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# THE HIGHMONT COPPER-MOLYBDENUM DEPOSITS, HIGHLAND VALLEY, BRITISH COLUMBIA

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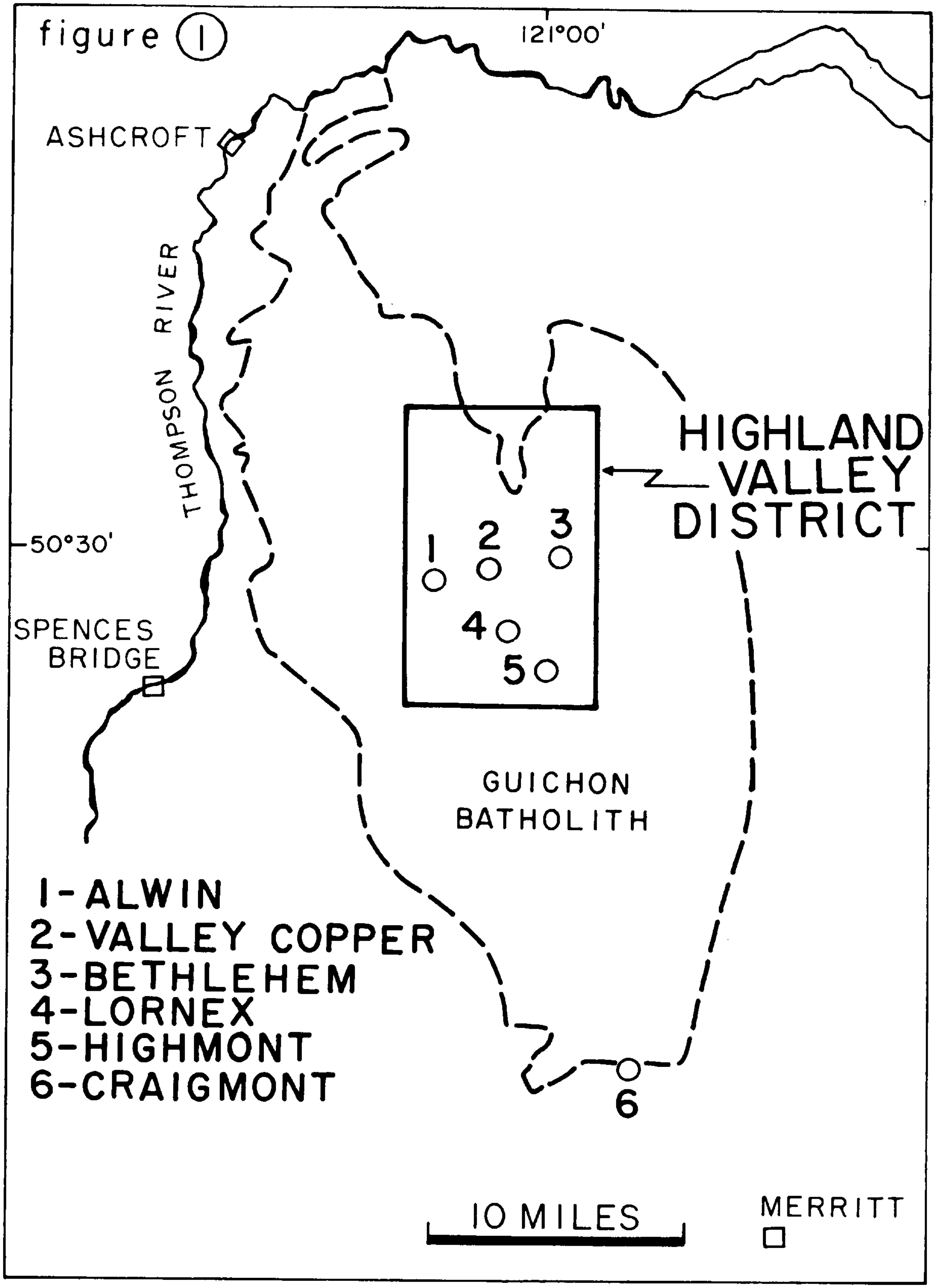
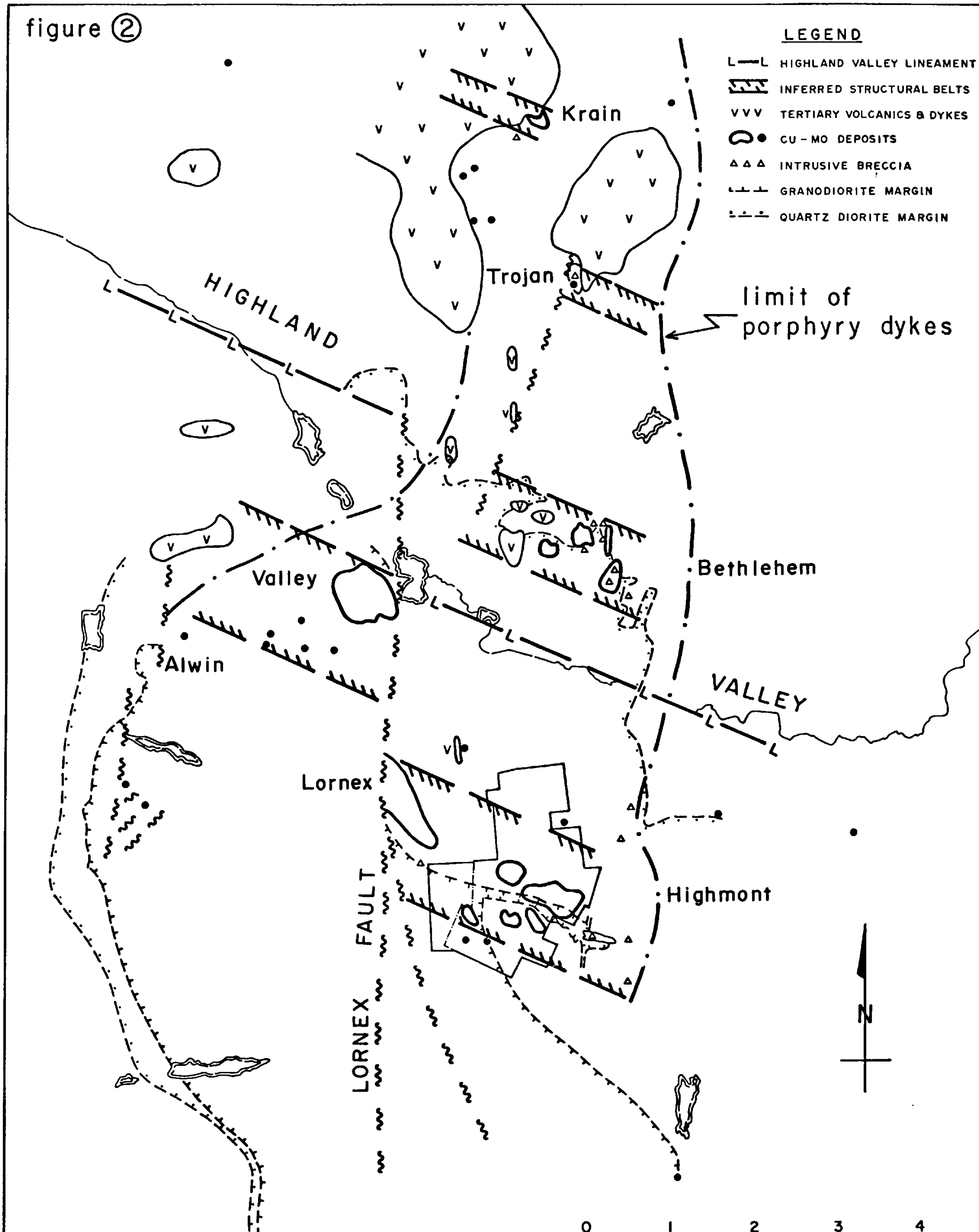
## ILLUSTRATIONS




INDEX MAP - HIGHLAND VALLEY - B. C.

figure ②




HIGHLAND VALLEY GEOLOGY

## INTRODUCTION

The Highmont copper-molybdenum deposits are in the south part of the Highland Valley porphyry copper district 125 miles northeast of Vancouver (Figure 1). They include five large, low grade mineralized zones which cluster together on the west slopes of Gnawed Mountain at surface elevations between 5200 and 5700 feet, of which Nos. 1 (East) and 2 (West) zones are fully explored and together contain sufficient open pit ore to sustain a 25,000 ton per day mining operation. The deposits lie 4 miles due south of the Bethlehem mine and 2 miles southeast of the Lornex mine.

Although the Highmont deposits were very largely hidden by a thin mantle of glacial till, the nearby higher ground exposes showings of copper and molybdenum sulphides, which apparently were explored by prospectors in the 1930s. Because of the widely scattered mineralization and favourable geology the Gnawed Mountain area was repeatedly investigated from 1957 onward, and a few short holes were drilled in the Highmont zones prior to 1960. In 1962 the Highmont property was acquired by Torwest Resources (1962) Limited which conducted an induced polarization survey and did diamond drilling that discovered a part of the No. 1 zone. In 1966, after a period during which the property was optioned to a major mining company, Highmont Mining Corporation was formed with Torwest as chief shareholder to continue the development. A large amount of percussion drilling and some diamond drilling was done on a grid pattern in 1966 and 1967 which outlined the No. 1 zone and indicated the existence of the No. 2 and other zones. This programme drew financial support from Nippon Mining Company Limited, and led to bulk sampling in the No. 1 zone by means of an adit and raises. The results of the initial phase of underground exploration deterred Nippon from further participation. Subsequently, new financing was arranged which allowed satisfactory completion of the sampling programme in the No. 1 zone and a continuation of the property exploration. In 1969 Teck Corporation Limited entered into a financial arrangement to continue the exploration, with the right to finance the property to production. By April 1971, metallurgical tests and all other phases of the feasibility study were completed.

## GEOLOGICAL SETTING

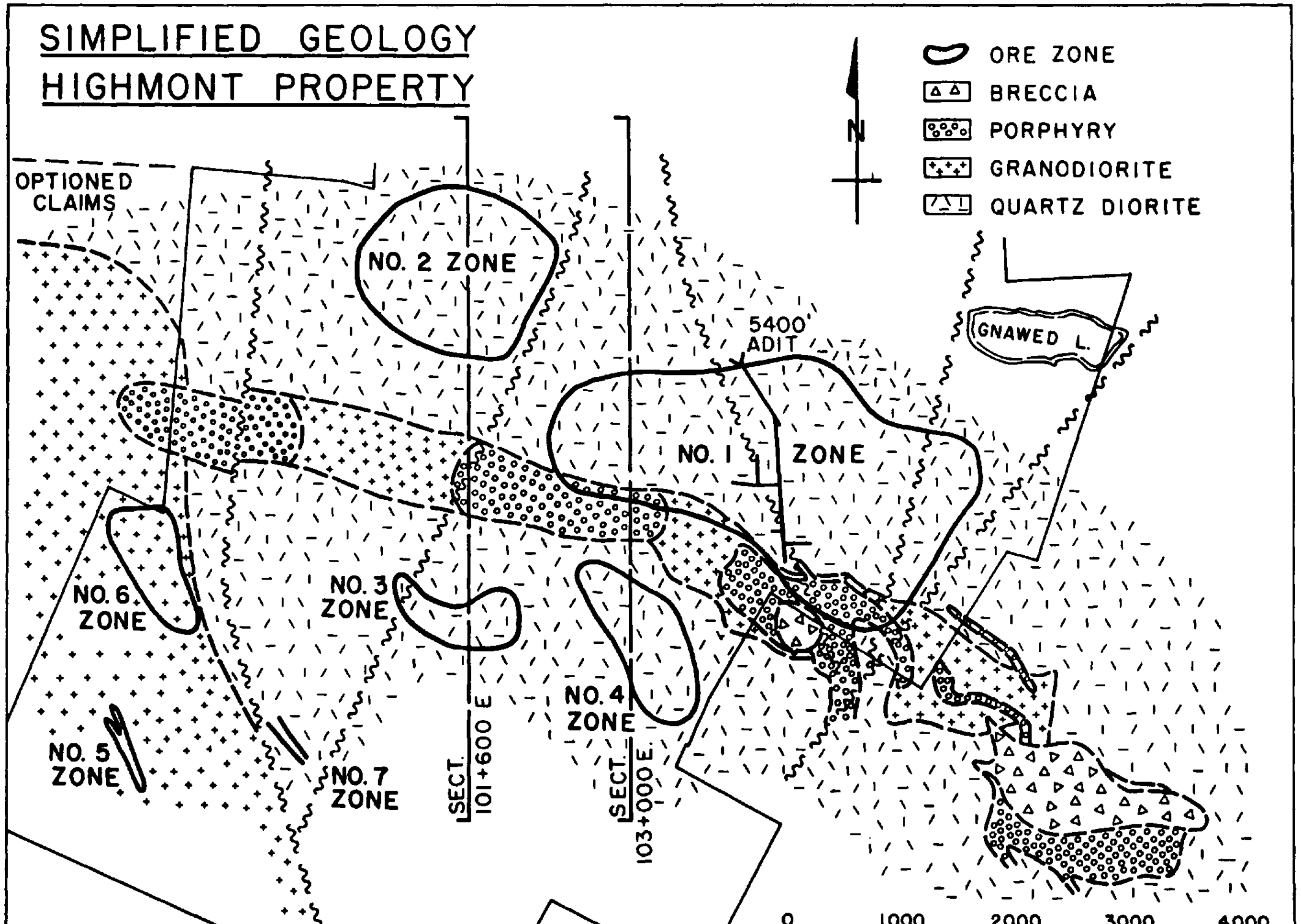
The Highland Valley district lies near the centre of the Guichon batholith. This Lower Jurassic batholith occurs in block-faulted terrain; it is facetted in plan, having an axis 40 miles long which is directly slightly west of north. The major phases of the batholith are concentrically disposed, with older quartz diorites occurring toward the margin, a younger quartz diorite as an intermediate ring, and a still younger granodiorite forming an elongate central core that is aligned along the axis from Highland Valley southward for a distance of about 12 miles (Northcote, 1969). From this core a 400-foot wide dyke of granodiorite projects eastward across the Highmont property to Gnawed Mountain.

In the Highland Valley district, all three phases are present and are dissected by a north-trending swarm of dacite and rhyolite porphyry dykes that is 10 miles long and several miles wide, as shown in Figure 2. Most of the porphyry dykes are steeply dipping and strike predominantly north. Some dykes within the swarm adopt other attitudes and may swell and branch to form irregular intrusions and associated intrusive breccias. These irregular porphyry and breccia intrusions mostly occur where northerly dykes intersect west-northwesterly contacts of the major phases and they include the localities of the Highmont, Bethlehem, Trojan (South Seas), and Krain (North Pacific) deposits.

The importance of northerly and west-northwesterly structural trends, and especially of intersections of these trends, is evidenced by the distribution of the major copper-molybdenum deposits and of other features including the following: (1) tourmaline alteration, which follows a northerly alignment roughly similar to that of breccia, (2) major faults and topographic lineaments of which the north-trending Lornex fault and the disjointed west-northwesterly Highland Valley lineament are examples, (3) post-mineral Tertiary volcanic flows and related minor intrusions. These trends and distributions suggest the existence of structural belts which may have resulted from stress patterns in the underlying basement (Figure 2). The porphyry dyke swarm appears to identify a north-trending structural belt which is crossed by several subsidiary, west-northwesterly belts in which fracturing, intrusion, rock alteration, and mineralization are concentrated. The most southerly subsidiary belt recognized is that which contains the Highmont and Lornex deposits. Any continuation along strike of this belt or of others is conjectural beyond the limits shown and could be affected by possible fault offsets.

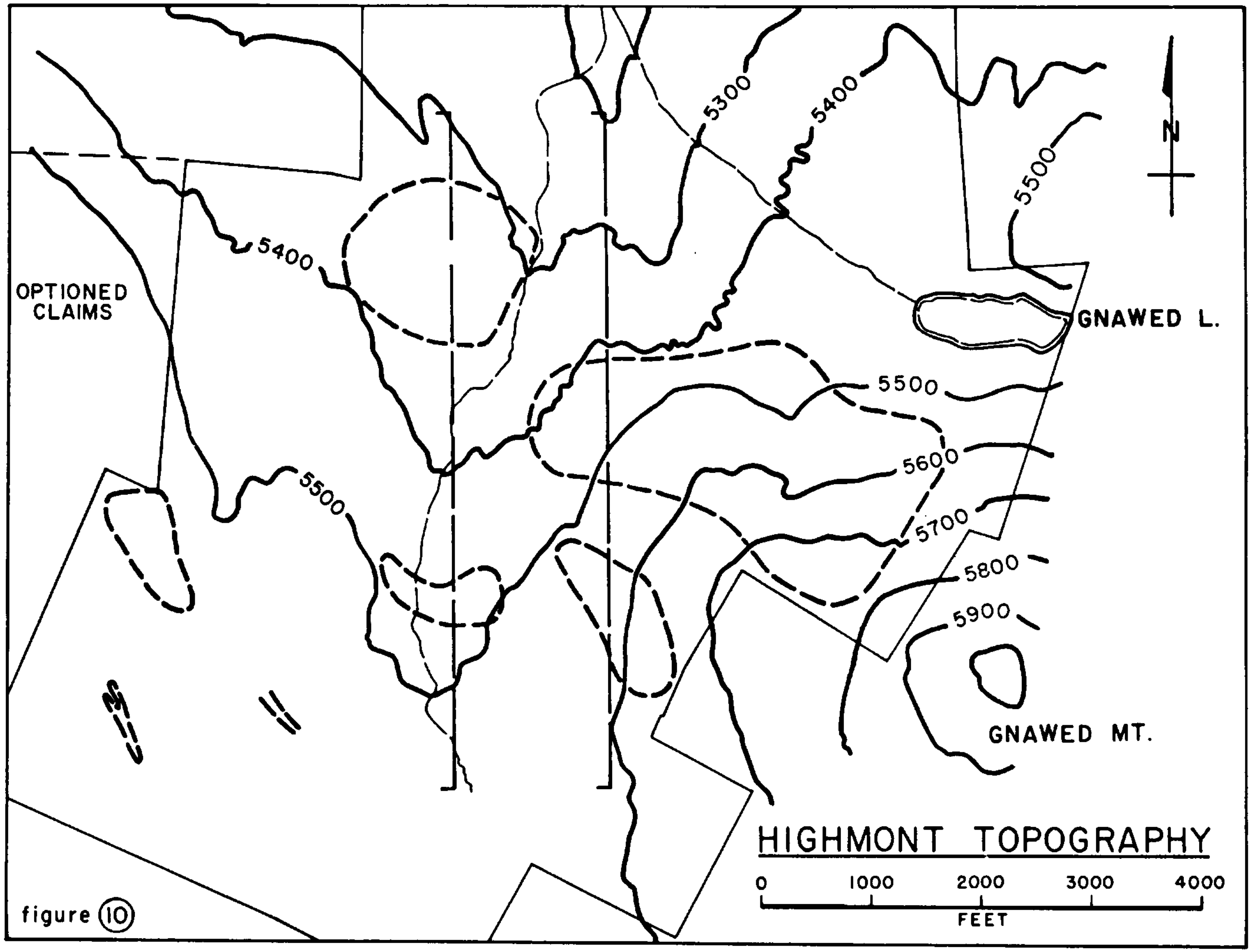
## LOCAL GEOLOGY

The Highmont property is underlain chiefly by the Bethlehem quartz diorite, representing the intermediate phase of the batholith (Figure 2). The extreme western part of the property is occupied by the Bethsaida granodiorite representing the central core of the batholith. The contact dips east at 65 degrees and is commonly faulted in drill holes. A composite dyke 400 feet wide extends east-southeastward for nearly 2 miles from this contact to the summit of



SIMPLIFIED GEOLOGY
HIGHMONT PROPERTY
N
ORE ZONE
BRECCIA
PORPHYRY
GRANODIORITE
QUARTZ DIORITE
OPTIONED CLAIMS
NO. 2 ZONE
5400 ADIT
GNAWED L.
NO. 1 ZONE
NO. 6 ZONE
NO. 3 ZONE
NO. 4 ZONE
NO. 5 ZONE
NO. 7 ZONE
SECT. 101+600 E.
SECT. 103+000 E.
0
1000
2000
3000
4000
FEET

figure ③


5300
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OPTIONED CLAIMS
GNAWED L.
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5500
5600
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5800
5900
GNAWED MT.
HIGHMONT TOPOGRAPHY
0 1000 2000 3000 4000
FEET

figure 10

Gnawed Mountain and is a principal geological feature of the property. The dyke is emplaced in strongly fractured quartz diorite. It comprises porphyritic Bethsaida granodiorite and later intrusions of quartz porphyry and breccia. Although considerably finer grained throughout than its counterpart in the central core to the west, the porphyritic granodiorite shows little decrease in grain size at its contacts with the quartz diorite. Quartz porphyry bodies, which are best exposed on the higher ground east of the property, possess irregular shapes and local offshoots that extend as dykes into the nearby quartz diorite. Some of these dykes possess aphanitic margins that indicate chilling. The remaining quartz porphyry has an aplitic groundmass that apparently indicates an arrested crystallization due to widespread and sudden loss of volatiles. This inferred explosive escape of volatiles from the porphyry is believed to have caused the formation of adjacent bodies of breccia, which consists of abundant angular fragments of the local rocks, including aphanitic quartz porphyry, that are embedded in a clastic matrix largely representing porphyry. Some fragments contain barren quartz veins, thus indicating that fracturing and alteration of the host rocks was initiated before brecciation and suggesting that the breccia bodies occupy parts of early fracture zones. The only breccia body recognized to date on the Highmont property is in the south part of the No. 1 zone.

Copper-molybdenum mineralization occurs in all the above-mentioned rock types. On the Highmont property, seven mineralized zones are recognised, of which the Nos. 1, 2 and 5 zones are proven orebodies and the other zones are partly explored. The two southwesternmost zones (Nos. 5 and 7) are small deposits occupying shear zones parallel to and on either side of the main granodiorite contact. The five other zones are larger and lower in grade and they are ranged on either side of the dyke mainly in quartz diorite except for the westernmost, or No. 6 zone, which lies wholly within the Bethsaida granodiorite. As presently known, these five deposits possess maximum dimensions ranging from 1,200 feet to 3,600 feet and are elongated either west-northwestward, which is parallel to the dyke, or north-northwestward. Together they occupy the best mineralized parts of a more or less continuous fracture zone that is more than a mile long and is roughly bisected by the dyke. This fracture zone probably continues north-westward along the granodiorite contact to the vicinity of the Lornex mine.

The Highmont ore zones lie beneath overburden which averages 12 feet thick over the Nos. 1 and 2 zones, and is mainly glacial till. The direction of ice movement during deposition of the till was from the northwest, as shown on the geochemical plans (Figure 8 (a) and (b)).

Oxidation of the ore is very limited and has penetrated downward only near faults; for example, along the east side of the No. 1 zone.

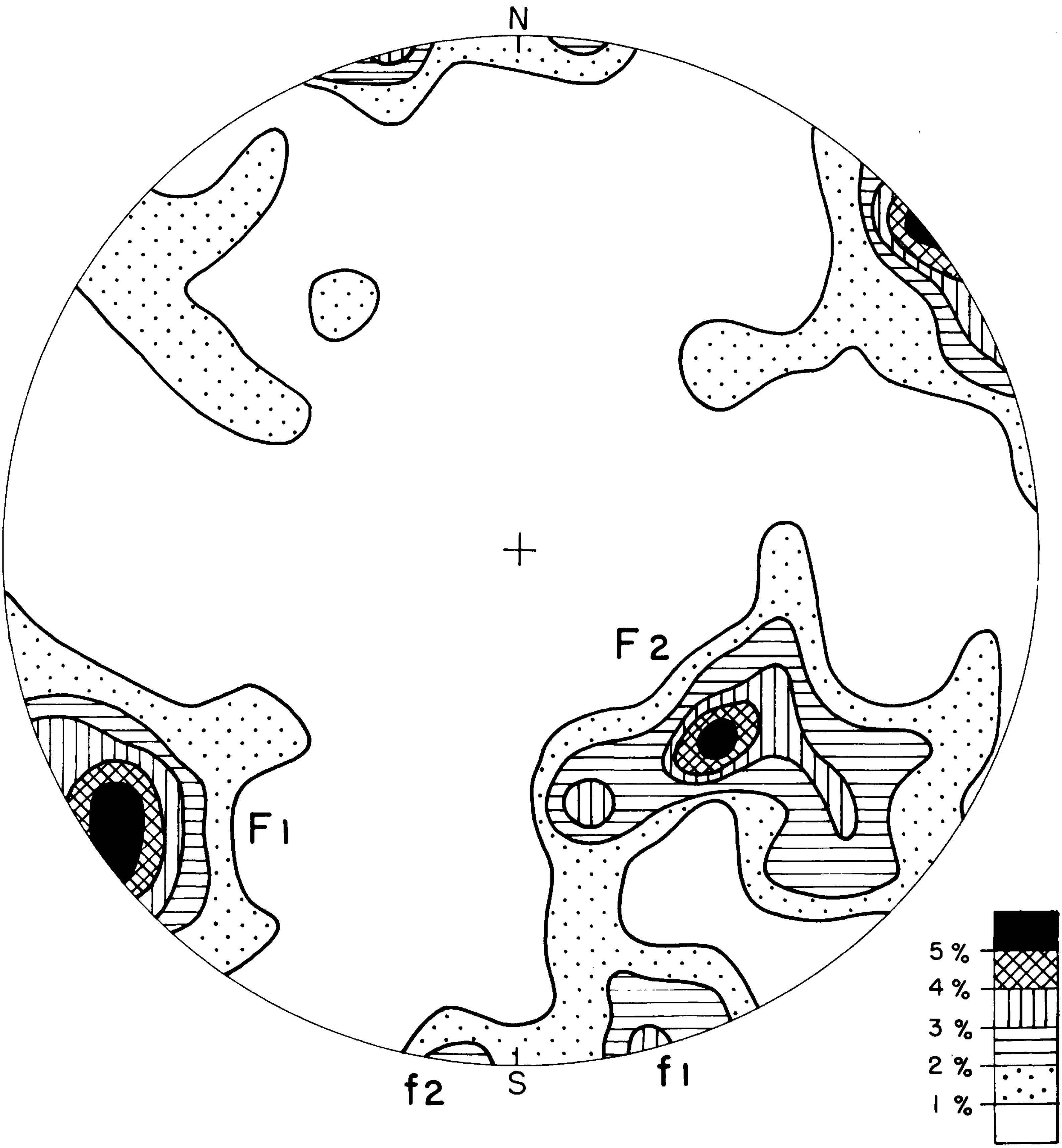
The principal economic minerals are chalcopyrite, bornite, and molybdenite which occur predominantly in veins and fractures but are also disseminated in significant amounts in the adjacent altered rock. The copper sulphides in the Nos. 1 and 2 zones show a distinct mineral zoning that is roughly parallel to the dyke, with bornite accompanying chalcopyrite approximately in equal amounts to distances of about 700 feet and 1,200 feet northward from the dyke in the Nos. 1 and 2 zones, respectively, then a zone of chalcopyrite with minor pyrite and rarely bornite, followed at the northern limits of ore by a decrease in the amount of pyrite which may locally amount to 1% of the rock. The presence of this mineral zoning north of the dyke is shown on the vertical geological sections (Figure 9 (a) and (b)). A similar zoning, which may extend southward from the dyke in the area of the Nos. 3, 4 and 6 zones, has not been substantiated. No systematic pattern is detected in the distribution of molybdenite, which is present throughout the ore. The only other metallic mineral introduced in appreciable amount is specular hematite, whose widespread distribution in mineralized fractures has not been studied in relation to zoning.

Four types of veins or fracture-fillings are commonly recognized within the orebodies:

Type (1) veins contain essentially quartz, chalcopyrite, and bornite in addition to scattered flaky molybdenite, and they range in width generally between 1/16 inch and 1 inch. In these veins quartz has a vuggy texture; chalcopyrite and bornite occupy the central part of the vein; and a 1 to 2 inch wide envelope of altered wallrock is characterized by relatively coarse (1 mm.) flakes of white sericite, and commonly by tourmaline clusters. This envelope is pink-coloured near the vein because of abundant K-feldspar, which is introduced principally on fractures containing types (1) and (2) veins.

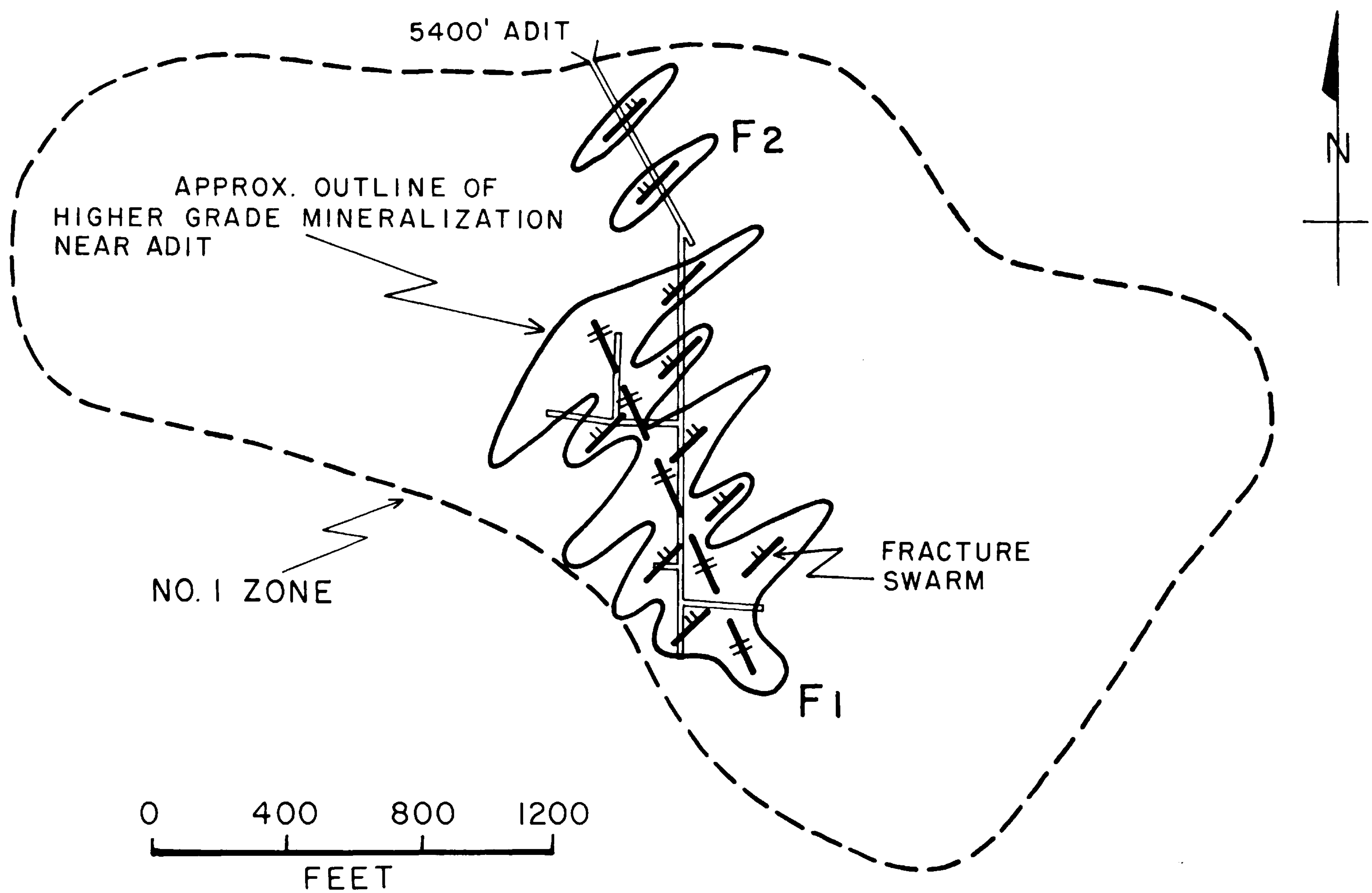
Type (2) veins contain quartz and chalcopyrite, in places with pyrite and minor molybdenite, and they range in width to 4 inches. The quartz is massive rather than vuggy and it may enclose tourmaline; chalcopyrite is not restricted to the centre of the vein, and sericite is not conspicuous in the wallrock.

Type (3) veins are certainly later than Type (1) veins and they figure ④




PROJECTION OF POLES OF VEINS & FRACTURES
HIGHMONT NO. 1 ZONE ADIT

figure 5




SKETCH MAP OF HIGHMONT 5400' ADIT

contain quartz, molybdenite and clay minerals in widths up to 3 feet. The quartz is greyish, brecciated, and seamed by molybdenite and chalky white clay minerals. The latter also occur at the edge of the vein as a variegated black, cream, or yellow gouge. These veins commonly occur in altered wallrock that is intensely argillic.

Type (4) veins are barren and apparently later than the mineralized veins. They consist of greyish-white quartz with a fine grained sugary texture.

Also occupying veins and fractures are calcite, siderite, epidote, zeolites (including prehnite), and gypsum. Wallrock alteration is largely controlled by fracturing and is locally intense. Several alteration types are recognized which include those mentioned above in discussion of veins as well as pervasive development of chlorite and green sericite.

The mapped fracture pattern on the 5400 Level in the No. 1 zone is well defined and mainly involves fractures of four distinct attitudes, whose relative abundance is illustrated by Figure 4. The majority of fractures in this part of the deposit belong to two major sets ($F_1$ and $F_2$) and many of the remaining fractures belong to two minor sets ($f_1$ and $f_2$). The attitudes of the fracture sets are as follows:

$F_1$ strike $140^\circ$ - $150^\circ$; dip $80^\circ$ northeast.

$F_2$ strike $040^\circ$ - $050^\circ$; dip $45^\circ$ northwest.

$f_1$ strike $075^\circ$; dip vertical.

$f_2$ strike $095^\circ$; dip vertical.

The fractures are not uniformly distributed in the deposit but rather they tend to be concentrated in swarms of parallel fractures. Each swarm extends parallel to the fracture direction and its width is as much as 200 feet. Swarms of mineralized $F_1$ and $F_2$ fractures coincide underground with higher-grade mineralization, as shown in Figure 5.

In the Nos. 3 and 4 zones which lie south of the dyke, mineralization probably is controlled largely by fractures possessing a component of southerly dip, as indicated on the vertical geological sections (Figures 9 (a) and (b)).

Shear zones and faults are numerous and partly follow the same directions as the veins and fracture swarms. Although showing evidence of post-mineral movement their actual displacements are unknown. Two northeasterly faults which apparently form the eastern limit of ore in the Nos. 1 and 2 zones, respectively, seem to involve no major displacement according to the mapped geology (Figure 3).

## DRILLING AND SAMPLING

### Percussion and Rotary Drilling:

Percussion drilling in 1966 and 1967 largely preceded diamond drilling and it effectively located most of the Highmont deposits. Altogether, more than 60,000 feet of wet percussion drilling was done in 2¼-inch diameter holes that were drilled vertically to a depth of 250 feet on 200-foot centres along east-west lines spaced 200 feet apart at the No. 1 zone and 400 feet apart at the Nos. 2, 3 and 4 zones. Rotary drilling was tried in 1966 and was discontinued after three holes were drilled, being found too slow and expensive.

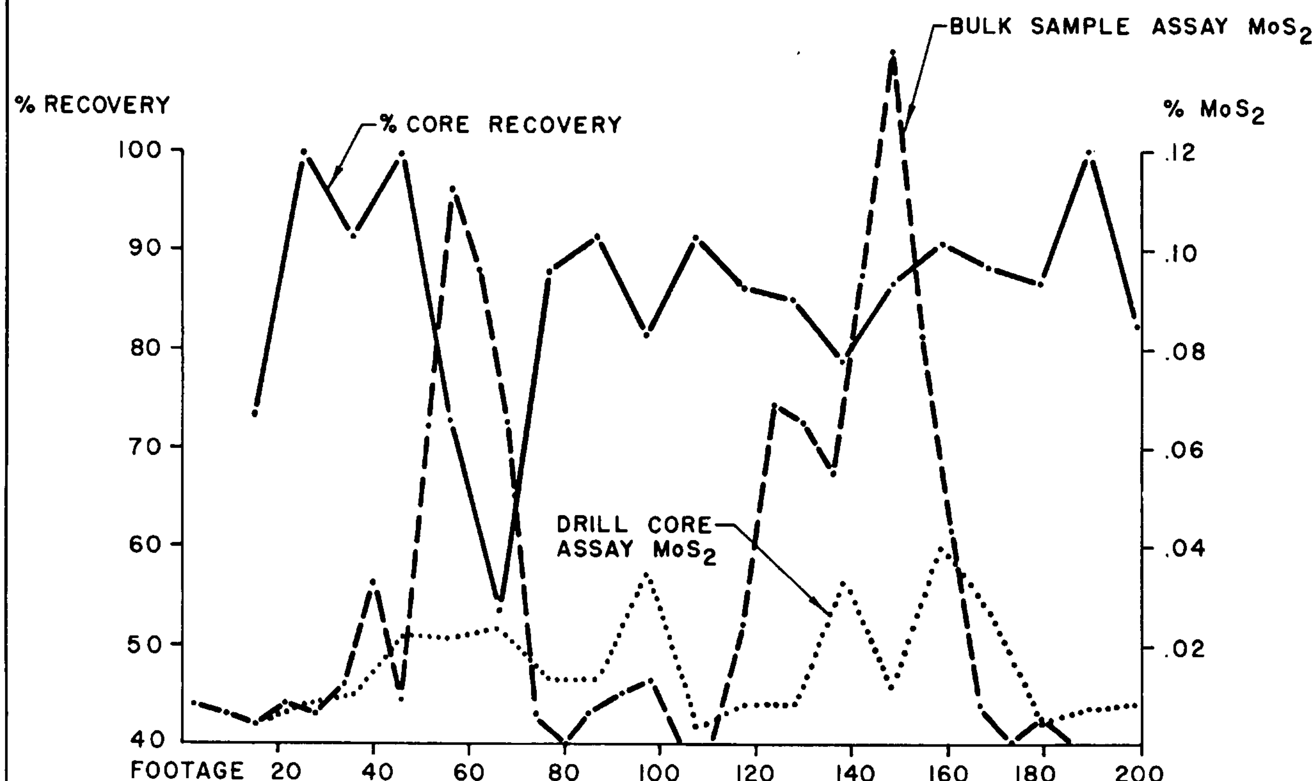
### Diamond Drilling:

Between 1966 and 1970 diamond drilling totalling more than 130,000 feet was done on the property, using BQ wireline equipment with conventional water circulation and sludge collection. Core recovery averaged about 85%. Drilling in 1968 tested the Nos. 1 and 2 zones to a vertical depth of 500 feet; later drilling was deeper and it revealed that mineralization persists to depths of at least 1,300 feet.

### Bulk Sampling and Ore Reserve Calculation:

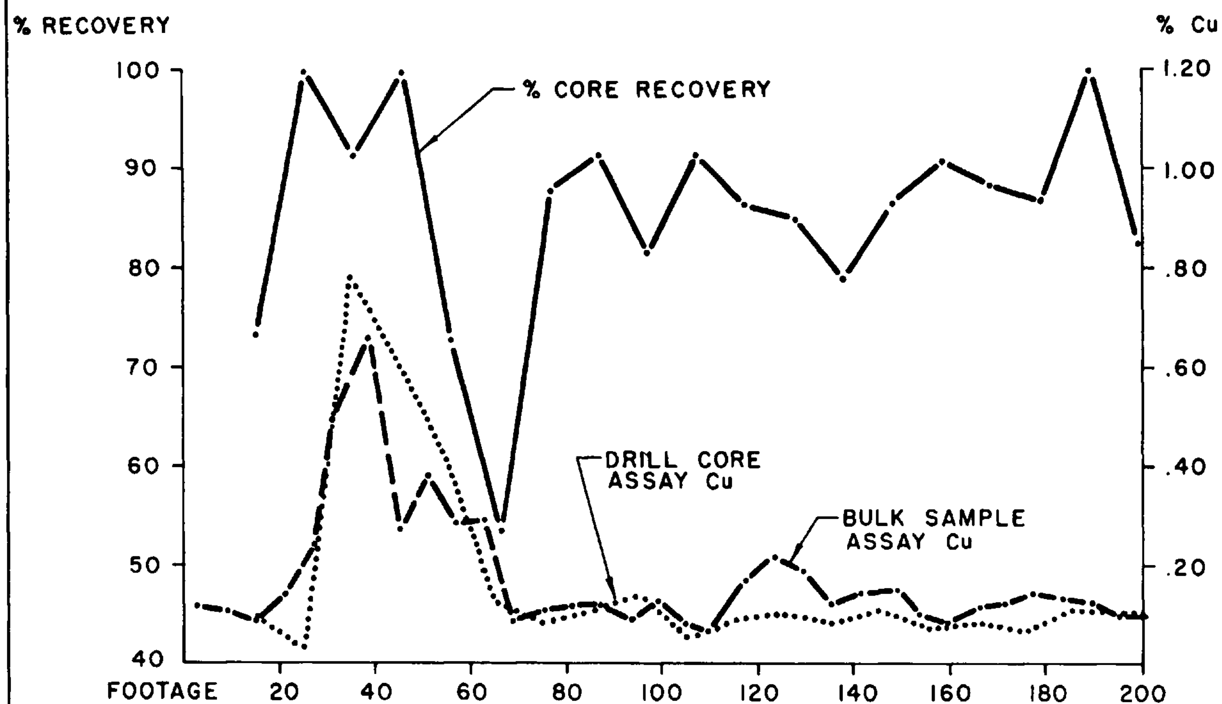
Bulk sampling was confined to the No. 1 zone and was done by means of a 5 x 7 foot adit drift which was collared at 5400 feet elevation and driven southward in the zone to obtain maximum backs of 250 feet. Drifting and cross-cutting totalled 2860 feet; raising totalled nearly 1,000 feet and included three vertical and four inclined raises.

Rounds were mucked, stored, crushed and sampled individually. The crushing and sampling plant could handle 200 tons per day and it included a jaw crusher and a set of rolls which reduced the




RELATIONSHIP OF DRILL CORE RECOVERY AND $MoS_2$ ASSAYS, WEST 2 DR. HIGHMONT NO. 1 ZONE

figure (6)




RELATIONSHIP OF DRILL CORE RECOVERY AND Cu ASSAYS, WEST 2 DR. HIGHMONT NO. 1 ZONE

figure 7

muck to minus 3/4 inch. This product was conveyed to the top of a tower where a Denver Cutter-type sampler took a 1/120th portion as sample and the remainder dropped into a bin for removal to field storage, where it was available for future reference. The 400 lb. sample was reduced by gyratory crusher to a 5-mesh product which was cut by a Vezin sampler in the ratio of 20:1. The larger portion (380 lbs.) was boxed and made available for metallurgical bench-testing. The 20 lb. sample was split four ways by a Jones riffle, one portion being retained at the property and the other three being sent for assay. Between rounds the muck bins and all plant and equipment were swept clean.

Assaying was checked constantly by using one principal assay laboratory and submitting pulp rejects to independent assayers.

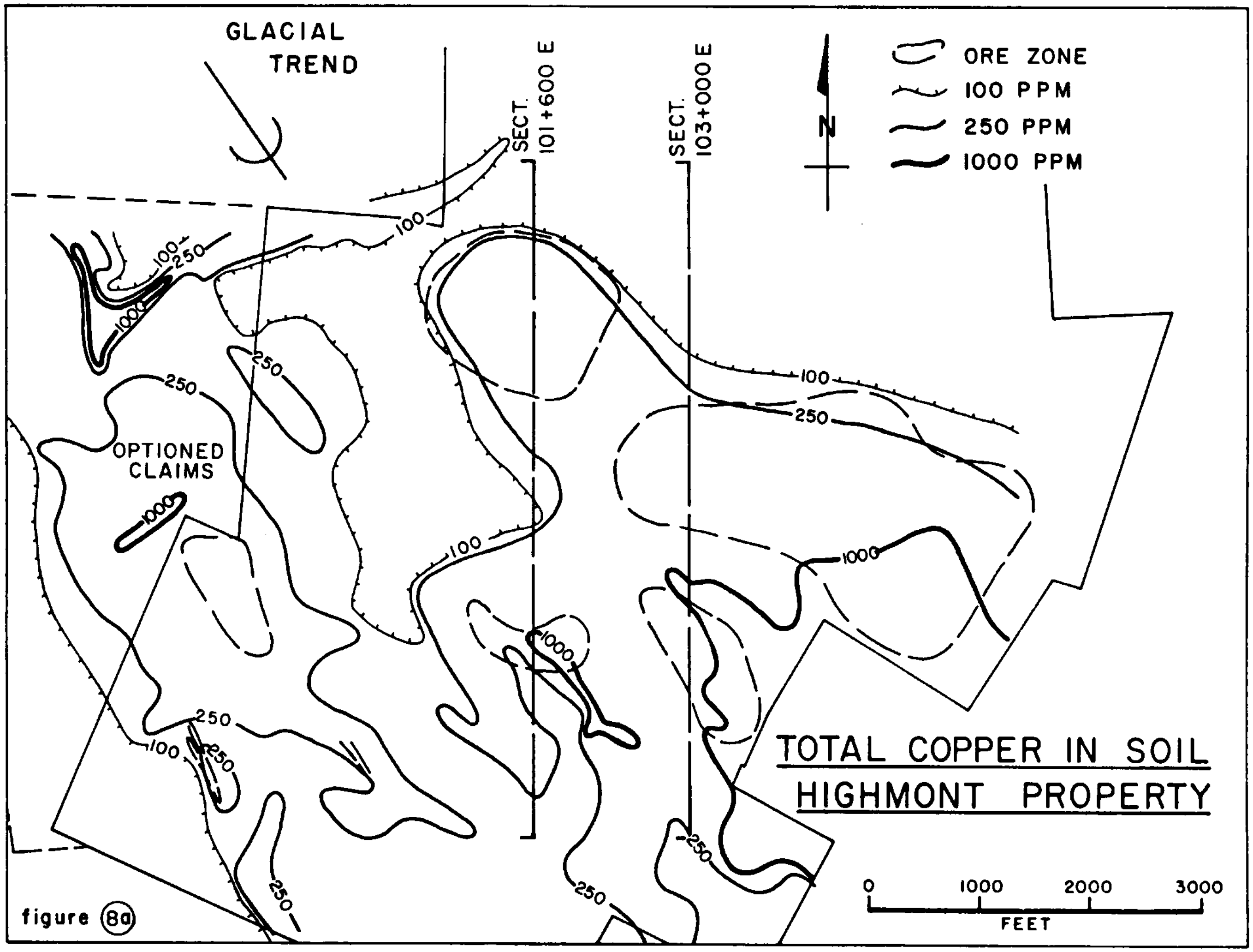
Totals of 1,144 feet of drifting and cross-cutting and 979 feet of raising coincide with diamond drill holes. Sampling data from these sections were used to establish the following correlations between bulk sample assays and diamond drill core assays:

% Cu in bulk sample = % Cu in diamond drill core x 1.12

% $MoS_2$ in bulk sample = % $MoS_2$ in diamond drill core x 1.15

These correlations indicate increases ot 12% in Cu content and 15% in $MoS_2$ content of bulk samples relative to recovered diamond drill core. The lower assays thus evidenced of diamond drill core are due to below-average recoveries in core of material of above-average grade. Altered and sheared ground gives the worst recovery and is commonly well mineralized, especially in regard to molybdenite, as illustrated by the following underground channel samples which were taken across three typical shear zones:

| | Channel (1) | | Channel (2) | | Channel (3) | |
|---|---|---|---|---|---|---|
| | % Cu | % $MoS_2$ | % Cu | % $MoS_2$ | % Cu | % $MoS_2$ |
| Hanging wall | 0.31 | 0.010 | 0.18 | 0.012 | 2.64 | 0.016 |
| Shear zone | 0.43 | 0.353 | 0.56 | 0.300 | 0.11 | 0.112 |
| Footwall | 0.94 | 0.060 | 0.20 | 0.052 | 0.21 | 0.052 |


GLACIAL TREND
SECT. 101+600 E
SECT. 103+000 E
N
ORE ZONE
100 PPM
250 PPM
1000 PPM
OPTIONED CLAIMS
100
250
1000
TOTAL COPPER IN SOIL HIGHMONT PROPERTY
0
1000
2000
3000
FEET
figure 8a

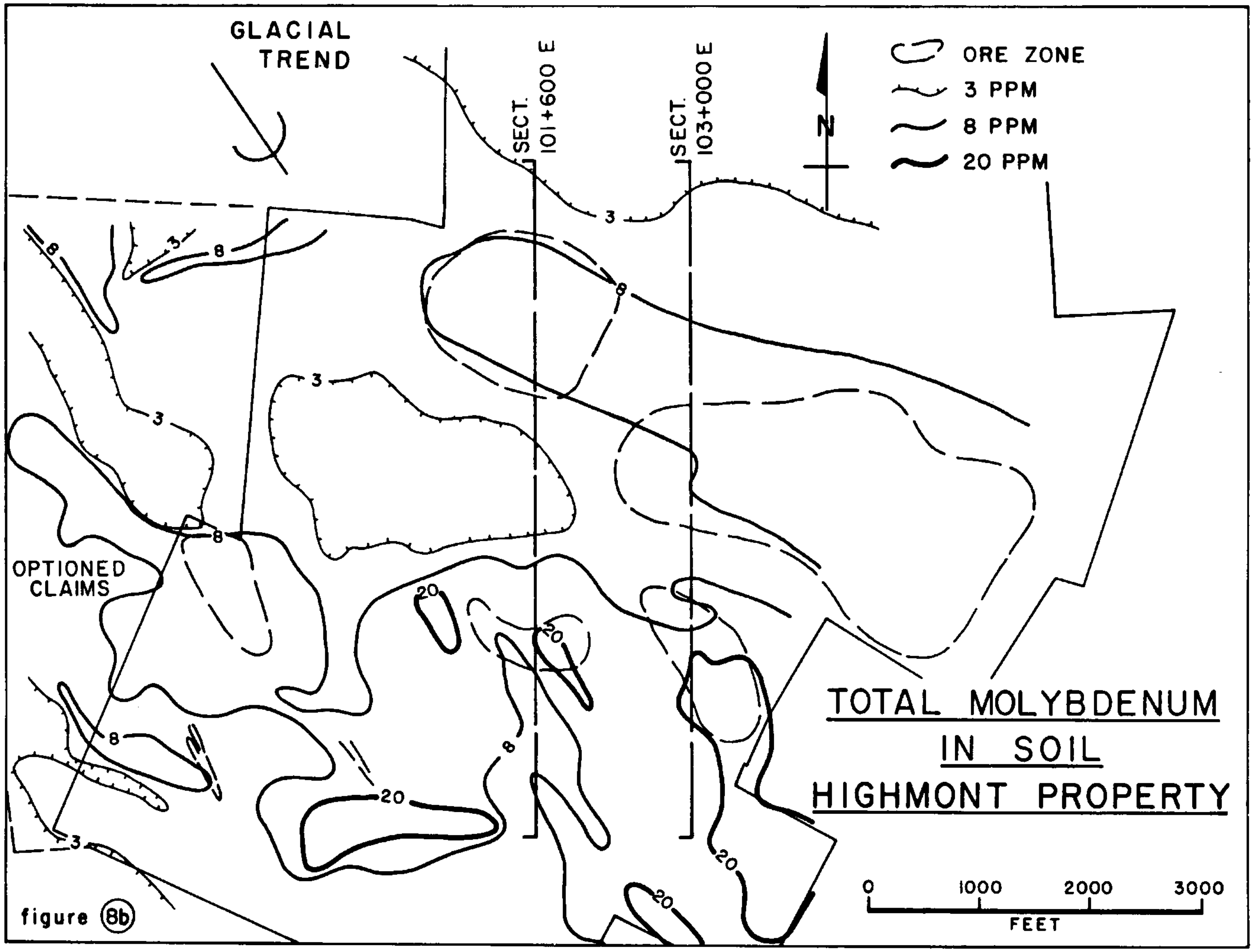

GLACIAL
TREND
SECT.
101+600 E
SECT.
103+000 E
N
ORE ZONE
3 PPM
8 PPM
20 PPM
OPTIONED
CLAIMS
3
8
20
TOTAL MOLYBDENUM
IN SOIL
HIGHMONT PROPERTY
0
1000
2000
3000
FEET

figure (8b)

Graphical comparisons of core recovery and assays with bulk sample assays (Figures 6 and 7) demonstrate the reduced recovery in core obtained from higher grade material and they illustrate the validity of using the above-mentioned correlations in calculation of ore reserves at Highmont.

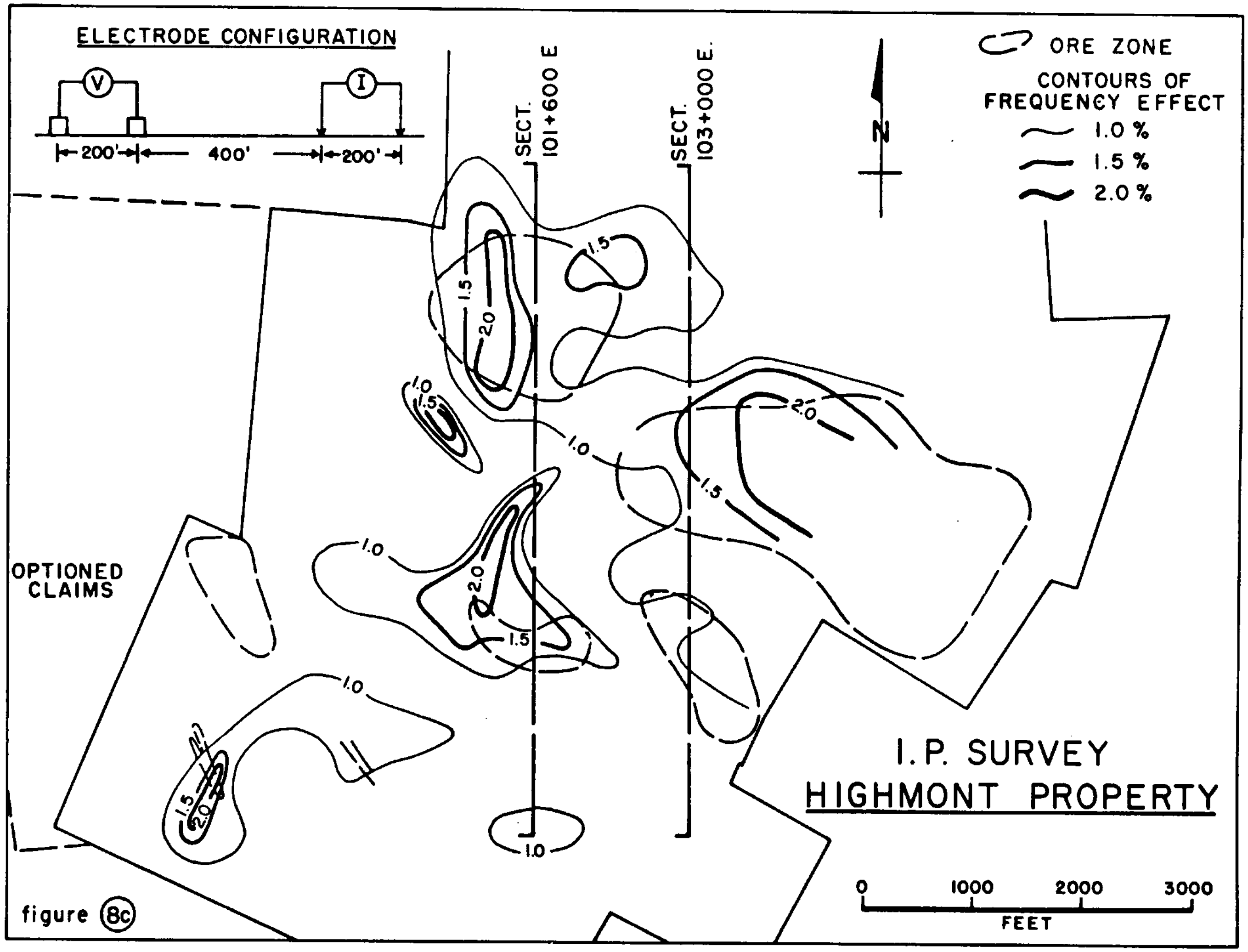
Sludge assays from the diamond drill holes were generally higher than assays of the corresponding core. Difficulty was experienced in obtaining uniform sludge recovery and consequently sludge assays were not employed for calculating ore reserves. Percussion hole assays were likewise not employed because they appeared too high in comparison with other available sample data. However, the relationships between core recovery, core assays and sludge assays were studied and found to be similar for both the Nos. 1 and 2 zones, thus further confirming the validity of the correlations used in calculating ore reserves.

## GEOCHEMICAL SURVEYS

Soil samples were collected at the base of the "B" Horizon at an average depth of about 10 inches. The samples were analysed for total copper, cold-extractable copper, and molybdenum. In addition, 20 vertical profiles were sampled in trenches and test pits.

Generalized contours of total copper and molybdenum are shown on Figures 8(a) and 8(b). The most notable feature is the abrupt increase in metal content near the northern and northwestern edges of the main ore zones. Background values in the northern portion of the property are less than 100 p.p.m. copper and less than 2 p.p.m. molybdenum. The orebodies are reflected by values of greater than 250 p.p.m. copper and 8 p.p.m. molybdenum. The geochemical pattern in the southern and western portions of the property is complex, apparently the result of glacial dispersion as well as of rather widespread copper-molybdenum mineralization. The strongest values for both copper and molybdenum occur over a broad area on the slope of Gnawed Mountain along the glacial trend southeast of the main ore zones. The drilling results in the area suggest that this is mainly a transported metal anomaly, augmented by local sub-economic mineralization.

The total copper:cold extractable copper ratios and the results of the profile sampling indicate that mechanical movement due to glaciation was of much greater importance than saline dispersion even in the immediate vicinity of the ore zones. However, saline dispersion is important locally and provides a clue to the source of the anomalous metal values.


ELECTRODE CONFIGURATION
V
I
200'
400'
200'
SECT. 101+600 E
SECT. 103+000 E.
N
ORE ZONE
CONTOURS OF FREQUENCY EFFECT
1.0 %
1.5 %
2.0 %
OPTIONED CLAIMS
1.0
1.5
2.0
I. P. SURVEY
HIGHMONT PROPERTY
0
1000
2000
3000
FEET
figure 8c

## GEOPHYSICAL SURVEYS

### Induced Polarization:

Several induced polarization surveys were carried out over portions of the property. These included both time-domain and frequency-domain methods. The generalized results of the most complete survey (McPhar frequency domain) are shown in Figure 8(c). Comparable response was obtained by the other surveys.

The I.P. method gave very weak but significant response over the known ore zones. The main deposits are reflected by frequency effects in the range of 1.0 to 2.5 per cent. Response of this magnitude is not unexpected in view of the very small sulphide content of the ore. The anomalous response extends some distance north of the ore zones, reflecting a partial pyritic halo.

### Resistivity:

The resistivity data which were obtained in the I.P. survey do not reflect the known economic mineralization. Hence the "Metal Factor" which is a function of resistivity as well as percent frequency effect can be misleading.

### V.L.F. Electromagnetic:

Electro magnetic surveys utilizing the VLF transmitter near Seattle were of limited use in outlining faults. The higher-grade No. 5 ore zone showed moderate VLF-EM response. However, the results are not diagnostic and the main usefulness of the method was in providing information on trend and continuity.

### Magnetic:

Airborne and ground magnetic surveys were carried out. Both techniques indicate that the magnetic property of the ore zones is indistinguishable from that of the adjacent rock. There apparently is no significant destruction or introduction of magnetite during alteration or metallization. A fairly strong magnetic gradient along the south side of the main ore zones reflects the greater magnetite content of the Bethlehem phase rocks north of the dyke (Figure 9(a) and (b)). A magnetic property difference between the Bethlehem and Bethsaida phases is indicated by a lower magnetic intensity over the rocks of the Bethsaida phase.

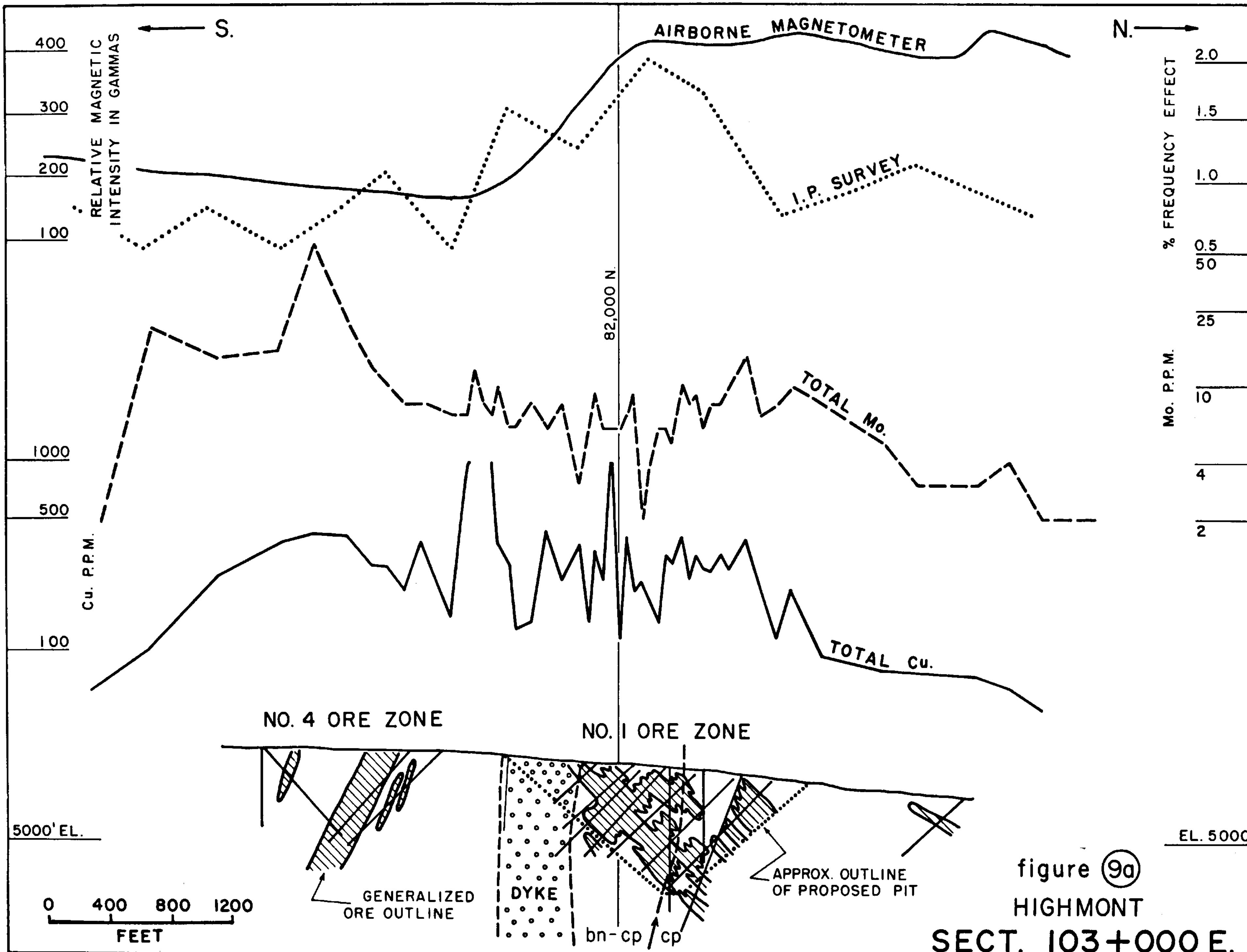



figure 9a
HIGHMONT
SECT. 103+000 E.

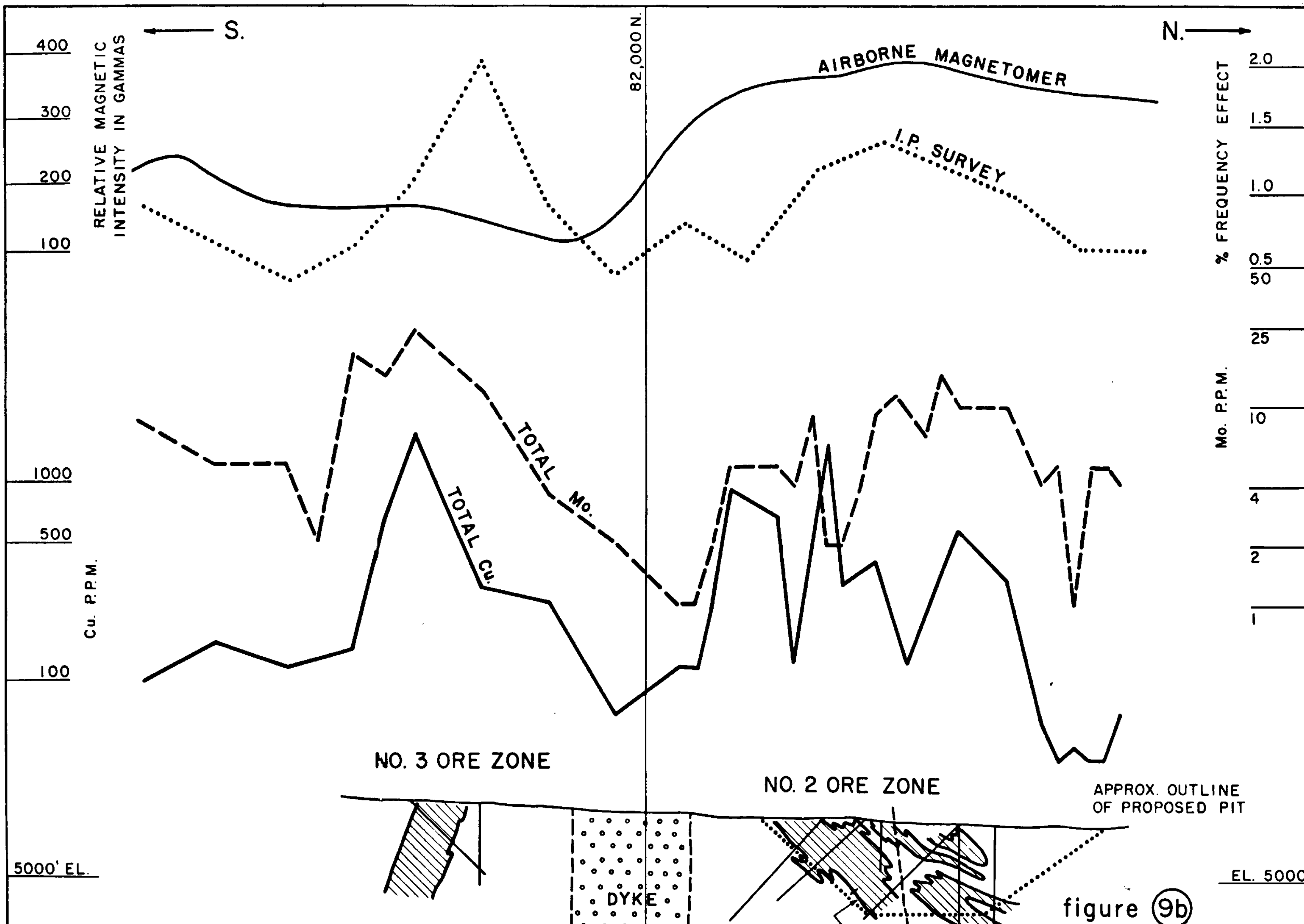


figure 9b
HIGHMONT
SECT. 101+600 E.

PLANNED MINING OPERATION

Completed feasibility studies indicate that the Highmont Nos. 1 and 2 zones can support a viable mining and milling operation at 25,000 tons per day.

The Nos. 1 and 2 zones will be mined as two separate pits. The East Pit (No. 1 zone) will be 870 feet deep yielding 123.5 million tons of ore at an average grade of 0.287% Cu and 0.042% $MoS_2$, with an indicated waste to ore ratio of 1.03:1. The West Pit (No. 2 zone) will be 610 feet deep yielding 26.5 million tons of ore grading 0.273% Cu and 0.093% $MoS_2$ with an indicated waste to ore ratio of 1.79:1.

During the first five years of operation the cut-off grade will be 0.25% copper equivalent and material grading between 0.20% and 0.25% copper equivalent will be stockpiled. (Copper equivalent = Cu, plus $MoS_2$ x 2.2)

Pilot scale metallurgical tests made on 400 tons of mined material indicated that over 90% of the copper and over 80% of the molybdenite will be recovered. The copper concentrate will grade at least 30% copper and 2 oz/ton silver. The molybdenite concentrate will grade about 54% molybdenum sulphide and approximately 0.017% rhenium.

Recent drilling has indicated the possibility that the Nos. 3 and 4 zones south of the dyke will support a single open pit 3,000 feet long and at least 500 feet deep.

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