 p.

CHARBONNEAU, D.J., 1993. Open pit optimization Hushamu. Unpublished company report, Moraga Resources Ltd., Vancouver, British Columbia.

GIROUX, G.H., 1990. Preliminary statistical evaluations. Unpublished company report, Moraga Resources Ltd., December 14, 1990, Vancouver, British Columbia.

GIROUX, G.H., 1993. A geostatistical study of Hushamu copper-gold deposit. Unpublished company report, Jordex Resources Ltd., Vancouver, British Columbia, February 25.

GRAHAM, J.D., 1993. Mining study, Hushamu copper-gold deposit, Quatsino district, Vancouver Island, British Columbia, Canada. Unpublished company report, Jordex Resources Inc., Vancouver, British Columbia, June 6, 10 p.

KESLER, S.E., RUSSELL, N., SEAWARD, M., RIVERA, J., McCURDY, K., CUMMING, G.L. and SUTTER, J.F., 1981. Geology and geochemistry of sulphide mineralization underlying the Pueblo Viejo gold-silver oxide deposit, Dominican Republic. Economic Geology, 76, 1981. p. 1096-1117.

MULLER, J.E., NORTHCOTE, K.E. and CARLISLE, D., 1974. Geology and mineral deposits of Alert Bay-Cape Scott map area, Vancouver Island, British Columbia. Geological Survey of Canada Paper 74-8.

NIXON, G.T., HAMMACK, J.L., KOYANAGI, V.M., PAYIE, G.J., PANTELEYEV, A., MASSEY, N.W.D., HAMILTON, J.V. and HAGGART, J.W., 1994. Preliminary geology of the Quatsino - Port McNeill map areas, northern Vancouver Island, (92L 12, 11). *In* Geological fieldwork 1993. *Edited by* B. Grant and J.M. Newell. British Columbia Ministry of Energy, Mines and Petroleum Resources, Paper 1994-1, p. 63-110.

PANTELEYEV A. and KOYANAGI, V.M., 1993. Advanced argillic alteration in bonanza volcanic rocks, northern Vancouver Island - transitions between porphyry copper and epithermal environments. *In* Geological fieldwork, 1992. *Edited by* B. Grant and J.M. Newell. British Columbia Ministry of Energy, Mines and Petroleum Resources, Paper 1993-1, p. 287-293.

PANTELEYEV A. and KOYANAGI, V.M., 1994. Advanced argillic alteration in bonanza volcanic rocks, northern Vancouver Island, lithologic and structural controls. *In* Geological Fieldwork, 1993. *Edited by* B.Grant and J.M. Newell. British Columbia Ministry of Energy, Mines and Petroleum Resources, Paper 1994-1, p. 101-109.

PERELLO, J.A., 1992. Comments on the exploration potential for epithermal Au and Cu at McIntosh, South McIntosh, and West Pemberton, Expo claims, Vancouver Island, British Columbia. Unpublished company report, BHP Minerals Canada Ltd., Vancouver, British Columbia, 19 p.

PERELLO, J.A., FLEMING, J.A., O'KANE, K.P., BURT, P.D., CLARKE, G.A., HIMES, M.D. and REEVES, A.T., Porphyry copper-gold-molybdenum mineralization in the Island Copper Cluster, northern Vancouver Island, British Columbia. *In* Porphyry Deposits of the Northwestern Cordillera of North America. *Edited by* T.G. Schroeter. Canadian Institute of Mining, Metallurgy and Petroleum, Special Volume 46.

UTAH MINES LTD., 1975. Hushamu Lake Zone copper mineral estimate 1975 (revised). Unpublished company report, BHP-Utah Mines Ltd., Vancouver, British Columbia.

YOUNG, M.J., 1969. Geological and geochemical assessment report on the Expo Claim group for Utah Mines Ltd. British Columbia Ministry of Energy, Mines and Petroleum Resources Assessment report No. 21902.