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# THE INTERRELATIONSHIP OF REGIONAL METAMORPHISM, HYDROTHERMAL ALTERATION AND MINERALIZATION AT THE GIBRALTAR MINES COPPER DEPOSIT, McLEESE LAKE, BRITISH COLUMBIA.


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# ABSTRACT

Gibraltar Mines is located on the western slope of Granite Mountain, 230 air miles north of Vancouver, B.C. and 38 miles north of Williams Lake, B.C. There are four mineable zones within the copper-molybdenite deposit: Gibraltar East, Gibraltar West, Pollyanna and Granite Lake. Open pit reserves are 358 million tons which average 0.37% Cu and 0.016% $MoS_2$ at a 0.25% Cu cut-off.

The Granite Mountain pluton is one of the several Jurassic-Cretaceous intrusions which outcrop along the east side of the Fraser River fault system between Williams Lake and Prince George, B.C. The original Granite Mountain quartz diorite has been metamorphosed by a cataclastic deformation which foliated the rock on a regional scale. Attendant to the development of the foliation, the rock was saussuritized such that the present mineralogy is compatible with that of the green schist facies. Presence of garnet-bearing assemblages is explained by a restricted increase in water pressure.

Pre-mineral intrusive phases within the saussuritized quartz diorite are (1) leucocratic quartz diorite, (2) aplite and (3) quartz-feldspar porphyry. A late chloritized hornblende dacite dyke is post-mineral.

Quartz-feldspar porphyry and leucocratic quartz diorite are locally present on the inner sides of the Gibraltar East, Pollyanna and Granite Lake pits such that their presence suggests a core around which occurs an elliptically-shaped sulphide-bearing stockwork. The stockwork which comprises four ages of vein development is imposed on and partly controlled by the regional foliation of the saussuritized quartz diorite.

## INTRODUCTION

The occurrence of a porphyry copper deposit in a regionally metamorphosed quartz diorite is somewhat geologically unique especially when considering the porphyry copper deposits that are currently known in the Canadian cordillera. This paper will describe the metamorphism of the Granite Mountain pluton and its relationship to porphyry intrusion, mineralization and hydrothermal alteration at the Gibraltar copper deposit.

## LOCATION

The copper orebodies of Gibraltar Mines Ltd. are located on the western slope of Granite Mountain in central British Columbia (Figure 1). The property is about 225 air miles north of Vancouver. Access is by 12 miles of gravel road from McLeese Lake which is 28 miles north of Williams Lake on Highway 97. Latitude and longitude are 52°30'N and 122°16'W respectively.

The area in and around the mine site has a moderate topographic relief with elevations ranging between 3,500 and 4,100 feet. The peak of Granite Mountain at 4,587 feet is one of the highest points in the area.

## HISTORY

The Pollyanna property had been known since 1917 and the original Gibraltar property since 1927. Work since those early days culminated in

1969 with the delineation of several orebodies and the formation of the present Gibraltar Mines property. A detailed historical development of the property has been presented by Rotherham, Tennant and Drummond (1972) and the details of the induced polarization history has been presented by Cannon, Thornton and Rotherham (in press).

On November 6, 1970, Placer Development Limited gave notice that it intended to equip the property for production. Official opening of the mine was held on June 13, 1972, and the concentration is currently operating at 43,000 tons per day.

Ore reserves at December 31, 1971 were 358,000,000 tons of mineable ore with an average grade of 0.37% copper and 0.016% molybdenite using a cut-off grade of 0.25% copper. Overall strip ratio is 2.15:1. During the early years of the mine operation, about 55,000,000 tons of 0.44% Cu will be available at a strip ratio of about 1.45:1.

## REGIONAL GEOLOGY

In the vicinity of Granite Mountain, the oldest rocks are regionally metamorphosed sedimentary and volcanic rocks of the Cache Creek group of Permian age (Tipper, 1959).

Batholithic intrusives of Jurassic-Cretaceous age intruded the Cache Creek group in the Granite Mountain area. An intermittent north-south trending line of batholithic rocks outcrop from Prince George on the north to as far south as McLeese Lake. These rocks occur along the east side of the Fraser River fault system. The batholiths are composed of granodiorite, quartz diorite, diorite and gneissic varieties of the above rocks. In the immediate vicinity of Granite Mountain, a regionally foliated and metamorphosed quartz diorite occurs which has a chlorite-rich diorite margin against rocks of the Cache Creek group. Calcareous members of the latter show locally some skarn development adjacent to the diorite contact. It is within the regionally metamorphosed and foliated quartz diorite that the Gibraltar-Pollyanna copper-molybdenum deposits occur.

## GEOLOGY OF THE GIBRALTAR COPPER DEPOSITS

The four copper/molybdenum orebodies of Gibraltar Mines are known as Gibraltar East, Gibraltar West, Pollyanna and Granite Lake. The Gibraltar East and West pits are outlined and occur to the west of the Pollyanna pit. The Granite Lake pit is south of the Pollyanna pit. The distance between the west end of the Gibraltar East pit and the east end of the Granite Lake pit is about 2 1/2 miles. The distance from the north side of the Pollyanna zone to the south side of the Granite Lake pit is about 1 mile. These four pits lie entirely within the quartz diorite of the Granite Mountain pluton (Figure 2).

A dioritic margin (Unit 2b) is exposed on the southwest portion of the pluton. Permian Cache Creek group rocks were intruded and adjacent to the contact, epidotized bands may be found locally. The trough in which Cuisson Lake occurs is probably part of the Fraser fault system.

## REGIONAL METAMORPHISM OF THE GRANITE MOUNTAIN PLUTON

The quartz diorite of the Granite Mountain pluton is extremely uniform in its mineral assemblage, but shows a variable degree of cataclastic deformation.

(a) Saussuritized Quartz Diorite (non-directional).

This rock is composed of quartz (25-30%), "plagioclase" which is presently a mixture of albite-epidote-zoisite-muscovite (50-55%), chlorite (20%) which originally was biotite with minor hornblende and disseminated magnetite (1% or less). The rock is equigranular and generally has a grain size of 2-4 mm (Figure 3 - photograph a). The grain size varies to the north and may be as much as 10 mm near the tailings pond about 1 1/2 miles north of the mine.

(b) Saussuritized Quartz Diorite (weak foliation).

In those areas of the pluton where deformation has been a little more intense, the rock exhibits a weak foliation. In thin section, the saussuritized "plagioclase" is the same as in the above but there is a recognizable alignment of muscovite, chlorite and a few quartz fragments along the foliation planes (Figure 3 - photograph b).

(c) Chloritized Quartz Diorite (strong foliation).

With further deformation, the foliation becomes much more notable as more definite slip surfaces develop (Figure 3, photograph c).

This rock contains less epidote macroscopically but the degree of saussuritization is the same as in the above described rocks. The foliation is defined by the alignment of "plagioclase", chlorite and muscovite. The cataclastic nature of the developed foliation is suggested by the presence of rotated quartz grains and by the presence of carbonate deposition in that area between the pulled apart portions of broken quartz grains.

(d) Chlorite Laminated "Quartz Diorite".

With still further deformation, the foliation planes come closer together such that the original quartz diorite has become a schist-like rock which has been named a chlorite laminated quartz diorite. The mineral assemblage is quartz-albite to oligoclase-chlorite-muscovite-magnetite (Figure 3 - photograph d). A variation of this rock is a chlorite-muscovite schist-like rock. Locally when the schistose zone occurs between bands of less intensely foliated quartz diorite, the schistose zone can be extremely distorted on a small scale as is shown in photograph e, Figure 3.

It was within a relatively restricted portion of a chloritic shear zone that a rather unique mineral assemblage was discovered. This particular rock contained quartz-chlorite-muscovite-garnet-pyrite. While this assemblage is common to metamorphic petrologists, its presence within a shear in an area of weakly saussuritized quartz diorite was not expected.

The affect of regional metamorphism on the Granite Mountain pluton can now be summarized as follows:-

1. The original quartz diorite has been saussuritized over the entire extent of the Granite Mountain pluton and not just around the mine site;

2. Within the pluton, there are mineralogical and textural changes associated with the intensity of cataclastic deformation;

3. Where the foliation is weakly developed, the mineral association is quartz-albite-muscovite-chlorite-epidote-zoisite-magnetite;

4. As the intensity of deformation increases, the quartz diorite becomes strongly foliated and eventually schist-like. The mineral assemblage is quartz-oligoclase-chlorite-muscovite-magnetite;

5. Epidote becomes much less abundant as the intensity of the foliation increases;

6. The above mineral assemblages and the textural variations are indicative of a suite of rocks compatible with the greenschist facies of regional metamorphism;

7. The garnet-chlorite assemblage represents upper greenschist facies metamorphism and indicates that there must have been a local increase in water pressure along that portion of the shear zone.

## INTRUSIVE PHASES OF THE GRANITE MOUNTAIN PLUTON

Within the saussuritized and foliated quartz diorite of the Granite Mountain pluton, there are three pre-mineral and one post-mineral intrusive phases.

A rock which exhibits both a sharp and a gradational contact against the saussuritized quartz diorite is a leucocratic porphyritic quartz diorite. This rock is composed of quartz (30%) and saussuritized plagioclase with albitic rims (45%) in grains which range from 1 to 5 mm. The remaining 25% of the rock is a fine-grained mosaic of quartz and albitic plagioclase with about 1-2% chlorite.

A more definite porphyry occurs in the same areas as the leucocratic phase. The quartz-feldspar porphyry cross-cuts the saussuritized quartz diorite and apparently cross-cuts the leucocratic phase. This latter relationship has not been conclusively demonstrated. The porphyry is composed of 3-5 mm phenocrysts of quartz (30%) and albitic plagioclase (10%) in a white aphanitic matrix which is composed of quartz, albitic plagioclase and some carbonate, muscovite and zoisite. Both the porphyry and the leucocratic phase are pre-mineralization.

A more intrusive phase is aplite which typically is very fine-grained and has a sugary texture. The aplite is pre-mineralization.

There has been only one post-mineralization rock encountered to date and that rock is a very fine-grained chloritized hornblende dacite which is known only in the Gibraltar East zone.

## MINERALIZATION AND HYDROTHERMAL ALTERATION

There are at least four stages of veining recognized within the Gibraltar deposits. The position of veins into stages is dependent on their relative age relations which means that the first listed is cross-cut by the next listed feature. The four stages are summarized below.

Stage 1. a) quartz-pyrite ± chalcopyrite <u>WITH</u> a sericitic envelope. (Sericite envelope assemblage is quartz, sericite, pyrite ± chalcopyrite with all saussuritized feldspar being made over to sericite-clay (?) mixture);

b) quartz-chlorite-pyrite-chalcopyrite-magnetite ± carbonate <u>WITH</u> a chloritic envelope (Chlorite envelope assemblage is quartz, chlorite, pyrite ± chalcopyrite with a pronounced absence of epidote in the saussuritized feldspar);

Stage 2. a) quartz-chlorite-pyrite ± magnetite;

b) quartz-chlorite-pyrite-chalcopyrite-epidote ± magnetite;

c) quartz-chlorite-pyrite-epidote ± magnetite;

d) quartz-chlorite-pyrite-chalcopyrite ± magnetite;

e) quartz-chalcopyrite-bornite ± pyrite (restricted to porphyry area between Pollyanna and Granite Lake zone) (all with ± carbonate);

Stage 3. quartz-molybdenite-chalcopyrite-pyrite ± magnetite ± carbonate;

Stage 4. bull quartz-blebs of fine-grained chlorite-chalcopyrite blebs.

Veins with sericitic and veins with chloritic envelopes are definitely cross-cut by Stage 2 veins which do not have envelopes. To date, a vein with a sericitic envelope has not been found to cross-cut a vein with a chloritic envelope. Consequently, those veins with either type of envelope are considered to be in Stage 1.

Veining can be parallel to the foliation in the host quartz diorite or it can cross-cut the foliation.

Hydrothermal alteration in the form of the sericitic and chloritic envelopes is similarly seen to be parallel to as well as cross-cutting the foliation in the host quartz diorite.

A second hydrothermal alteration feature was observed in a petrographic study (Simpson, 1970) of the saussuritized plagioclase across the Pollyanna and Gibraltar East zones. It was noted that the amount of sericite relative to epidote in the saussuritized plagioclase could be correlated reasonably well to the copper grade.

The veining with or without envelopes and a pervasive increase in sericite associated with a sulphide zone are typical physical and chemical features of a porphyry copper stockwork which has been imposed on the previously saussuritized and foliated quartz diorite of the Granite Mountain pluton.

## SUPERGENE ZONE

Secondary enrichment is economically important and occurs to varying degrees in all the Gibraltar deposits. There is a leached weak to strong limonite zone above the supergene copper zone which is irregular in development and thickness.

Supergene copper minerals include chalcocite with minor amounts of malachite, azurite and cuprite plus trace amounts of native copper covellite and chrysocolla. Occurrence of chalcocite is generally as coatings on pyrite, on chalcopyrite and pyrite or as small discrete chalcocite grains within vuggy mineralized veins.

## STRUCTURE WITHIN THE GRANITE MOUNTAIN PLUTON

Progressive development of the mineralized structure may be considered as follows. It is felt that the saussuritization and the development of the regional foliation is related to a very large scale stress pattern. The large scale is necessary because the foliated metamorphosed quartz diorite is everywhere present throughout the Granite Mountain pluton.

Within the pluton, the detailed consideration must be restricted to the drilled area (Figure 4). Each dot on Figure 4 represents a drill hole. The scale from west to east is about 2 1/2 miles long and from north to south is about 1 mile wide. Within this area, porphyritic rocks are found most commonly in the center of the drilled area. Induced polarization surveys of the drilled area (Figure 5) show that the sulphide zone is peripheral to the area in which porphyritic rocks are most commonly found. The pattern is essentially a low I.P. center (about 1 P.F.E.) surrounded by a higher I.P. rim (5 to 10 P.F.E.). The rough elliptical shape indicates that in part the sulphide zone is guided by the regional foliation.

The effect of the dip of the regional foliation can be seen in Figure 6. While the individual veins parallel and cross-cut the foliation, the overall dip of the mineralization is 20 to 30 degrees to the south. Figure 6 is a north-south section with the Pollyanna zone on the north and the Granite Lake zone on the south. Figure 6 also illustrates the mineral zoning that is present. Starting on the north, the south dipping pyrite zone contains pyrite and minor chalcopyrite and corresponds to an I.P. response of 6 to 10 percent Frequency Effect. The Pollyanna pit occurs inward from the pyrite zone as the chalcopyrite/pyrite ratio increases toward the core. The I.P. response decreases across the Pollyanna pit. On passing into the low sulphide porphyry-bearing core area, the mineral assemblage becomes chalcopyrite and bornite with only trace amounts of pyrite. I.P. response in the core area is about 1 to 2 P.F.E. The same sequence is repeated in reverse across the Granite Lake pit with the exception that the pyrite zone and the I.P. response are more pronounced to the south of the Granite Lake pit because the pyrite zone now lies close to the surface.

Within the Gibraltar East pit, a system of folds is exposed. Individual bands of varying width within the overall south dipping zone of fracturing may be folded or intimately contorted while adjacent bands are relatively undisturbed. Fold axes plunge 10 to 15 degrees to the southeast. Stage 3 and 4 veins show a tendency to locate in the axial zones of the more contorted folds but these veins are definitely not restricted to this mode of occurrence.

An inferred structural block as outlined in Figure 7 is suggested for the general Gibraltar area. The western boundary is the Fraser fault system. The two double lines which extend outside the block represent the regional foliation which has an azimuth of 110° and a dip of 20° to 30° southerly. Figure 7 shows a stockwork development around the porphyry-bearing core. The stockwork could be developed either by the effect of a couple or by a doming-collapse type of mechanism. Either mechanism could produce the four stages of cross-cutting veins that are observed in the mineralized zones.

Figure 8 is essentially the same as the last except that the position of the copper is shown with respect to the porphyry-bearing core and to the total extent of the stockwork.

It is important to appreciate that the saussuritization and the development of the foliation is pre-mineralization. Intrusion of the porphyritic rocks produced the stockwork which mineralized and hydrothermally altered the regionally foliated and metamorphosed quartz diorite host. The elliptical shape of the zone in which the Gibraltar deposits occur indicates that the presence of the regional foliation has in part acted as a structural control. The long axis of the elliptical zone is parallel to the trend of the foliation.

## SUMMARY

The interrelationship of all the geological features encountered in the Gibraltar copper deposits may be summarized chronologically as follows:-

1) During Jurassic-Cretaceous time, Permian Cache Creek group rocks were intruded by the Granite Mountain pluton. The pluton is primarily a quartz diorite which has a dioritic border phase.

2) Deformation of the pluton has produced simultaneously widespread saussuritization and foliation in the quartz diorite. The mineral assemblages produced vary with the intensity of the development of the foliation and are compatible with those of the greenschist facies of regional metamorphism.

3) As the development of the foliation lessened, the leucocratic porphyritic quartz diorite and the quartz-feldspar porphyry were intruded. The feldspars in these rocks are saussuritized but the rocks are not foliated.

4) A fracture system was developed spatially around the porphyry-bearing area. This stockwork which is imposed on, and partly controlled by, the regional foliation, contains a locally wide but regionally restricted sulphide zone. Within the sulphide zone, a chalcopyrite-secondary chalcocite-minor

molybdenite zone occurs between the low sulphide core and a pyritic halo.

It can be seen that regional metamorphism of the Granite Mountain pluton preceded the intrusion of porphyry which in turn caused the development of the stockwork with its four stages of mineralization and its hydrothermal alteration. Thus, Gibraltar is a porphyry copper deposit which is unique in that it occurs entirely within a previously metamorphosed pluton.

ACKNOWLEDGMENTS

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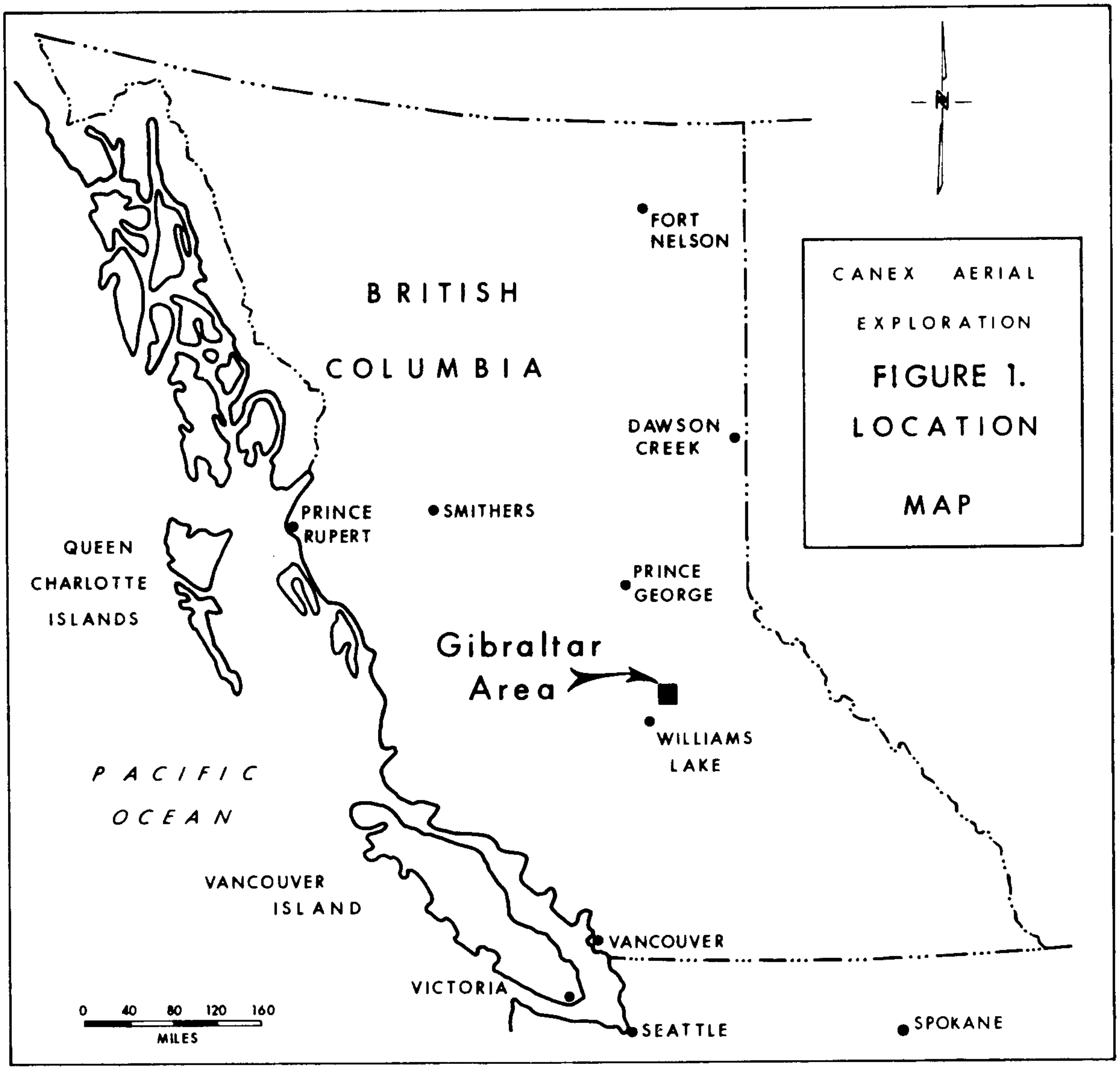
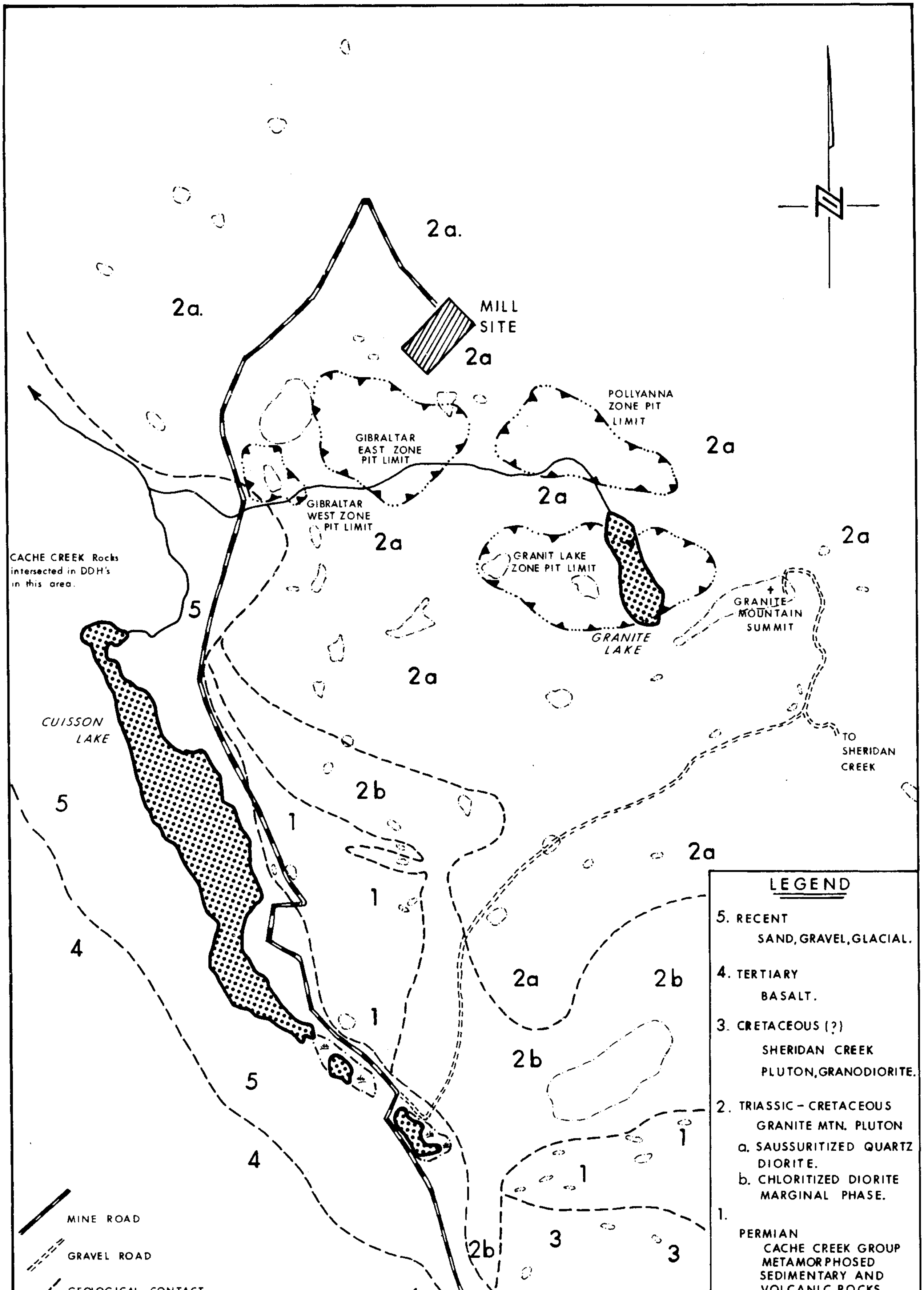



CANEX AERIAL EXPLORATION

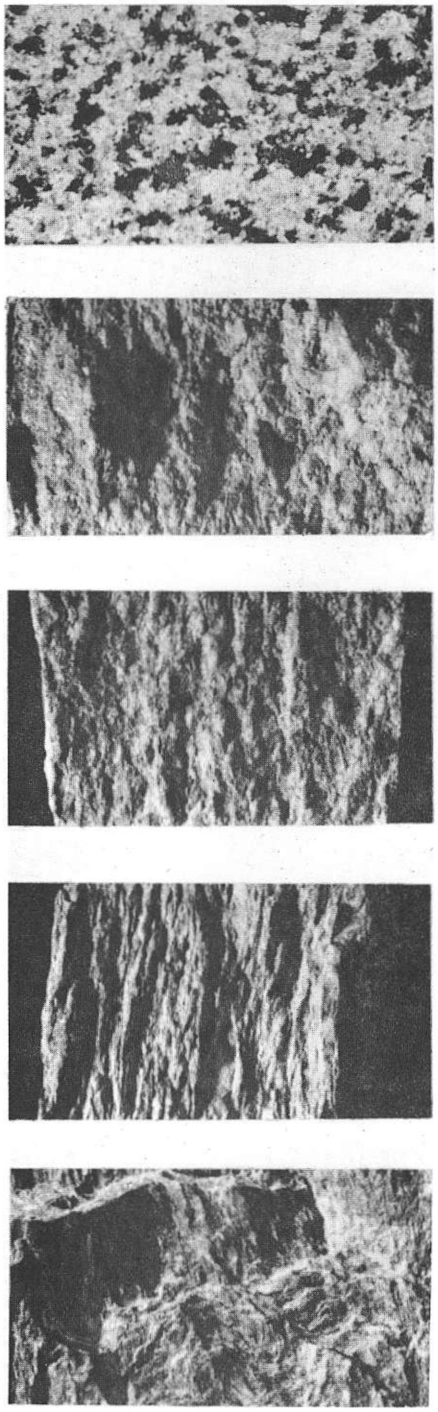
FIGURE 1. LOCATION MAP




CANEX AERIAL EXPLORATION LTD.

**Generalized Geological Map**
**Gibraltar - Pollyanna Area.**

SCALE: 1" = 2000' - JULY, 1972 - **FIGURE 2.**



(a) Saussuritized Quartz Diorite.
(Non - directional)

(b) Saussuritized Quartz Diorite.
(Weak foliation)

(c) Chloritized Quartz Diorite.
(Strong foliation)

(d) Chlorite Laminated 'Quartz Diorite.'

(e) Contorted Chlorite Laminated.
'Quartz Diorite'

FIGURE 3.: Photographs of Granite Mountain plutonic rocks showing the variation in rock type with degree of foliation.

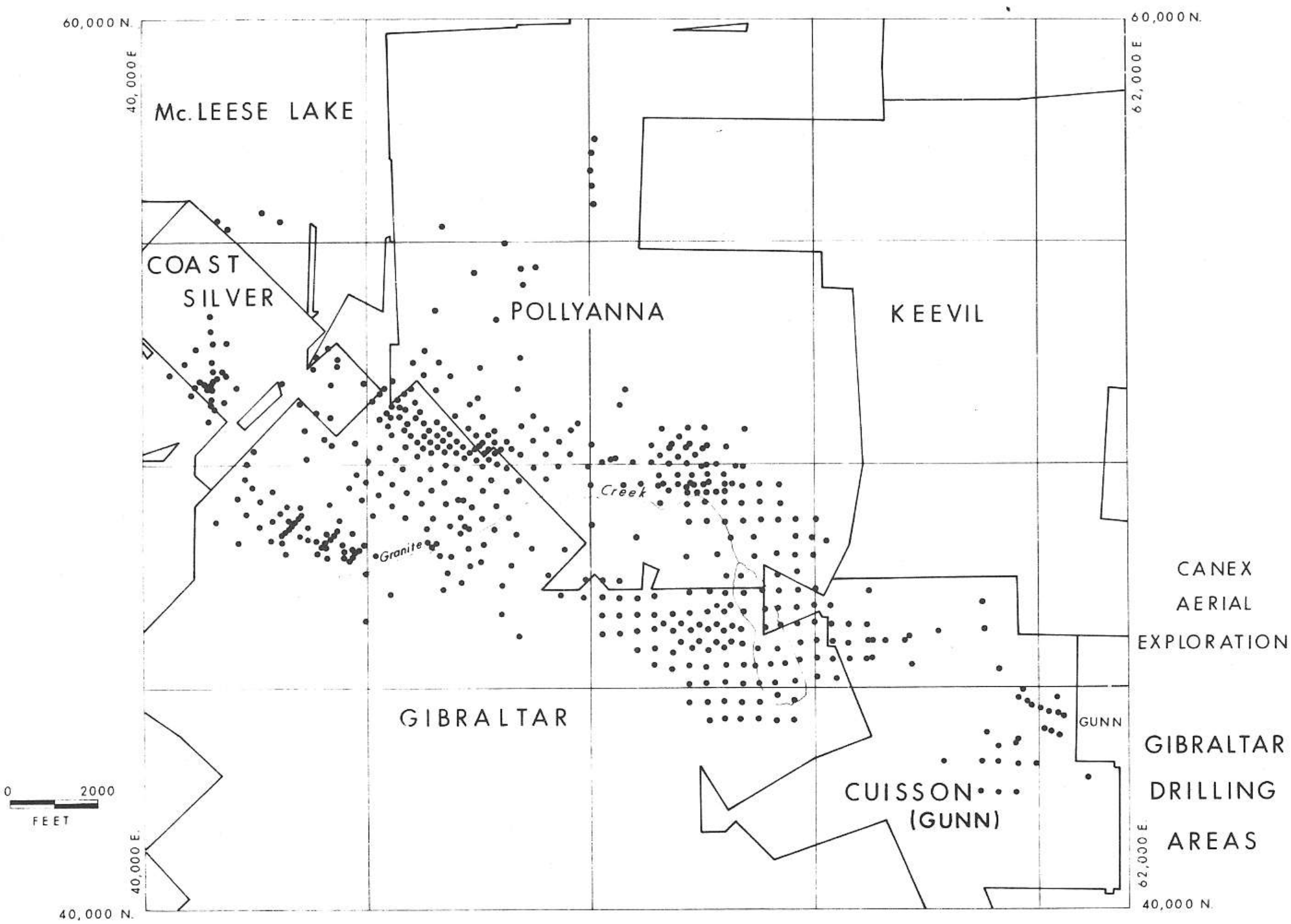
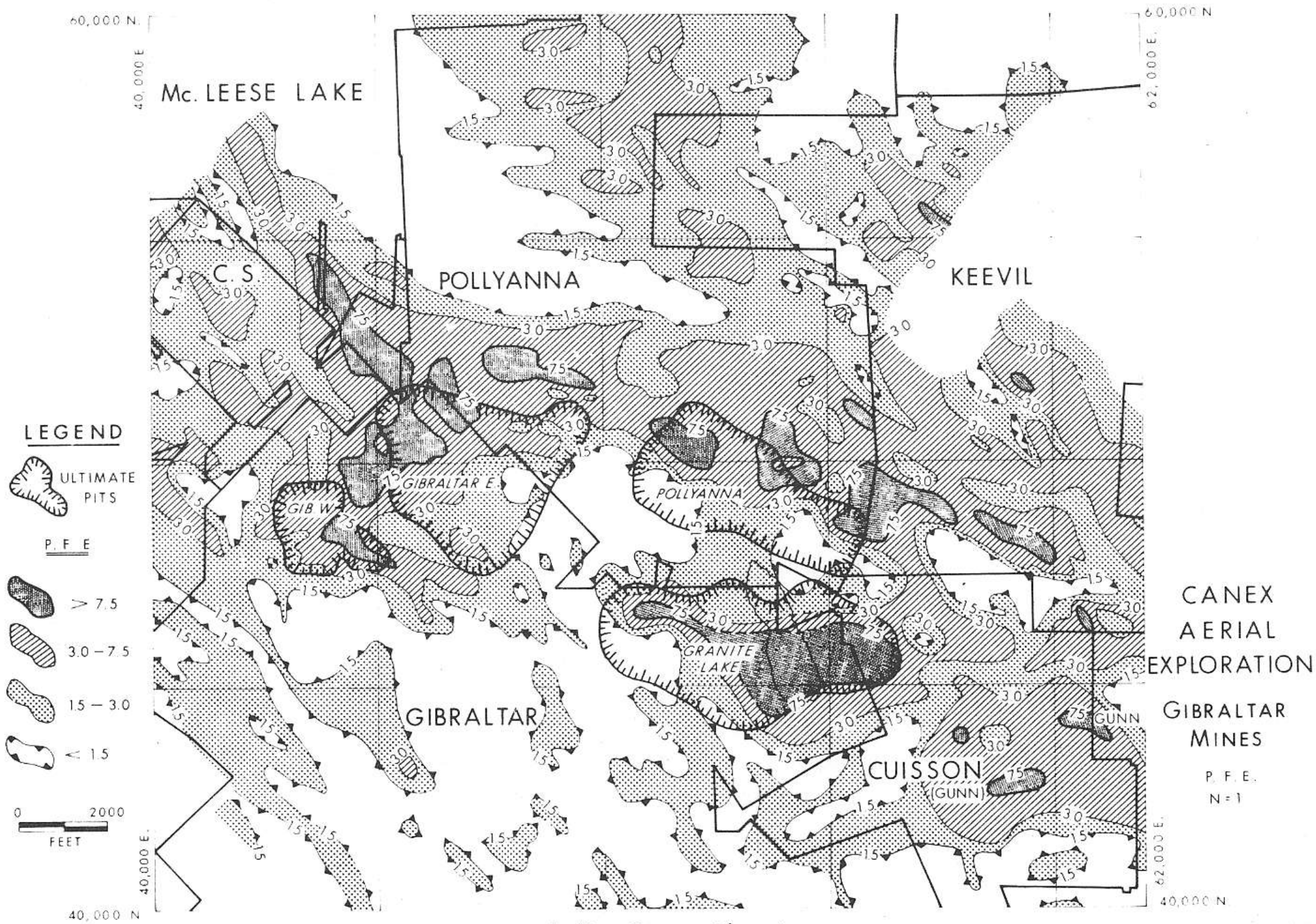
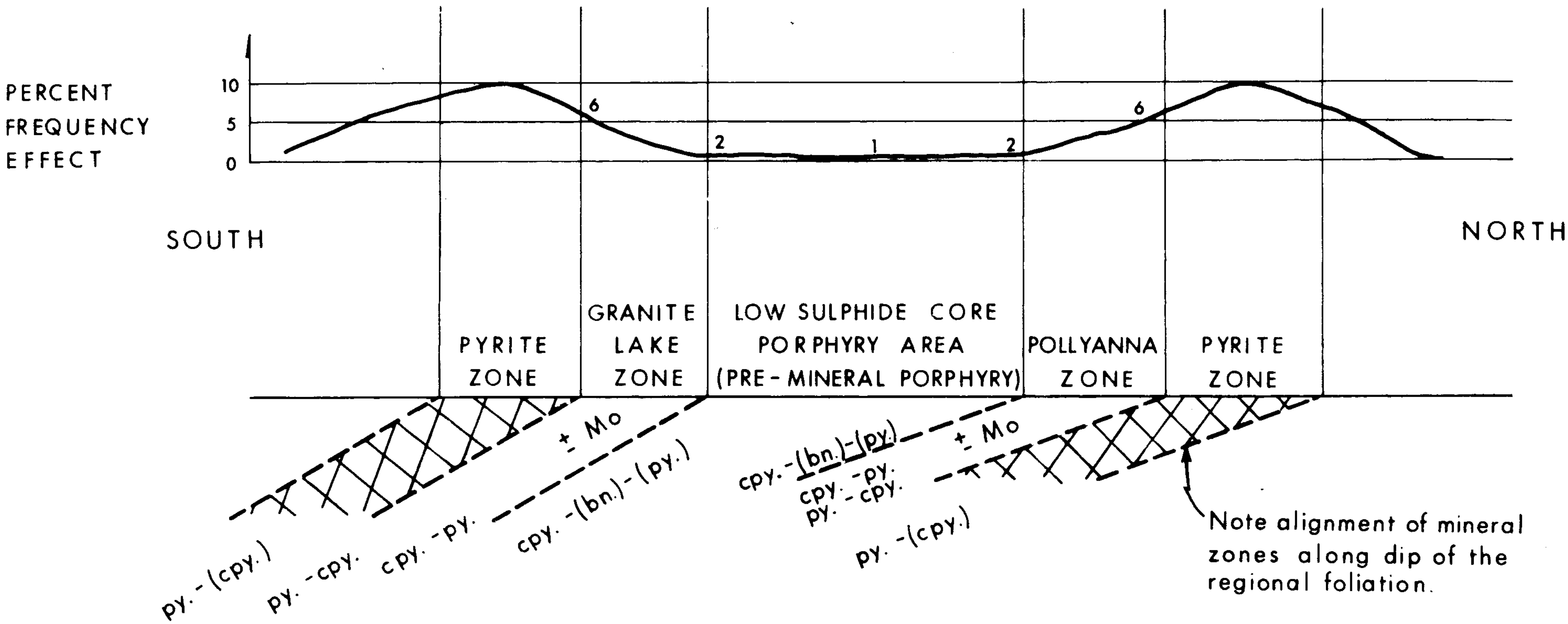

60,000 N.
40,000 E.
Mc.LEESE LAKE
60,000 N.
62,000 E.
COAST
SILVER
POLLYANNA
KEEVIL
Creek
Granite
CANEX
AERIAL
EXPLORATION
GIBRALTAR
GUNN
GIBRALTAR
DRILLING
AREAS
CUISSON
(GUNN)
0
2000
FEET
40,000 E.
40,000 N.
62,000 E.
40,000 N.

FIGURE 4.



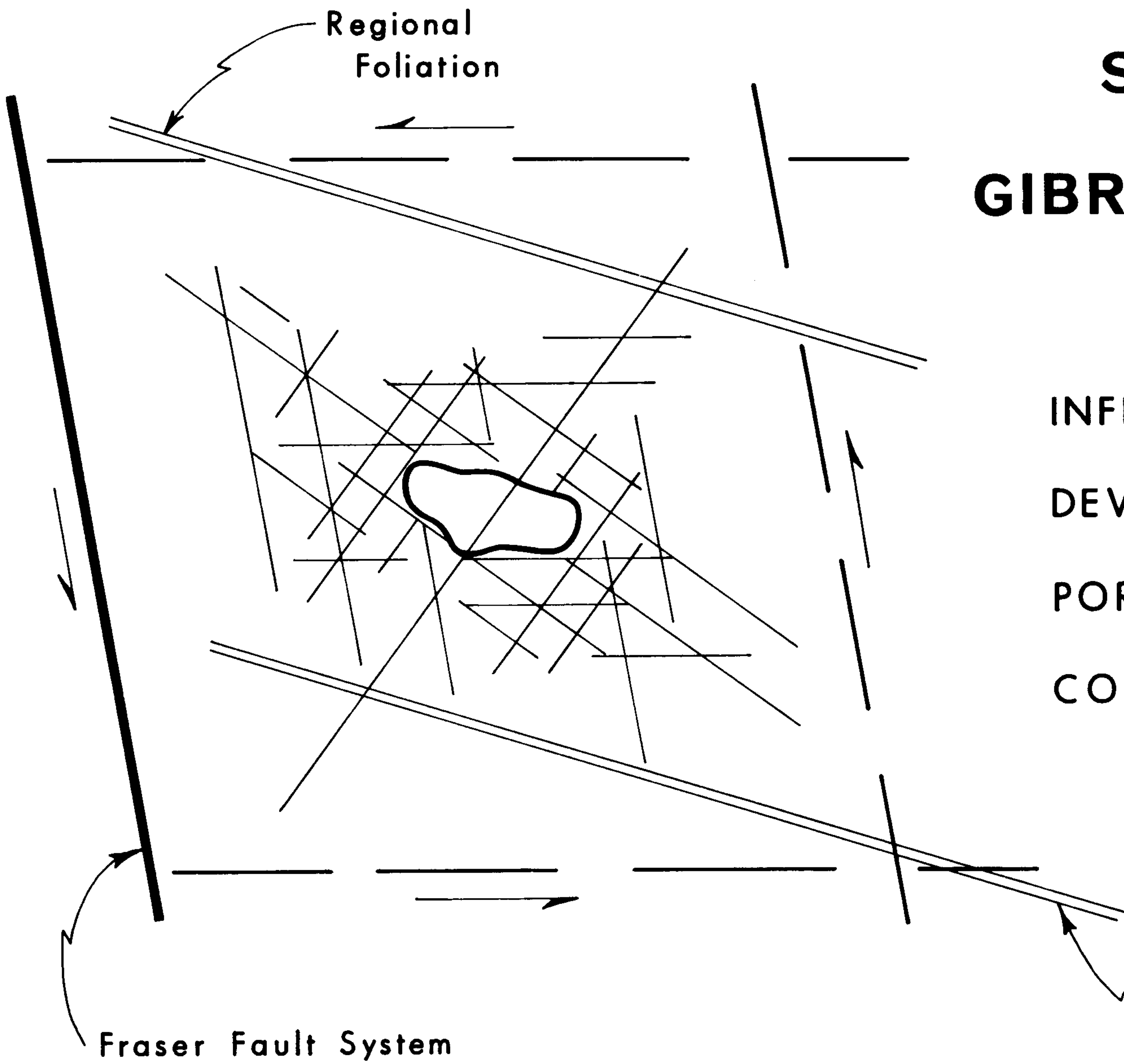

I. P. Compilation

FIGURE 5.




DIAGRAMMATIC NORTH-SOUTH CROSS-SECTION OF THE POLLYANNA AND GRANITE LAKE ZONES SHOWING THE RELATIONSHIP OF I.P. RESPONSE, PRIMARY SULPHIDE MINERAL ZONING AND LOCATION OF THE RESPECTIVE OPEN PITS.

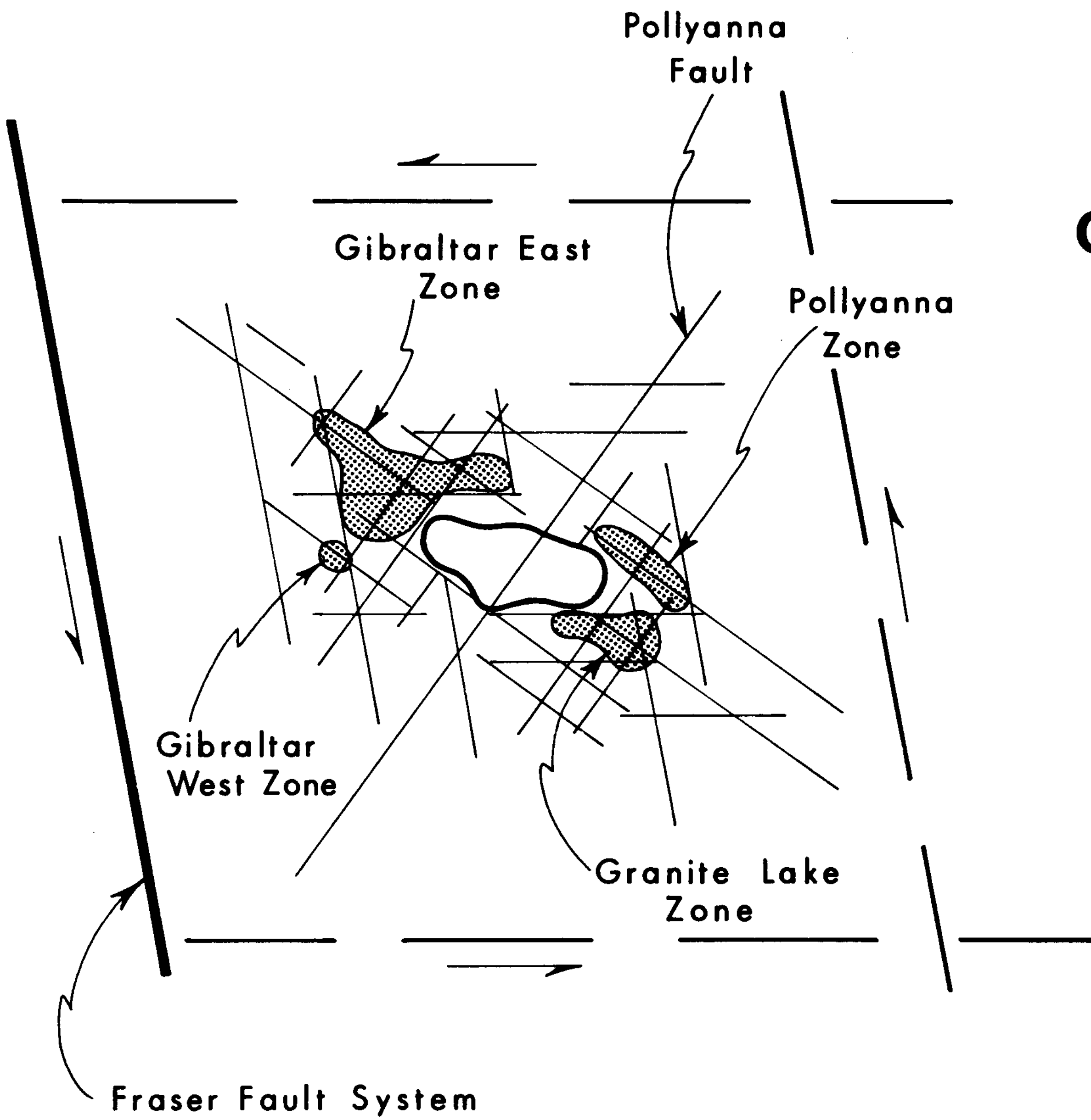
**FIGURE 6.**




# STRUCTURE GIBRALTAR AREA

INFERRED STOCKWORK DEVELOPED AROUND PORPHYRY - BEARING CORE.

FIGURE 7.




# STRUCTURE
# GIBRALTAR AREA

LOCATION OF

Cu — Mo

DEPOSITS WITHIN

DEVELOPED

STOCKWORK.

FIGURE 8.