British Columbia Geological Survey
Geological Fieldwork 1993

GEOLOGY OF THE CRESCENT ALKALIC PORPHYRY COPPER-GOLD DEPOSIT, AFTON MINING CAMP, BRITISH COLUMBIA (92I/9)

By James R. Lang
Mineral Deposit Research Unit, University of British Columbia

(MDRU Contribution 036)

KEYWORDS: Economic Geology, Porphyry, Copper, Gold, Iron Mask Batholith, Pothook Diorite, Cherry Creek Monzonite, Alkalic, Quesnellia

INTRODUCTION

The Crescent deposit is one of several porphyry-style deposits located within the Iron Mask batholith. Other mined deposits in the district include the Afton, Ajax East and West, and Pothook deposits; the Big Onion, DM, and Python zones have published reserves but have had no production (Figure 1; Kwong, 1977). The Iron Mask is a composite intrusion of alkalic affinity which was emplaced at about 207±3 Ma (Ghosh, 1993) into coeval volcanic rocks of the Nicola Group which is part of the Quesnellia oceanic island-arc terrane (Souther, 1992). The copper-gold deposits within the batholith have been classified within the silica-saturated group of alkalic porphyry deposits (Lang *et al.*, 1993). The Crescent deposit is located 3 kilometres due east of the Afton deposit, the largest orebody in the district (Figure 1), and yielded 1.36 million tonnes of ore with an average grade of 0.46% copper and 0.2 gram per tonne gold during production in 1989 and 1990.

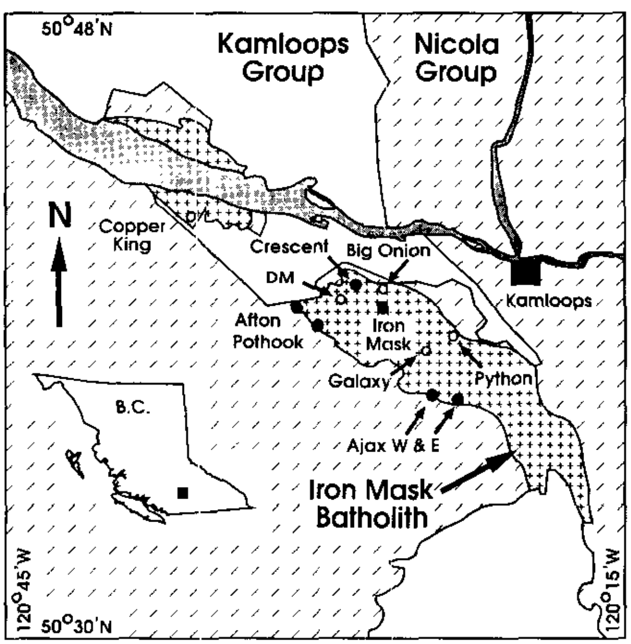

Figure 1. Location of the Iron Mask batholith and associated mineral deposits. Closed and open symbols respectively distinguish deposits with production from those that have not been mined. Dark grey is Kamloops Lake.

The work reported here is based on a map of the open pit prepared at a scale of 1:600 (Figure 2), an outcrop map at 1:2400 scale for areas outside the pit (see Stanley *et al.*, 1994), and examination of diamond drill core. Only preliminary thin section work has been conducted as of this writing, and geochemical data are not yet available. This report summarizes the geology within the open pit, the characteristics of hydrothermal alteration and mineralization, and the currently recognized controls on the distribution of mineralization.

GEOLOGY

The geology of the open pit (Figure 2) is dominated by Pothook diorite and a finer grained, porphyritic monzodiorite to diorite which intrudes the Pothook and is tentatively assigned to the Cherry Creek phase of the Iron Mask batholith (Snyder and Russell, 1993). Minor rock types include andesite dikes and plagioclase diorite porphyry dikes. The contact zone between the diorite and monzodiorite is afforded special treatment because it is the locus for development of economic copper-gold mineralization.

POTHOOK DIORITE

The Pothook diorite is the oldest unit and dominates the south and west portions of the pit (Figure 2). Least-altered samples of the diorite are greenish grey and equigranular, with a mineral assemblage comprising euhedral to subhedral plagioclase and pyroxene, poikilitic biotite, anhedral magnetite and potassium feldspar, and accessory euhedral apatite (Table 1); subhedral titanite was observed in one sample. Grain size is typically 1.5 to 3 millimetres, but more fine-grained areas have been recognized, particularly close to the contact with the Cherry Creek monzodiorite. Within the batholith as a whole, the Pothook diorite is notable for a magnetite

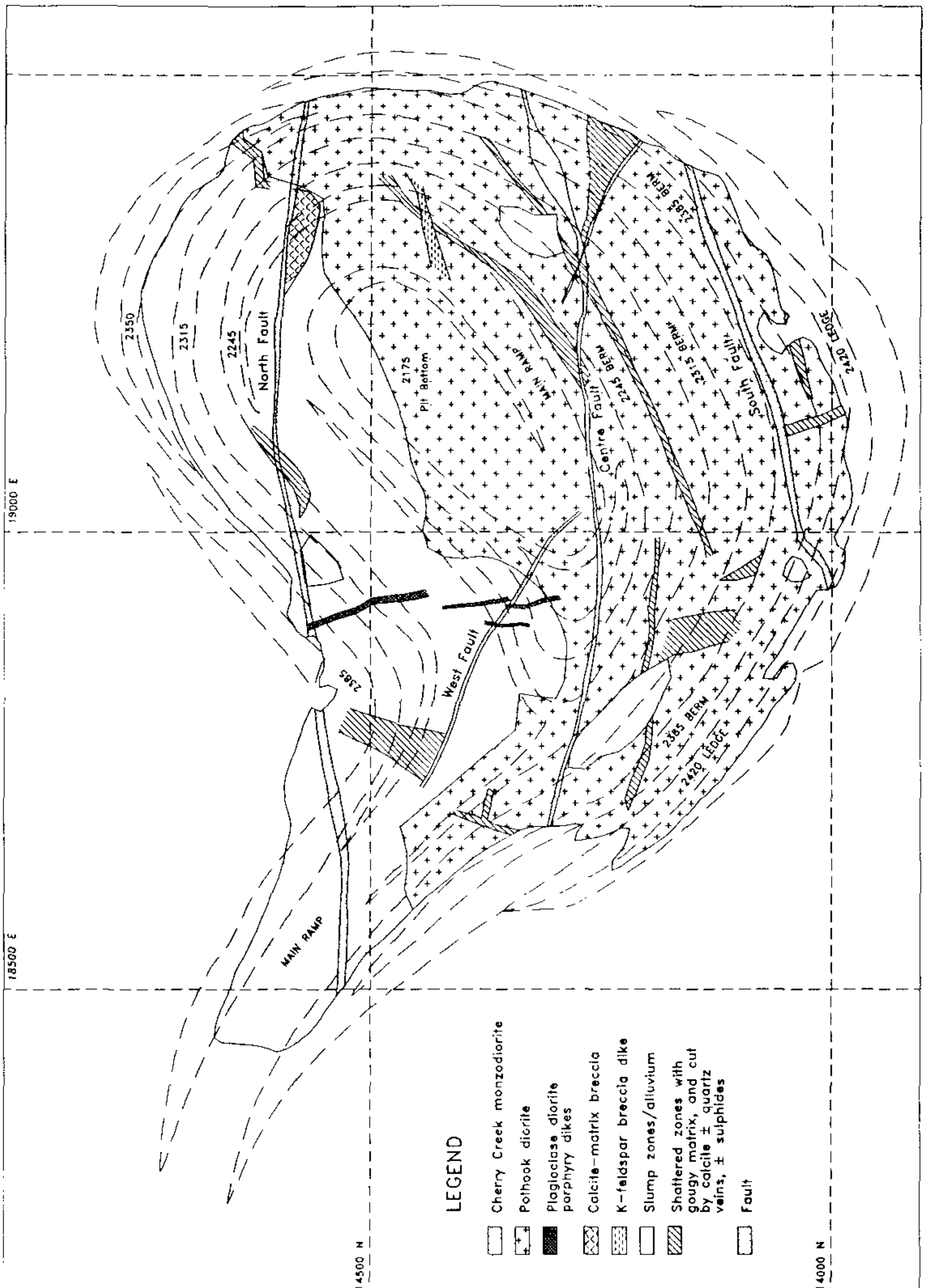

Figure 2. Geologic map of the Crescent open pit.

content which locally exceeds 15%, large poikilitic biotite grains which enclose plagioclase and augite (Snyder and Russell, 1993), and magnetite veins and segregations which may reach several metres in width (Stanley *et al.*, 1994; Cann, 1979); these features are also present in and adjacent to the Crescent deposit. Near its contact with the Cherry Creek monzodiorite, Pothook diorite has been affected by strong potassium metasomatism which has locally given it a pseudoporphyritic texture as a result of conversion of the margins of plagioclase grains to massive, pink potassium feldspar. Subangular to rounded xenoliths of an amphibolitized mafic rock, interpreted as a Nicola volcanic unit, are only rarely present.

CHERRY CREEK MONZODIORITE

The northern part of the pit (Figure 2) is dominated by a monzodioritic to microdioritic intrusion that is assigned to the Cherry Creek phase of the batholith (Stanley *et al.*, 1994). Although it is treated as a single intrusive phase, substantial variation in texture, and possibly in mineralogy, do not preclude the presence of several discrete units. In general, Cherry Creek monzodiorite is more fine grained than Pothook diorite, is variably porphyritic, and ranges from light pinkish grey to greenish grey in colour. Phenocrysts include euhedral plagioclase laths and less abundant, more equant, subhedral to euhedral pyroxene. Strongly altered, subhedral amphibole was observed in trace to minor amounts in a few samples. The aphanitic to fine-grained groundmass comprises potassium feldspar, magnetite, biotite, plagioclase, and sporadic occurrences of apatite (Table 1). Locally, and particularly near intrusive contacts, the plagioclase phenocrysts have a trachytic texture. Strong to intense potassium metasomatism has locally obliterated the porphyritic texture and has converted the rock to a dense, maroon-coloured, nearly aphanitic rock with few visible grains.

MINOR ROCK TYPES

ANDESITE DIKES

Andesite dikes are rare in the Crescent pit and are typically less than a metre wide, black to dark green in colour, aphanitic, and commonly discontinuous. Larger examples observed elsewhere in the northern part of the Iron Mask batholith have pyroxene phenocrysts to 3 millimetres and may also contain equant plagioclase phenocrysts less than 2 millimetres in size. The groundmass is always macroscopically aphanitic. These rocks have not been affected by alteration or mineralization events, and may be related to the Eocene mafic volcanism of the Kamloops Group. In the pit, andesite dikes are cut by flat fractures and faults but offsets in excess of 2 metres were not observed.

TABLE 1. PETROGRAPHIC CHARACTERISTICS OF THE POTHOOK DIORITE AND CHERRY CREEK MONZODIORITE.

	Pothook Diorite	Cherry Creek Monzodiorite
N	8	5
Pyroxene	17 to 22	1[illegible] to 15*
Amphibole		[illegible] to 5*
Biotite	5 to 15	2 to 10*
Magnetite	7 to 10	[illegible].5 to 7
Plagioclase	50 to 55	5[illegible] to 65*
K-Feldspar	<5 to 10	[illegible] to 15
Apatite	trace to 0.5	0 to low 0.x
Quartz		15 in one spl
Grain Size	1.25 to 3mm	Matrix: [illegible]0-40 microns; Pheno [illegible] 0.2-1.5mm
Phenocryst %	0	[illegible] to 80
Texture	equigranular to seriate	equigranular to porphyritic

* Observed as a phenocryst phase

PLAGIOCLASE DIORITE PORPHYRY DIKES

Plagioclase diorite porphyry dikes are common throughout the northern end of the batholith but are rare and of very minor volume in the Crescent pit. As a group, they are typically dark green in colour, and range from less than 1 metre to about 5 metres in width. Narrow examples are commonly aphyric or have only very small plagioclase phenocrysts. Wider dikes have cores characterized by subhedral plagioclase, and more rarely pyroxene phenocrysts, in a fine-grained to aphanitic, dark grey-green groundmass, and chilled, dark grey, aphanitic margins up to 1 metre in width. Contacts with the hostrock are typically sharp but are commonly irregular. Xenoliths, where present, are limited to the immediate wallrock and are volumetrically minor. These dikes intruded during the waning stages of the pervasive potassium metasomatism event described below; in the Crescent pit, however, they are cut by later mineralized veins.

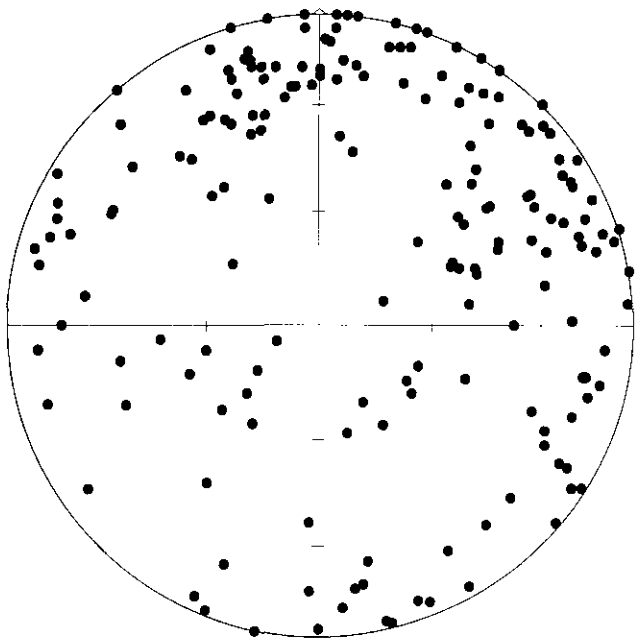

Figure 3. Lower hemisphere projection of poles to faults and fractures, Crescent deposit. Only those fractures continuous over at least one full bench face are included.

STRUCTURES

Major faults which could be traced visually across the pit include the North, Centre, South and West faults (Figure 2). The absence of marker units has, however, severely limited assessment of offset. The North fault is the largest break and varies in width from 1 to about 5 metres along its easterly trace. It may be offset slightly by the West fault. The North fault cuts the plagioclase diorite porphyry dike but does so right at the bedrock surface on the 2385 bench (Figure 2) and offset cannot be determined. The Centre fault is parallel to the North fault but less prominent. On the southernmost margin of the pit, the South fault forms a major fracture zone of unknown offset with a trend of 070°. The West fault is visible in the south wall of the pit as a major structure, but it disappears beneath the flooded pit bottom and projects beneath the main ramp; displacement of the plagioclase diorite porphyry dikes between benches 2245 and 2315 suggests a maximum offset of a few metres. The Centre fault may have effected left-lateral offset of the West fault by up to 35 metres. These major fault zones are dominated by gougy or strongly shattered material with abundant calcite and chlorite; locally they contain calcite-quartz±pyrite veins, very rarely with trace chalcopyrite.

All rocks exposed in the open pit are intensely fractured. Typically these fractures are planar and many can be traced over more than one bench. The fractures are filled with strongly shattered rock which is usually cut by veins and vein swarms comprising calcite-chlorite-quartz±pyrite±epidote±trace chalcopyrite. The width of the broken material is usually less than 10 centimetres, but may range up to several metres. Hydrothermal veins may be the dominant fill in narrower fractures but form only a small portion of the filling of larger structures. Most of the fractures dip more steeply than 60° and have orientation modes of roughly 350°, 060° and 120° (Figure 3). Fractures with relatively shallow dip were also noted. Steeply dipping fractures almost invariably host hydrothermal veins but veins are largely absent from flatter fractures. The preferred orientations are roughly parallel to the major faults, the contact zone between the Pothook and Cherry Creek intrusions, and the zone of mineralization.

CONTACT BETWEEN POTHOOK AND CHERRY CREEK INTRUSIONS

The contact zone between the two major intrusive phases provided the locus for hydrothermal alteration and mineralization in the Crescent deposit. Vein density and alteration are most intense immediately adjacent to the contact zone. The most important features along this contact are development of intrusion breccias, pervasive potassium metasomatism, and the formation of pseudobreccia textures as a consequence of hydrothermal veining. The intensity of the metasomatism commonly obscures the nature and exact location of the contact itself.

Near its contact with the Pothook diorite, the Cherry Creek monzodiorite contains exotic inclusions which increase in abundance as the contact zone is approached and which become sufficiently abundant locally for the rock to be called an intrusion breccia. The fragments are mostly angular, but range to subrounded. They are dominated by Pothook diorite which displays various degrees of development of potassium metasomatism. Less common xenoliths include fragments of amphibolitized Nicola volcanic units, and fragments of massive magnetite veins which are similar to the magnetite segregations common in the Pothook diorite. Even more rarely, fragments macroscopically similar to the Cherry Creek intrusion itself are present; these are either ripped up margins of the Cherry Creek intrusion or strongly metasomatized Pothook diorite which has assumed a pseudoporphyritic texture, as described above.

To the south of the contact lies what may be an intrusion breccia in the form of a dike (Figure 2). The matrix is similar to the Cherry Creek phase but is not macroscopically porphyritic. Fragments include Pothook diorite with various degrees of potassium metasomatism, finer grained porphyries similar to the Cherry Creek unit and, more rarely, fragments of a mafic rock now converted to amphibolite. The fragments are typically angular, but some are milled to a subrounded form. The dike has a constant thickness of about 2 metres in the single exposure on the main ramp. It is not mapped on the overlying bench, but may widen to the west where it is exposed in a narrow rill on the floor of the main ramp.

The main contact is typically obscured by intense potassium metasomatism. This alteration event was contemporaneous with intrusion of the Cherry Creek monzodiorite, and affects both the Pothook and Cherry Creek intrusions. Typically, primary igneous plagioclase and white potassium feldspar are selectively replaced by salmon-pink potassium feldspar. Magnetite is destroyed in strongly altered areas. The alteration is centred on the contact and strong effects extend up to 75 metres into the Pothook diorite, at which point the intensity of alteration decreases gradationally but rapidly, although local effects are visible well beyond the pit boundary to the southeast. In many places near the contact the Pothook diorite acquires a 'spotted' texture resulting from formation of ovoid clots up to 7 millimetres across, comprising chlorite with lesser calcite; this texture reliably indicates proximity to the contact both within the Crescent deposit and elsewhere in the northern end of the batholith. Nearly identical occurrences of potassium metasomatism are present in many exposures of Pothook diorite in the northern end of the batholith and these have commonly been mapped as Cherry Creek monzonite and syenite. This alteration is best described as deuteric. It preceded the introduction of sulphides into the Crescent deposit; later mineralizing fluids overprinted the early deuteric alteration but apparently followed similar flow paths.

ALTERATION AND MINERALIZATION

SEQUENCE OF VEIN TYPES

Six vein types have been recognized in the pit. Crosscutting relationships are well defined and permit a paragenetic sequence to be established (Table 2).

MAGNETITE VEINLETS

Magnetite veinlets have irregular forms and are most common near the main intrusive contact. They are usually less than 1 millimetre wide but may exceed 1 centimetre. They have narrow, distinct alteration envelopes of pink potassium feldspar. Although minor chalcopyrite has been observed, these veins are not abundant and did not carry significant copper.

POTASSIUM FELDSPAR VEINS/DIKELETS

Throughout the deposit, veins of pink potassium feldspar with minor biotite have the appearance of syenite dikelets. In the pit, most of these veins formed as replacements of wallrock along tight fractures, but an intrusive origin cannot be ruled out for larger examples with very sharp contacts with their host. An intrusive origin is not inconsistent with observations in other parts of the northern end of the batholith where similar dikelets have been noted near the contact between Pothook diorite and Cherry Creek intrusions. Sulphide is rare in these veins and they did not contribute substantially to ore grade.

CHLORITE-SULPHIDE VEINS

Chlorite-sulphide veining is best developed within the tabular ore zone and its hangingwall in the Pothook diorite. The altered and mineralized rocks have a distinct mottled colour in shades of pink, black and green. Individual veinlets are narrow and discontinuous and may impart a brecciated appearance to the rock. The dominant minerals are chlorite and magnetite. Chlorite may be a replacement of biotite, which has been observed locally. Magnetite either coexists with or is replaced by hematite. Calcite is common, potassium feldspar is usually present as a trace mineral, and epidote was observed in one case. Quartz is minor and sporadically present and pyrite is absent to minor. Several percent chalcopyrite may be present within veinlets of calcite, chlorite and minor quartz, or in their alteration envelopes. Hostrock between the veinlets is usually altered by potassium feldspar, chlorite, magnetite/hematite and calcite. In the most intensely veined rocks, magnetite is often destroyed, but may be preserved only millimetres away from veins. This alteration type is largely coincident with the ore zone, and the high abundance of chalcopyrite in these veins suggests that they carry most of the copper.

EPIDOTE VEINS

Epidote veins are abundant and widespread but are most common peripheral to the tabular ore zone. They vary from planar structures to more irregular, diffuse veins and, more rarely, they form the matrix to small breccia zones. They range from less than a millimetre to several centimetres in width. Epidote and calcite are the major minerals but pyrite and chalcopyrite locally constitute up to 10%. Minor potassium feldspar and albite(?) were observed, together with rare quartz. Distinct alteration envelopes were not observed, but the veins are often associated with clots of alteration minerals similar to those found in the veins themselves. Chlorite is common in the alteration clots and in the wallrocks to the veins, and is associated with

TABLE 2. PETROGRAPHIC CHARACTERISTICS AND SEQUENCE OF HYDROTHERMAL VEINS.

Vein/Alteration Stage	Major Minerals	Minor Minerals	Envelopes	Morphology
Early				
Magnetite	mag	cpy	K-spar	sinuous
K-spar-dominated	K-spar	bio-cpy-mag-hem	K-spar	irregular
Chlorite-Sulfide	chl-mag-hem-calc-cpy	K-spar-ep-qtz-py	mag?	irregular
Calcite-Quartz	calc-qtz	hem-py-cpy-K-spar-ep	K-spar-mag-cpy	planar
Epidote-dominated	ep-cac-py-cpy	K-spar-qtz	K-spar-chl	planar
Calcite Only	calc	py-chl	none	planar
Late				

Abbreviations: chl, chlorite; calc, calcite; ep, epidote; qtz, quartz; py, pyrite; cpy, chalcopyrite; mag, magnetite; hem, hematite; K-spar, potassium feldspar

disseminated chalcopyrite. Beyond the pit boundary these veins carry magnetite, hematite, epidote and minor calcite, in some cases with alteration envelopes of albite and/or epidote.

CALCITE-QUARTZ VEINS

Calcite-quartz veins are broadly distributed through the deposit. They range from 2 millimetres to several centimetres in width, have sharp contacts with their host, and are usually planar. Calcite usually, but not always, exceeds quartz in abundance. Hematite, pyrite, chalcopyrite, and potassium feldspar are present, and epidote was observed in one sample. Envelopes of pink potassium feldspar similar in width to the veins themselves are almost always developed. In one sample an alteration envelope grades from an inner zone comprising potassium feldspar with minor magnetite and chalcopyrite to an outer zone of magnetite with minor chalcopyrite. Commonly, the grain size of calcite and the abundance of quartz increase toward the core of these veins; the reverse is rare.

CALCITE VEINS

Veins dominated by calcite, with common but minor chlorite and very rare pyrite, occur throughout the deposit. They range from fracture coatings to dilatant veins many centimetres wide, are continuous and planar, have sharp contacts with their hosts, and lack alteration envelopes. Similar veins have been recognized throughout the northern end of the batholith; they have been observed to cut Eocene dikes and are unrelated to mineralization in the Crescent deposit.

OPEN SPACE BRECCIAS

True open-space hydrothermal breccias are common. Fragments are typically angular and have not been milled. The matrix of breccias is usually dominated by calcite with lesser quartz and, less commonly, chalcedony. Typically the matrix contains little or no sulphide although rare, small examples with up to 10% chalcopyrite have been observed. Most sulphide contained in hydrothermal breccias occurs in the fragments. One sample shows two stages of brecciation. The later stage has an unmineralized calcite matrix. Fragments within this matrix are themselves an earlier breccia with a matrix of calcite and minor hematite, chalcopyrite and pyrite; the fragments in this earlier breccia are altered by potassium feldspar and chlorite, and contain over 5% sulphide with a high chalcopyrite to pyrite ratio. The sulphides are in part disseminated and in part contained within calcite-quartz veins that are restricted to the fragments. Larger examples of these breccias are spatially related to major faults.

DISTRIBUTION OF ALTERATION MINERALS

A visual estimate of the percentage of epidote, magnetite, potassium feldspar, chlorite, albite, calcite, pyrite, chalcopyrite, quartz and hematite was made for the bench face at stations spaced 15 metres apart. The

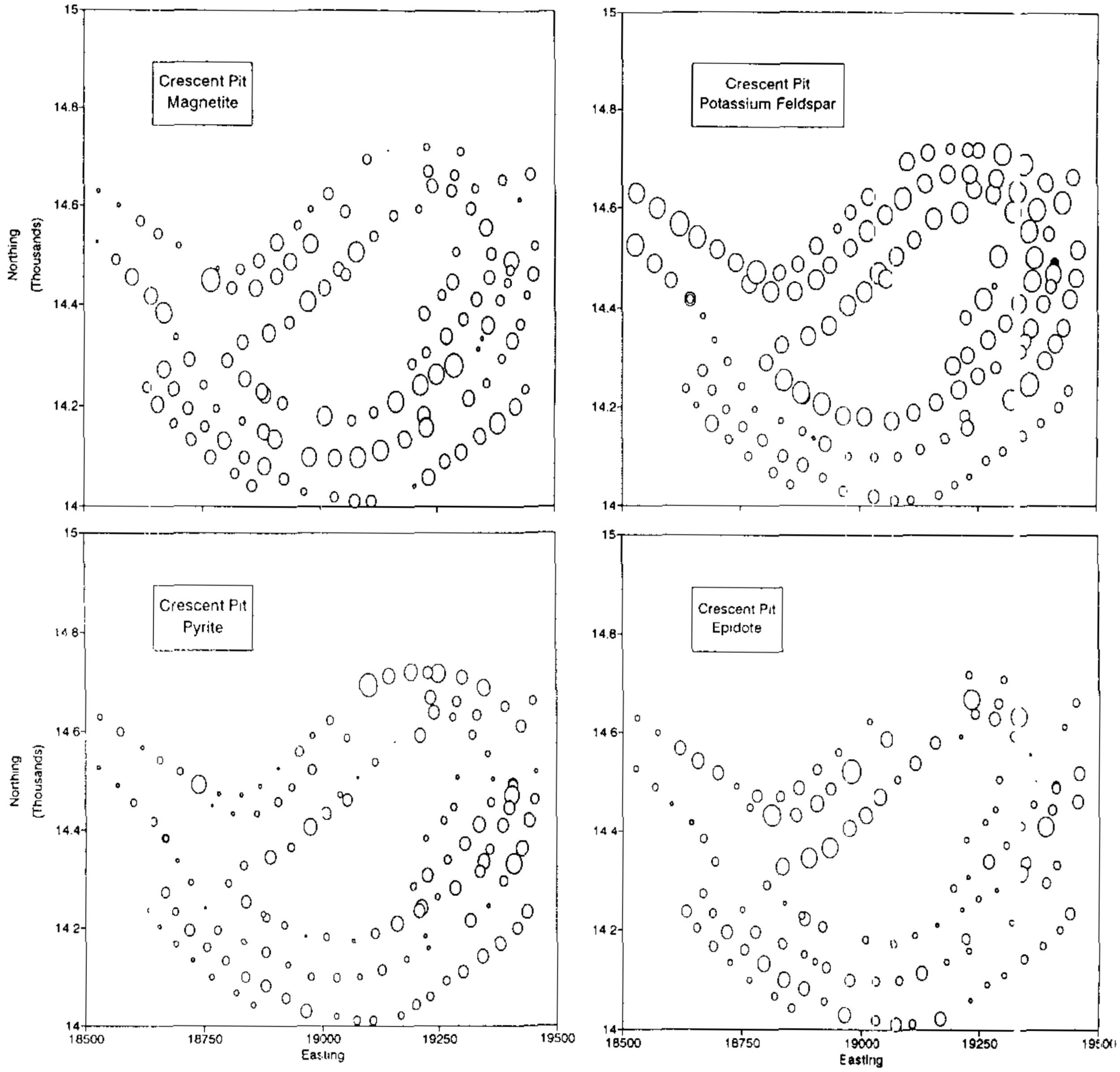

Figure 4. Bubble plots of alteration mineral distribution. Data are visual estimates at 15-metre stations along each accessible bench. Bubble diameter is proportional to value. Maximum values for potassium feldspar, magnetite, pyrite, and epidote are 65%, 15%, 7%, and 20%, respectively.

data were analyzed on bubble plots (Figure 4). Among the minerals not shown on Figure 4, calcite and chlorite are very evenly distributed, and quartz, hematite and albite are erratically distributed with no apparent pattern. A reconnaissance examination of thin sections has shown that visual estimates of chalcopyrite have unacceptably large errors because of its finely disseminated occurrence. Magnetite, potassium feldspar, pyrite and epidote are shown on Figure 4. Magnetite is largely disseminated and is consistently abundant throughout the deposit, even though the Pothook diorite contains nearly twice as much primary magnetite as the Cherry Creek monzodiorite; this reflects the partial destruction of magnetite during potassium metasomatism of the Pothook diorite.

Potassium feldspar is more abundant in the Cherry Creek monzodiorite and in the areas of Pothook diorite affected by strong potassium metasomatism; a sharp decrease is apparent on the south and west sides of the pit. The abrupt decrease on the west occurs at an atypically sharp contact between the Pothook and Cherry Creek units that is not characterized by the usual intrusion or hydrothermal brecciation present elsewhere; the 'tightness' of the contact may have limited fluid flow at this point. Pyrite and epidote abundance is highest on the margins of the deposit and reflects a propylitic, pyritic halo surrounding the ore zone.

At each alteration station (Figure 5), the relative abundance of each vein type was assigned a value from 0

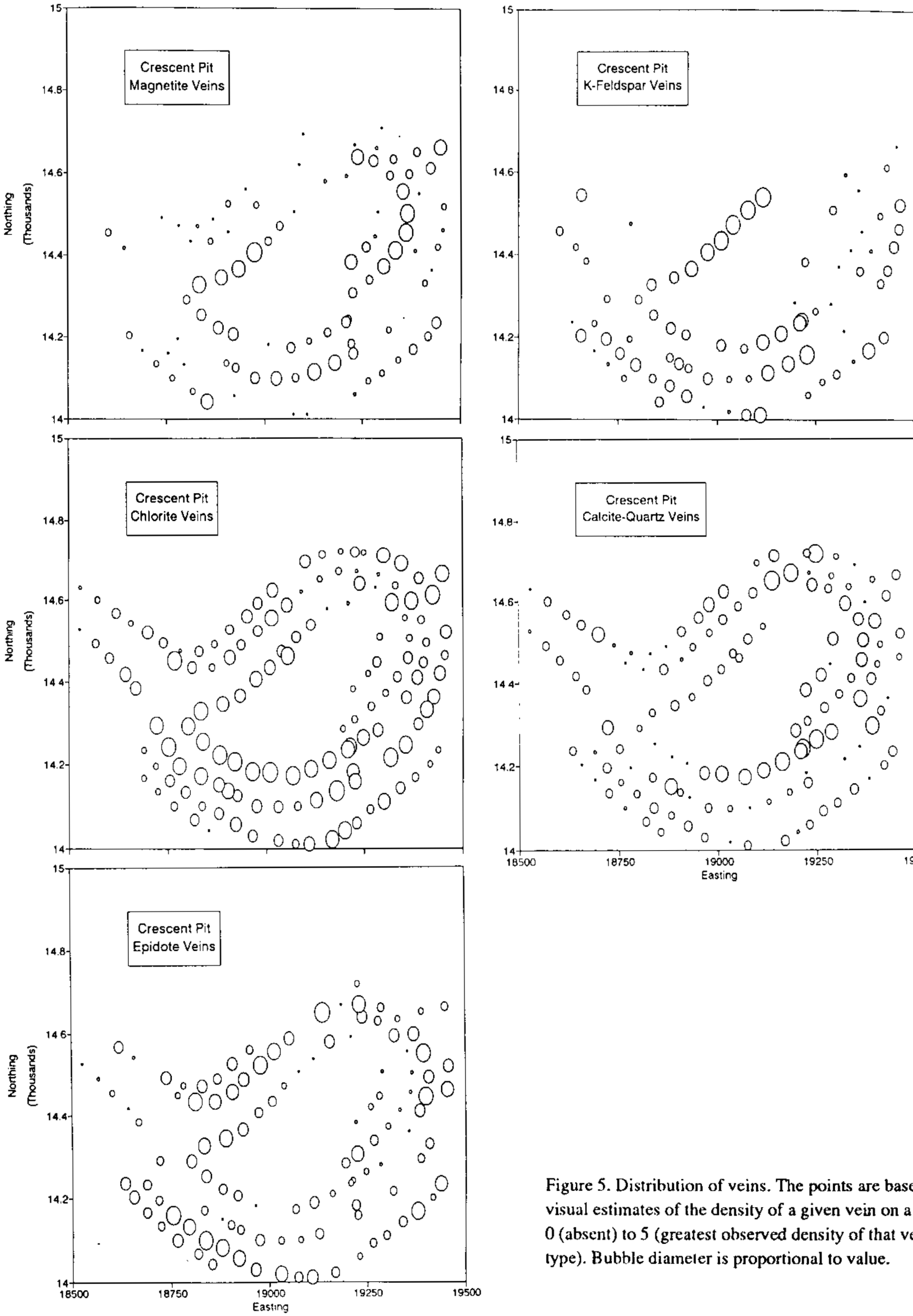

Figure 5. Distribution of veins. The points are based on visual estimates of the density of a given vein on a scale of 0 (absent) to 5 (greatest observed density of that vein type). Bubble diameter is proportional to value.

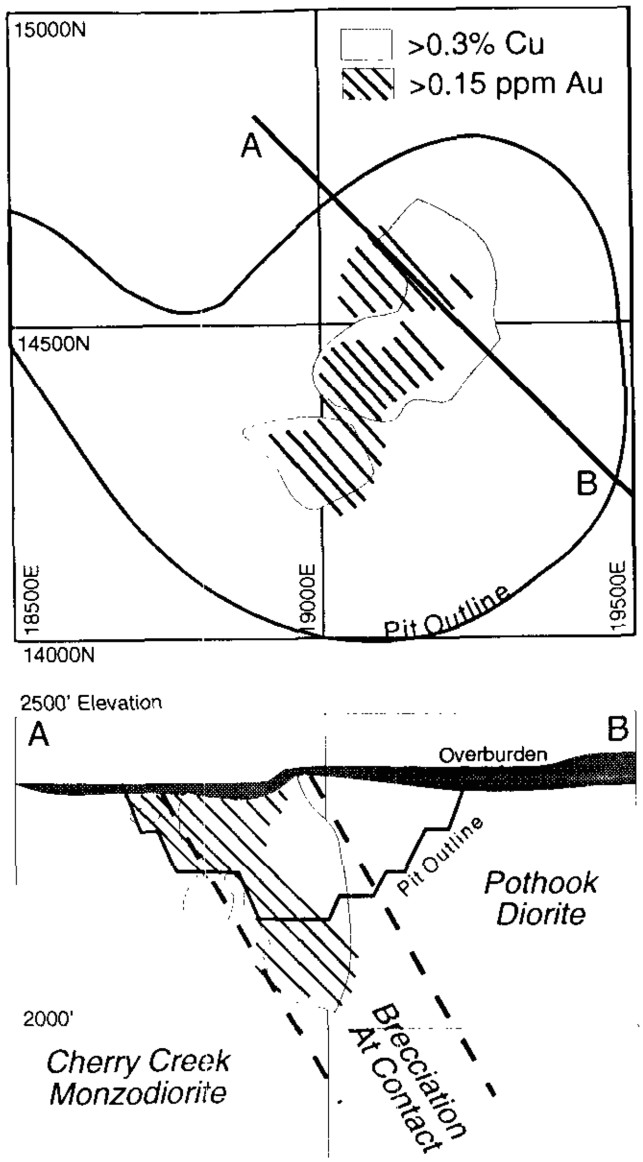

Figure 6. Plan and cross-section distribution of mineralization in the Crescent deposit. Simplified from Bond and Tsang (1988).

(absent) to 5 (greatest number of that particular vein type observed). Magnetite veins occur in both the Pothook diorite and the Cherry Creek monzodiorite but are most abundant near the contact zone. Potassium feldspar veins are more commonly developed in the Pothook diorite, but their greatest and most consistent abundance is on the 2245 level, near the contact zone. Chlorite-sulphide veins are more abundant in the hangingwall of the contact, roughly coincident with the ore zone. Calcite-quartz veins show no distinct distribution pattern. Epidote veins are most abundant on the margins of the pit. The only vein type that is well developed outside the confines of the pit is epidote-magnetite veins which occur sporadically in many exposures of the Pothook diorite throughout the northern end of the Iron Mask batholith; these veins are indigenous to the Pothook diorite itself and are not directly related to the formation of the copper-gold deposits.

DISTRIBUTION OF MINERALIZATION

The ore reserve in the Crescent pit formed a tabular zone oriented about 050° with a southerly dip of 60° (Figure 6; Bond and Tsang, 1988). Mineralization continues downward to at least the 300-metre limit of drilling (L.H.C Tsang, personal communication, 1993). Chalcopyrite was the dominant ore mineral and insignificant amounts of bornite and molybdenite are also reported (Bond and Tsang, 1988). Figure 7 illustrates the distribution of copper and gold as determined from blast-hole assays. A comparison with Figure 2 shows that the higher grades were present along the contact zone and its immediate hangingwall but that sporadic high values were present throughout the deposit. Gold has a more erratic distribution, but Figure 8 shows a good correlation between copper and gold at a nearly constant ratio of about 25,000. This ratio is consistent with values observed at other alkalic porphyry copper-gold deposits and is apparently a fundamental feature of this deposit type (Stanley, 1993). The absence of samples with lower Cu/Au ratios indicates that a late stage episode of gold enrichment, similar to that which has affected some deposits of this class such as the nearby Pothook deposit (Stanley, 1994) and the 66 zone at Mount Milligan (Stanley and DeLong, 1993), has not affected the Crescent deposit. In the Crescent deposit, gold was deposited with chalcopyrite in a single hydrothermal event.

SUMMARY

The Crescent deposit formed in the earliest Jurassic in response to the intrusion of alkalic igneous rocks of the Iron Mask batholith. A proposed sequence of events is presented in Table 3. Mineralization, alteration, and vein formation were localized at the brecciated contact between the older Pothook diorite and the younger Cherry Creek monzodiorite. Relatively more permeable intrusion breccias may have focussed fluid flow. Early deuteric alteration related to intrusion of the Cherry Creek monzodiorite effected intense potassium metasomatism but did not deposit sulphide minerals in the system. This event was closely followed in sequence by magnetite, potassium feldspar, chlorite-sulphide, calcite-quartz, and epidote veins. Ore grade mineralization is associated with chlorite (after biotite?) veining and alteration, and forms a tabular zone along the contact that extends southward into Pothook diorite in the hangingwall. Epidote and pyrite extend beyond the deposit and form a weak halo surrounding the ore zone.

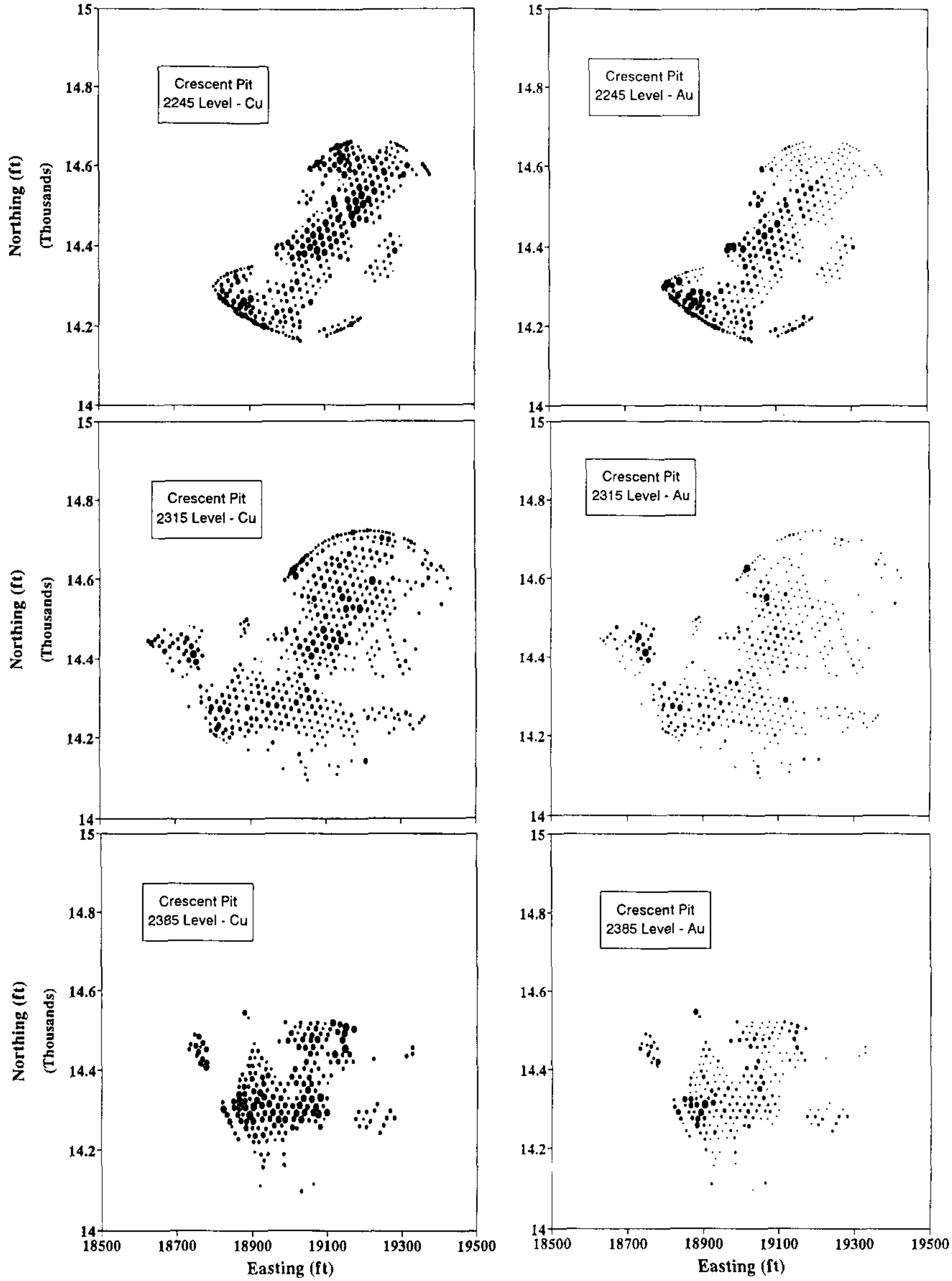

Figure 7. Bubble plots of copper and gold blast-hole assays. Data are shown for each of the four main benches. Bubble diameter is proportional to value. For each respective level N, the number of data points, maximum and minimum copper grade (wt. %), and maximum and minimum gold grade (g/t) are: 2175 level, 258, 2.09, 0.09, 0.82, 0.035; 2245 level, 349, 1.41, 0.06, 0.86, 0.00; 2315 level, 511, 1.83, 0.11, 1.82, 0.00; 2385 level, 236, 1.25, 0.13, 1.41, 0.035.

TABLE 3. SEQUENCE OF EVENTS AFFECTING THE CRESCENT DEPOSIT.

Timing	Geologic Event
1	Intrusion of Pothook diorite
2	Intrusion of Cherry Creek monzodiorite
3A	Formation of intrusion breccias at contact
3B	Potassium metasomatism at contact
3C	Formation of pseudobreccias by K-feldpsar veining (Cu-Au mineralization)
4	Intrusion of plagioclase diorite porphyry dikes
5A	Formation of hydrothermal veins (Cu-Au mineralization)
5B	Movement along major faults; formation of major fractures
5C	Formation of barren calcite-quartz+/-pyrite veins
6	Intrusion of andesite dikes
7	Minor additional fault movement; formation of barren calcite veins

Hydrothermal breccias closely related to faults are common but generally postdate main-stage copper mineralization. A constant Cu/Au ratio of 25000 is similar to other alkalic suite porphyry deposits and indicates that copper-gold introduction was related to a single hydrothermal event.

REFERENCES

Bond, L.A. and Tsang, L.H.C. (1988): Diamond Drilling on the CID1, CID2, and Winty C. G. Mineral Claims; Afton Operating Corporation, Private Report, i3 pages.

Cann, R.M. (1979): Geochemistry of Magneti e and the Genesis of Magnetite-Apatite Lodes in the Iron Mask Batholith, British Columbia; unpublish d M.Sc. thesis, *The University of British Columbia*, 19(pages.

Ghosh, D.K. (1993): Uranium-Lead Geochronc logy; *Mineral Deposit Research Unit - The University of British Columbia*, Copper-Gold Porphyry Syste ns of British Columbia, Annual Technical Report - Year 2, pages 11.1-11.26.

Kwong, Y.T.J. (1987): Evolution of the Iron Mask Batho ith and its Associated Copper Mineralizatic n; *B.C. Ministry of Energy, Mines and Petroleum Resou ces*, Bulletin 77.

Lang, J.R., Stanley, C.R. and Thompson, J.F.H. (1992): Quartz-Alkalic and Nepheline-Alkalic: Two Distinct Subtypes of Porphyry Deposits Related o Alkalic Igneous Rocks; *Geological Society of A nerica*, Abstracts With Programs, Volume 24, page A143

Snyder, L.D. and Russell, J.K. (1993): Field C onstraints on Diverse Igneous Processes in the Iron Mask Batholith (92I9,10); *in* Geological Fieldwork 199?, Grant, B. and Newell, J.M., Editors, *B.C. Ministry of Energy, Mines and Petroleum Resources*, Paper 1993-1, pages 281-286.

Souther, J.G. (1992): Volcanic Regimes; *in* Geology of the Cordilleran Orogen in Canada, Gabriel e, H. and Yorath, C.J., Editors, *Geological Society of America*, The Geology of North America Decade of North American Geology Series, Volume G-2 pages 457-490.

Stanley, C.R. (1993): A Thermodynamic Geochemical Model for the Co-precipitation of Gold and Chalcopyrite in Alkalic Porphyry Copper-Gold Deposits; *Mineral Deposit Research Unit-The University of British Columbia*, Copper-Gold Porphyry Systems of British

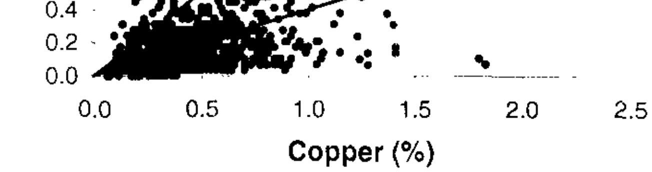

Figure 8. Copper and gold blast-hole assay data, Crescent deposit.

Columbia, Annual Technical Report - Year 2, pages 12.1-12.17.

Stanley, C.R. (1994): Geology of the Pothook Alkalic Porphyry Copper-Gold Deposit, Afton Mining Camp, British Columbia (92I/9,10); *in* Geological Fieldwork 1993, Grant, B. and Newell, J.M., Editors, *B.C. Ministry of Energy, Mines and Petroleum Resources*, Paper 1994-1, this volume.

Stanley, C.R. and DeLong, C. (1993): A Crystal Chemical Analysis of Hydrothermal Biotite From the MBX and 66 Zones, Mt. Milligan Cu-Au Porphyry Deposit; *Mineral Deposit Research Unit - The University of British Columbia*, Copper-Gold Porphyry Systems of British Columbia, Annual Technical Report - Year 2, pages 9.1-9.12.

Stanley, C.R., Lang, J.R. and Snyder, L.D. (1994): Geology and Mineralization in the Northern Part of the Iron Mask Pluton, Iron Mask Batholith, British Columbia (92I/9,10); *in* Geological Fieldwork 1993, Grant, B. and Newell, J.M., Editors, *B.C. Ministry of Energy, Mines and Petroleum Resources*, Paper 1994-1, this volume.