Fieldwork

896652

Report on Highmont Operation

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Appendix: Rock and thin section descriptions.

RECOMMENDATIONS

1. Mapping of orientations and frequency of mineralized fractures and veins is critical. Density controls grade; orientation controls trend and dip; intersections of mineralized fracture sets control plunges of ore shoots.

2. Grade estimating should be based on mineralized fracture and vein density and the mineralogy of each fracture set combined with blast hole assays. This approach should make correlations from bench to bench more reliable. At other mines (for example, Island Copper) estimates from pit mapping and blast hole assays must be multiplied by a 'geological constant' that has been empirically developed before they consistently match mill head grades - pit estimates are consistently too high there.

3. A proposed scheme is appended (Figure 1); it concentrates on features related to grade control. It could easily be duplicated and used for 'check-off' mapping in the pit; data collected could easily be made computer accessible. Mapping could be done in say 5 or 10-metre wide strips to simplify data collection.

4. Other factors may be important. Bornite distribution should be mapped for the reason that it is more copper-rich than chalcopyrite.

5. It may be important to map secondary biotite alteration, particularly if Reed and Jambor's interpretation is correct and it represents the main stage of mineralization.

6. Secondary K-feldspar is generally vein and fracture controlled albeit much of it comprises alteration selvedges; it is associated with ore minerals. Information from my sampling program is insufficient to define its distribution and potential significance.

ALTERATION

Introduction

The general level of alteration in the rocks is highly variable and very much related to the density of mineralized fractures. Fresh-looking rocks and more altered rocks lie side by side; widespread pervasive alteration zones are not common. Mapping should be done in blocks of say 5 or 10-metre width in terms of relative percentage of weak, moderate, and intense plagioclase alteration. Plagioclase alteration indicates the intensity of the hydrothermal activity; it may relate to ore grade.

Summary of Alteration Sequence interpreted by Reed and Jambor (1976)

Timing	Alteration	Mineralogy
early	potassic core and propylitic fringe	Biotite K-feldspar chlorite epidote albite
	phyllic	Quartz, flakey sericite
	propy-argillic overprint	Sericite kaolinite montmorillonite chlorite epidote
	argillic	kaolinite
	propylitic	chlorite epidote albite
late	calcite, zeolite veins	

Secondary Biotite Distribution

Secondary biotite was evidently widespread. It filled fractures, replaced primary hornblende, and formed overgrowths on primary biotite (Reed and Jambor, 1976; this study). This event was early; much of the secondary biotite developed was subsequently chloritized and/or epidotized. Recognition now rests on textural interpretation but can be done with a hand lens; altered hornblende crystals have a distinctive felted texture and grain borders are finely ragged, not sharply defined.

The distribution of secondary biotite should be studied to define its relationship, if any, to ore distribution. It seems to be most common in the ore zone and near the Gnawed Mountain dyke.

Plagioclase Alteration

Plagioclase alteration should be considered from two points of view. On one side, fresh plagioclase is glassy but as intensity increases grains become completely clouded. On the other side, the colours reflect the alteration mineralogy. Grey colour is generally caused by clays and sericite, chalky white by kaolinite; greenish white by sericite-carbonate-epidote; olive green or pink by sericite and carbonate; and emerald green by sericite.

K-feldspar Distribution

K-feldspar is a relatively common vein and alteration product in the East Pit. Most forms alteration fringes on veins and fractures; some is in quartz veins or quartz sericite zones. Pervasive K-feldspar alteration is rare.

K-feldspar is a shade of pink that is distinguishable from other pink plagioclase alteration. The other alterations represent either a dusting of hematite or sericite plus carbonate alteration.

Primary K-feldspar is interstitial and 10 to 15 per cent by volume. It often was destroyed in olive green alteration zones.

Flakey Sericite Distribution

Flakey sericite is common in better grade copper zones and generally present in lower grade zones. In accordance with Reed and Jambor's interpretation (1976) it is a good indicator mineral for ore grade material and its distribution should be carefully mapped in the deposits.

Distribution maps show that flakey sericite is poorly correlated with molybdenite, unless there is a coincident molybdenum-copper high.

While it does not always itself constitute ore, the distribution of mineralization in veins and fractures associated with flakey sericite alteration more or less delineates the East Pit orebody (Reed and Jambor, 1976; this study).

Chlorite and Epidote Distribution

Chlorite is ubiquitous but mapping degree of mafic alteration (1 fresh, 2 weak, 3 moderate, 4 total) and distinguishing areas of sericite alteration of mafics will be worthwhile.

Epidote occurs in veins and fractures and as an alteration product in mafic minerals or plagioclase. It is found throughout the deposit but intensity varies and should be mapped to see if it relates to grade distribution. Alteration and fracture-controlled types should be distinguished from one another. The distribution of epidote and chlorite shows that propylitic alteration characterizes the ore zone. It is, judging by alteration of early developed biotite, a retrogressive overprint. Peripheral propylitic alteration, however, was an early event (Reed and Jambor, 1976).

Other Alteration Minerals

Other alteration minerals that occur are actinolite and tourmaline. Actinolite occurs both in fractures and replacing primary amphibole. Tourmaline is fracture controlled and is an important constituent in breccia zones (see Reed and Jambor, 1976).

HYPOGENE MINERAL ZONING

Hypogene mineral patterns are related both to the Gnawed Mountain dyke and fracture swarms. Although the dyke apparently acted as a heat source, hot fluids probably dominated heat transfer; therefore fracture density probably controlled temperature distribution. The rock mass as a whole was hot but the temperature was not likely as high as that represented by the hydrothermal veins. Zoning patterns are subparallel to the dyke (see Reed and Jambor, 1976). Although the bornite zone is mainly in and near the dyke, 'fingers' of it extend out into the pyrite zone. These coincide with zones of higher copper grade that are controlled by northeast fracture swarms; permeability was a factor. Fluids moving outward in highly permeable zones evidently moved faster and stayed hotter than those in adjacent, less permeable zones.

The relative abundance of bornite relative to chalcopyrite will be important in predicting grades and grade trends. The mineralogy and frequency of mineralized veins and fractures is also important. For example, at HE11 (Figure 2) veins with flakey sericite halos are bornite rich and constitute ore, even though they comprise only one fracture set.

HIGHMONT STRUCTURE

Copper Distribution in the East Pit

Introduction

Copper contours show very clear trends that relate to several fracture directions (Figures 3 and 4). However, several interpretations are possible for weaker trends because overlapping patterns become diffuse. Pit mapping indicates (G. Sanford, personal communication) that average dominant trends are 025 degrees, 040 to 050 degrees, and 140 to 150 degrees; lesser trends are 075 and 095 degrees.

Copper 5270 Level

On 5270 level, contoured blast hole assays for copper give patterns that allow more than one interpretation, although dominant elements are common.

Two possible interpretations of dominant trends in the patterns are as follows:

Interpretation I (based on contour patterns only)

035
060
120
090

Interpretation II [based on patterns and on field information from G. Sanford (personal communication, 1983)]

025
140
060
090

It is clear that contoured blast hole assays confirm that mineralized vein and fracture orientations largely control copper grade patterns. However, anomalies remain that require mapping to resolve; why is there a slight angular discrepancy between dominant northeast and southeast trends estimated visually and those measured during pit mapping?

Grade trends on 5270 level confirm very strong development of northeasterly oriented, better grade copper zones. From west to east these apparently fan slightly - from 040 to 060 degreesin the west, to 030 to 040 degrees centrally and in the east.

This northeast pattern is dominant centrally; it is weaker in the west and weaker still in the east, where southeast-trending fractures are prominent. The southeast set trends consistently 115 to 125 degrees across the width of the pit. It seems likely that the northeast fractures are younger; they apparently overprint the southeast set.

Adjacent to and in the Gnawed Mountain dyke, grade patterns are elongated parallel to the borders of the dyke.

The influence of fractures trending 140 to 150 degrees is not evident from contoured blast hole assays - pit mapping is needed.

Copper 5310 Level

Near the dyke on 5310 level, east-west trends predominate. Elsewhere dominant trends are northeast and southeast, subparallel to those on 5270 level (described above).

Orientation of Copper Zones

Copper zones dip, plunge, coalesce, split and reorient between 5310 and 5270 levels. In spite of the variations, though, general trends are fairly consistent. Zones that trend 025-035 degrees range in dip from 45 degrees northwest through to subvertical. East-west zones along the Gnawed Mountain dyke have moderate north or moderate south dips; zones trending 060 degrees generally dip about 60 degrees southward. Better grade zones tend to form dipping sheets. Zones trending 120 degrees dip steeply southward and tend to form elliptical pipe-like zones at junctions with northeast-trending zones; these pipes usually plunge northwestward.

In several instances zones dominated by northeast fractures on 5310 level are dominated by northwest fractures on 5270 level. An example is near 76000N 115000E.

Summary

Higher copper grades reflect strong fracturing in a northeast direction; grade patterns indicate interaction of several crossing fracture sets. The fractures are not vertical (G. Sanford, personal communication, 1983), so better grade ore zones can be expected to be in the form of dipping sheets or plunging elliptical 'pipes.' Fracture mapping should enable ore trends and plunges to be predicted.

Molybdenite Distribution in the East Pit

Introduction

Molybdenite occurs in thick quartz veins with chalcopyrite and in fractures and veins with chalcopyrite and lesser bornite. The thick veins generally have an olive green alteration selvedge several metres in width. As at Lornex, they apparently post-date main stage mineralization. Molybdenite is apparently not abundant in the older veins and fractures. In the East Pit, veins of this type strike about 030 degrees or 060 to 080 degrees and dip 040 to 060 degrees, usually toward the northwest.

Distribution Patterns

Molybdenite in the East Pit is more restricted in distribution than copper but better grade copper zones correlate reasonably well with zones in which the molybdenum grade exceeds 0.016 per cent (Figures 5 and 6).

Locally, particularly along the east side of the pit on 5270 level, molybdenum highs occur in areas with low copper concentrations. Another such area is near 111250E, 76200 N on both 5310 and 5270 levels. Molybdenite values are relatively low near the Gnawed Mountain dyke.

Fracture and vein mineralogy show at least two distinct episodes of molybdenum mineralization. The earlier accompanied chalcopyrite-bornite mineralization; the later occurs in quartz veins with chalcopyrite -- some are up to 1 metre wide.

The thick younger veins may carry spectacular molybdenum values and could be missed if blast hole drilling is not accompanied by mapping. For example, between sample sites M1 and M2 there is a molybdenite vein that strikes 080 degrees and dips 040 degrees northward. Contours drawn only from the blast hole assay data would not show real grade trends - part of the vein would be designated waste! Similarly, the vein between sites M9 and M10 was intersected by only one blast hole and most of it would show as waste.

On 5270 level molybdenum values are relatively low close to the Gnawed Mountain dyke, especially on the east side of the pit. Dominant fracture systems are apparently northeast (about 025 to 045 degrees) and east-northeast (090 to 095 degrees). Weaker zones are oriented southeast (115 degrees).

The dominant controlling fracture set for molybdenum mineralization on 5310 level trends 030 to 045 degrees. Distribution patterns of molybdenum are complicated by interaction of these and less intense fracture sets at 050 to 060 degrees, 085 to 090 degrees, and 120 to 125 degrees.

These trends correlate closely with those controlling copper mineralization on both 5310 and 5270 levels.

Orientation of Molybdenite Zones

Molybdenite zones apparently plunge and dip; they narrow slightly from 5310 to 5270 level and zones that are coherent on 5310 level may split on the lower level.

Near Gnawed Mountain dyke, centered on 110600E, 75800N, ameboid zones apparently plunge 30 degrees eastward. Away from the dyke and from west to east, four major northeast-trending zones apparently dip northwest at about 45 degrees. Associated east to southeast-trending fracture systems apparently either dip southwest or are vertical.

Copper and Molybdenum Trends

Better grade copper and molybdenum zones are generally closely associated in Highmont East Pit. Overlays of assay plans also show similar dips for zones of copper and molybdenum mineralization. Pit mapping should define the fractures controlling distribution of each metal and aid in projection of ore to depth. It is noteworthy that molybdenite zones apparently diminish in size and begin to split from 5310 to 5270 level.

CONCLUSION

The Gnawed Mountain dyke acted as a heat sink that influenced the hydrothermal regime at Highmont. Alteration and hypogene mineral zoning patterns are irregular in detail but subparallel in general to the dyke (Reed and Jambor, 1976). Near the dyke bornite is an important ore mineral; away from it chalcopyrite becomes dominant, then there is a weak pyrite 'halo.' Ore grades occur locally in the pyrite halo and parts of the bornite zone are waste. Silicate alteration assemblages were similarly influenced but more intense alteration zones reflect fracture intensity, hence porosity, more than proximately to the dyke.

Fracture density during mineralization controlled permeability and ore fluid flow paths. Fractures occur in swarms; they are not uniformly distributed. Therefore grade and alteration patterns, which were controlled by the ore fluids, are irregular in outline and variable in intensity.

Fractures that control ore zones have several orientations and moderate to steep dips. Therefore ore zones dip and zones that are controlled by intersections of fracture swarms plunge. Careful mapping, particularly of mineralized fracture orientation, density and mineralogy, is needed to enable accurate downward projections of ore zones.

APPENDIX

HIGHMONT SAMPLES
September, 1983 - W.J. McMillan
Synopsis of Thin Section Analysis

M1E	Skeena granodiorite - weakly altered. Chalcopyrite-pyrite veins cut quartz-pyrite (K-feldspar halos). Mafics chloritized in alteration halos. Sulphides fracture controlled and in altered mafics. Feldspars altered to hydromica (sericite) and clays.
M2E-1	Skeena granodiorite - pink and green alteration. Quartz bornite chalcopyrite veins carry molybdenite also. Sulphides in veins and disseminated; pervasive. The quartz sulphide vein is cut by quartz - flakey sericite-carbonate fractures. Plagioclase pervasively replaced by K-feldspar.
M2E-2	Skeena granodiorite with olive green alteration. Cut by late carbonate fractures. K-feldspar vein controlled; sericitic fractures have chalcopyrite and bornite. Plagioclase only weakly altered.
M3E-1	Skeena granodiorite with pink to green alteration (moderate). Primary K-feldspar destroyed. Plagioclase saussuritized (mica-zoisite, etc.) and mafics gone to chlorite and epidote.
M4E	Skeena granodiorite - grey. Epidote is a minor component in altered mafics. Plagioclase averages 15% alteration to sericite and clay (?) (with local epidote).
M5E	Skeena granodiorite. K-feldspar envelopes occur on quartz epidote bornite veinlets. K-feldspar also fills fractures. Plagioclase alters to sericite, K-feldspar, carbonate and epidote. Calcite veins are late stage. Mafics alter to chlorite epidote carbonate and actinolite - there may be some secondary biotite

M6E-1	Skeena granodiorite - weakly altered. Mafics are fresh. Biotite has minor secondary biotite overgrowths. Plagioclase is weakly altered to hydromica and clays (?) Accessory minerals are magnetite, apatite and sphene.
M6E-2	Skeena granodiorite - weakly altered. Veins of quartz K-feldspar bornite chalcopyrite ± epidote with lesser chlorite and actinolite have pink K-feldspar alteration halos; these are cut by quartz sericite sulphide fractures which have associated epidote alteration. Away from vens, alteration is like M6E-1.
M7E	Skeena granodiorite - dark olive green alteration. Pyrite and chalcopyrite are fracture controlled and disseminated. Plagioclase is half altered to sericite and carbonate; mafics were replaced by chlorite, epidote and leucoxene (?)
M8E	Skeena granodiorite - weakly altered, grey. Has quartz K-feldspar epidote chlorite veins that carry chalcopyrite and pyrite. Sulphides are also in altered hornblende crystals. Fractures carry quartz, K-feldspar, chalcopyrite and MoS_2. Hornblende was largely altered to biotite that is now mainly chlorite. Plagioclase is weakly to pervasively altered to sericite and clay (?)
M9E-1	Skeena granodiorite - pink and green alteration. Veins are tourmaline-epidote with bleach halos that carry weak secondary K-feldspar but in which primary K-feldspar was destroyed. Fractures carry quartz-chalcopyrite-MoS_2, chlorite-bornite, or zeolite. Mafics are now chlorite, epidote and sphene (not sure if it is primary or secondary). Plagioclase is pervasively replaced by sericite and carbonate (the pink colour does not indicate K-feldspar alteration). Carbonate fractures are late.
M9E-2	A vein of quartz, MoS_2, carbonate and minor flakey sericite that is multiphase. Late carbonate fractures cut it.

M9E+15	Skeena granodiorite - weakly altered, greyish white. Veined by epidote-carbonate. Fractures have argillic alteration. Primary K-feldspar has been destroyed. Plagioclase mostly 10-20% sericitized.
M10E	Skeena granodiorite - olive green alteration. Dark zones have bornite sericite fractures. There are also quartz bornite veinlets with minor K-feldspar. Primary K-feldspar has been destroyed. One veinlet carried quartz - MoS_2. Late barren quartz cuts mineralized quartz-sericite veins. Plagioclase is pervasively gone to sericite and clay (?) with local carbonate.
M10E-2	Quartz-veined rock with chalcopyrite bornite and molybdenite mineralization. Multiphase.
M11E-1	Skeena granodiorite - weakly altered. Cut by quartz chalcopyrite bornite vein with quartz flakey sericite halo. Biotite is chloritized; hornblende apparently altered to biotite that is now replaced by chlorite and epidote. Plagioclase is 15 to 75% altered to sericite and carbonate.
M11E-2	Skeena granodiorite with weak pink and green alteration halos around epidote chlorite bornite fractures. It is altered plagioclase, not K-feldspar.
M12E	Skeena granodiorite - sericitized, emerald green plagioclase and flakey sericite occur; molybdenite and chalcopyrite are disseminated and fracture controlled. Plagioclase is altered to sericite and carbonate; mafics are gone to sericite and chlorite.
M13E	Skeena granodiorite - moderate pink and green alteration. Three sets of chlorite-bornite fractures. Primary K-feldspar has been destroyed adjacent to some fractures. One zone of quartz-flakey sericite-K-feldspar carries bornite and molybdenite. Biotite is chloritized; hornblende was replaced by actinolite or chlorite-sericite and carbonate. Plagioclase is partly replaced by sericite and carbonate.

M14E Grey moderately altered Skeena granodiorite cut by granophyric quartz K-feldspar zones with associated chalcopyrite which are cut by chloritic fractures. K-feldspar elsewhere is primary and open interstitial.

In thin section the granophyric zone consists mainly of quartz and K-feldspar. K-feldspar is aligned normal to vein borders; quartz zones consist of interlocking networks of crystals. It is cut by carbonate fractures. Mafic minerals are altered to chlorite-sericite or chlorite-epidote or chlorite-carbonate. Plagioclase is 30 to 80% altered to very fine sericite and clay (?). Fibrous texture in the altered hornblende suggests it may have been replaced by biotite.

M15E Altered Skeena granodiorite with quartz-K-feldspar-chalcopyrite veins with pink K-feldspar alteration halos, and fractures with flakey sericite halos. Most primary K-feldspar has been removed; that seen is mainly in fractures and alteration halos. Mafics are chloritized or altered to secondary bioite (?).

In thin section, mafic is altered to chlorite epidote quartz and carbonate and plagioclase pervasively to sericite, clay and epidote. Remnants of plagioclase twins are still visible.

M16E Grey weakly altered Skeena granodiorite cut by chlorite-bornite-chalcopyrite fractures less than 1 centimetre apart. There are also chalcopyrite flakey sericite fractures (parallel). The fractures have quartz and some K-feldspar also. Most K-feldspar is interstitial and primary. The fractures cut coarse quartz-K-feldspar veins ("aplite").

In thin section, red-brown biotite is locally kinked and has subtle overgrowths of brown to greenish brown hydrothermal biotite. The biotite has knots of sericite stretched out in the cleavage. Hornblende is altered to biotite - now gone to chlorite in part. Elsewhere it is altered to a mixture of biotite, actinolite, chlorite and other products. Plagioclase is relatively fresh and complexly zoned and twinned. Fractures carry quartz biotite and chlorite with minor epidote; they have sericitic alteration halos in plagioclase (not flakey sericite).

M17E-1	Weakly altered grey Skeena granodiorite cut by a K-feldspar-rich vein zone that is cut by biotite-chlorite-chalcopyrite fractures that are 3 millimetres to 1 centimetre apart. The K-feldspar-rich zone has bleach halos. The fractures also have K-feldspar alteration envelopes. In thin section the fracture fillings are seen to be biotite chlorite and quartz with lesser carbonate and opaques. Hornblende has been pervasively replaced by biotite, actinolite and a clear mineral. Plagioclase alteration is too fine to be sure but may also be to biotite in part.
M17E-2	Skeena granodiorite cut by quartz tourmaline epidote bornite veins with pink K-feldspar-rich alteration envelopes; there are also bornite-MoS_2 fractures with sericite-quartz-K-feldspar envelopes. The stained specimen is networked with K-feldspar fractures. Plagioclase away from veins is moderately altered to products too fine to identify and sericite, carbonate and epidote. Mafic minerals have been roplaced by chlorite and epidote. Near veins plagioclase is widely altered to K-feldspar (in patchy zones). Where K-feldspar alteration is recognizable in thin section, plagioclase twinning has been wiped. Veins are quartz-chlorite-carbonate-opaque, tourmaline (sheafs)-epidote-quartz-sodic plagioclase. Carbonate veins cut tourmaline veins and quartz-sericite-opaque zones. There is one quartz-MoS_2 fracture that may be cut by a quartz bornite vein.
M18E	Grey weakly altered Skeena granodiorite cut by quartz sericite zones with quartz chalcopyrite bornite veins. A vuggy quartz fracture cuts the flakey sericite zone. Staining shows only interstitial primary K-feldspar. In thin section, quartz sericite zones are crossed or associated with chlorite veinlets. Mafic minerals have been variably replaced by chlorite and epidote. Biotite may be relatively fresh but with secondary overgrowths. Hornblende may be replaced by a mixture of biotite and quartz. The secondary biotite is greenish brown to almost tourquoise in colour. Plagioclase is lightly altered, except near quartz sericite zones where alteration is intense. Fractures with secondary biotite also occur. Some with flakey sericite halos consist of quartz carbonate epidote and sulphides.

HE1-1	Grey fresh-looking Skeena granodiorite. K-feldspar is primary and open interstitial (12%). In thin section, biotite is red-brown, hornblende is fresh but has internal biotite (primary ?). Mafics are locally partly chloritized. Plagioclase is generally only very lightly altered to sericite. Fractures are coated by carbonate-kaolinite (argillic alteration).
HE1-2	Skeena granodiorite that is grey-green and weakly altered. Fractures are coated with chalcopyrite-bornite. K-feldspar is mainly primary but some fractures with bornite carry K-feldspar. Thin section shows minor secondary biotite overgrowths on biotite and replacement of hornblende. All mafics are partially altered. Plagioclase is generally 30 to 60% altered to sericite and clays (?).
HE1-3	Dull olive green modorately altered Skeena granodiorite. Molybdenite coats fractures. K-feldspar is primary; much of the plagioclase takes a pale stain (sericite ?). Plagioclase alters mainly to sericite but intensity varies from 15 to 85%. Biotite is fresh with narrow secondary biotite overgrowths; hornblende is partly chloritized or partially biotite altered - epidote is a minor product. Biotite coats some fractures. Networks of carbonate fractures are late stage features; they pinch and swell depending on the minerals being cut. Quartz is coarse and anhedral to open interstitial; it is crackled. Accessory minerals are magnetite, apatite and sphene.
HE1-4	Molybdenite coats fractures in this pink altered rock. It has no K-feldspar; mafics are bleached. Carbonate fractures network the rock. The rock shows tectonic breccia zones with carbonate and sericite in the matrix. These carry molybdenite. Alteration is pervasive; feldspars are pink and replaced by microscopic sericite, carbonate and hydromica. Veinlets are carbonate and quartz-sericite-MoS_2.

HE2-1	Moderate pink and green plagioclase alteration in Skeena granodiorite. Sulphides occur in fractures and in chloritized mafics. One quartz chalcopyrite chlorite 'zone' has associated K-feldspar alteration. There are three sets of sulphide-bearing fractures. Plagioclase is heavily dusted by alteration products - including sericite. Mafics are chloritized but hornblende was probably previously altered to secondary biotite. Some grains have adjacent zones of epidote alteration. Biotite is altered to chlorite and epidote. Cut by epidote carbonate and quartz K-feldspar epidote chlorite sulphide veinlets with K-feldspar altered halos.
HE2-3	Dull olive green altered Skeena granodiorite in which all primary K-feldspar has been destroyed. Mafics are sericitized. Carbonate coats fractures. Hornblende is replaced by carbonate, apatite and pale green chlorite. Biotite is dark and altered but the minerals are not determinable (perhaps sericite and Fe carbonate). Plagioclase is mainly altered to fine 'flakey' sericite. The remnant matrix mineral is of lower relief than the original plagioclase. Sericite fractures and local quartz sericite zones occur.
HE3-3	Pink and green altered Skeena granodiorite; it also has pink (not K-feldspar) alteration adjacent to quartz chalcopyrite fractures; ocherous hematite carbonate-bearing veinlets occupy the same fracture. Altered mafics carry chalcopyrite. Some fractures carry K-feldspar and some have K-feldspar alteration halos. Primary K-feldspar is interstitial. Much of the pink-coloured alteration is not K-feldspar. Mafic is altered to chlorite and carbonate or sericite. Plagioclase is pervasively dusted by sericite and some carbonate. Rock cut by carbonate-quartz and carbonate-epidote fractures.

HE3-4 Grey Skeena granodiorite is bleached or altered to pink and green colours near veins. Quartz chalcopyrite bornite veins have a pink K-feldspar alteration halo that gives way outward to pink and pale olive green plagioclase alteration. Later quartz fractures along or with bleach zones cut the quartz chalcopyrite bornite vein and are cut by quartz-sericite-chlorite-chalcopyrite fractures (these have negligible alteration halos). Other fractures are coated with kaolinite (argillic alteration). Staining shows local K-feldspar alteration adjacent to sericitic fractures; primary K-feldspar has been destroyed in vein alteration halos.

Hornblende is altered to chlorite, epidote and carbonate; it may have been biotite altered earlier. Primary biotite is generally altered to a dark fibrous mat (secondary biotite ?) with spindles of sericite along cleavages. Some crystals are kink folded. Plagioclase is pervasively altered; grains are dull brown with sericite dusted through a lower relief matrix. In thin section only sericitic fractures were seen.

HE4 Weakly altered grey Skeena granodiorite cut by K-feldspar tourmaline chalcopyrite stringers and chalopyrite-bearing chloritic fractures. Bleached zones have no obvious structural control but probably represent an outer envelope on minerelized fractures - the sequence was fracturing then greenish plagioclase alteration then bleaching.

Plagioclase is generally pervasively repleced by sericite [50% disseminated sericite; remnants of twins preserved; in one area alteration is light (10%)]. Biotite is altered to chlorite, sericite, carbonate and miscellaneous semi-opaque products. In less altered zenes, hornblende is partly altered to actinolite and carbonate and biotite is 80% chloritized. Fractures contain quartz chlorite and carbonate with sulphides. No tourmaline was seen in thin section.

HE5-1 Weakly altered Skeena granodiorite with local zones that have green and white plagioclase alteration. Mafics look relatively fresh in hand specimen. Primary K-feldspar is open interstitial; most is destroyed in the quartz chlorite vein alteration halo.

In the thin section plagioclase is clouded by sericitic alteration; grain cores have local dustry epidote carbonate (?) zones. Biotite is partly or wholly chloritized with finely crystalline sericite spindles along cleavage planes. Hornblende is also altered to chlorite sericite and carbonate. Locally textures suggest biotite replaced hornblende.

HE5-2	Pervasive dark olive green plagioclase alteration and sericitized mafics in Skeena granodiorite. Primary K-feldspar has been destroyed. Magnetite has also been hematized. The rock is criss-crossed by a fine network of carbonate fractures. Sericite and carbonate pervasively replace platioclase. Mafics are replaced selectively along the cleavage by white mica (hydromica ? birefringence low, length slow) or sericite carbonate and opaque products.
HE5-3	Cream and green altered Skeena granodiorite that is cut by quartz-epidote-tourmaline veinlets. All primary K-feldspars has been destroyed. Plagioclase is altered pervasively to sericite chlorite, epidote and carbonate. Mafic minerals altered to chlorite epidote and opaque products. Tourmaline is dark brown to tan or dark tourquoise; it is intergrown with chlorite, quartz and carbonate. Sphene is abundant nearby; perhaps it is a vein mineral here.
HE6-1	Relatively fresh Skeena granodiorite is altered to pink and green adjacent to a fracture filled by epidote and chlorite. There are local chlorite-chalcopyrite fractures. Primary interstitial K-feldspar was destroyed in the alteration halo. Mafics are fresh to chloritized. Plagioclase is generally sericitized but locally saussuritized (epidote masses); local areas are almost unaltered. In these areas hornblende is partly chloritized and biotite is altered to fibrous masses or eroded grains with local secondary biotite overgrowths. In more altered areas hornblende is partly biotite altered. Fractures contain epidote and chlorite.
HE6-2	Grey-green weakly altered Skeena granodiorite cut by chalcopyrite-chlorite epidote carbonate and bornite chalcopyrite chlorite fractures. Plagioclase is lightly sericitized along fractures generally (5 to 10%). Hornblende is partly altered to biotite chlorite epidote and carbonate. Biotite is fresh to chloritized; locally it has narrow secondary biotite overgrowths. The chloritic fractures have quartz-sericitic alteration halos that are of variable width.

HE-7	Dark olive green feldspar alteration of Skeena granodiorite characterizes this sample. It is cut by chalcopyrite-bearing quartz chloritic carbonate fractures. One fracture set with K-feldspar-sericite alteration halos is cut by a second set with no halos. Veinlets are quartz-chlorite-carbonate-opaque; halos are K-feldspar-sericite-carbonate. Fractures filled with carbonate are common and cut other veins. Away from veinlets plagioclase is lightly altered to sericite. Biotite is red-brown with local narrow secondary overgrowths. Hornblende is altered to chlorite, carbonate and opaques.
HE-8	Dark grey-green altered Skeena granodiorite. Cut by chalcopyrite and chalcopyrite bornite fractures and two sets of chalcopyrite-chlorite fractures. Primary K-feldspar has survived; plagioclase takes a pale potassium stain. Plagioclase is relatively lightly altered (10 to 15%) overall. Hornblende has altered to biotite chlorite epidote carbonate and albite (?). Biotite is fresh or slightly chloritized. Fractures included networks of carbonate, biotite-chlorite, and chlorite-quartz-carbonate.
HE9-2	Fairly intense dark olive green feldspar alteration in Skeena granodiorite. Primary interstitial K-feldspar has survived. One quartz-chalcopyrite fracture and minor pyrite were noted. In thin section, sulphide-bearing fractures also carry biotite and hydromica or sericite. Plagioclase is tan coloured, dusted with sericite (40%) or carbonate and hydromica (?) or kaolinite (?). Mafic minerals have altered to hydromica, opaque and quartz.
HE10-2	Olive green plagioclase alteration and destruction of primary K-feldspar highlight this sample. Chalcopyrite occurs on fractures. Plagioclase away from veins is weakly sericitized (10 to 35%). Mafics are gone to chlorite, carbonate and epidote. Chlorite replaces secondary biotite and in one instance the biotite is preserved. Fractures carry carbonate-chlorite-opaque, quartz-carbonate, carbonate (younger) and there is a quartz-sericite-carbonate-opaque zone.

HE11-1	Grey Skeena granodiorite cut by quartz flakey sericite zones with chalcopyrite and quartz chalcopyrite veinlets and a pink K-feldspar quartz zone. Zeolite and carbonate fractures occur. Primary biotite has secondary overgrowths and there are biotite chlorite fractures. The quartz-sericite zones have pockets of biotite that may be part of the zone. Primary biotite is partially altered to chlorite and epidote; hornblende is completely altered. Most of the secondary biotite is brown; some is green and distinguishable from chlorite only by birefringence. Accessory minerals are apatite, sphene and magnetite.
HE11-2	The rock has one well developed set of mineralized fractures with narrow flakey sericite selvages. They carry chalcopyrite and bornite. Plagioclase is grey and weakly altered. Primary K-feldspar survived except in flakey sericite halos. Hornblende has altered to brown and green biotite and chlorite, and quartz (?) (or feldspar ?). Primary biotite is partly chloritized, often bent, and locally has overgrowths. Plagioclase is generally weakly sericitized. Fractures of chlorite and biotite have halos in which sericitic alteration is enhanced in adjacent plagioclase crystals.
H11-3	More altered Skeena granodiorite with wider flakey sericite quartz bornite zones with central quartz bornite veins. Pink alteration (K-feldspar ?) along fractures has local tourmaline blebs. Fractures are zeolite coated. Plagioclase is variably weakly to pervasively altered to sericite. Mafics alter to chlorite, epidote and quartz. If there was secondary biotite it is chlorite now. Veinlets are quartz albite chlorite and tectonized (?) kaolinite quartz.
HE11-4	Weakly altered granodiorite cut by aplitic stringers and epidote fractures. Mafics are apparently altered to secondary biotite; they carry chalcopyrite. Fractures carry chalcopyrite-biotite. The K-feldspar staining worked poorly but primary K-feldspar apparently survived and the aplite is K-feldspar rich. Plagioclase alteration is weak to locally fairly intense in sericite and clays (?). Hornblende has been replaced by secondary biotite. Primary biotite looks partly altered; it has overgrowths. There are pods with epidote alteration, veinlets of epidote-chlorite-quartz and a vein of quartz-epidote cemented by fine carbonate.

HE11-5 Weak grey-green feldspar alteration, chloritized mafics and local epidote alteration characterize the rock.
Staining and slabbing reveal quartz tourmaline veins with K-feldspar-free borders and chloritic fractures that cut quartz K-feldspar veinlets that have no alteration fringes.
Plagioclase is moderately to weakly altered to sericite and carbonate.
Mafic minerals are gone to chlorite, carbonate and epidote.
Chlorite is pervasive but textures suggest secondary biotite as a precursor.
Fractures contain quartz-chlorite and chlorite-epidote with or without intense adjacent fine sericitic alteration of plagioclase. They have several orientations.

HE11-6 Grey Skeena (?) granodiorite cut by quartz K-feldspar bornite veins that are cut (?) by quartz sericite chalcopyrite fractures with central quartz veins. Fractures have intense argillic alteration. Some mafics are fresh. Mineralized fractures are less than 1 centimetre apart.
Plagioclase is moderately altered to sericite.
Zones of quartz sericite carbonate reflect several events; most have quartz sulphide veins. Biotite is fresh or slightly chloritized; hornblende is partially altered to biotite.
Some quartz sericite zones have pockets of secondary biotite.