

REPORT ON THE EAST PIT OF THE HIGHMONT OPERATION  
 (921/7E)

By W. J. McMillan

INTRODUCTION

The work described here is based on a three-day visit to the Highmont operation (Fig. 23) this summer. Emphasis both in discussions and during pit examinations was on alteration, metallic mineral zoning, and structural features in order to determine the impact of structural features on ore distribution and to assess the utility of alteration and zoning as grade indicators. Work was mainly on 5270 level, although blast-hole information for 5310 level was considered.

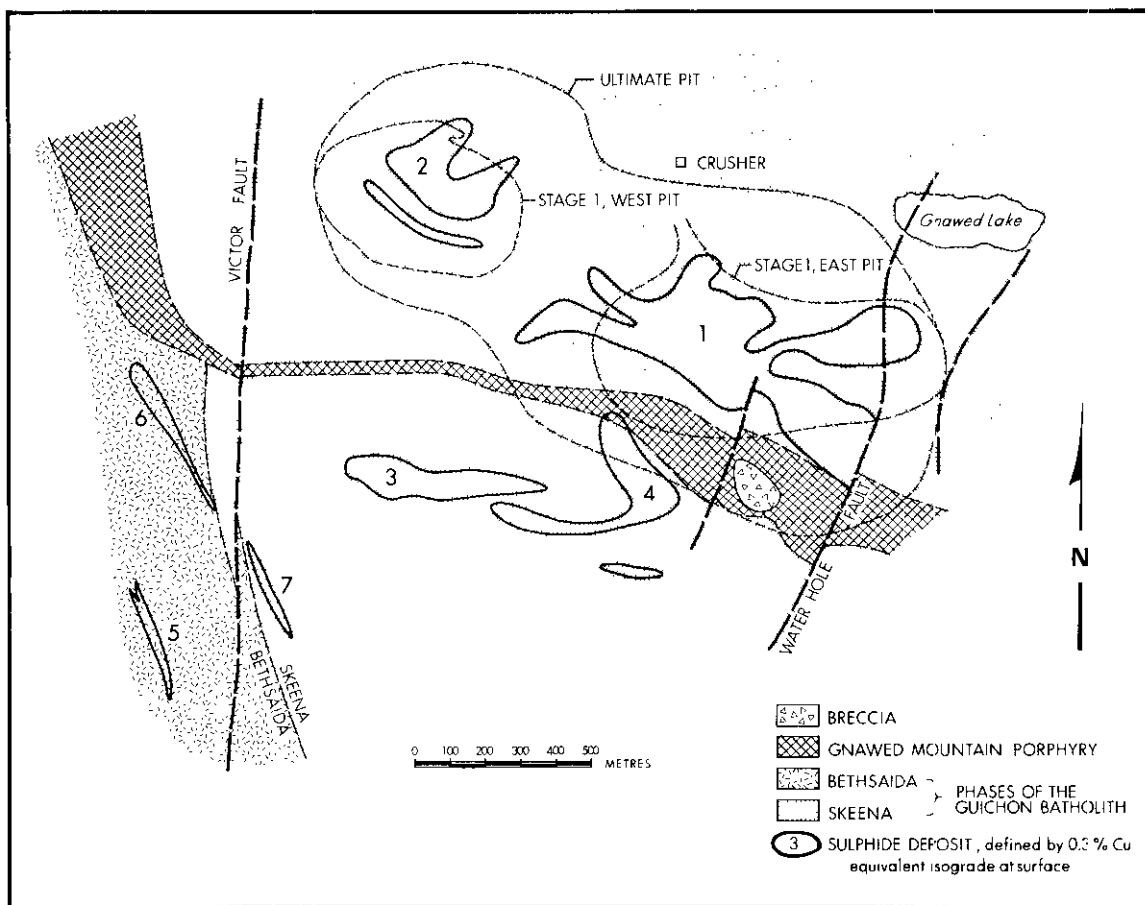


Figure 23. Location map of the Highmont deposit.

## ALTERATION

### INTRODUCTION

The degree of alteration in the rocks is highly variable and closely related to the density of mineralized fractures. Fresh-looking rocks and more altered rocks lie side-by-side; widespread pervasive alteration zones are uncommon. The amount of weak, moderate, and intense plagioclase alteration is important because it indicates the relative intensity of the hydrothermal activity; it may relate to ore grade.

The following alteration sequence is mainly after Reed and Jambor (1976):

TIMING	ALTERATION	MINERALOGY
Early	Potassic core and propylitic fringe Phyllic Propy-argillic overprint Argillic Propylitic	Biotite, K-feldspar, chlorite, epidote, albite Quartz, flaky sericite Sericite, kaolinite, montmorillonite, chlorite, epidote Kaolinite 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, thus recognition in thin section often rests on textural interpretation. In hand specimen it can be recognized 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 further 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; clarity of crystals and colour. On one hand plagioclase changes from glassy to clouded as alteration increases, in addition, colour changes 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 relatively common both as a vein filling and in alteration envelopes in the East Pit. It is most abundant in alteration fringes on veins and fractures; some also occurs in quartz veins or quartz sericite zones. Pervasive K-feldspar alteration of matrix and phenocrysts is rare.

K-feldspar is a shade of pink that is visually distinguishable, with practice, 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 survives most alteration but is usually destroyed in olive-green alteration zones.

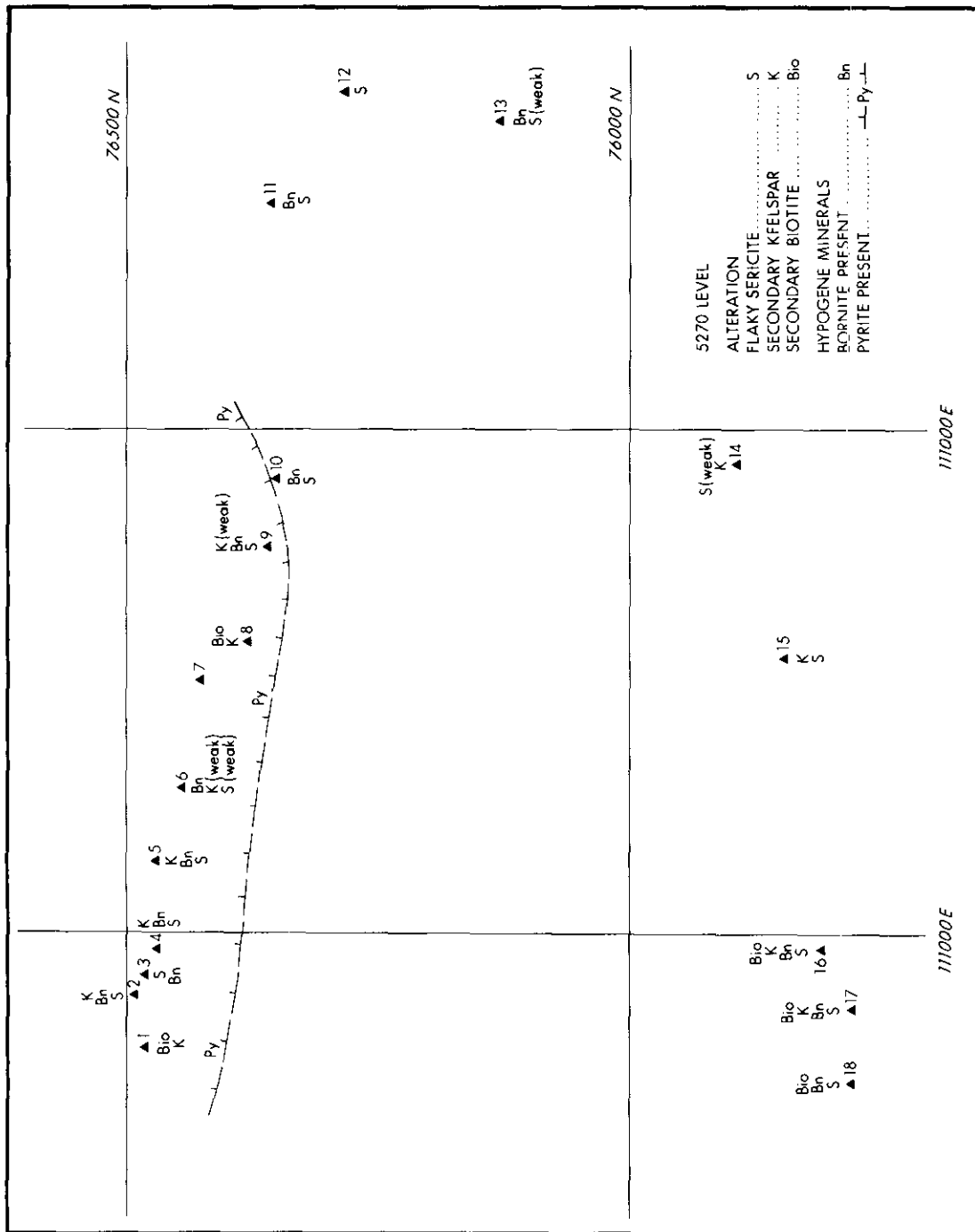


Figure 24. Highmont East Pit, distribution of alteration and hypogene sulphides.

## FLAKY SERICITE DISTRIBUTION

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

Distribution maps show that flaky sericite correlates poorly with molybdenite, unless there is coincident molybdenum and copper enrichment.

## ALTERATION OF MAFIC MINERALS

Chlorite is ubiquitous but the degree of mafic alteration varies; no patterning that would act as ore guides was recognized. Locally, mafics are sericitized; usually in areas with olive-green feldspar alteration.

Epidote occurs in veins, fractures, and as an alteration product in mafic minerals or plagioclase. It is found throughout the deposit but abundance varies; it is not known if it relates to grade distribution. Epidote and chlorite are distributed throughout the ore zone; that is, propylitic alteration characterizes the ore zone. Judging by alteration of early developed biotite, it is a retrograde overprint in the ore zone. Peripheral propylitic alteration, however, was an early event (Reed and Jambor, 1976).

## OTHER ALTERATION MINERALS

Other alteration minerals are actinolite and tourmaline. Actinolite occurs both in fractures and as a replacement of primary amphibole. Tourmaline is fracture-controlled and is an important constituent in breccia zones (*see* Reed and Jambor, 1976).

## HYPOGENE MINERAL ZONING

Hypogene mineral zoning patterns are related to both the Gnawed Mountain dyke and fracture swarms. Although the dyke acted as a heat source, hot fluids probably dominated heat transfer and fracture density-controlled temperature gradients. The rock mass as a whole was hot but post-emplacement temperature was not likely as high as that in hydrothermal veins. Zoning patterns are subparallel to the dyke (*see* Reed and Jambor, 1976). Although the bornite zone occurs 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 north-east fracture swarms, that is, zones with high permeability. Fluids moving outward in these highly permeable zones evidently moved faster and stayed hotter than those in adjacent, less permeable zones.

The relative abundance of bornite relative to chalcopyrite is important in predicting grades and ore trends. The mineralogy and frequency of mineralized veins and fractures are also important. For example, at HE11 (Fig. 24) veins with flaky 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 (Figs. 25 and 26). However, several interpretations are possible for weaker trends because overlapping patterns become diffuse. Pit mapping indicates (G. Sanford, personal communication) that dominant trends average 025 degrees, 040 to 050 degrees, and 140 to 150 degrees; lesser trends are 075 and 095 degrees.

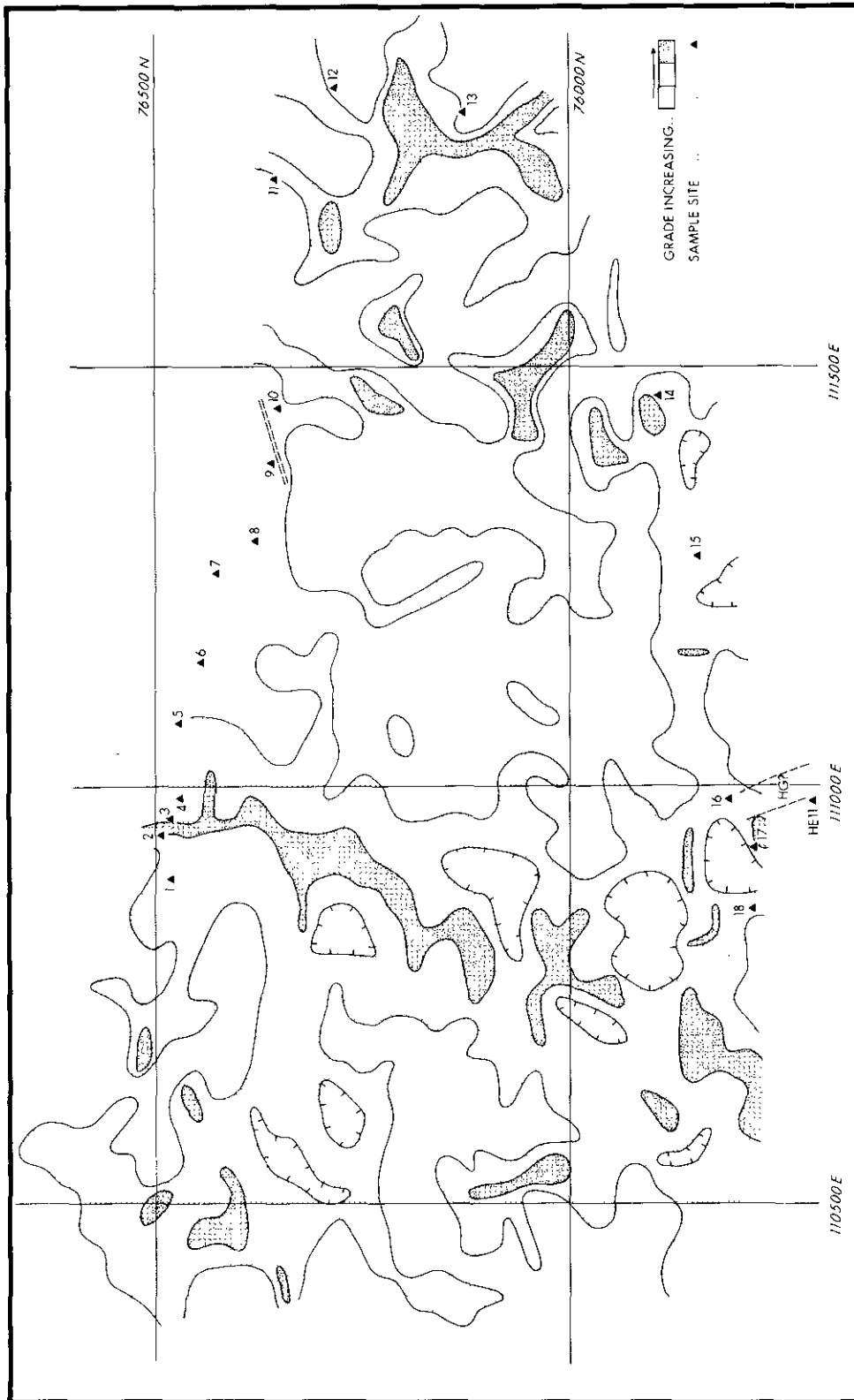


Figure 25. Highmont East Pit, 5270 level, contoured copper values from blast hole assays.

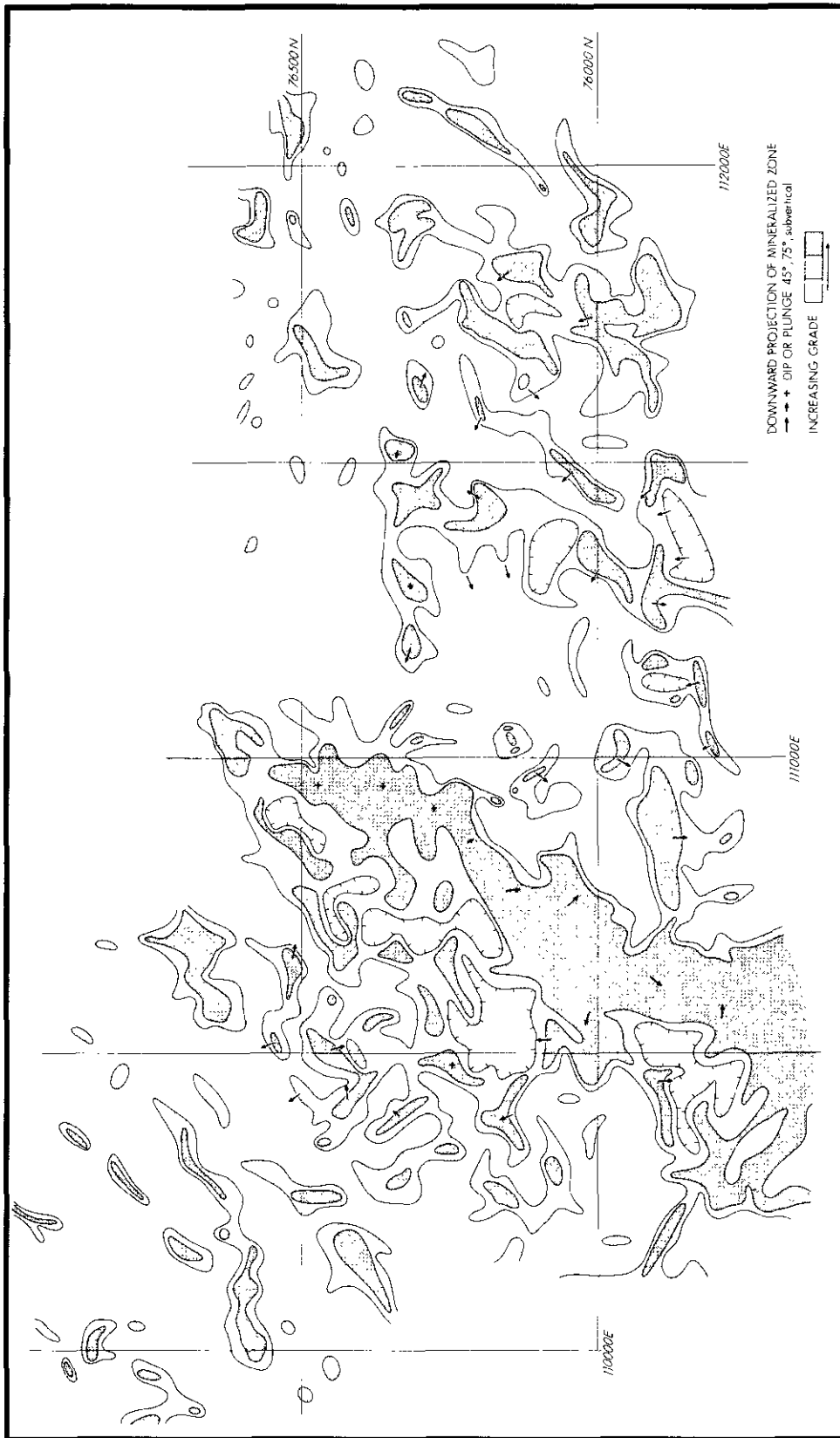


Figure 26. Highmont East Pit, 5310 level, contoured copper values from blast hole assays.

**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; in degrees azimuth:*

Interpretation I (in sequence of relative abundance based on contour patterns only): 035, 060, 120, 090.

Interpretation II (based on patterns and utilizing field information from G. Sanford, personal communication): 025, 140, 060, 090.

Contoured blast-hole assays clearly confirm that mineralized vein and fracture orientations largely control copper grade patterns. However, some anomalies remain; for example, there is a slight discrepancy in azimuth between dominant northeast and southeast trends estimated from blast-hole assays and those measured during pit mapping.

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

This northeast pattern dominates in the central area; it is weaker in the west and weaker still in the east, where southeast-trending fractures are prominent. Consistently, the southeast set trends 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 and parallel to the borders of the dyke.

The relative importance of fractures trending 140 to 150 degrees is not evident from contoured blast-hole assays.

**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 previously).

**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 to 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 'shoots' 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. Stanford, personal communication), 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 with chalcopyrite in thick quartz veins and with chalcopyrite and lesser bornite in fractures and veins. The thick veins generally have an olive-green alteration selvage several metres in width. As at Lornex, they apparently post-date main-stage mineralization. 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. Molybdenite is apparently not abundant in the older veins and fractures.

**DISTRIBUTION PATTERNS:** Molybdenite in the East Pit is more restricted in distribution than copper but better grade copper zones (Figs. 25 and 26) correlate reasonably well with better grade molybdenite zones (Figs. 27 and 28).

Locally, particularly along the east side of the pit on 5270 level, molybdenum is concentrated in areas with low copper concentrations. Another such area is near 111250E, 76200N 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 one metre wide.

The thick younger veins may carry spectacular molybdenum values but could be missed if blast-hole drilling was not accompanied by mapping. For example, between sample sites M1 and M2 (Fig. 27) 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 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.

## 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



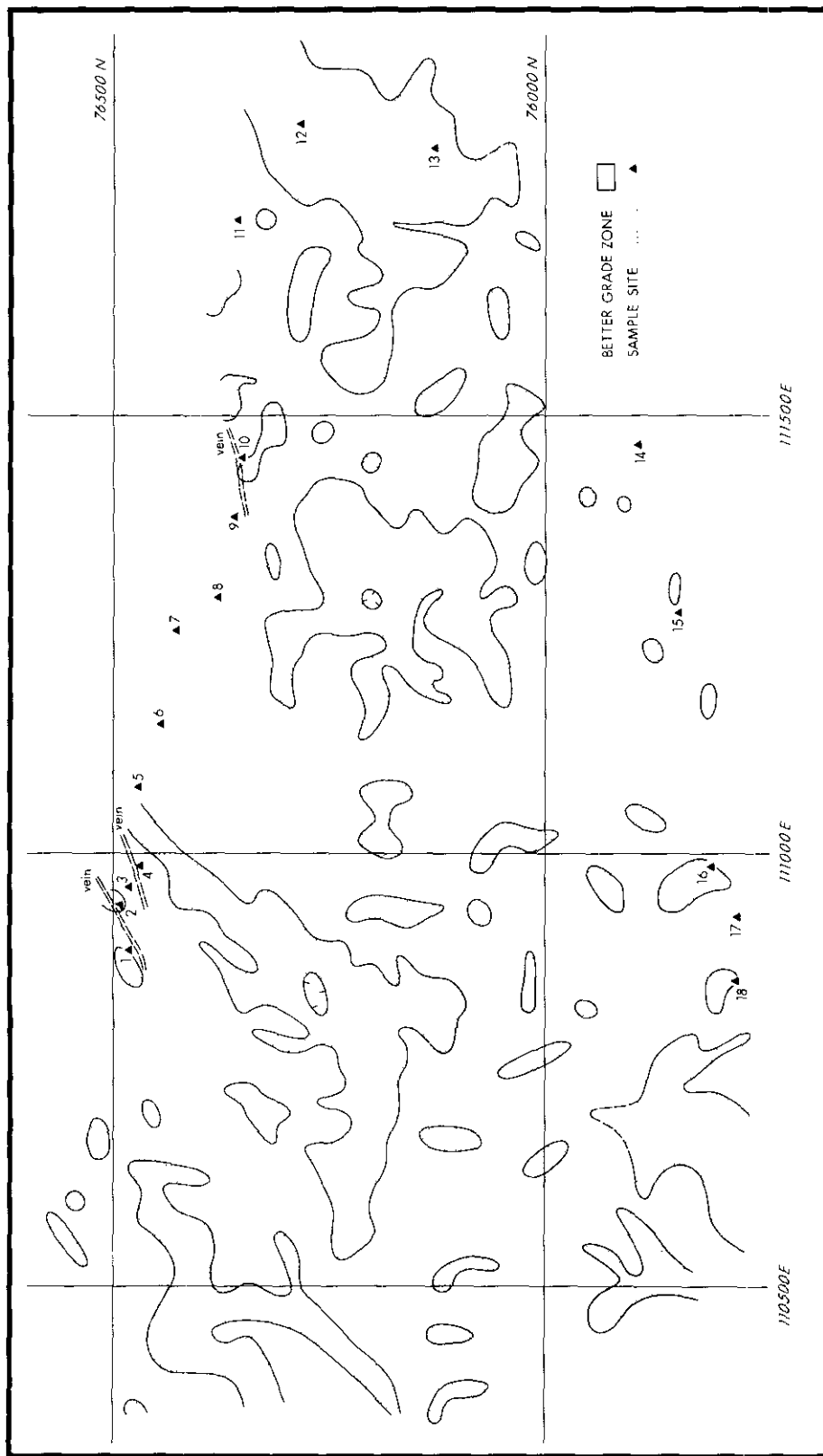


Figure 27. Highmont East Pit, 5270 level, contoured molybdenum values from blast hole assays.

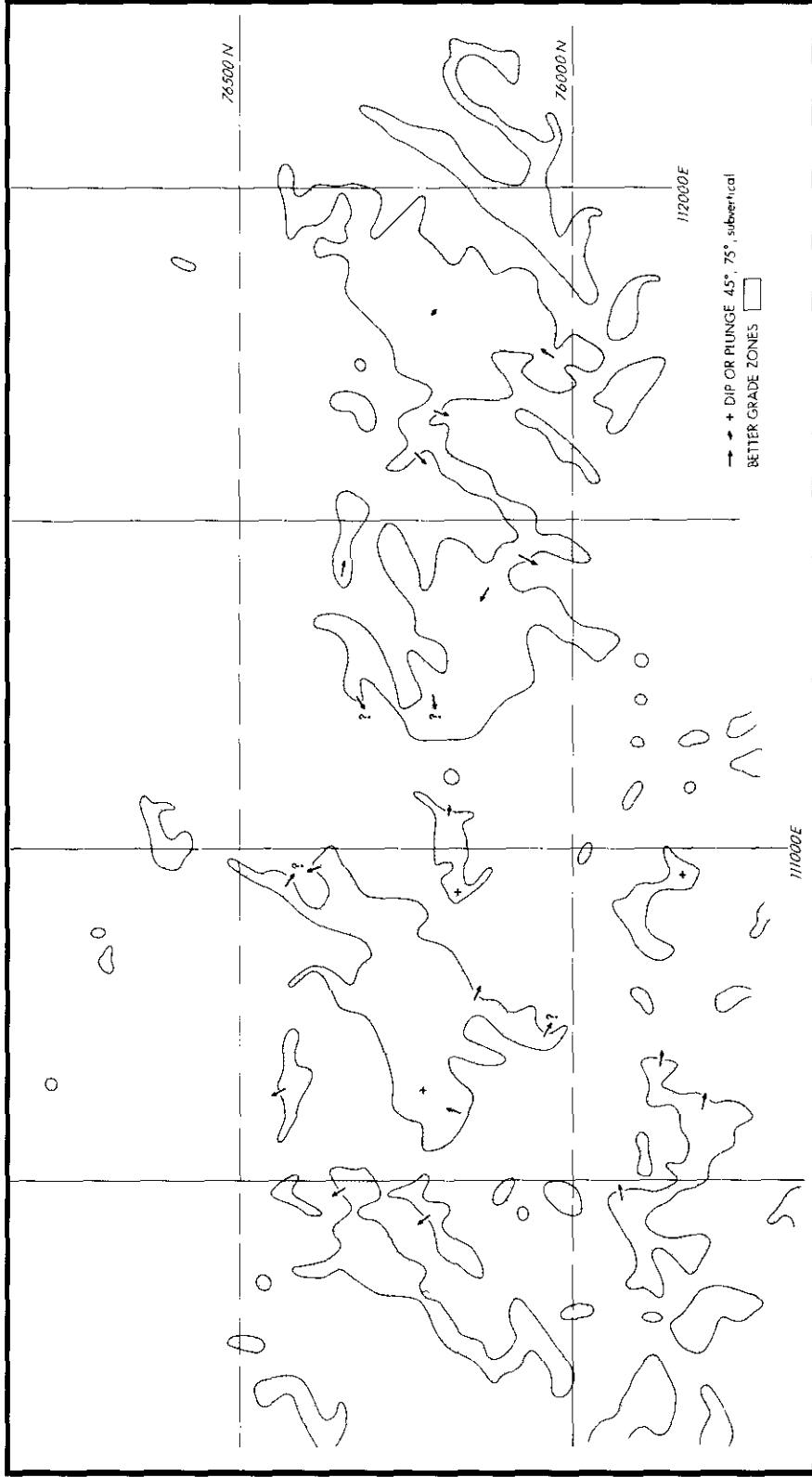


Figure 28. Highmont East Pit, 5310 level, contoured molybdenum values from blast hole assays.

dyke (Reed and Jambor, 1976). Near the dyke bornite is an important ore mineral; away from it chalcopryrite 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 zones of more intense alteration reflect fracture intensity, hence porosity, more than proximity 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.

#### **ACKNOWLEDGMENTS**

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#### **REFERENCE**

Reed, A. J. and Jambor, J. L. (1976): Highmont: Linearly Zoned Copper-Molybdenum Porphyry Deposits and Their Significance in the Genesis of Highland Valley Ores, *C.I.M.M.*, Spec. Vol. 15, pp. 163-181.

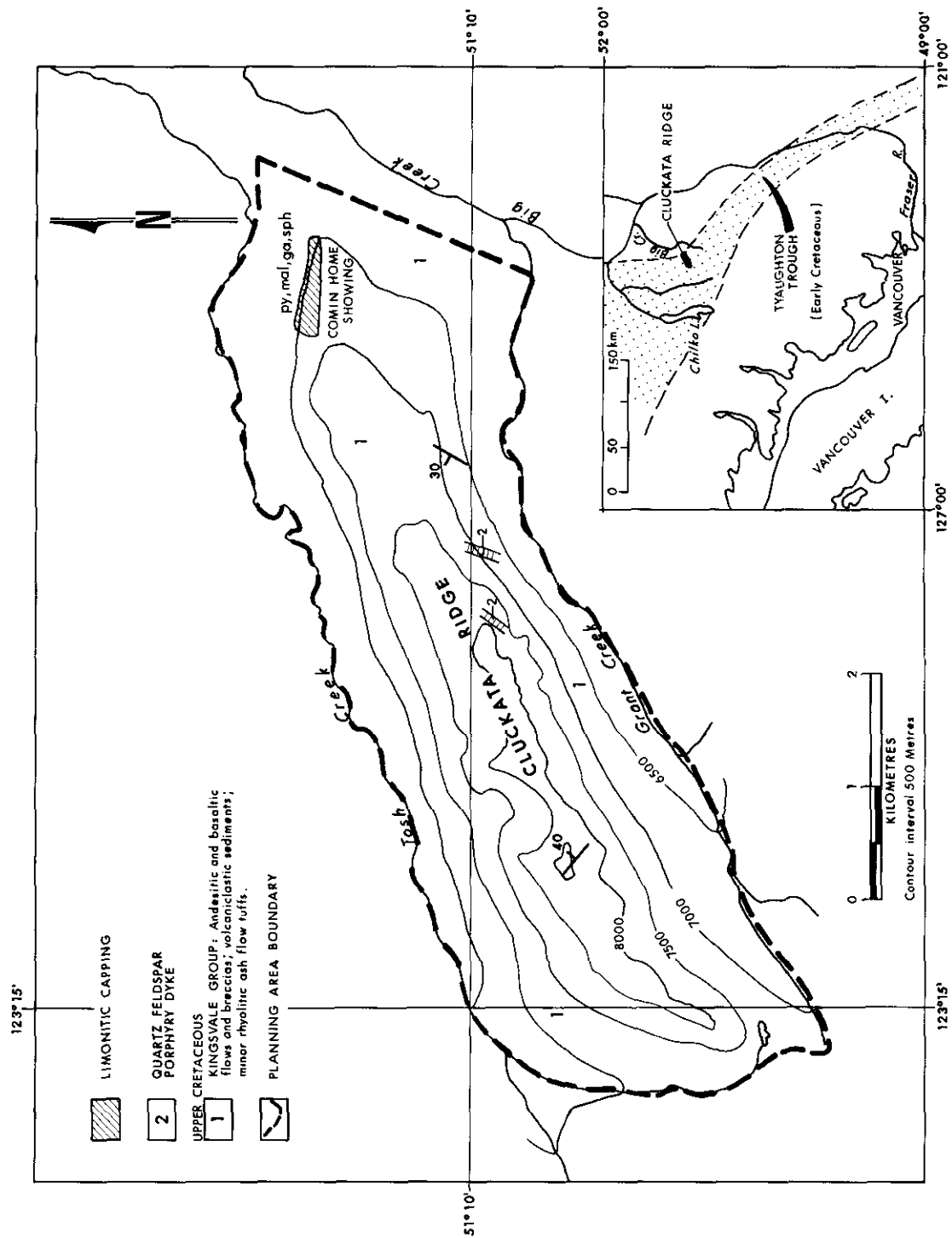


Figure 29. Cluckata Ridge planning area (920).