Paper 19

014124 (final corrected)

93B/8E-07
ME 175

GIBRALTAR - REGIONAL METAMORPHISM, MINERALIZATION, HYDROTHERMAL ALTERATION AND STRUCTURAL DEVELOPMENT

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ABSTRACT

The Gibraltar porphyry copper-molybdenum deposit is unique within the Canadian Cordillera because it occurs within the regionally metamorphosed Granite Mountain pluton.

Gibraltar Mines is located on the western slope of Granite Mountain 362 km north of Vancouver, B.C. and 60 km north of Williams Lake, B.C. There are four mineable zones within this porphyry copper-molybdenum deposit: Gibraltar East, Gibraltar West, Pollyanna and Granite Lake. Open pit reserves in June 1972 were 326,500,000 metric tons which averaged 0.37 percent Cu and 0.016 percent MoS_2 at a 0.25 percent cut-off.

The Granite Mountain pluton which has been dated at 204 m y intrudes volcanic rocks of the Cache Creek group and is one of several Mesozoic intrusions which occur along the east side of the Fraser River fault system between Williams Lake and Prince George, B.C. At the margin of the pluton a sheared and chloritized diorite occurs peripherally to a saussuritized and cataclastically foliated quartz diorite which forms the main phase of the pluton. The mineralogy of the main phase is compatible with that of the greenschist facies.

Pre-mineral intrusive phases within the main saussuritized quartz diorite phase are: (1) leucocratic porphyritic quartz diorite (2) quartz-feldspar porphyry and (3) aplite which form a core to the pluton. A chloritized microdiorite dyke is post-mineral.

The four mineable zones occur peripherally to later intrusive leucocratic and porphyry phases and indicate an elliptically shaped sulphide-bearing stockwork which is 4 km long and 1.6 km wide. The stockwork which comprises four ages of vein development has been imposed on and modified by continuing deformation within the saussuritized main quartz diorite phase. Earlier vein stages have been folded while the last vein stage filled late tensional fractures.

INTRODUCTION

The occurrence of a porphyry copper deposit within a regionally metamorphosed and foliated quartz diorite is unique within the Canadian Cordillera. This paper will describe a continuum of events which started emplacement of the zoned Granite Mountain pluton which was metamorphosed and deformed while a vein system was initiated. The latter was further deformation, mineralization and hydrothermal alteration.

LOCATION

The copper orebodies of Gibraltar Mines Ltd. are located on the western slope of Granite Mountain in Central British Columbia, NTS 93B/9W (Figure 1). The property is about 362 km northeast of Vancouver. Access is by 20 km of paved road from McLeese Lake, which is 45 km 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 1068 m and 1251 m. The peak of Granite Mountain at 1399 m is one of the highest points in the area.

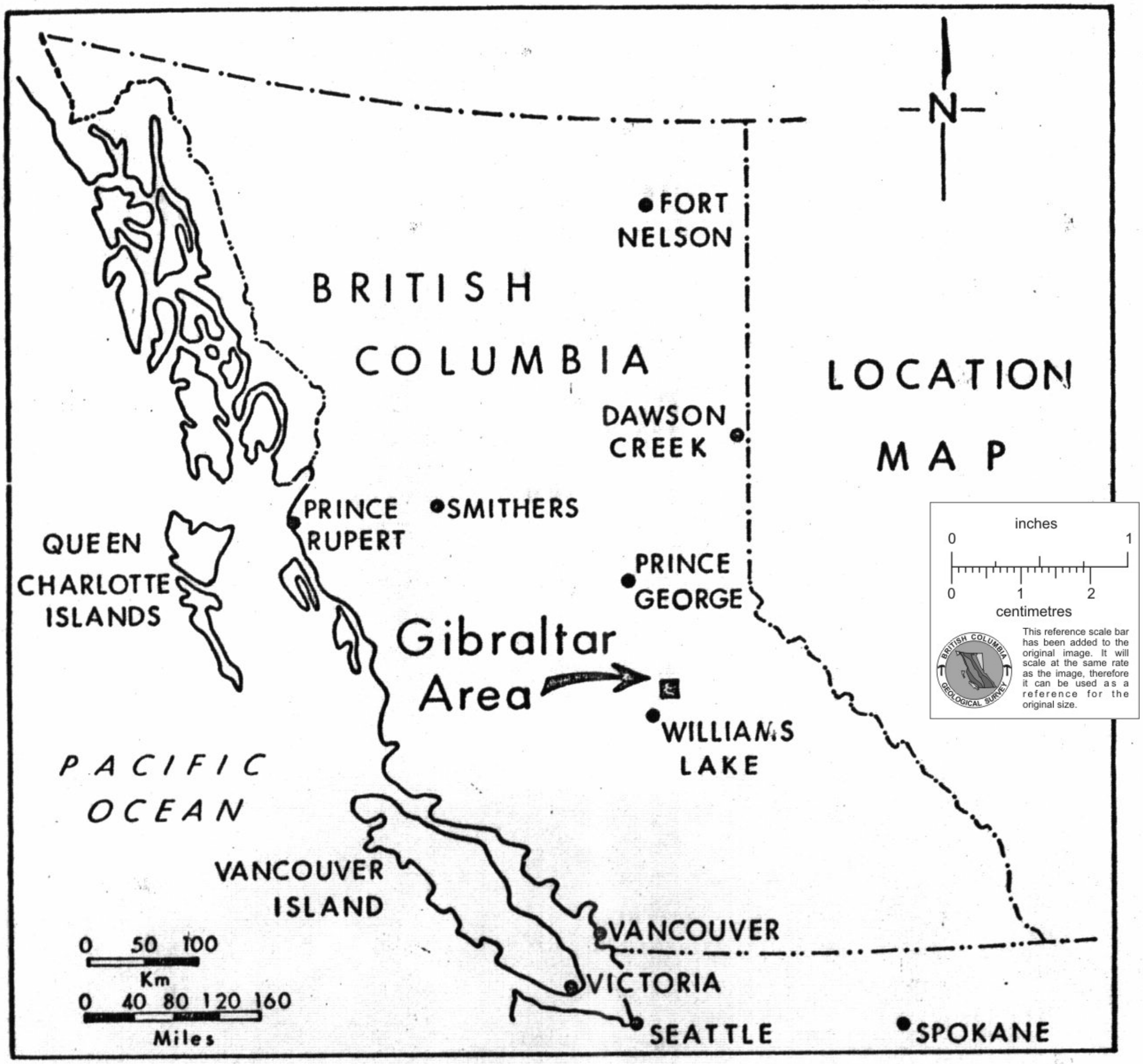

BRITISH
COLUMBIA
LOCATION
MAP
N
FORT
NELSON
DAWSON
CREEK
PRINCE
RUPERT
SMITHERS
PRINCE
GEORGE
QUEEN
CHARLOTTE
ISLANDS
Gibraltar
Area
WILLIAMS
LAKE
PACIFIC
OCEAN
VANCOUVER
ISLAND
VANCOUVER
VICTORIA
SEATTLE
SPOKANE
0 50 100
Km
0 40 80 120 160
Miles

FIGURE 1

Ambient air temperature ranges from a winter minimum of -34°C to a summer maximum of 35°C. Annual precipitation at the minesite is approximately 51 cm of which about 17 cm falls as snow. Maximum snow depth is about 1 m , most of which falls in late February.

HISTORY, OWNERSHIP AND PRODUCTION

The Gibraltar and Pollyanna properties were for the most part explored separately until 1969.

The original Gibraltar property was discovered in 1927 and was known as the Hill property (Lay, 1929). In 1957, Kimaclo Mines Ltd. drove a 36 metre adit into the Sunset shear zone, now known as Gibraltar West. During 1958, the property was sold to Major Mines Ltd. which allowed the property to lapse. John Hilton restaked the property on January 1, 1962 and optioned it to Keevil Mines Ltd. until 1964, when Gibraltar Mines Ltd. acquired it from Hilton. Cominco Ltd. then optioned the property from Gibraltar and, in partnership with Mitsubishi Mining Co., delineated the Gibraltar West zone before terminating their option in 1967. The property was finally optioned in 1969 by Canex Placer Limited and Duval Corporation, who were exploring the adjacent Pollyanna property. The Gibraltar East zone was then developed along the border of the Gibraltar and Pollyanna claims.

Pollyanna, which was originally known as the Rainbow Group, was discovered in 1910 and prospected again in 1925. The showings were restaked as the Copper King in 1949 when a shipment of 454 kg of 10.5 percent copper was made. Kimaclo Mines held the property between 1954 and 1956. Restaked in 1963 by Robert Glen, the property was optioned until 1964 by Keevil

Mines Ltd. Duval Corporation Ltd. then optioned the property and was joined in 1967 by Canex Placer Limited, which acquired the Duval interest in 1969. By 1970, when the Granite Lake zone was discovered, Canex Placer Limited held more than 70% of the issued shares of Gibraltar Mines Ltd. A production decision was made in November of that year and the mine opened in June 1972. The concentrator is currently operating at a rate of about 36,000 tonnes per day.

Ore reserves at December 31, 1971, using a cutoff grade of 0.25 percent copper, were:

Zone	Short Tons	Copper (%)
Gibraltar East	150,000,000	0.372
Granite Lake	120,000,000	0.373
Pollyanna	81,000,000	0.360
Gibraltar West	9,000,000	0.400
TOTAL	360,000,000	0.371 (plus 0.016% MoS_2)
	(326,500,000 tonnes)	

Overall strip ratio is 2.15 : 1. During the early years of the mine operation, about 50,000,000 tonnes of 0.44% Cu will be available at a strip ratio of about 1.45 : 1. To December 31, 1974 a total of 35,686,251 tonnes have been milled. Not included in the total reserves is 12,700,000 tonnes of ore in the Granite Lake orebody, which is held by Cuisson Lake Mines Ltd.

REGIONAL GEOLOGY

The precise nature of the setting of the Granite Mountain pluton, within which the Gibraltar copper-molybdenum deposits occur, is obscured by glacial drift, alluvium and Miocene plateau basalts. The Granite Mountain pluton is situated near the boundary between two major longitudinal elements of the Intermontane Tectonic belt, that is, the Pinchi geanticline and the Quesnel trough (Figure 2). The Quesnel trough is underlain by Triassic volcanic rocks and flaggy limestone and younger Mesozoic volcanic and classic rocks. A major fault bordering the Triassic components of the trough strikes northwestward about 16 km east of the Granite Mountain pluton. Jurassic volcanic and sedimentary rocks occur to the west of the main fault-bounded trough in a belt that may also be bordered on the west by a fault. Further west on the Pinchi geanticline, these rocks also overlap the Cache Creek Group and probably also the Granite Mountain pluton. The basal conglomerates of this Lower Jurassic sequence on Dragon Mountain contain granitic cobbles, petrographically similar to rocks comprising the Granite Mountain pluton.

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). The Granite Mountain area has been described by Sutherland Brown (1958, 1967 and 1974), Eastwood (1970), Humphrey (1968), and Drummond, Tennant and Young (1973). The general Gibraltar Mine area was discussed by Rotherham, Drummond and Tennant (1972) and Drummond (1972), while the geophysical aspects have been covered by Cannon, Thornton and Rotherham (1972).

Batholithic intrusives of Triassic to Cretaceous age intrude 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

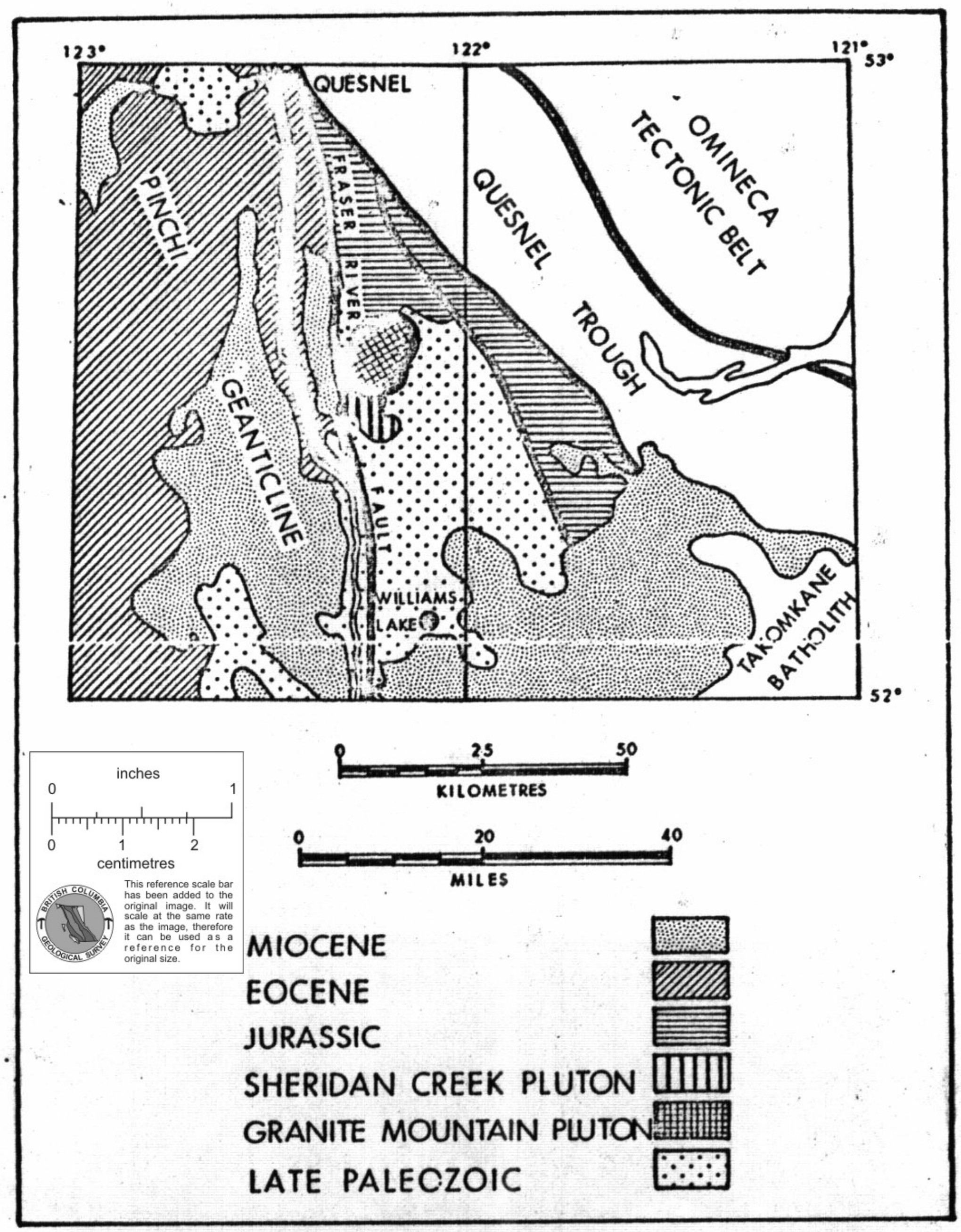


FIGURE 2 Tectonic sketch map of Central Cariboo

~~(Modified after A. Sutherland Brown (1974)).~~

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 with a chlorite-rich diorite margin cuts rocks of the Cache Creek Group (Figure 3). Calcareous members of the latter show some local skarn development adjacent to the diorite contact. The Gibraltar copper-molybdenum deposits occur within the regionally metamorphosed and foliated quartz diorite (Figure 3).

The Late Mesozoic and earliest Tertiary appear to have been times of erosion but in the Eocene Epoch acidic and basic volcanic rocks plus some sedimentary rocks accumulated. These units now outcrop west of McLeese Lake and are tilted and faulted. Their eastern boundary appears to coincide with a major northerly striking fault zone followed by the Fraser River. The youngest rocks in the area are Miocene olivine basalt flows that cap the plateaus on both sides of the Fraser River. These flood basalts are flat lying and appear to be unfaulted. They form buttes west of Cuisson and McLeese Lakes and diamond-drill core shows that they also fill the valley of Cuisson Lake to a depth of about 92 m overlying Granite Mountain plutonic rocks.

PETROLOGY OF THE MAIN PHASES 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.

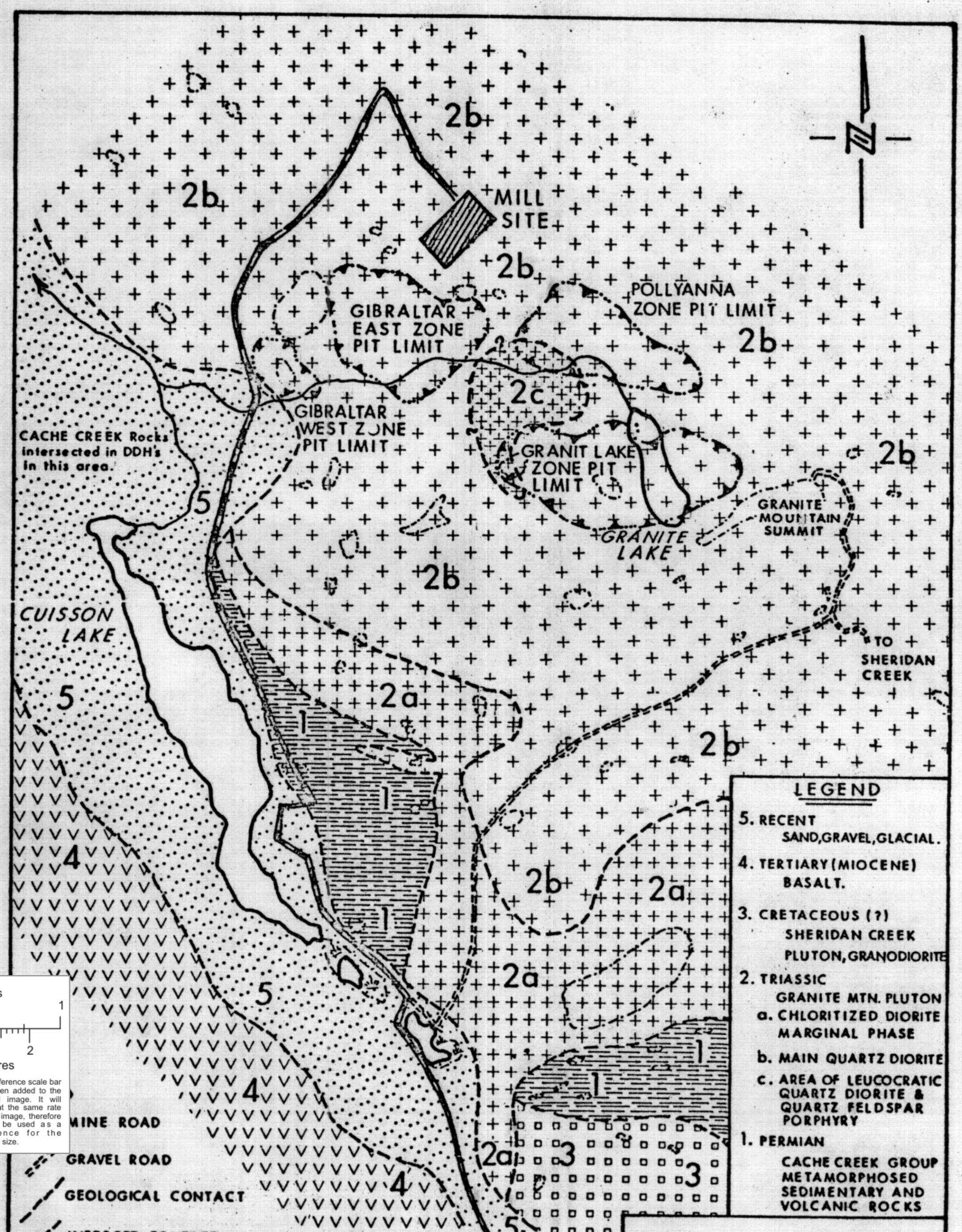

MILL SITE
2b
GIBRALTAR EAST ZONE PIT LIMIT
POLLYANNA ZONE PIT LIMIT
2c
GIBRALTAR WEST ZONE PIT LIMIT
CACHE CREEK Rocks intersected in DDH's in this area.
GRANIT LAKE ZONE PIT LIMIT
GRANITE MOUNTAIN SUMMIT
GRANITE LAKE
CUISSON LAKE
TO SHERIDAN CREEK
2a
1
3
4
5
LEGEND
5. RECENT SAND,GRAVEL,GLACIAL.
4. TERTIARY (MIOCENE) BASALT.
3. CRETACEOUS (?) SHERIDAN CREEK PLUTON, GRANODIORITE
2. TRIASSIC GRANITE MTN. PLUTON
a. CHLORITIZED DIORITE MARGINAL PHASE
b. MAIN QUARTZ DIORITE
c. AREA OF LEUCOCRATIC QUARTZ DIORITE & QUARTZ FELDSPAR PORPHYRY
1. PERMIAN CACHE CREEK GROUP METAMORPHOSED SEDIMENTARY AND VOLCANIC ROCKS
MINE ROAD
GRAVEL ROAD
GEOLOGICAL CONTACT
INFERRED CONTACT
OUTCROP AREAS
Km
Miles
TO McLEESE LAKE
Generalized Geological Map
Gibraltar Mine Area
inches
centimetres
This reference scale bar has been added to the original image. It will scale at the same rate as the image, therefore it can be used as a reference for the original size.

FIGURE 3

(a) Saussuritized Quartz Diorite (isotropic)

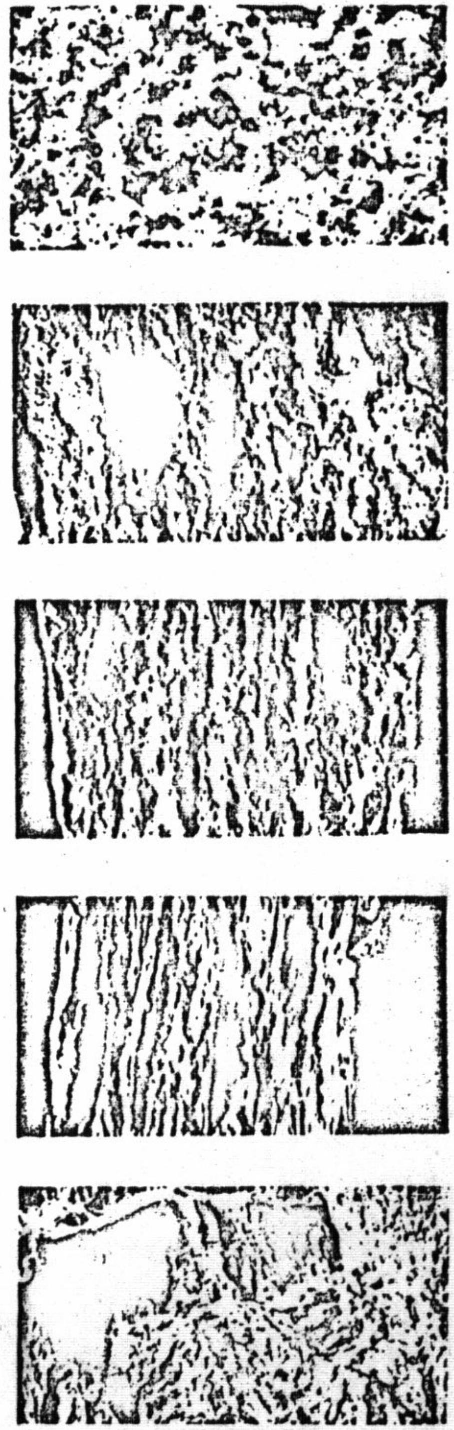
This rock is composed of quartz (25-30%), "plagioclase", which is normally a mixture of albite-epidote-zoisite-muscovite (50-55%), and chlorite (20%, which originally was biotite with minor hornblende and disseminated magnetite (1% or less). Where least altered, the composition of the plagioclase is shown to be An_{35}. The rock is equi-granular and generally has a grain size of 2-4 mm (Figure 4 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 4 b).

(c) Chloritized Quartz Diorite (strong foliation)

With further deformation, the foliation becomes much more notable as more definite slip surfaces develop (Figure 4 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



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

(b) Saussuritized Quartz Diorite. (Weak foliation) (S_2)

(c) Chloritized Quartz Diorite. (Strong foliation) (S_2)

(d) Chlorite Laminated "Quartz Diorite." (S_2 with F_3)

(e) Contorted Chlorite Laminated. "Quartz Diorite" (folded S_2)

FIGURE 4 : Photographs of Main Phase, Granite Mountain plutonic rocks showing the variation in rock type with degree of deformation.

rotated and crushed quartz grains and by carbonate deposition in the 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 so that the original quartz diorite has become a schist which has been named a chlorite-laminated quartz diorite. The mineral assemblage is quartz-albite to oligoclase-chlorite-muscovite-magnetite (Figure 4 d). A variation of this rock is a chlorite-muscovite-schist.

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 Figure 4 e.

LATER 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 area 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 composed of quartz, albitic plagioclase and some carbonate, muscovite and zoisite. Both the porphyry and the leucocratic phase are pre-mineralization.

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

The leucocratic rocks appear to be common northwest of Granite Lake in the area between the three main orebodies (Figure 3). Unfortunately, this zone or core is sparse in outcrop and drill holes are widely spaced so that the leucocratic rocks cannot be outlined with complete assurance at present. Within this core zone most of the rocks are leucocratic and quartzose, and have been cut by quartz stockwork that is commonly barren or almost barren, of primary sulphides. Some main phase rocks are interfingered with the leucocratic phase and both are cut by extensive barren or low sulphide bearing quartz stockwork. The contacts between the leucocratic and main phase appear to be parallel to the foliation which is abnormally flat in the central part of the core zone. Some of the drill holes in the central core show not only much quartz feldspar porphyry, but also gradations between this type and truly leucocratic quartz diorite. Other contacts between these two types are sharp and intrusive. The quartz feldspar porphyry in turn grades into aplite that constitutes one of the few dyke types present in the area. Hence, there is an apparently complete gradation from leucocratic quartz diorite of the central core to quartz feldspar porphyry and outward to thin aplite dykes. This transition in space is evident also petrologically. The leucocratic variety has a semi-porphyritic nature with a framework of chunky plagioclase up to 5 mm long and equant grains of quartz and rare masses of chlorite after biotite or hornblende crystals of about the same size. A sparse matrix consists of aplitic fine quartz, plagioclase, and alkali feldspar. Alteration minerals commonly include much sericite, particularly at plagioclase grain boundaries and fractures, poikiloblastic carbonate grains in matrix, and clinozoisite disseminated in plagioclase and chlorite.

One post-ore dyke was found in the Gibraltar East pit. It is a microdiorite dyke about 60 cm wide that strikes N 20° E and dips about 75° west. Microscopically, the rock has an insertal holocrystalline texture and is composed of about 60 percent thin andesine laths, 25 percent chlorite after hornblende, 5 percent quartz, and 10 percent porphyroblastic epidote.

CHEMICAL ANALYSIS

Two specimens were collected about 31 m apart near the western rim of the Granite Lake pit. Specimen 73-AB-24 is representative of the main phase and 73-AB-25 is relatively leucocratic. Table 1 ~~(after A. Sutherland Brown, 1974)~~ shows chemical analyses for these two specimens as well as Nockolds' (1954) average tonalite (quartz diorite) and granodiorite. A comparison indicates that the specimens are between Nockolds' averages.

TABLE I

CHEMICAL ANALYSES

GRANITE MOUNTAIN PLUTON

	73-AB-24	73-AB-25	Average Quartz Diorite	Average Granodiorite
SiO_2	68.0	70.5	66.15	66.88
Al_2O_3	15.16	14.75	15.56	15.66
MgO	1.51	1.39	1.94	1.57
CaO	3.99	3.03	4.65	3.56
Na_2O	3.93	4.02	3.90	3.84
K_2O	1.99	2.38	1.42	3.07
TiO_2	0.45	0.37	0.62	0.57
MnO	0.076	0.075	0.08	0.07
FeO	1.76	1.54	3.42	2.59
Fe_2O_3	1.91	1.61	1.36	1.33
$+H_2O$	1.24	1.00	0.69	0.65
$-H_2O$	0.16	0.04	-	-
CO_2	0.07	0.055	-	-
P_2O_5	0.18	0.18	0.21	0.21
S	0.01	0.01	-	-

1) Main phase - Granite Mountain pluton from 2,000 feet west of Granite Lake. Analysis - P.F. Ralph, Analytical Laboratory, B.C. Department of Mines and Petroleum Resources.

2) Leucocratic phase - Granite Mountain pluton, 31 m northwest of 73-AB-24. Analysis - P.F. Ralph, Analytical Laboratory,

B.C. Department of Mines and Petroleum Resources.

3) Nockolds' average tonalite (quartz diorite).

4) Nockolds' average granodiorite.

AGE

The age of the Granite Mountain pluton indicated by stratigraphic relationships is as follows: the pluton cuts Late Paleozoic Cache Creek rocks; and boulders similar to it occur in basal conglomerates of Lower Jurassic age. Specimans 73-AB-24 and 73-AB-25 collected west of Granite Lake were the freshest found in the pluton and provided clean, unaltered hornblende separates in both cases and in 73-AB-24, biotite with very minor interleaved chlorite. These separates were sent to the Department of Geological Sciences at the University of British Columbia and were analysed under the direction of J. Harakal. The clean hornblendes gave a 204 $\pm$ 6 m y and 203 $\pm$ 6 m y or a Triassic age. Biotite from 73-AB-25 which contained very minor interleaved chlorite gave 82 $\pm$ 2.5 m y and 84 $\pm$ 2.5 m y ages in two analysis which may suggest a late Cretaceous age but this age is also associated with metamorphism and intrusion in the general Intermontane Belt. The 204 m y age would seem to be the most likely.

MINERALIZATION AND HYDROTHERMAL ALTERATION

There are at least four stages of veining recognized within the Gibraltar deposits. The grouping 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: (V_1)

(a) quartz-pyrite $\pm$ chalcopyrite WITH a sericite envelope (sericite envelope assemblage is quartz, sericite, pyrite $\pm$ chalcopyrite, with all the saussuritized feldspar being made over to sericite-clay (?) mixture);

(b) quartz-chlorite-pyrite-chalcopyrite-magnetite $\pm$ carbonate WITH a chloritic envelope (chlorite envelope assemblage is quartz, chlorite, pyrite $\pm$ chalcopyrite, with a pronounced absence of epidote in the saussuritized feldspar);

Stage 2: (V_2)

(a) quartz-chlorite-pyrite $\pm$ magnetite;

(b) quartz-chlorite-pyrite-chalcopyrite-epidote $\pm$ magnetite;

(c) quartz-chlorite-pyrite-epidote $\pm$ magnetite;

(d) quartz-chlorite-pyrite-chalcopyrite + magnetite;

(e) quartz-chalcopyrite-bornite $\pm$ pyrite (restricted to porphyry area between the Pollyanna and Granite Lake zones) (all with $\pm$ carbonate);

Stage 3: (V_3)

quartz-molybdenite-chalcopyrite-pyrite $\pm$ magnetite $\pm$ carbonate;

Stage 4: (V_4)

massive white quartz - blebs of fine-grained chlorite - chalcopyrite blebs.

Veins with sericitic and 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 (V_1).

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. A pervasive increase in sericite or potassium associated with a sulphide zone is a typical chemical feature of a porphyry copper stockwork.

MINERAL ZONING

Within the pluton, the detailed consideration must be restricted to the exposed or mined area. The area encompassing the pits is about 4 km long from west to east and from north to south about 1.6 km wide. Porphyritic rocks are found most commonly in the centre of the main mineralized zones (Figure 3). Induced polarization surveys (Figure 5) show that the sulphide zone is peripheral to the area in which leucocratic porphyritic rocks are most commonly found. The pattern essentially shows a low Induced Polarization (about 1 Percent Frequency Effect) surrounded by a higher-I P rim (5 to 10 P F E).

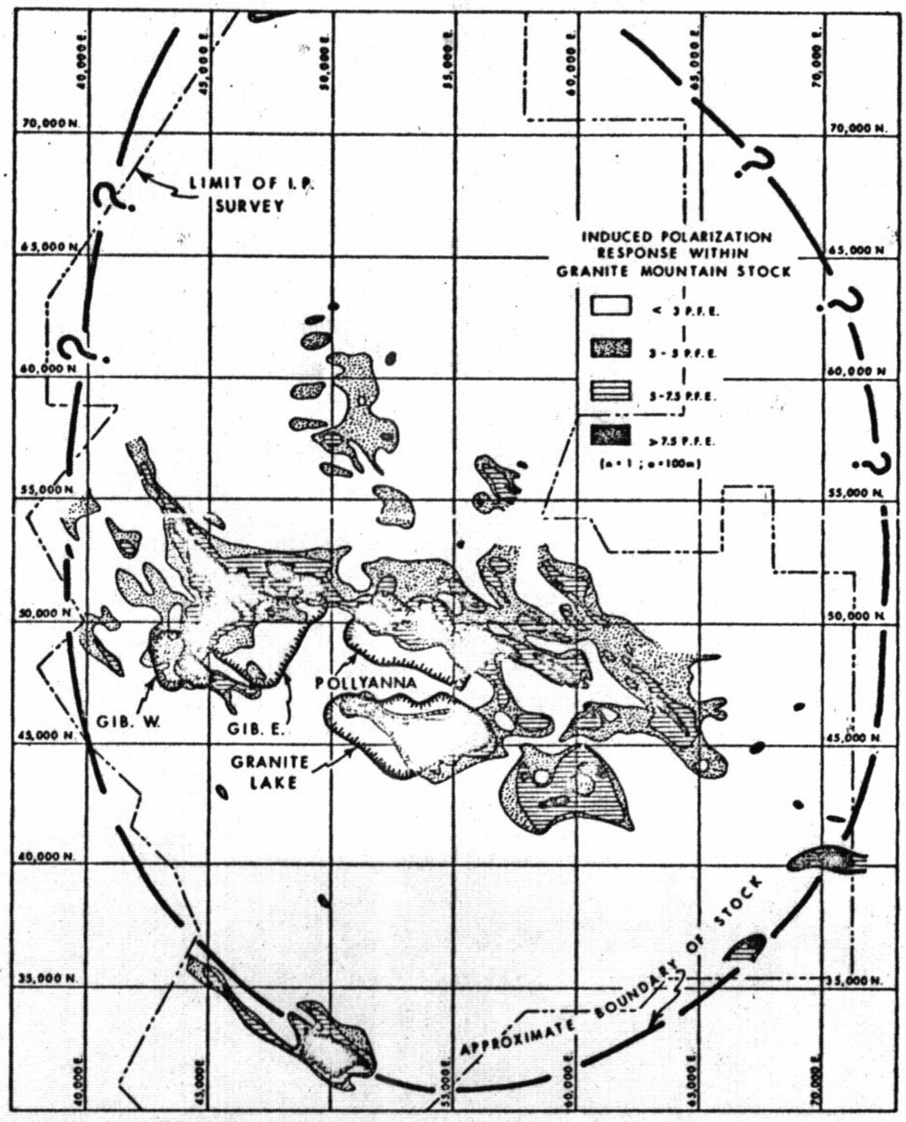

LIMIT OF I.P. SURVEY
INDUCED POLARIZATION RESPONSE WITHIN GRANITE MOUNTAIN STOCK
< 3 P.F.E.
3 - 5 P.F.E.
5 - 7.5 P.F.E.
> 7.5 P.F.E.
(n = 1 ; a = 100m)
70,000 N.
65,000 N.
60,000 N.
55,000 N.
50,000 N.
45,000 N.
40,000 N.
35,000 N.
40,000 E.
45,000 E.
50,000 E.
55,000 E.
60,000 E.
65,000 E.
70,000 E.
POLLYANNA
GIB. W.
GIB. E.
GRANITE LAKE
APPROXIMATE BOUNDARY OF STOCK

FIGURE: 5

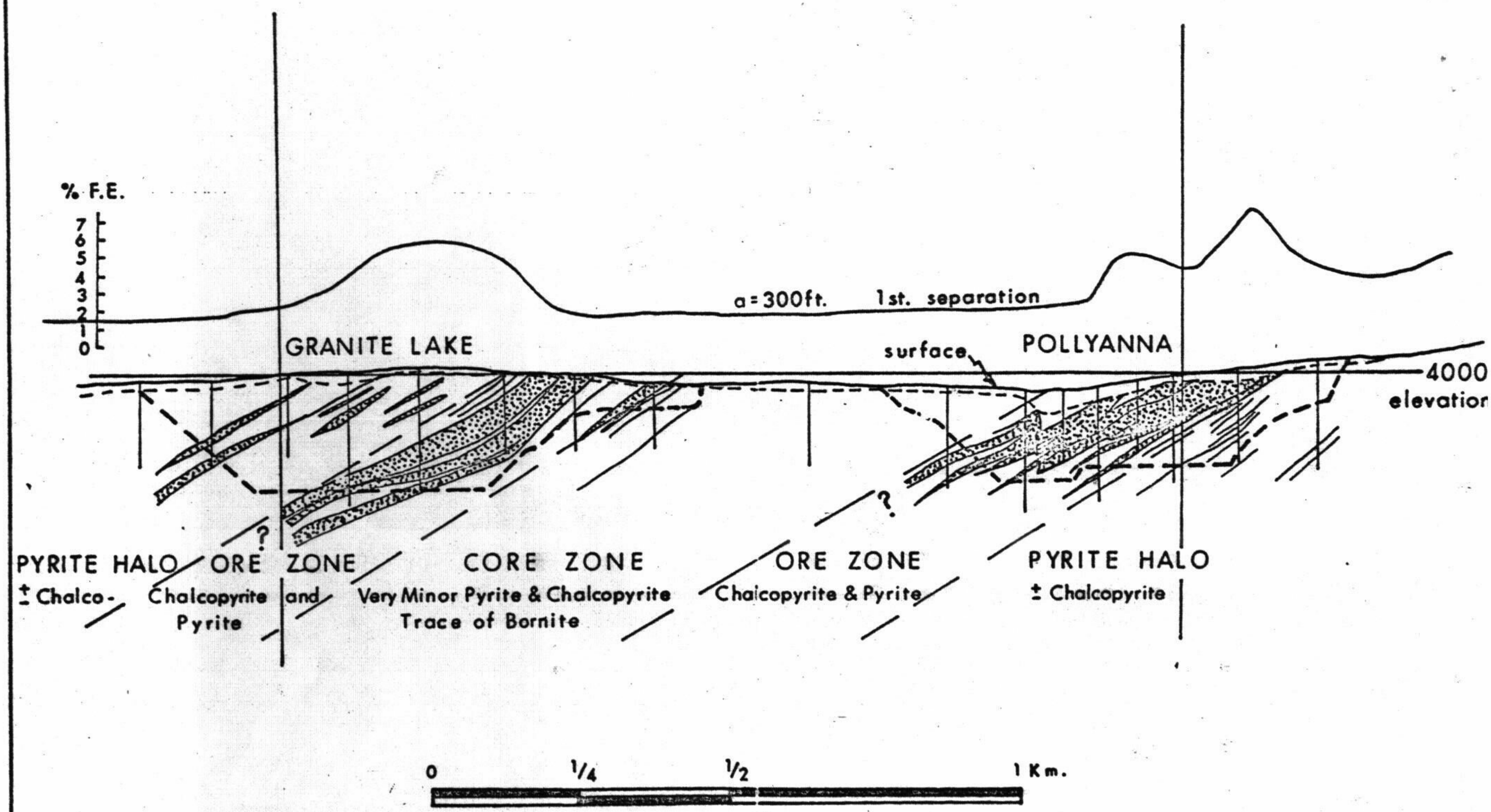
The rough elliptical shape indicates that, in part, the sulphide zone is guided by the regional foliation.

The effect of the dip of the regional foliation can be seen in Figure 6. Although the individual veins parallel and cross-cut the foliation, the overall dip of the mineralization is about 30° to the south. Figure 6 is a north-south section through the Pollyanna zone on the north and the Granite Lake zone on the south and 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 is located 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 changes to 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, except 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.

SUPERGENE ZONE

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

The Gibraltar East orebody has a leached cap extending 15 to 20 m



LEGEND

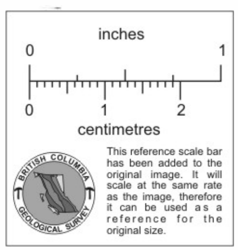
Plus 0.25 % Total Copper

Overburden

Induced Polarization Profile

Diamond Drill Hole

Outline of Ultimate Pits



SECTION 52600E

THROUGH GRANITE LAKE AND POLLYANNA ORE ZONES.

FIGURE 6

deep as a subdued reflection of the bedrock surface. An enriched zone extends 30 to 60 m below the leached cap and is related, in part, to zones of intense fracturing or faulting and presumably, ground-water flow. Most of the enrichment consists of chalcocite which coats and replaces pyrite and chalcopyrite. Malachite and azurite are found only near the upper surface of the enriched zone. Cuprite is most commonly found in the upper part of the zone and especially within fault zones. During the Pleistocene Epoch, glacial ice moving from the southeast out of the Cariboo Mountains overrode the area and bedrock was actively eroded and shaped. Therefore, the close relationship between the shape of the enriched and leached zones to the present surface indicates that the oxidation and leaching continued after the Pleistocene, although much of the process may date from the Tertiary.

STRUCTURE

To allow an interpretation of the structure within not only the Granite Mountain pluton but also the Gibraltar deposits, the following structural elements are herewith defined.

The Granite Mountain pluton had an original igneous foliation herein defined as S_1. This foliation is noted macroscopically in locales where later deformation is minimal. S_1 grades imperceptibly into a sub-parallel second foliation (S_2) that results from penetrative deformation. Microscopic evidence suggests partial parallelism of S_2 to S_1. It is thought that S_2 has developed in the pluton by being guided in most part by the original igneous foliation.

Within the Gibraltar East pit, the intensity of foliation has been arbitrarily defined as follows:

F_1, the lowest order, has a noticeable orientation of mafic minerals and possibly plagioclase laths and is normally primary igneous flow foliation; F_2 has a modest foliation; F_3, pronounced foliation; F_4, intense foliation; and F_5 is, in fact, a phyllonitic schist. These macroscopic intensity values are consistently related to various microscopic textural criteria.

F_1, as described above, has an alignment of large inequant grains without cataclasis.

F_2 has strained quartz with slight shattering, minor and widely spaced trains of new sericite, and mosaic recrystallized quartz. Biotite (chlorite), with cleavage close to the orientation of S_2, is distorted and drawn out.

F_3 commonly has a variable texture resulting from channeling of deformation and movement along S_2 planes between which cataclasis is substantially less. Movement planes are rarely greater than 5 millimeters apart. Between movement planes quartz is shattered and mosaic quartz common, mafic minerals are converted to chlorite and substantially strung out. Feldspar is largely converted to sericite but is coherent. On movement planes feldspars are converted to trains of sericite and fine quartz; mafic minerals to trains rich in chlorite; and quartz to trains of fine mosaic quartz. Dolomite porphyroblasts are commonly present.

F_4 has a more uniform flaser-like texture, with movement planes wrapping around augen of recrystallized quartz that are commonly three times as long as thick. Plagioclase is largely destroyed or, if present, occurs as minor small grains of albite. In contrast, dolomite porphyroblasts are significant. Mafic grains have been completely transformed to chlorite-rich schlieren. In addition, kink bands forming S_3 are a common feature.

F_5 has a fairly uniform, fine schistose texture and is characterized by carbonate, chlorite-sericite, and quartz.

The vein system as described in this paper will be defined by the symbols V_1 for the oldest vein stage through V_2, V_3 to V_4 for the youngest.

(a) Structure and Metamorphism

Structural elements within the pluton, either in the vicinity of the copper deposits or several kilometres away from the mineralized area, show both relatively non-foliated quartz diorite and foliated to schist-like quartz diorite in juxaposition. The primary foliation (S_1) when observed strikes westerly and dips steeply southward (approximately N 70°W/60° S). When the primary foliation was subjected to a penetrative deformation, S_2 formed which has a general attitude of approximately N 70°W/30°S but which is N 48°W/44°SW in the Gibraltar East pit area. Depending on the local stress distribution, the S_2 planes acted as loci for relieving the stress and caused the rock to develop foliation planes some of which took up relatively more deformation and thus relieved stress on the intervening rock. The effect of this was to develop, in essence plates of quartz diorite which show varying degrees of foliation. Where the local stress was more continuous, the initial S_2 fractures has been the locus for chemical and structural changes of varying widths and degrees of foliation from F_1 to F_5. For example, it was within a relatively restricted portion of a strong chloritic shear zone that the assemblage of quartz-chlorite-muscovite-garnet-pyrite was noted in an area of weakly saussuritized quartz diorite.

Within the western half of the East Gibraltar pit folding of S_2 foliation is common and intensity varies from 3 to 5. Fold axes of these minor folds strikes S 31°E and plunge 18°SW on the average (Figure 7). A weak girdle of plots of S_2 is shown in Figure 7 which gives an average of N 48°W/44°SW and which is virtually normal to the plunge of the fold axes.

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

1. The entire Granite Mountain quartz diorite pluton has been saussuritized.

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.

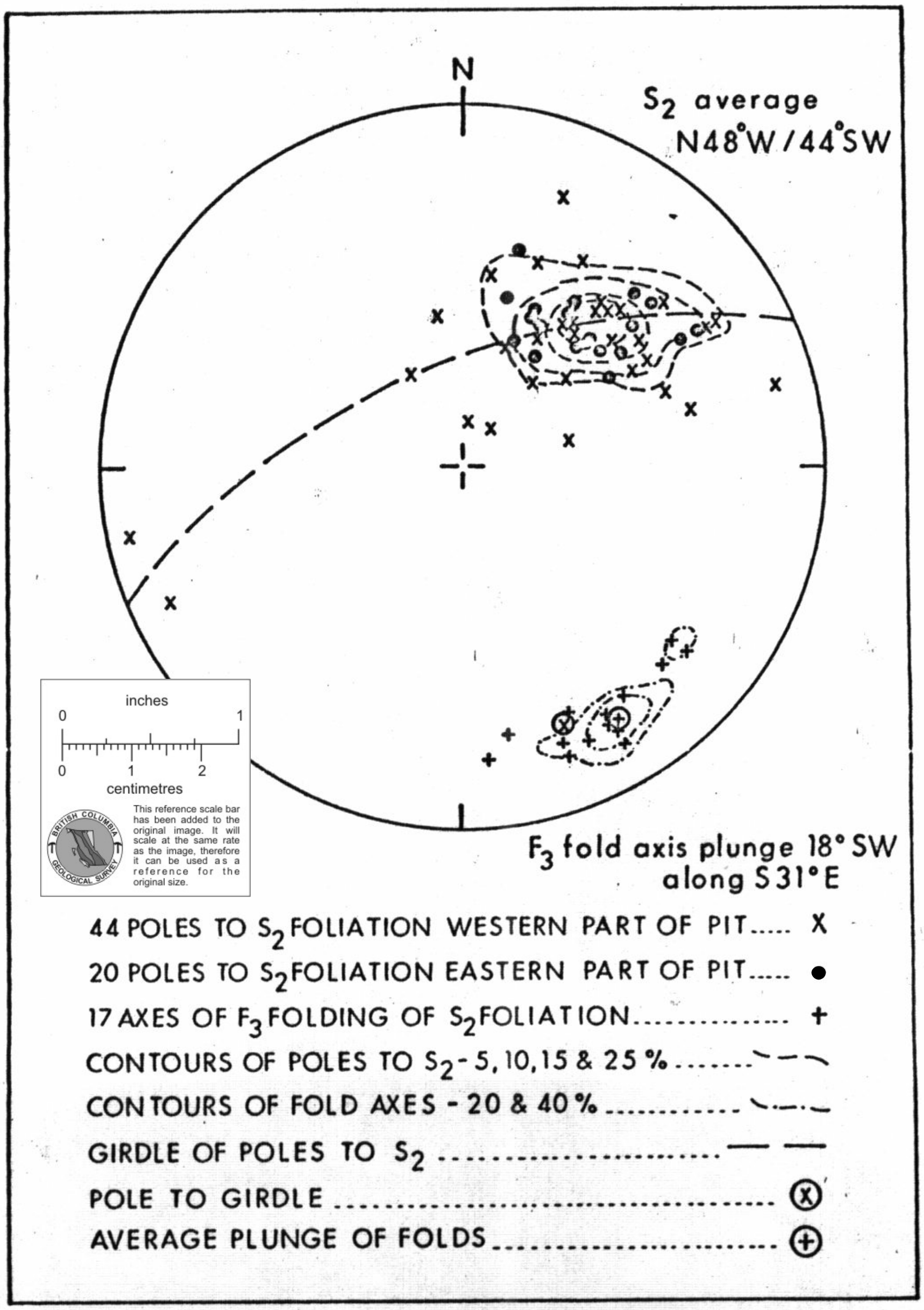


FIGURE 7 Gibraltar East pit, stereoprojection of structural elements related to S_2 foliation.
(After A. Sutherland Brown (1974))

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

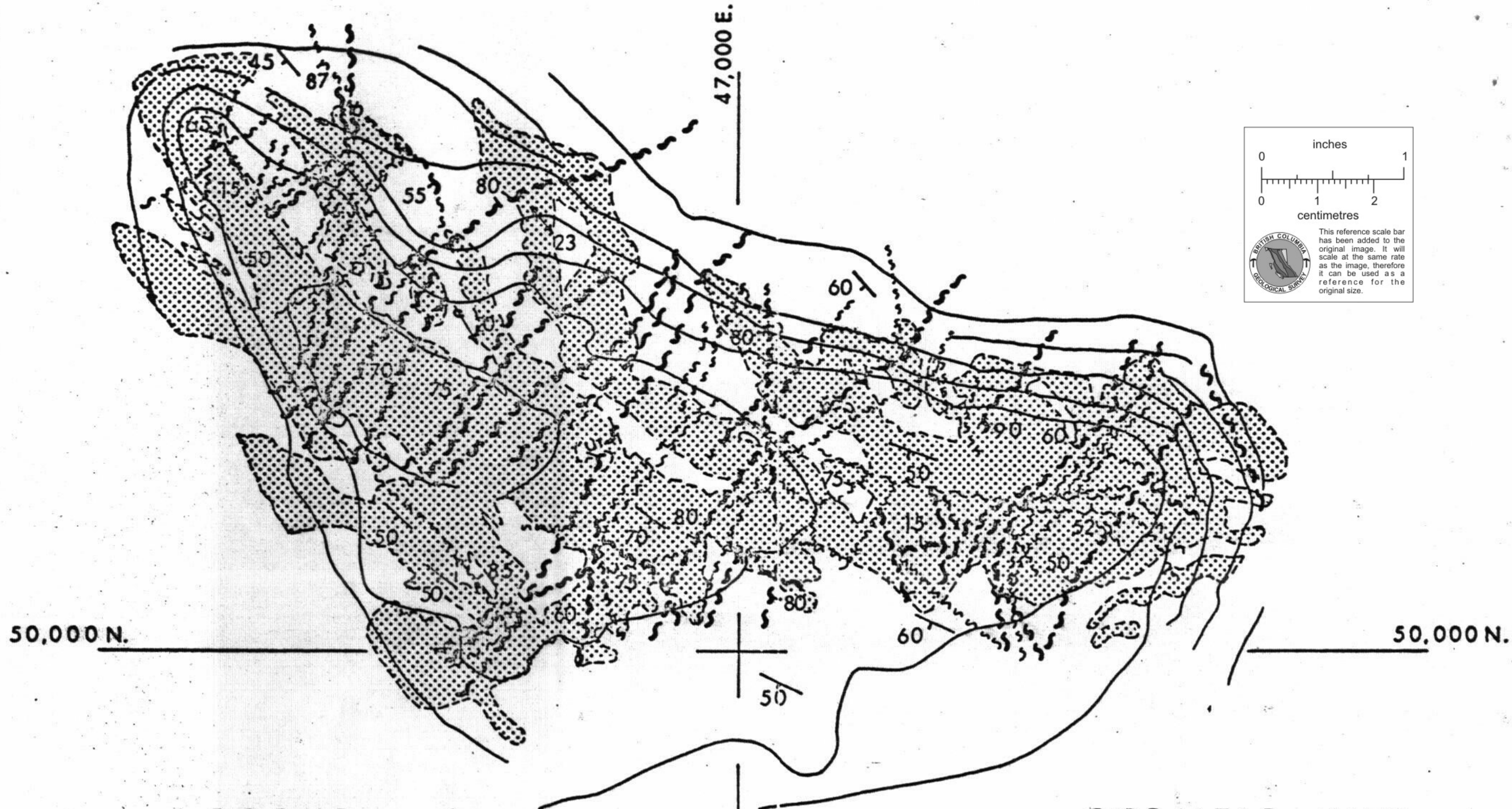
6. The above mineral assemblages and the textural variations are indicative of a suite or rocks compatible with the greenschist facies of regional metamorphism.

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.

(b) Structure and Veining

The mutual relationship between the structural elements has been developed primarily from a study of the Gibraltar East pit (Figure 8) and in part from the Granite Lake pit (Figure 9). Specimens of the Granite Mountain pluton that are little deformed (no directional texture or possess S_1) show chemical changes consistent with saussuritization. From the petrology of the main phase rocks, there is a definite correlation between abundancy of chlorite and degree of foliation as it is those area of minor folds or kink folds that are predominantly devoid of epidote. Where the folds are more gentle or open, epidote and chlorite are present.

The interrelation of metamorphism to veining can be seen in the Gibraltar East and Granite Lake pits. The veins with sericitic or chloritic envelopes (V_1) either parallel S_2 (with foliation intensities F_1 to F_5) or less commonly cross-cut



LEGEND

Major Fracture System (mineralized)

Major Fault with gouge and area of intensely broken rock.

Fold Axis ; with axial plane dip

Orp Zone (>0.25% Cu)

47,000 E.

GIBRALTAR MINE

Geology of Gibraltar East Pit Composite Plan

FIGURE 8

0 400 800 FEET

0 100 200 300 METERS

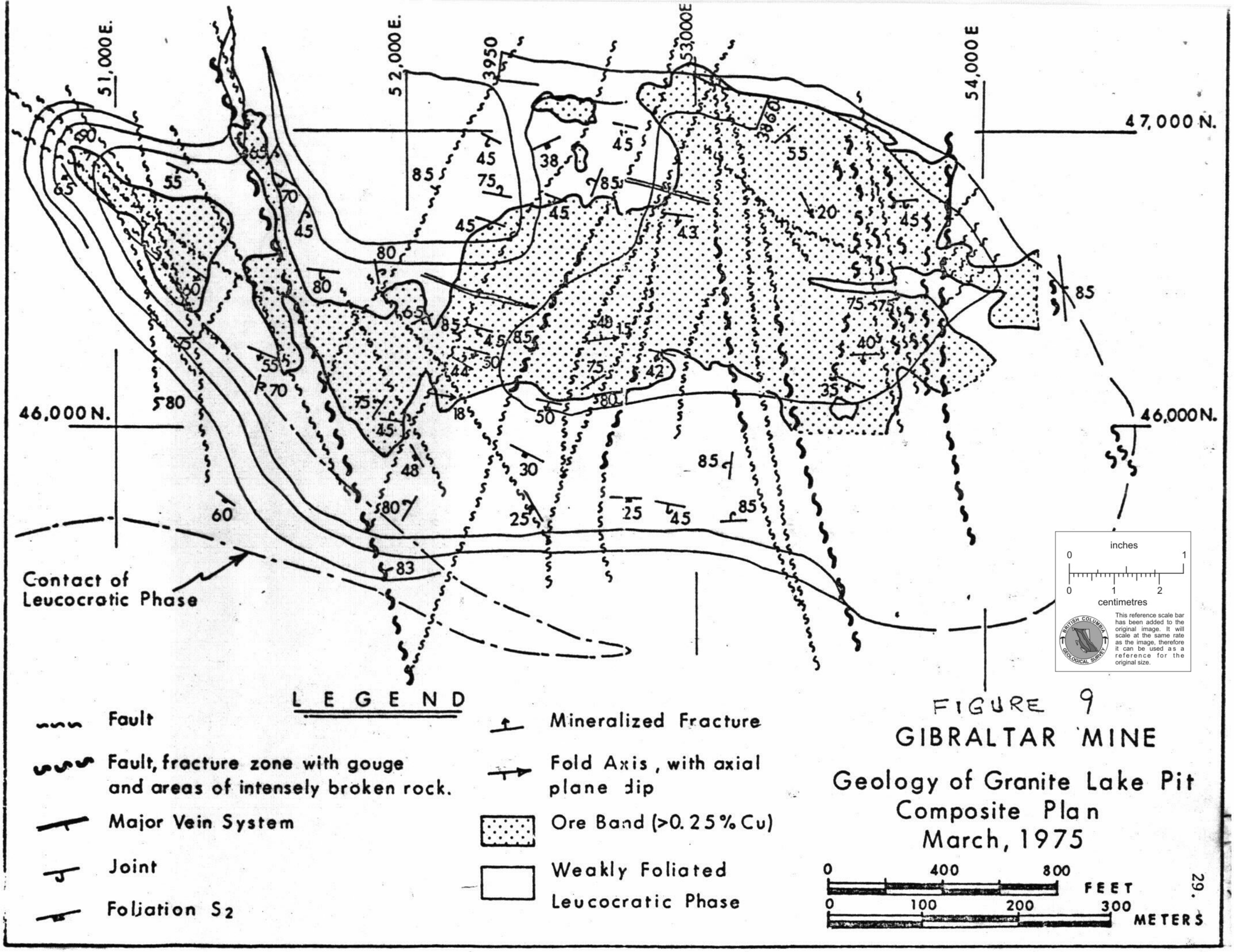


FIGURE 9

GIBRALTAR MINE

Geology of Granite Lake Pit
Composite Plan
March, 1975

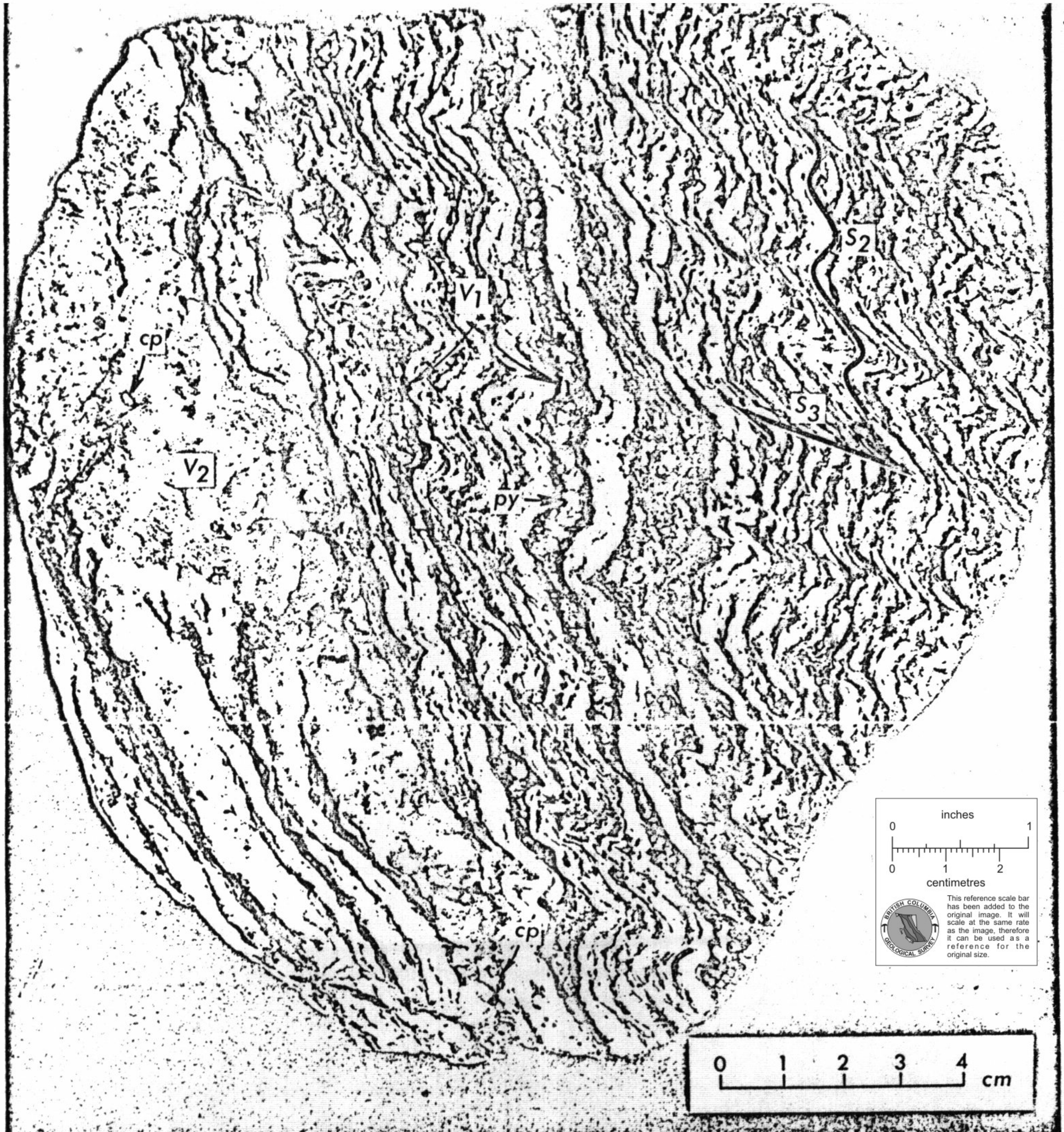


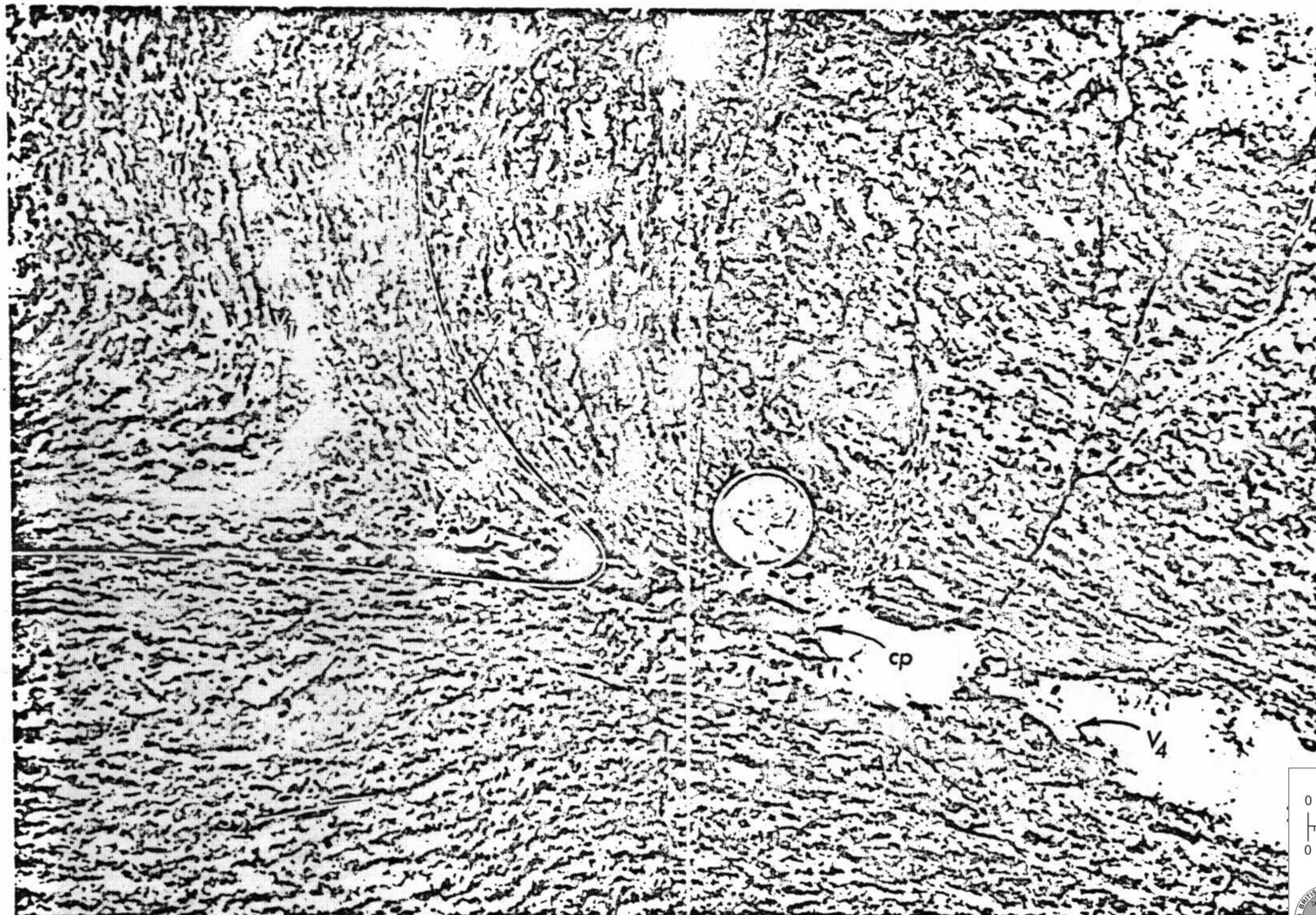
FIGURE Foliated quartz diorite, East pit, showing intense S_2 foliation (F_4), crenulation of S_2 to form S_3, dark V_1 veins with pyrite (white) crenulated with S_2, drusy V_2 vein with minor decollement and chalcopyrite (nearly white). After A. Sutherland Brown (1974) p. 317.

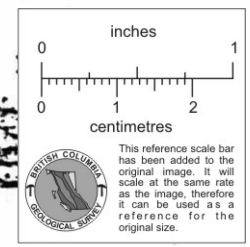
S_2. The initial stages of the stockwork developed around the low sulphide area between the three pits and was guided by the existing structure. The sericite in the envelopes was also deformed which indicates that after emplacement of V_1, the S_2 planes were the site of either renewed or continuous deformation. Depending on the distribution of stress from the intrusion, V_1 either cross-cut or parallel S_2. In areas of very intense deformation, the V_1 veinlets may only be apparent as trains of pyrite (and chalcopyrite) in quartz, muscovite and chlorite schist. Figure 10 shows both V_1 and S_2 folded by S_3.

Copper-bearing veins without envelopes (V_2) cut those with envelopes (V_1) and either parallel or cross-cut S_2. A continuation of the deformation must have occurred because V_2 and S_2 have been folded. The V_2 type is commonly drusy.

The ribboned structured molybdenite-bearing veins (V_3) cross-cut V_1 and V_2 and have locally been folded which indicates further relief of stress through continued deformation.

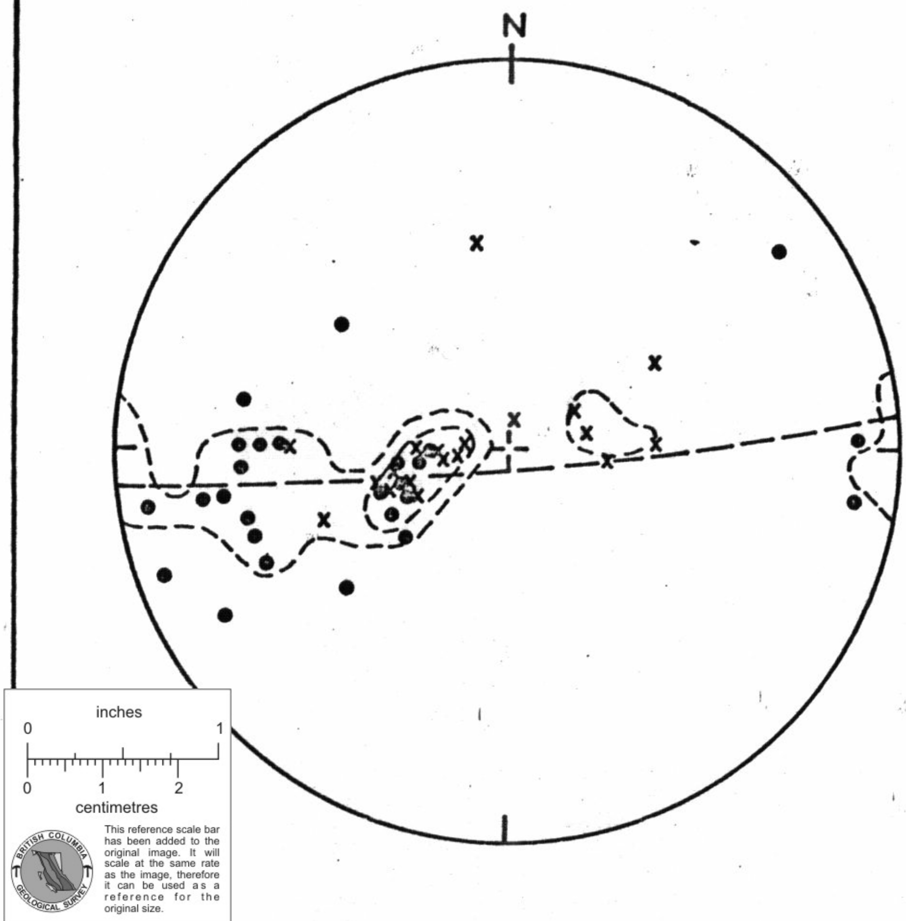
V_4 is a late phenomenon (Figure 11) and occurs in the axial planes of folded S_2. These gash veins (V_4) were formed in response to remobilization into low pressure areas in either folds about S_3 or along late tension joints. Figure 12 is a stereoprojection of poles to S_3 in the Gibraltar East pit which shows a partial girdle and appears to have an axial plane relationship to folded S_2 (Figure 11). The late V_4 veins tend to have the same spatial relationship and are parallel to S_3 which suggests that both were formed at the end of the deformational and mineralizing process.





FIGURE

Sharp synclinal keel in folded foliation, East pit (3365 bench). Note variable intensity of foliation, dark V_1 vein folded with foliation, boudinaged V_4 vein with chalcopyrite below coin. After A. Sutherland Brown (1974) p. 312.



30 POLES TO V_4 VEINS .... ●

20 POLES TO S FOLIATION x

CONTOURS ON COMBINED POLES,
4 AND 12% ....

GIRDLE .... — — — —

FIGURE 12 Gibraltar East pit, stereoprojection of structural elements, S_3 foliation and V_4 veins.
(After A. Sutherland Brown (1974))

The character of these V_4 type veins appears to change outward from the copper deposits in that within the copper areas they contain blebs of chalcopyrite while outside of the copper deposit, they contain predominantly massive white quartz.

A summary of the relationship in space and time between the structural development and mineralization can be rationalized on the basis of the foregoing. Primary igneous foliation S_1 was intensified by a continuing couple with the "upper" plates moving upward and northward, as in a deck of cards. After initial formation of S_2, the V_1 fracture stockwork formed parallel and movement was channeled along these planes until filled and "frozen". However, general movement continued on S_2, intensifying it, eventually forming the strike faults with coinciding crumpling of S_2, and later filling with V_2 and V_3. During the process of folding S_2, the S_3 foliation developed and secretional mobilization from earlier veins and wall rocks moved into the low pressure sites (V_4).

From the above we establish that intrusion of the leucocratic phases, being less deformed than the main phase were emplaced after deformation had been initiated. Furthermore, the mineralization occurs over a period later than intrusion of the felsic phases but that overlapped deformation of the Granite Mountain pluton with the youngest veins (V_4) filling the S_3 foliation that developed during major folding of S_2 and V_1 veins. V_2 & V_3 are only folded in a minor way. Therefore, we conclude that Gibraltar deposit illustrates a continuum between intrusion, deformation, metamorphism and mineralization.

(c) Synthesis

A synthesis has been made from the data available. Geologic mapping and petrologic study indicate the existence of a modest zoning of the Granite Mountain pluton from a mafic rich diorite exterior to a more felsic quartz diorite core. A consistent foliation occurs transverse to the orientation of the long dimension of the pluton which is not observed in the wall rocks remote from the pluton. Study of the relationship between primary igenous foliation, the secondary deformational foliation, and vein formation indicates a continuum of movement of similar orientation. The relationship between the second foliation (S_2), third foliation (S_3), and the structural relationship of the four vein sets indicates the mineralization was an integral part of this process. The Granite Mountain pluton would thus appear to have been intruded as a tongue-shaped pluton rooted to the south and probably steepening downward. A central tongue of leucocratic nature formed a domal core with peripheral bodies characterized by quartz-sulphide stockworks. Emplacement, deformation and mineralization appear to have been a continuous process.

ACKNOWLEDGEMENTS

The authors are indebted to the geologists who are currently and were previously associated with Gibraltar Mines Ltd., for their part in geologic mapping and the compilation of data. The co-operation of the B.C. Department of Mines and Petroleum Resources has lead to a better understanding of structural development and is herewith acknowledged.

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(General production information has been taken from the 1972, 1973 and 1974 Annual Reports of Gibraltar Mines Ltd.)