93K 006

W.A. No. ....

015143

NAME Endako (Mine)

SUBJECT 1. Geology of Endako Mine (Summary)

2. Notes, Talk on Endako, by Don Rotheram of Canex Aerial Exploration Ltd.

3. Hydrothermal Alteration at Endako Mines - A comparison to experimental studies, by A.D. Drummond & E.T. Kimura

4. Geology of the Endako Molybdenum Deposit

5. Production Report, Canex Placer Ltd.

6. Correspondence (L. Alie → J.M. Carr) re: Endako Mine

Copy please - GLeB

CANEX AERIAL EXPLORATION LTD.

DIVISION OF CANADIAN EXPLORATION LIMITED

700 BURRARD BUILDING VANCOUVER 5, B. C. CANADA

22 February 1965

File: Endako 6-2

1035

Mr. J. M. Carr,
Dept. of Mines and Petroleum Resources,
Victoria, B. C.

Dear Mr. Carr:

With reference to your letter of 10 February requesting further information on Endako to ensure accuracy in your report, I would like to pass on the following information to you.

A. At present Endako Mines Limited comprises 197 mineral claims, 13 of which are presently under a 21-year mineral lease. The total claims would include the six Deer m.c.'s transferred by an agreement with Julian Mining Co.

B. The total diamond drilling in the vicinity of the Endako ore body in 1964 may be summarized as follows:

By Canex Aerial Exploration Ltd. - 20 new holes plus one hole deepened, for a total footage of 7,609 feet. By Endako - 16 holes totalling 6,371 feet. This would thus give 36 holes plus one deepening for a total footage of 13,980 feet.

37 — 13980
12 — 1250
25 — 12730

C. Total drilling up to 31 December 1964 by both Canex Aerial and Endako is 89,549 feet in a total of 206 holes. Out of this total six drill holes totalling 862 feet were drilled on the Pat group of claims and six holes were drilled on the Deer group totalling 388 feet.

I trust that the foregoing is sufficient for your report. However, if you would like to have a map showing locations of drill holes I would be pleased to request this information from Ed Kimura at Endako.

Yours very truly,

L. Adie /ja

L. ADIE
Exploration Manager-Canada

	206	89549
Pat	6	862
Deer	6	388
	194	88299

LA:ja

1973

CANEX PLACER LIMITED
ENDAKO MINES DIVISION

March 21, 1974

The Honorable L. T. Nimsick
Minister of Mines
Department of Mines and Petroleum Resources
Parliament Buildings
Victoria, B.C.

Dear Sir:

On behalf of Canex Placer Limited, Endako Mines Division, the information required under Section 71 of Bill 101, An Act to Amend the Mineral Act, is enclosed.

Yours truly,

A. J. Petrina
Asst. Vice President, Operations

REFERRED TO	DATE	INITIAL
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C.C.		
D.C.G.C.		
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Encl:

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PROPERTY FILE
93K006-07
#5

PRODUCTION REPORT

(in compliance with Mineral Act, Section 71)

for

CANEX PLACER LIMITED, ENDAKO MINES DIVISION

and

DENAK MINES LTD.

DESCRIPTION OF LEASES

A total of 23 mineral leases are held by Canex Placer Limited, Endako Mines Division and Denak Mines Ltd. Twenty-two of these are registered under Canex Placer Limited, Endako Mines Division and one lease under Denak Mines Ltd. The contiguous group of leases are situated four to five miles southwest of Endako, B.C. in the Omineca Mining Division, Range 5 Coast District. The spatial location of twenty-three mineral leases in relation to current open pit limit and mine plant site are shown on appended 1" - 1,000' scale map.

The following tabulation details the pertinent information for each mineral lease.

I. LESSEE: Canex Placer Limited, Endako Mines Division

Mineral Lease	Mineral Claim	Record No.	Lot No.	Acreage	Lease Date
M31	Boot 1	13122	7759	48.30	23/9/64
M32	Boot 2	13123	7760	45.77	"
M33	Boot 3	13124	7761	48.80	"
M34	Boot 6	13127	7764	51.65	"
M35	Boot 5	13126	7763	51.43	"
M36	Mo 4 Fr.	21626	7796	1.80	"
M37	Mo 5	13179	7775	44.95	"
M38	Jay 10	12385	7758	46.56	"
M39	Mo 3 Fr.	21625	7794	5.07	"
M40	Boot 14	13173	7770	17.60	"
M41	Boot 8	13167	7766	41.47	"
M42	Mo 6	13180	7776	42.66	"
M43	Mo 2 Fr.	21624	7799	0.50	"
M68	Boot 4	13125	7762	49.88	5/1/67
M69	Boot 15	13174	7769	40.16	"
M70	Boot 15 Fr.	24467	7803	0.227	"
M71	Mo 7	13181	7777	40.28	"
M72	Bar 2 Fr.	14055	7792	5.09	"
M114	Boot 9	13168	7767	37.26	29/1/71
M115	Boot 10	13169	7768	49.32	"
M116	Tan 3	13428	7782	51.61	"
M117	Tan 4	13429	7783	51.16	"

II. LESSEE: Denak Mines Ltd.

M113	Elk 6	13443	1552	6.71	29/1/71

DESCRIPTION OF THE MINERAL DEPOSIT

The orebody in plan is roughly an elongated cigar-shaped zone of stockwork. The 11,000-foot-long westerly-plunging body strikes N 70 W. The westerly two-thirds of orebody length dips 30° to 60° south, whereas conjugating 50° south and 20° northwest dips prevail for easterly portion. Cross-cutting and proximal to the orebody, the host Endako quartz monzonite is intruded by pre-mineral aplite, porphyritic granite and quartz-feldspar porphyry dykes. These dykes occur predominantly in two and possibly three concentrated swarms which are aligned to regional northwest and northeast trends. Post-mineral basalt dykes intrude several major faults. Movement along post-mineral faults, which predominantly trend northeasterly, northwesterly and easterly, is generally less than 25 feet. Larger inferred offsets up to 300 feet are apparent along several major northeasterly faults. The major north-dipping South Boundary Fault is located 500 feet of present East Pit and delimits ore deposit at depth.

Mineralization is simple and consists of molybdenite, pyrite, magnetite and minor chalcopyrite. Calcite and chalcedony are late vein minerals. The ore minerals are intimately associated with quartz veining and occur in two types of veins: 1. as large four-inch- to four-foot-wide veins in which molybdenite typically occurs as thin closely-spaced laminae, and 2. as fine fractures-fillings and veinlets in the form of a stockwork. Orientation and limits of economic stockwork are controlled by major subparallel sets of south-dipping and complementary flat-lying, southeasterly and northwesterly-dipping vein systems.

A pyrite zone bounds the orebody to the south. The zone consists of fine quartz and pyrite, minor magnetite and rare molybdenite mineralization as fracture-fillings in a poorly-developed stockwork. The zone has not been recognized in other peripheral areas of the orebody.

Three distinct hydrothermal alteration products are recognized in the Endako ore zone. Orange-pink K-feldspar has been developed as 1/8-inch envelope to two-foot-wide zones on veins and fractures. A quartz-sericite-pyrite phase is also developed as 1/8- to two-inch-wide envelopes on veins. Pervasive kaolinization of the Endako quartz monzonite is widespread, and varies from a slight development of kaolinite in plagioclase in otherwise unaltered rock to complete alteration of both plagioclase and K-feldspar to a soft creamy white or green clay.

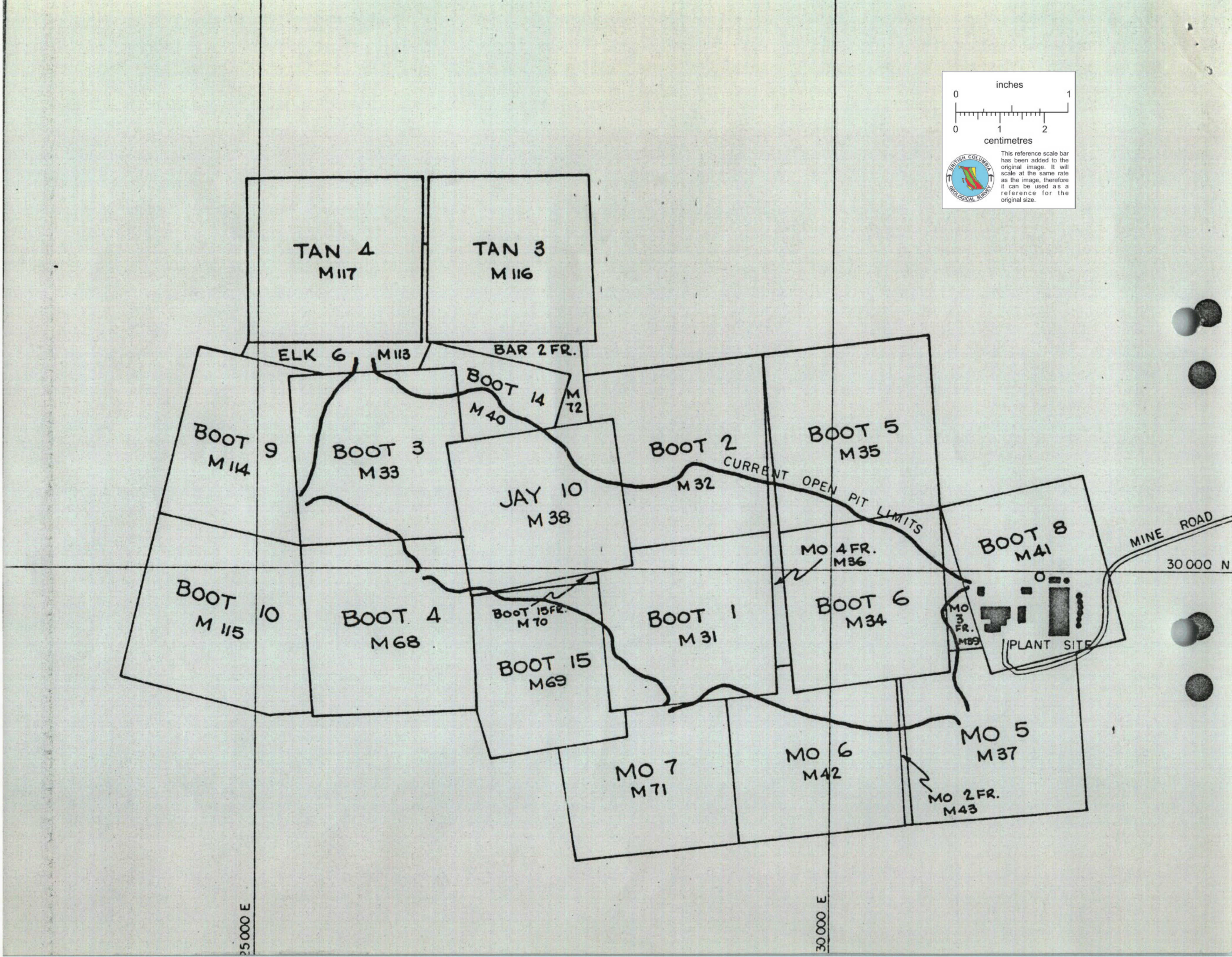
A concept of elongated doming near or at an intersection of regional northwest and easterly structures is proposed for possible development of restricted Endako stockwork. Longitudinal major faulting, with attendant antithetic faulting and repetitive periods of concomitant fracturing across domal structure, are visualized for localization of a favourable fracture system for hydrothermal alteration and economic mineralization.

Mineable ore reserves within an ultimate pit design as of 31 December, 1973, are calculated as follows:

	Tons	%MoS_2
Endako Pit (0.08% MoS_2 cutoff)		
Proven and probable	153,000,000	0.143
Possible	40,000,000	
Denak Pit (0.08% MoS_2 cutoff)		
Proven and probable	21,000,000	0.159
Possible	4,000,000	

RATE OF PRODUCTION OF MINERALS

Production is currently being maintained at 27,500 tons per day at an average ore grade of 0.15% MoS_2. Two products, molybdenum sulphide and molybdenum oxide are produced.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BOOT 14
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BOOT 3
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JAY 10
M38
BOOT 2
M32
BOOT 5
M35
CURRENT OPEN PIT LIMITS
BOOT 8
M41
MINE ROAD
30 000 N
MO 4 FR.
M36
BOOT 6
M34
MO
3
FR.
M89
PLANT SITE
BOOT 10
M 115
BOOT 4
M68
BOOT 15FR.
M70
BOOT 15
M69
BOOT 1
M31
MO 5
M37
MO 7
M71
MO 6
M42
MO 2 FR.
M43
25 000 E
30 000 E

JMCARR

ENDAKO MINES LTD. (N. P. L.)

PHONE: FRASER LAKE 261

ENDAKO, B.C. CANADA

GEOLOGY OF THE ENDAKO MOLYBDENUM DEPOSIT

PRESENTED AT CIM, B.C. SECTION MEETING

VICTORIA, B.C.

October 29, 1966

By

E. T. Kimura

A. D. Drummond

ENDAKO MINES LTD. (N.P.L.)

ENDAKO, B. C.

INTRODUCTION

Endako Mines is located 100 miles west of Prince George, and is near the geographic center of British Columbia. The property is six miles south-west of the village of Endako which is situated on Highway 16 and on a branch line of the CNR.

HISTORY

The history of the molybdenite deposit dates back to 1927 when two local men staked four mineral claims to cover an area of quartz-molybdenite float. A short shaft was sunk on the so-called two foot wide Stellar vein, and a short adit was driven on another vein by the owners in 1934; some analyses of the vein material were carried out for metallurgical testing. During the period 1934 to 1961, the property was examined by many geologists and several mining companies, but physical work was confined primarily to trenching and some sampling. In 1961, Andrew Robertson optioned the property and in addition to trenching, a diamond drilling program was commenced in May 1962. Canex Aerial Exploration Ltd. entered the exploration of the property in October 1962, and after completion of 190 diamond drill holes for a total of 80,000 feet and 2,700 feet of underground work for bulk sample testing, the decision to develop the property for production was announced in March 1964. Construction of the 10,000 ton per day mine plant and development of the open pit began in June 1964, and the mine was officially opened on 8 June 1965. At present Endako Mines Ltd. (N.P.L.) is operating at 17,000 tons per day at an average grade of 0.24% MoS_2. Two products, molybdenum sulphide and molybdenum oxide are produced.

REGIONAL GEOLOGY

The Endako molybdenite orebody occurs in the Topley Intrusive which is considered to be of late Jurassic age, and is intruded into early Mesozoic sediments and volcanics. Regional distribution of the Topley rocks stretches from Babine Lake to Quesnel, a distance of about 180 miles along a regional northwesterly trend. The Topley is a composite batholith in which granite, quartz monzonite, grandiorite, quartz diorite and diorite have been identified. (See map showing Regional Distribution of Topley Intrusive.)

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LOCAL GEOLOGY

Four distinct rock types of the Topley Intrusive are noted in the mine area and listed below.

a) Endako Quartz Monzonite:

The rock is generally equigranular (3 - 4 mm) with some K-spar crystals occasionally as large as 7 mm. This size difference imparts a suggestion of a porphyritic texture, but is not sufficiently distinctive to warrant the term "porphyritic". The rock type is readily recognized by the characteristic pink K-spar in a greyish rock.

Composition is quartz (30%), pale pink to orange-tinged K-spar (40%), white to greenish-tinged plagioclase (20%), and chloritized black biotite (5 - 10%). The K-spar/total feldspar ratio may vary from 2/3 to 1/2, but is predominantly 1/2 and therefore, the rock type is referred to as quartz monzonite rather than granite.

b) Casey Alaskite:

A fine-to medium-grained (1 - 3 mm) sugary textured leucocratic rock outcrops in the Casey Lake area. Composition is quartz (40%), pale pink K-feldspar (50%), white plagioclase (5%), partially chloritized biotite (2 - 3%), and accessory pyrite and hematite (1%).

c) Glenannan Granite:

A coarse-grained rock of granite to quartz monzonite composition outcrops to the northeast of the mine and north of the Casey alaskite. Composition ranges between quartz (25%), pink K-feldspar (55%), white plagioclase (15%), biotite (5%), and quartz (20%), K-feldspar (40%), plagioclase (30%), biotite (10%). Texturally, the rock changes from essentially equigranular (5 - 6 mm) to porphyritic with K-feldspar and plagioclase crystals up to 2 cm.

Locally, the rock is pegmatitic with very coarse crystals of quartz (25%) (1 cm.), K-feldspar (70%) (2 cm.), plagioclase (5%) (1 cm.), and less than 1% mafic.

d) Francois Granite:

This distinctive red rock lies to the south of the Endako quartz monzonite. Rock is equigranular (3 - 4 mm) and composition is quartz (34%), perthitic K-spar (45%), white plagioclase with greenish cores (14%), biotite (5%), and accessory minerals (2%).

............/

The distribution of the above and other rock types is shown on the map of the Geology of Endako Mine Area. The oldest rocks in the area are those of the Takla Group of lower Mesozoic age. The Topley has intruded these rocks. Within the Topley, the Endako quartz monzonite is one of the older rocks. The adjacent Francois granite to the south and Casey alaskite to the north are younger as evidenced by dykes which are correlated with these rocks being intruded into the Endako. Two small outliers of Endako quartz monzonite appear to be roof pendents within the Casey alaskite. The Glenannan granite is older than the Casey, as the Casey porphyry intrudes the Glenannan. As yet, no age relation is possible between Endako and Glenannan.

The quartz latite porphyry is restricted to the area of Takla volcanic rocks, but there is not sufficient evidence to suggest that it is pre- or post-Topley. The Tertiary Endako Group volcanic rocks overlie the entire area.

The molybdenum deposit occurs wholly within the Endako quartz monzonite. The orebody is roughly an elongated elliptical-shaped body which strikes S20E, dips 20° to 50° south, and measures 5,500 feet long by 1,200 feet wide.

MINE GEOLOGY

The geology is relatively simple, with host Endako quartz monzonite intruded by pre-mineral aplite, porphyritic granite and quartz feldspar porphyry and post-mineral basalt dykes.

The aplite is a typically pink fine sugary grained rock which shows quartz and K-spar in a graphic intergrowth. The aplite occurs throughout the orebody as 1/4 inch to 4 foot wide unoriented dykes.

The term porphyritic granite is applied to a pink massive, 3% large K-spar phenocrysts in a fine-grained phaneritic granite matrix. These dykes vary from four to fifty feet in width, and generally trend to the northeast.

like Grd-P dykes (the float spec" E of Endako)?

The most abundant dyke rock is the quartz feldspar porphyry which is a brown to pink rock composed of 10% to 15% phenocrysts of quartz and K-spar in a near aphanitic matrix. The quartz feldspar porphyry dykes range from several inches to 100 feet in width, and typically show very close jointing.

Basalt dykes have been intruded in association with post-mineral fault movements.

............/

The only observed relationship between the aplite, porphyritic granite and quartz feldspar porphyry is that the quartz feldspar porphyry is the youngest. Cross-cutting relations between aplite and porphyritic granite have not been observed.

Local attitudes of individual dykes may be observed to strike at any angle from the general trend, due to the angular and blocky faulting within the Endako quartz monzonite. The general trend of the dykes is predominantly northeasterly and northwesterly and dip steeply west. These dykes occur as concentrated swarms in two localities within the orebody.

HYDROTHERMAL ALTERATION

Three distinct hydrothermal alteration phases are seen in the Endako ore zone.

a) Introduced K-spar:

The presence of introduced K-spar is noted in two distinct forms: 1. K-spar envelopes developed adjacent to veins and fractures and vary in width from 1/8 to 2 inches; 2. K-spar-biotite zones developed as irregular lenses and bands along fractures in widths up to 8 inches. These zones are less common than envelopes.

b) Quartz-Sericite-Pyrite Envelopes:

A second type of envelope seen adjacent to veins and fractures is a fine-grained grey band composed of quartz sericite and finely disseminated pyrite. The envelopes range in width from 1/8th to 2 inches and are not as common as K-spar envelopes.

c) Kaolinization:

Pervasive kaolinization of the Endako quartz monzonite indicates several degrees of intensity. The degrees of kaolinization are classified on the break down of feldspar as follows:

1. Fresh quartz monzonite

   The following minerals are present:

   (a) Quartz

   (b) K-Feldspar (pink, hard)

   (c) Plagioclase (whitish grey, hard)

   (d) Biotite (black)

............/

2. Weak Kaolinization

(a) Quartz

(b) K-feldspar (pink, hard)

(c) Plagioclase (greenish tinged, hard rim with soft greenish and possibly white cores) (Plagioclase is attacked and is breaking down to kaolinite and minor sericite)

(d) Biotite and/or Chloritized Biotite

3. Moderate Kaolinization

(a) Quartz

(b) K-feldspar (pink, hard)

(c) "Plagioclase" (soft greenish clay with some whitish clay) (Plagioclase has completely broken down)

(d) Biotite and/or Chloritized Biotite

4. Intense Kaolinization

(a) Quartz

(b) "K-feldspar" (whitish pink but may be relatively hard depending on degree of breakdown; important point is that K-feldspar is breaking down to Kaolinite)

(c) "Plagioclase" (greenish to whitish green soft clays, Plagioclase has completely broken down)

(d) "Biotite" (generally less mafic present than in less intense alteration types, chloritized and if black, probably secondary)

The extent of significant pervasive alteration approximates the outline of economic mineralization.

............/

MINERALIZATION

Metallic mineralization in the orebody is simple. Molybdenite and pyrite are the most abundant with minor amounts of hematite and magnetite and trace amounts of chalcopyrite.

Two types of molybdenite mineralization occur within the orebody. The most prominent mineralization is the 6 inch to 4 foot wide continuous quartz veins with characteristic ribbons of molybdenite mineralization; some moly occurs as very finely divided grains within the quartz veins.

The second type of mineralization occurs as fine fractures filled with quartz-moly in the form of a stockwork adjacent to and surrounding the major quartz veins. This zone of stockwork is essentially a halo around the quartz veins which varies in width from 20 to 200 feet.

The distribution of high and low grade molybdenum mineralization is shown on the appended map, Endako Orebody, Plan and Sections. A pyrite halo is noted only on the south side of the orebody where pyrite and quartz without molybdenite occur as fracture fillings.

STRUCTURE

Structural elements of the Endako orebody are illustrated on the attached map Geology of 3399 Bench.

The prevalent attitude of the major quartz-molybdenite veins is roughly easterly to northeasterly and dipping southeasterly as shown on left stereogram.

A plot of 475 major and minor veins is shown on the middle stereogram. Once again the majority of the veins shows up as east-west to N 70 E with southeasterly dip. Some are N 50 W with southwesterly dip which parallels the regional trend; a minor concentration trends N 52 E with a northwesterly dip. Some very prominent flat-lying sets of veins are also encountered.

The concentrations of 163 non-mineralized faults and fractures are seen as northeast and due north attitudes. The EW and NW fault systems generally occur along existing veins and are seen as gouge along contacts and brecciation within the vein.

............/

In summary, the major veins are striking east-west and south dipping with finer veins to the northwest and north-east; these attitudes are subparallel to the post mineral EW, NW and NE fault movements. This is significant beacuse the vein and fault attitudes within the orebody correspond to the regional NW and EW structural trends.

The area outside of the Endako orebody is virtually devoid of quartz veins and any structural interpretation must explain the restricted extent of the Endako stockwork. It is our opinion that the intersection of the regional EW and NW structures is not sufficient to produce the necessary degree of fracturing which is seen in the Endako stockwork. However, the intersection area of these two zones could be the focal point for intrusion and attendent doming. The doming hypothesis requires that the stockwork be restricted, and it also requires that mineralization and hydrothermal alteration be similarly restricted. The presence of these conditions, plus the intrusions of dykes and the presence of prominent flat-lying vein structures is in agreement with the concept of intrusion and doming.

The Endako orebody is then visualized as hydrothermal alteration and quartz-molybdenite mineralization in a restricted stockwork which was formed along an elongated EW dome by uplift and intrusion at the intersection of regional EW and NW fault systems.

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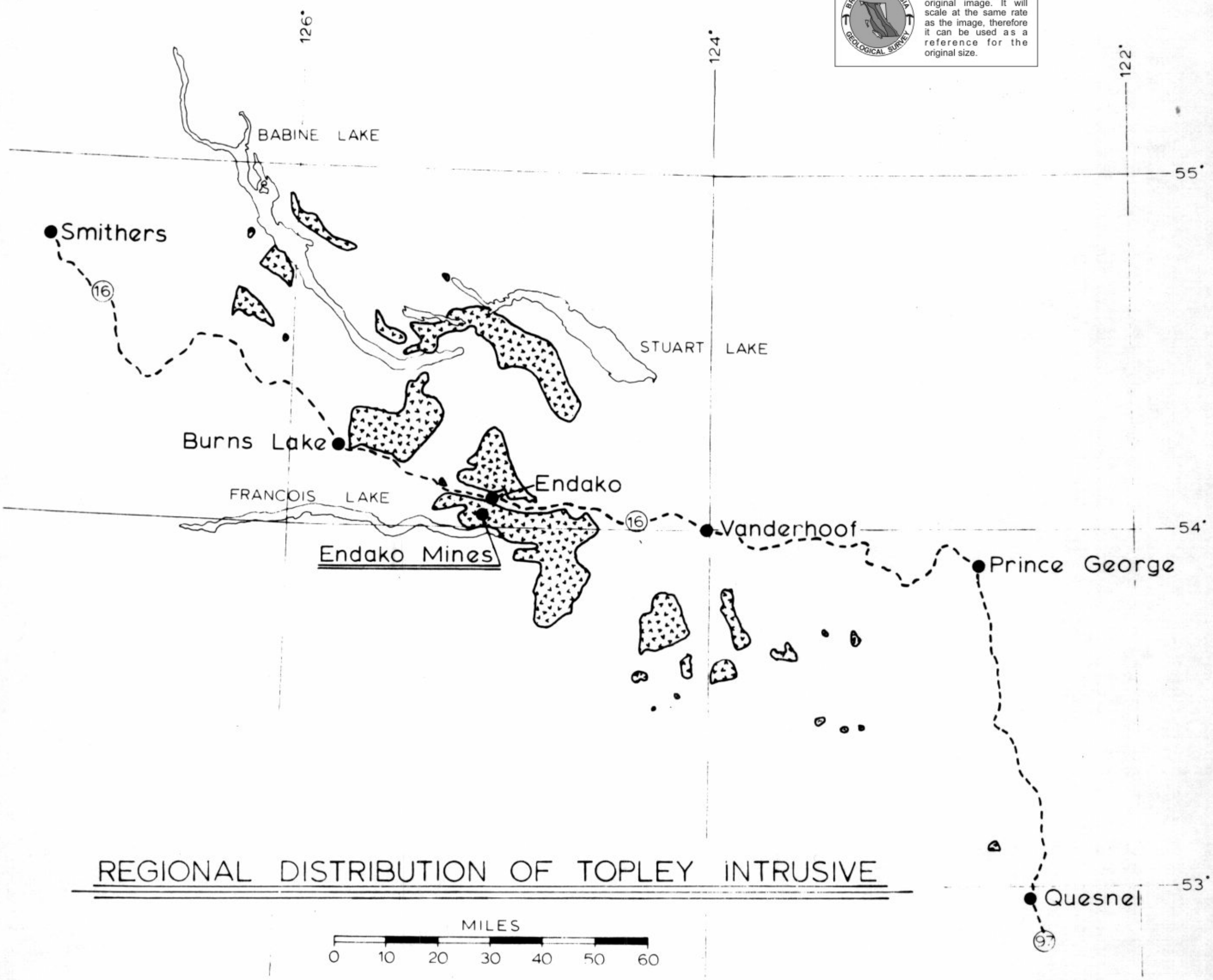
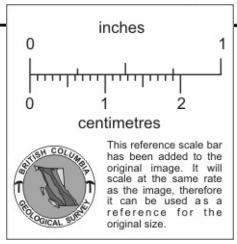
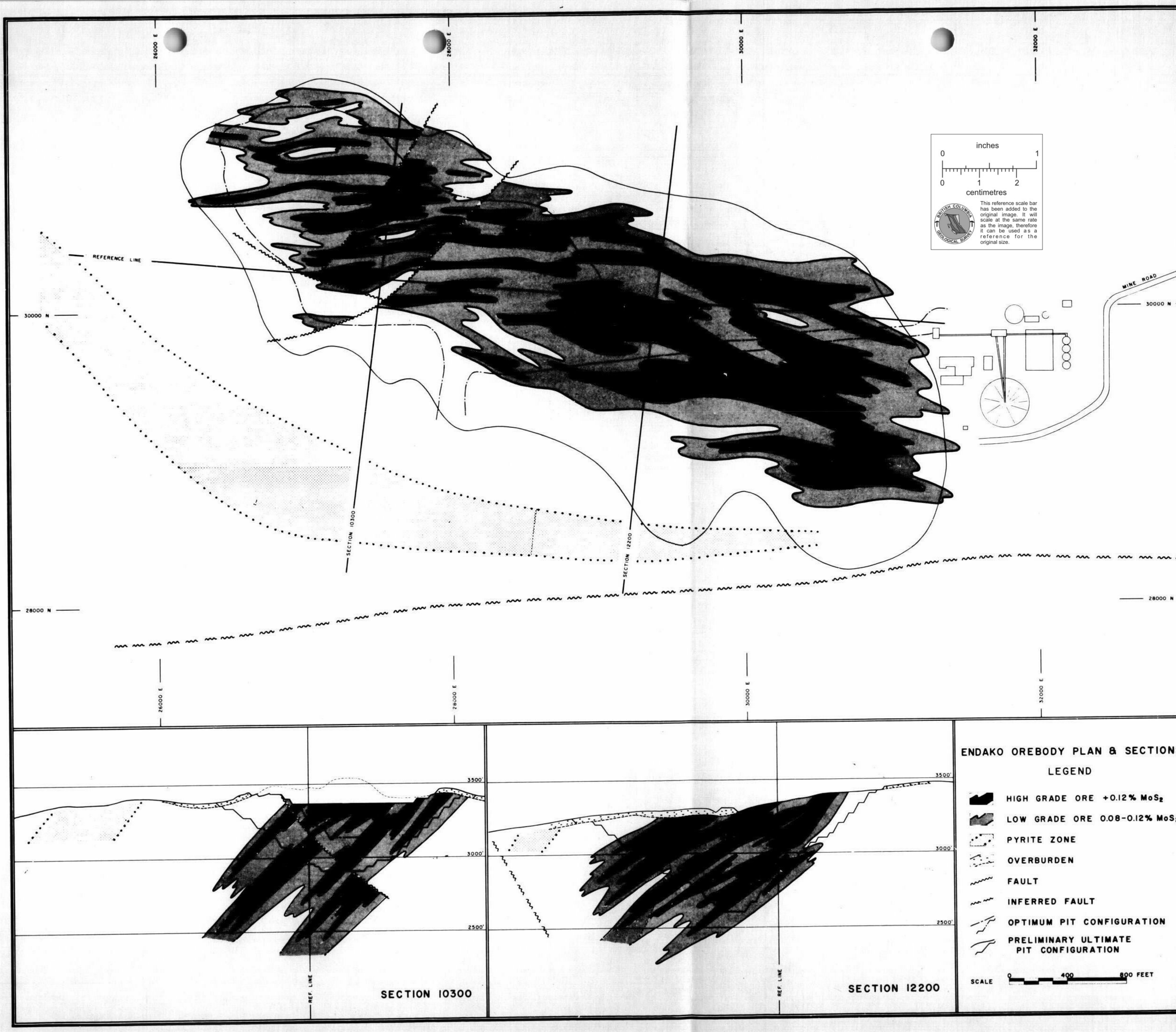


REGIONAL DISTRIBUTION OF TOPLEY INTRUSIVE

AFTER G.S.C. MAP 932A (2nd Ed.)




ENDAKO OREBODY PLAN & SECTIONS
LEGEND
HIGH GRADE ORE +0.12% MoS_2
LOW GRADE ORE 0.08-0.12% MoS_2
PYRITE ZONE
OVERBURDEN
FAULT
INFERRED FAULT
OPTIMUM PIT CONFIGURATION
PRELIMINARY ULTIMATE PIT CONFIGURATION
SCALE 0 400 800 FEET
SECTION 10300
SECTION 12200
REFERENCE LINE
MINE ROAD
26000 E
28000 E
30000 E
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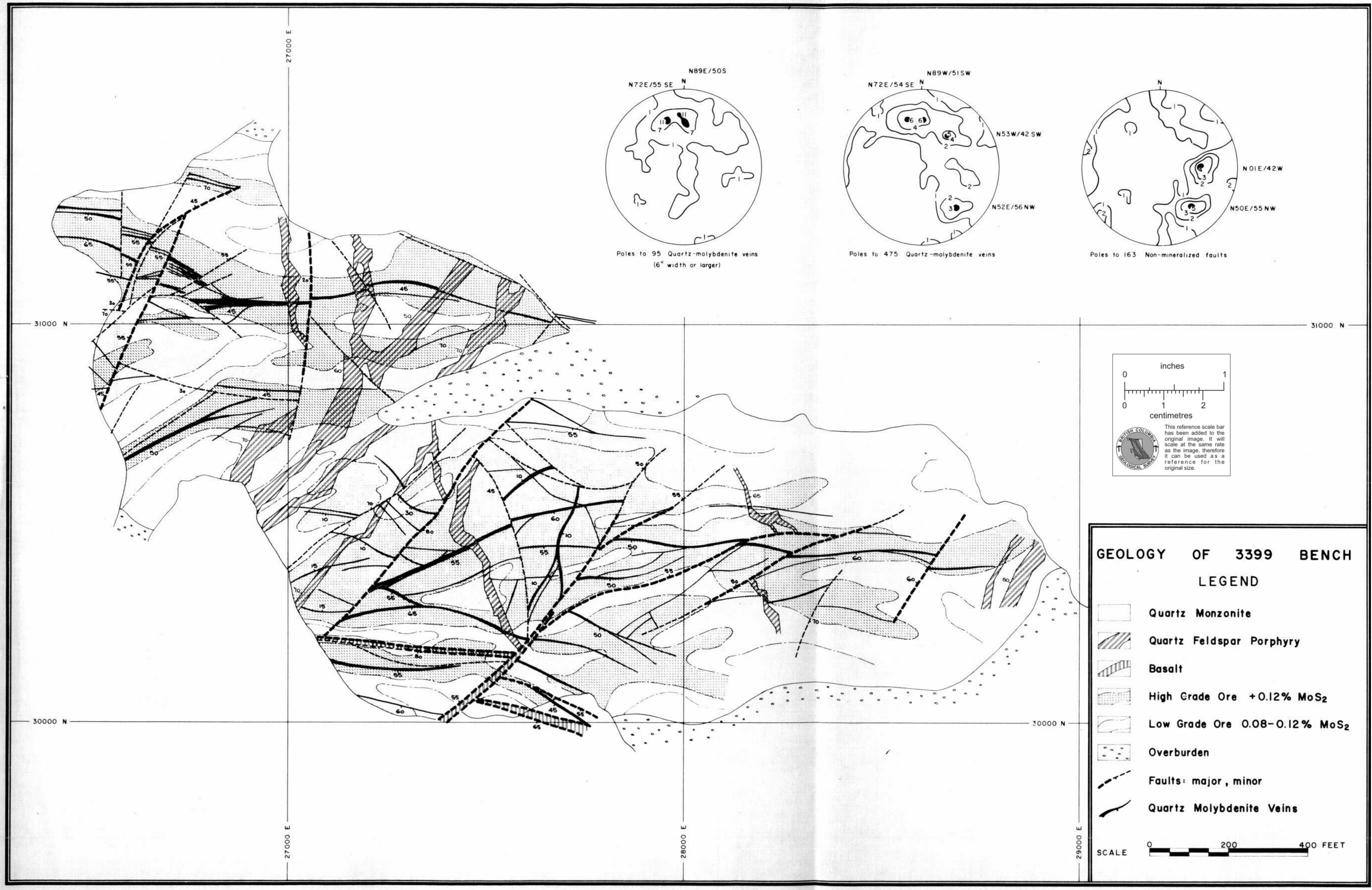
BRITISH COLUMBIA GEOLOGICAL SURVEY


GEOLOGY OF 3399 BENCH
LEGEND
Quartz Monzonite
Quartz Feldspar Porphyry
Basalt
High Grade Ore +0.12% MoS2
Low Grade Ore 0.08-0.12% MoS2
Overburden
Faults: major, minor
Quartz Molybdenite Veins
SCALE 0 200 400 FEET
Poles to 95 Quartz-molybdenite veins (6" width or larger)
N89E/50S
N72E/55 SE
Poles to 475 Quartz-molybdenite veins
N89W/51SW
N72E/54 SE
N53W/42 SW
N52E/56 NW
Poles to 163 Non-mineralized faults
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N50E/55 NW
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HYDROTHERMAL ALTERATION AT ENDAKO MINES -

A COMPARISON TO EXPERIMENTAL STUDIES

BY

A. D. DRUMMOND*

AND

E. T. KIMURA**

* Research Geologist, Canex Aerial Exploration Ltd., Vancouver, B. C.

** Senior Geologist, Endako Mines Ltd., Endako, B. C.

ABSTRACT

The significance of K-feldspar-bearing and sericite-bearing envelopes within the pervasively kaolinized rocks of the Endako molybdenite deposit may be explained in the light of experimental studies by J. J. Hemley in the system K_2O - Al_2O_3 - SiO_2 - H_2O.

Relative vein sequence of hydrothermal alteration products is illustrated more distinctly at Endako Mines than in many of the porphyry copper deposits. Cross-cutting relations indicate a relative age sequence among the various silicate stages which is in agreement with a chemical control based on the activity ratio of K^+/H^+ in a nearly isothermal environment.

INTRODUCTION

This paper is presented to illustrate that the products of hydrothermal alteration and their interdependence can be readily explained in terms of the experimental work of J. J. Hemley in the system K_2O - Al_2O_3 - SiO_2 - H_2O. Many of the porphyry copper type of deposits (excluding Butte) do not show the relative alteration sequence as distinctly as it is seen at the Endako molybdenite deposit (Titley and Hicks (1966)).

Endako Mines is located 100 miles west of Prince George and about 350 miles north of Vancouver at the geographical center of British Columbia. The molybdenum deposit occurs in the Endako quartz monzonite which is one of the oldest rock types of the composite Topley intrusive and which has been dated at 140 m.y. (White et al (1967)). The batholith is considered to be of Jurassic age (Armstrong (1949) p. 92). Regional geology and structural interpretation of the Endako deposit was presented at the 1966 C.I.M. - B.C. Section convention in Victoria (Kimura and Drummond (1966)).

The Endako orebody is an elongated elliptically-shaped stockwork which strikes N70W, dips 20 to 50 degrees south, and measures about 6,000 feet long by 1,200 feet wide. Ore reserves as of March 15, 1968 at an 0.08% MoS_2 cutoff are 239,000,000 tons grading 0.15% MoS_2. The mill capacity has been expanded to 22,000 tons per day. The average strip ratio for the ore reserves within the current ultimate pit outline is 0.5:1.

MINE GEOLOGY

The Endako quartz monzonite and three mineralogically distinct pre-mineral dykes form the host for the mineralized stockwork. The Endako quartz monzonite is generally equigranular (3 - 4 mm.) with some K-feldspar crystals occasionally as large as 7 mm. This size difference imparts a suggestion of a porphyritic texture but is not sufficiently distinctive to warrant the term "porphyritic". Composition is quartz (30%), pale pink to orange-tinged K-feldspar (perthitic orthoclase, $2V_x$ large) (35%), white to greenish-tinged plagioclase (An_{20}) (30%), and partially chloritized black biotite (5%). Apatite, zircon, pyrite and magnetite comprise the accessory minerals. The K-feldspar/total feldspar ratio may vary between 2/3 and 1/2, but is predominantly 1/2. Therefore, the rock type is classified as quartz monzonite rather than granite.

Aplite is the least abundant dyke rock in the mine. It is typically fine-grained, pink, graphic textured, and is composed of quartz (40%), pink orthoclase (40%), white plagioclase (An_{20}) (20%), and less than 1% chloritized biotite.

Porphyritic granite is more abundant and has large Carlsbad-twinned orthoclase phenocrysts (1 cm.) (3%) scattered throughout a finer grained, phaneritic, seriate-textured matrix (0.1 - 1 cm.). Seriate matrix is composed of quartz (20%), K-feldspar (45%), plagioclase (25%), and biotite (5%). Zircon and apatite comprise the accessory minerals. Porphyritic granite dykes have only been observed to intrude the Endako quartz monzonite in the mine area and are, in turn, intruded by quartz-feldspar porphyry.

Quartz-feldspar porphyry is the most abundant dyke rock in the mine vicinity. Two phases have been observed: (1) a brown to pink rock composed of K-feldspar (orthoclase, $2V_x$ large) (2 mm.) (1-5%) and (2) a brown rock with quartz (5-10%), K-feldspar (1-5%), and sagenitic biotite (1-3%) phenocrysts (1-2 mm.) in a dense, aphanitic matrix (0.05 mm.). The latter is termed quartz-feldspar porphyry-biotite phase in which characteristically, scattered K-feldspar phenocrysts may be up to 1 cm. in length. Matrix is composed of quartz (50%), K-feldspar (40%), plagioclase (5%), biotite (5%), and accessory minerals of apatite and zircon. Quartz-feldspar porphyry intrudes the Endako quartz monzonite, aplite and porphyritic granite which makes this dyke the latest pre-ore dyke in the mine area.

Post-ore basalt dykes cross-cut the quartz monzonite, the pre-ore dykes and the mineralization.

MINERALOGY, ALTERATION, AND RELATIVE VEIN AGE

Detailed megascopic, petrographic, and X-ray diffractometer studies have been conducted on the vein mineralogy and on the attendant hydrothermal alteration. Comparison of vein and specific types of alteration allow formulation of a mineralization sequence.

A. ALTERATION MINERALOGY

The presence or absence of specific mineral phases and their relationship to each other is the essence of an alteration study. It is essential that introduced or secondary features are not mistaken for primary variations within the Endako quartz monzonite host.

X-ray analysis of the fine-grained alteration clay minerals without the use of D.T.A. (Differential Thermal Analysis) or heat treatment facilities will allow only an approximate identification. Consequently, the terms, sericite, kaolinite, and montmorillonite refer respectively to the presence of a 10Å mica group mineral, a 7Å kaolinite group mineral, and a 14Å montmorillonite-type mineral. Where present, the latter are glycolated and the shift in 14Å peak is checked. Polymorphs of sericite as outlined by Velde (1965) were not determined as this aspect of the mineralogy was beyond the scope of this study.

Three distinct hydrothermal alteration phases are observed within the Endako ore zone: (1) envelopes with K-feldspar; (2) envelopes with sericite; and (3) pervasive kaolinization. An envelope is defined as a band or zone of introduced silicates around a central vein or fracture. Pervasive alteration of the quartz monzonite is always present to some degree on the outward side of the envelope.

1. K-feldspar-Bearing Envelopes

Evidence of introduced K-feldspar is seen in three distinct megascopic forms. Envelopes of 1/8 to 2 inches width which may be developed adjacent to either quartz or quartz-molybdenite veins, are composed of either K-feldspar (100%) or K-feldspar (95%) and quartz (5%). No other silicates or metallic phases are present in the envelope.

A second type of envelope is composed of K-feldspar (90%) and biotite (10%) in which quartz may locally be present up to 5%. The K-feldspar-biotite assemblage may also form lenses without the presence of a central vein. These lenses appear to have been developed along fractures and veins in widths up to 24 inches. Envelopes are much more common than the lenses.

A third type of envelope is distinctly different in that it contains K-feldspar (60% or more), quartz (30%), biotite (up to 5%), and altered plagioclase (5% or more). This type appears to be a relative increase in K-feldspar/total feldspar ratio over that which occurs in the adjacent pervasively altered quartz monzonite (quartz (30%), K-feldspar (35%), plagioclase (30%), and biotite (5%)).

Field or textural evidence appears to be the only reliable method to distinguish hydrothermal K-feldspar (envelopes) and primary K-feldspar (original constituent of quartz monzonite). Petrographic work shows that the introduced K-feldspar has replaced the constituents of the original rock adjacent to the vein.

The degree of triclinicity between primary and secondary K-feldspar was compared using an X-ray diffractometer. Two modifications of K-feldspar are orthoclase (monoclinic, disordered) and microcline (triclinic, ordered). With falling temperature, disordered orthoclase will become more ordered and its structure will become progressively triclinic. Results of the X-ray analysis showed only the disordered, monoclinic form, orthoclase.

Observations indicate that pink or salmon coloured K-feldspar can exist either in envelopes or as a primary constituent. It is also possible to get both colours in the K-feldspar crystals without any apparent optical difference in thin section. Occasionally under high magnification, the salmon pink coloured portion will show the presence of minute red specks which could be finely divided powdery hematite. X-ray patterns of the two colour types eliminated the possibility of more than one K-feldspar modification. The conclusion is that salmon pink coloured K-feldspar does not necessarily indicate the presence of hydrothermal K-feldspar and that the probable cause of the colouration is finely divided hematite.

2. Sericite-Bearing Envelopes

A grey, megascopically sharp envelope is developed on quartz-molybdenite and/or magnetite and on quartz-pyrite veins in widths from 1/8th to 2 inches. This type of envelope is composed of quartz (55 to 60%), sericite (10Å) (30 - 35%), and finely disseminated pyrite (1 - 5%). X-ray diffractometer patterns of the envelopes show an absence of kaolinite (7Å) or montmorillonite (14Å) peaks. Within the envelope, the original rock K-feldspar, plagioclase, and biotite have been replaced by sericite and quartz. Iron from the breakdown of the biotite has been sulphidized to form pyrite. The majority of grey envelopes have this mineralogy. Sericitic envelopes are less common than K-feldspar-bearing envelopes.

In only a few cases, the development of the envelope does not appear to be complete. In these, sericitized biotite, relict feldspar, and a very fine-grained presently unidentified mineral may be present in addition to the quartz, sericite, and pyrite. The unidentified mineral is white or grey and has the following properties in thin section: colourless, untwinned, low negative relief with respect to Canada balsam, birefringence of about .007, optically positive (?) with $2V_Z$ large (?), and with 'r' less than 'v' about Z. These properties agree with gypsum but the presence of gypsum has not been confirmed.

To date, three examples of quartz-sericite-pyrite envelopes have been observed adjacent to a vein in which a pink mineral occurs in addition to the regular vein phases. Peterson, Gilbert, and Quick (1946) who worked on the Castle Dome deposit in Arizona described quartz-sericite-pyrite envelopes in which the original rock orthoclase is unstable and is altered to sericite while at the same time, adularia (disordered, low temperature modification of orthoclase) is deposited in the vein. Their description could also agree with those few cases of a pink mineral in a vein with a sericitic envelope at Endako. The significance of this assemblage is difficult to assess because their abundance is extremely minor.

3. Pervasive Kaolinization

Plagioclase is the most sensitive indicator of progressive pervasive alteration between the outward limit of an envelope and fresh quartz monzonite. The mineralogical change from hard grey plagioclase in fresh rock to a soft greenish mixture of kaolinite and sericite is sufficiently distinct to allow classification.

(a) Unaltered Quartz Monzonite

Fresh equigranular quartz monzonite is composed of quartz (30%), pink K-feldspar (perthitic orthoclase, $2V_x$

large) (35%), hard grey plagioclase (twinned and generally not zoned, $2\theta(131) - 2\theta(1\bar{3}1) = 1.50$ (An_{20})) (30%), and black biotite (5%). Accessory minerals are apatite, zircon, sphene, and magnetite.

(b) Weak Kaolinization

Weakly kaolinized quartz monzonite has quartz (30%), pink orthoclase (35%), greenish grey plagioclase (30%), and black or chloritized biotite (5%). Accessory minerals are apatite, zircon, and magnetite or powdery hematite. The greenish-tinged plagioclase generally shows a hard grey rim and a softer greenish core. X-ray analysis of the core and rim indicate that the plagioclase is An_{20} ($2\theta(131) - 2\theta(1\bar{3}1) = 1.50$) and that the major alteration products are kaolinite and sericite. Minor amounts of a montmorillonite-type clay are locally present when the soft core has white 'specks' which will noticeably swell when a freshly broken rock surface is exposed to the air.

In thin section, minute amounts of a carbonate, probably calcite are seen along with a brownish to greenish, weakly pleochroic mineral which may possibly be a mixture of the clay minerals and chloritized biotite or chlorite. This greenish mineral is generally confined to certain more calcic zones which existed in the original plagioclase. It may also be found along minute fractures which cross-cut the zoning in the plagioclase. The carbonate and chlorite (?) are not present in sufficient quantities to be detected by X-ray.

Recognition of this classification is based on the presence of zoned plagioclase crystals with a hard grey rim and a soft green core which locally may show white 'specks' that swell on exposure in air, and on the presence of K-feldspar which has not been attacked.

(c) Moderate Kaolinization

Moderately kaolinized quartz monzonite has the same relative mineral percentages as the weakly kaolinized rock. Accessory minerals are also the same. K-feldspar is not attacked and the mafic is either black or chloritized biotite. The 'plagioclase' has completely broken down and is either a soft homogeneously pale green or white coloured mixture of clay minerals. X-ray analysis indicates only the presence of kaolinite and sericite. Montmorillonite is not present and appears only as an alteration phase when the pervasive alteration is weak.

In thin section, the soft white or homogeneous pale green 'plagioclase' shows sericite, kaolinite, carbonate (calcite (?)), and chloritic material in a pattern which resembles the relict core described for the Weak Kaolinization. Since the degree of alteration is relatively more intense, the hard rim is now seen as a kaolinite-rich band which surrounds the above described altered core. Sericite flakes have not been observed in this kaolinite replacement of the original plagioclase rim. Biotite may be sagenitic and generally has minute rutile grains clustered around the periphery of the biotite flake.

Recognition of this classification is based on the presence of unattacked pink K-feldspar and the complete breakdown of plagioclase.

(d) Intense Kaolinization

Intensely kaolinized quartz monzonite has quartz (30%), pale bleached 'K-feldspar' (30 - 35%), pale greenish or whitish areas (originally plagioclase) (30 - 35%), and fresh black to bleached biotite (0 - 5%). Accessory minerals are apatite, zircon and sphene (?). Magnetite, powdery hematite or pyrite may be present in trace amounts. Petrography and X-ray analysis indicate that original plagioclase has completely broken down to kaolinite and sericite and that the residual K-feldspar has been replaced by kaolinite and a little sericite.

Some whitish (originally plagioclase) material occurs within a greenish area (also originally plagioclase) and adjacent to bleached pink orthoclase. X-ray patterns of both types of altered plagioclase were identical. Petrographic evidence indicated a greater development of very fine-grained biotite plates in the white kaolinite-rich altered plagioclase grains relative to the greenish altered plagioclase. This suggests that iron which may impart a greenish colouration to kaolinite in one case, has been fixed in biotite in the other case and consequently the coexisting kaolinite is white. This agrees with the coexistence of secondary biotite with kaolinite in the intensely kaolinized rocks.

Recognition of this classification is based on the presence of completely altered plagioclase and noticeably attacked K-feldspar.

B. VEIN MINERALOGY

Metallic mineralization in the orebody is simple. Molybdenite, magnetite and pyrite are the most abundant with trace amounts of chalcopyrite, bornite, scheelite, and specularite. Bornite and specularite are subordinate to chalcopyrite in abundance.

Two types of molybdenite mineralization occur within the orebody. The most prominent mineralization is the 6 inch to 4 foot wide continuous quartz vein with characteristic ribbons of molybdenite. Some molybdenite occurs as very finely divided grains within the quartz veins. The second type occurs as fine fractures filled with quartz-molybdenite in the form of a stockwork adjacent to and surrounding the major quartz veins. This zone of stockwork forms a halo of economic mineralization around the major quartz veins and may vary in width from 20 to 200 feet.

The appearance and magnetic susceptibility of magnetite in quartz-magnetite veins varies with depth. Near surface, 'magnetite' is termed 'powdery hematite' as it has a red streak, is non-magnetic and gives only hematite peaks on an X-ray pattern. With depth, powdery hematite becomes weakly to strongly magnetic and the colour and streak change simultaneously from red to brownish black or black. A polished section of a black magnetite with a brownish streak showed that very fine hematite grains had developed along unoriented fractures within the magnetite. Iron, originally in magnetite has been dissolved as ferrous iron and oxidized to insoluble ferric oxide or hematite. A reaction of the following type is thought to occur:

$$2Fe^{++} + \tfrac{1}{2}O_2 + 2H_2O = Fe_2O_3 + 4H^+.$$

This variation in the magnetite with depth suggests that the development of hematite is secondary and is probably related to a Tertiary erosion surface.

It must be noted that quartz-specularite veins do occur as a late feature in the development of the Endako stockwork. These veins should not be confused with the above secondary change of magnetite to powdery hematite.

Occurrence of chalcopyrite is generally coincident with pyrite and magnetite in the larger quartz-molybdenite veins. Specks of bornite are rarely seen but when observed they are on fractures near chalcopyrite.

C. AGE RELATIONS OF VEIN AND ALTERATION TYPES

A sequence of relative vein ages and alteration types has been compiled from numerous observations of cross-cutting relationships in logging drill core and in mapping the open pit. These are listed in Figure 1. The various stages outlined in Figure 1 are superimposed on each other with their net result being the Endako stockwork. It must be noted that five to seven individual cross-cutting features may be present in a single hand specimen.

The following type of observation is the basis for Figure 1. A quartz-molybdenite vein with a K-feldspar envelope may be intersected by a quartz-molybdenite vein with a quartz-sericite-pyrite envelope

STAGE	VEIN	ENVELOPE
1 (oldest)	Qu, Qu-Mo Qu-Mag ($\pm$ Py)	a) K-spar b) K-spar-Bio., c) Qu-K-spar-Bio-(minor altered plagioclase)
2	(Qu-Mo-minor K-spar) Qu-Mag Qu-Mo Qu-Mag-Mo (all $\pm$ Py, Cpy, Bn) Qu-Py ($\pm$ Mo, Mag)	(Qu-Ser-Py) ((?)) Qu-Ser-Py, Qu-Ser-Py Qu-Ser-Py Qu-Ser-Py ((Pyrite Zone))
3*	Qu-Mo Qu-Mag Qu-Mag-Mo ($\pm$ Py, Cpy)	((No envelopes))
4*	Qu-Py	((No envelopes)) (Occasionally, may have 'bleached halo' around veins)
5	Spec-minor Qu Calcite Chalcedony	((No envelopes))
6 (youngest)	Late unfilled fractures	

FIGURE 1: Table showing relative ages of veins and envelopes. (The following notation is used: Qu - quartz; K-spar - K-feldspar; Bio - biotite; Ser - sericite; Mo - molybdenite; Mag - magnetite; Py - pyrite; Cpy - chalcopyrite; Bn - bornite; Spec - specularite).

* Barren quartz veins may also occur with Stages 3 and 4.

without any offset. The relative age can be deduced because the introduced K-feldspar of the first envelope has been replaced by sericite at the intersection area of two veins. The problem of geometry of zoned alteration around central veins or fractures has been discussed by Meyer and Hemley (1967) p. 180 - 183.

Three K-feldspar-bearing envelopes are shown in Stage 1. There does not appear to be any correlation between a specific type of envelope and the vein mineralogy. Similarly, there is no apparent correlation between specific vein minerals and sericitic envelopes. However, within the orebody, the following generalization is true: K-feldspar-bearing envelopes are more commonly developed on quartz-molybdenite veins and sericitic envelopes are more commonly developed on quartz-magnetite veins. The presence of magnetite and molybdenite with both envelope types only points out that magnetite has played an integral part in the mineralization history.

Width of envelopes does not appear to bear any relation to vein width and/or vein mineralogy. For example, observations indicate that a 1 inch K-feldspar envelope can occur on a 1/8th inch quartz-molybdenite vein as often as a ¼ inch K-feldspar envelope can occur on a 1 inch quartz-molybdenite vein. The width of the envelope is dependent on the length of time that the original fracture was open to the altering and mineralizing fluid. Maximum envelope width recorded is 8 inches.

There are a few quartz-molybdenite veins which contain a pink K-feldspar and which have a quartz-sericite-pyrite envelope. Their relative position in Figure 1 is not accurately known. They are grouped with the other examples of sericitic envelopes and are thought to be a possible transition phase between Stages 1 and 2.

A 200 to 500 foot zone rich in pyrite occurs along the south side of the orebody. Within this zone, sericitic envelopes up to 1/2 inch are developed on quartz-pyrite ($\pm$ molybdenite and/or magnetite) veins but within the orebody sericitic envelopes are developed on quartz-magnetite-molybdenite ($\pm$ pyrite) veins.

The stockwork must have been under tensional stress during the formation of the large rich quartz-molybdenite veins without envelopes (Stage 3). These veins have been reopened several times to allow the precipitation of as many as 21 individual molybdenite ribbons over a width of approximately 8 inches. Assuming that two ribbons were formed along the walls during each fracture period, there would have been a minimum of 10 fracture periods in the formation of a vein of this type.

Quartz-pyrite veins without sericitic envelopes in the orebody and pyrite zone occasionally have a 'bleached halo' with a width up to ½ inch. There is no difference in rock texture within the halo but the following features can be noted: (1) biotite is not present; (2) altered greenish plagioclase in the rock has turned white;

(3) pink or salmon pink K-feldspar may be present, and (4) the accessory within the halo is pyrite while outside, it is an iron oxide. This suggests that within the halo Mg and Fe have been leached as biotite has been removed, altered plagioclase has been bleached white and that Fe has been sulphidized and fixed as pyrite. The distinction is made between envelope and halo because the envelopes have changed the rock mineralogy adjacent to a vein while this bleached halo indicates only the leaching of Mg and Fe and the reprecipitation of the Fe as pyrite. These halos are of minor abundance and cannot be shown as a separate stage in Figure 2.

Outward from Stage 3 and 4 veins, the degree of kaolinization may vary from Weak to Intense. There is no correlation between the intensity of pervasive alteration and the vein mineralogy. However, within the stockwork, the most commonly encountered alteration type would lie between Weak and Moderate Kaolinization. Therefore, in general, the pervasive alteration type outward from a Stage 3 or 4 vein or Stage 1 or 2 envelope will range between Weak to Moderate Kaolinization.

It is doubtful if there is any alteration of the quartz monzonite by veins or fractures of Stages 5 or 6. A few quartz-specularite veins were observed within an intensely kaolinized shear zone but as the vein was not broken, it may have followed a previously developed shear. Calcite occurs as late veins, as open space filling (calcite rhombs up to 1 inch) and as a breccia matrix to quartz-molybdenite veined and altered quartz monzonite. Chalcedony may be found with the calcite.

D. CHEMICAL CONTROLS

Development and understanding of the sequential nature of the mineralization and its attendant hydrothermal alteration within the Endako stockwork allows postulation of some of the chemical controls involved.

The interrelationship of K-feldspar- and sericite-bearing envelopes and the presence of pervasive kaolinization is suggested by Hemley (1959) and Hemley and Jones (1964). K-feldspar envelopes were developed earlier than sericite envelopes as seen by cross-cutting relations where sericite has replaced the introduced K-feldspar. Outward from these envelopes and outward from the Stage 3 and 4 veins, the rock has been pervasively kaolinized. Textural evidence indicates that the kaolinization must have developed during the formation of the veins with and without envelopes. Late veins and fractures of Stage 5 and 6 are considered to be post alteration and consequently, are not part of this discussion.

The question of control would depend on the method that Time 1 conditions were changed to Time 2 or Time 3 conditions (see Figure 2). From the experimental work of Hemley (1959) (Figure 3), the mechanism could be either temperature or the activity ratio of K^+/H^+.

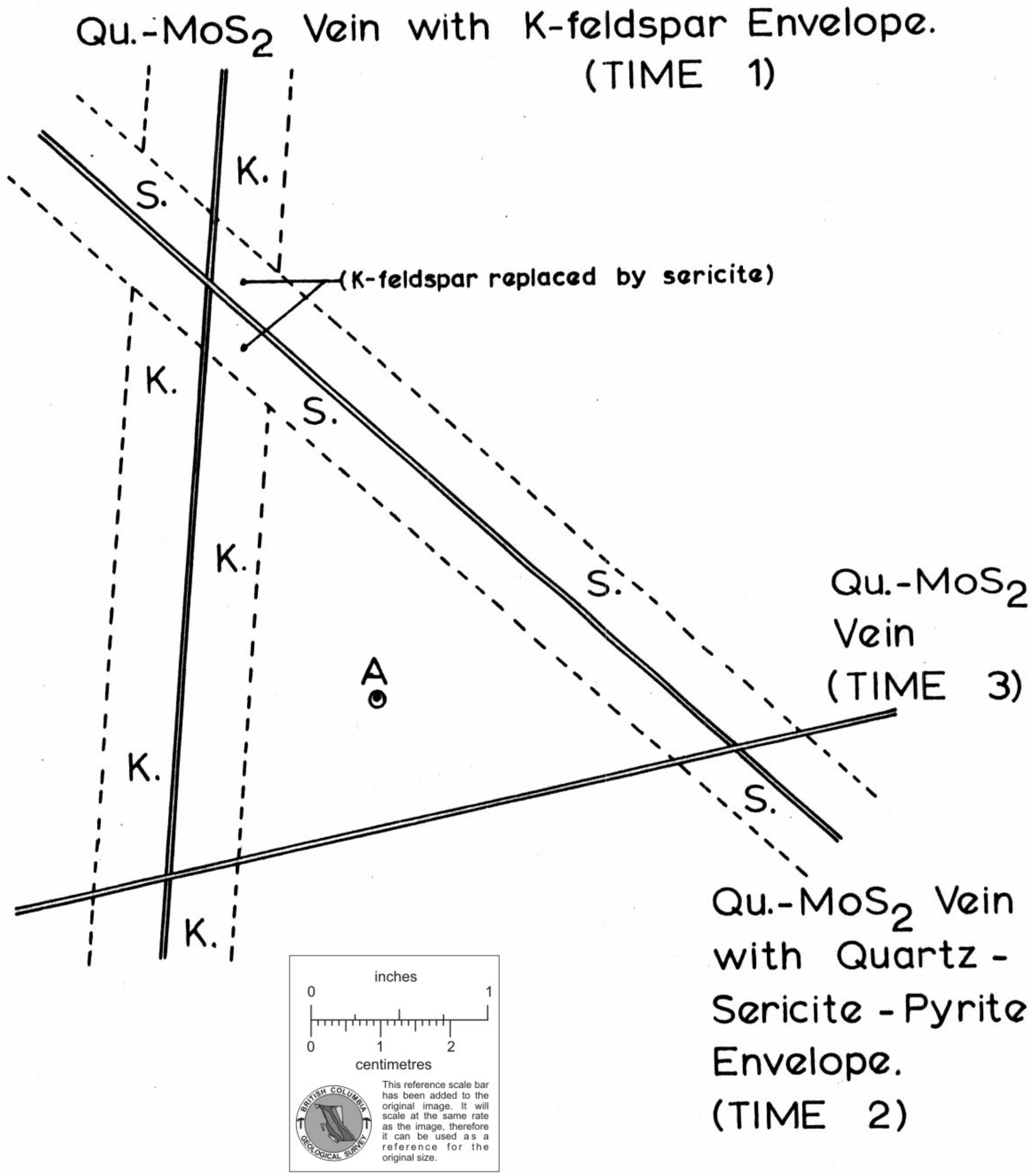
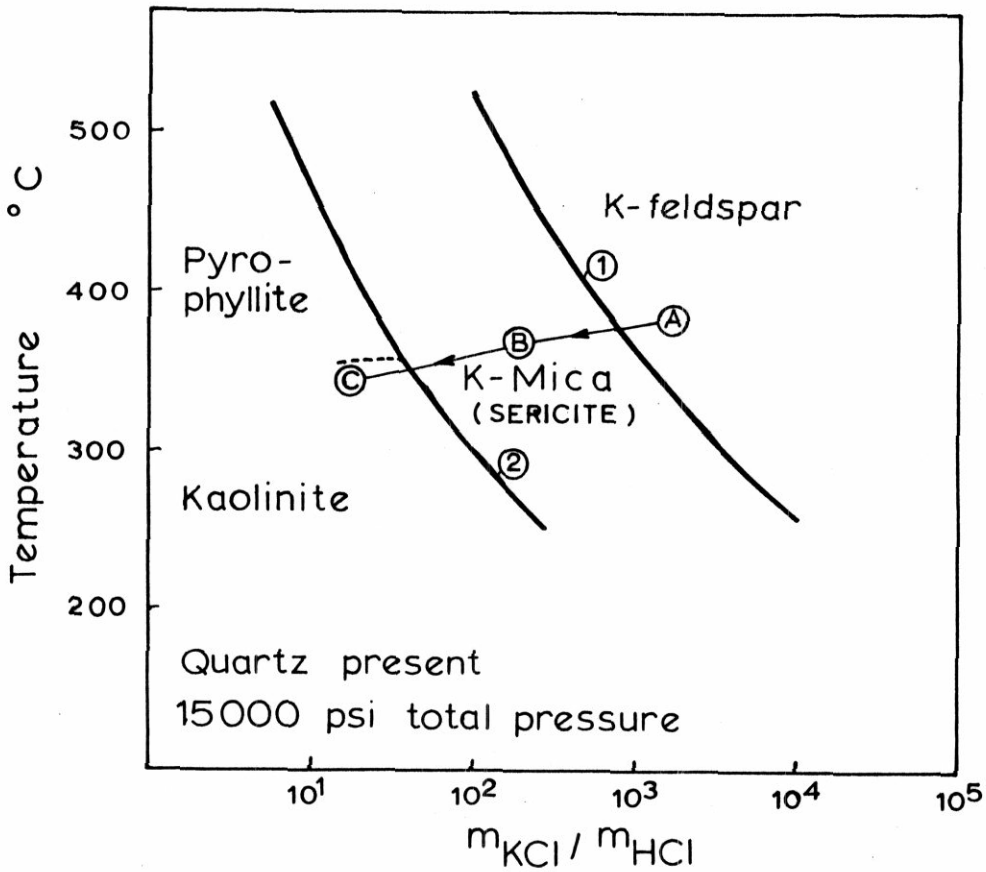
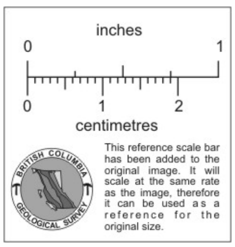


Figure 2 : Diagram illustrating time relationships of major veining events during mineralization. (Host rock is pervasively altered outward from veins with or without envelopes.)





Circled numbers relate curves to following equations:

$$3/2KAlSi_3O_8 + H^+ = 1/2KAl_3Si_3O_{10}(OH)_2 + 3SiO_2 + K^+, \quad (1)$$

(K-feldspar) (sericite)

$$KAl_3Si_3O_{10}(OH)_2 + H^+ + 3/2H_2O = 3/2Al_2Si_2O_5(OH)_4 + K^+. \quad (2)$$

(sericite) (kaolinite)

Figure 3: Reaction curves for the system $K_2O-Al_2O_3-SiO_2-H_2O$. After Hemley (1959). (Line A-B-C is explained in text.)

Temperature must have changed between Time 1 and Time 3 conditions but it is possible that the temperature difference was not great. Consider a case such as shown in Figure 2 where a quartz-molybdenite vein is imposed on a quartz-molybdenite vein with a quartz-sericite-pyrite envelope which has been imposed on a quartz-molybdenite vein with a K-feldspar envelope. Temperature variation from the vein with the K-feldspar envelope would have to be in the order of 100 degrees C. over perhaps an inch. A gradient of this magnitude is unlikely and would be a very difficult mechanism to explain the resultant mineralogy. The Endako deposit can be considered to be more or less isothermal during mineralization but it must be concluded that some temperature change occurred between Time 1 and Time 3. The major control is more logically assigned to variations in the activity ratio of K^+/H^+.

The relative ages and the different mineral assemblages are in agreement with the experimental observations of Hemley (1959). The mechanism suggests a progressive ion leaching or migration of Ca^{++}, Na^+, Mg^{++}, Fe^{++}, and Fe^{+++} toward the vein with a simultaneous migration of K^+ and H^+ outward from the vein. H^+ and K^+ would diffuse into the rock in response to concentration gradients from the vein. The K^+/H^+ activity ratio would then vary outward from the vein in some non-linear manner which is dependent on the rate of supply of heat, K^+, pH, and on the rate of removal of leached constituents. Iron may not be removed in the case of the K-feldspar-biotite or quartz-sericite-pyrite envelopes where the iron is fixed in the biotite or sulphidized to pyrite respectively. Using this concept of two-way migration and fixation, development of K-feldspar and sericite-bearing envelopes and the absence of an envelope can be explained by the same chemical control in essentially an isothermal environment.

Using Hemley's curves, it is suggested that for Stage 1 veins with K-feldspar envelopes, the activity ratio of K^+/H^+ at Time 1 must have been in the K-feldspar field. K-feldspar adjacent to these veins has completely changed the mineralogy and texture of the original rock. At some later time (Time 2), the activity ratio was within the K-mica (sericite) field as sericite replaces the earlier introduced K-feldspar as well as changing the mineralogy and texture of the original rock. The K^+/H^+ ratio would further decrease with time (Time 3) and would move into the field of kaolinite. It must also be noted that a K^+/H^+ decrease will occur outward from veins with or without envelopes. This latter mechanism is the cause of the pervasive kaolinization.

The general trend in the change of the activity ratio with TIME is illustrated by line A-B-C (Figure 3). Point A would represent the Stage 1 veins and development of K-feldspar envelopes at Time 1; point B would represent Stage 2 veins and development of sericitic envelopes at Time 2; and point C would represent the development of Stage 3 veins without envelopes. Slope of line A-B-C would necessarily be low and positive because the temperature difference would be small. Absolute location of the trend line is unknown because the temperature at point C is unknown. Point C must be below the pyrophyllite field (about 350C) as pyrophyllite is absent. Consequently, this line indicates only the generalized trend in chemical change during mineralization.

Several other possible variables must be mentioned but their individual role is not fully understood. The activity of silica has been reported by Fournier (1967) to be responsible for the coexistence of the pair K-feldspar-kaolinite. At Ely, Nevada, Fournier found that plagioclase broke down to a mixture of hydrothermal K-feldspar and kaolinite at low temperature and high silica activity at 1,000 bars. At Endako, K-feldspar may replace altered plagioclase within K-feldspar-bearing envelopes but the pair K-feldspar-kaolinite are not observed to be a breakdown product of plagioclase. This is in agreement with Meyer and Hemley (1959) who suggest that K-feldspar was metastable at the time of formation of kaolinite in the argillite zone at Butte, Montana.

There must have been some control by the partial pressure of both sulphur and oxygen since sulphides (molybdenite and pyrite) as well as oxide (magnetite) exist in the veins. Meyer and Hemley (1967) note a strong correlation between hydrogen metasomatism and fugacity of sulphur in ore mineral assemblages and state that "strong hydrogen metasomatism exists only when the S/O fugacity ratio is relatively high, not merely when oxygen fugacity is high" (p. 222).

SUMMARY AND CONCLUSIONS

Three characteristic alteration features of the Endako quartz monzonite within the Endako molybdenum deposit are: (1) K-feldspar-bearing envelopes, (2) quartz-sericite-pyrite envelopes, and (3) pervasive kaolinization. Quartz-molybdenite (minor magnetite) veins with K-feldspar-bearing envelopes are more common within the orebody than quartz-magnetite-molybdenite veins with quartz-sericite-pyrite envelopes. Pervasive break-down of the original plagioclase to kaolinite and some sericite occurs on the outward side of the envelopes and adjacent to quartz-molybdenite veins without envelopes. Kaolinization imparts a characteristic greenish hue to the original quartz monzonite. Cross-cutting relations indicate a relative age sequence among the various silicate stages which is in agreement with a chemical control based on the activity ratio of K^+/H^+ in a nearly isothermal environment.

The relative vein sequence of hydrothermal alteration products is illustrated more distinctly at Endako than in many of the porphyry copper deposits. The change in silicate mineralogy with time follows very closely the chemical controls outlined by the experimental work of J. J. Hemley. It is hoped that more examples of mineral deposits will be published which stress the variation of silicate and metallic mineralogy with time during mineralization such that experimentalists may more closely approximate natural alteration assemblages in their laboratory investigations.

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UTAH CONSTRUCTION & MINING COMPANY
MINERAL DEVELOPMENT AND GEOLOGY DIVISION
[redacted]

INTER-OFFICE CORRESPONDENCE

TO: THE FILES

DATE: April 29, 1964

FROM: C. AIRD and A.G. HUMPHREY

COPIES TO: E.S. Rugg
G.A. Noel
A.G. Humphrey
M.J. Young
C.A. Aird

SUBJECT: NOTES ON M.E.G. MEETING, DATED APRIL 21, 1964

REFERENCE: TALK ON ENDAKO, BY DON ROTHERHAM OF CANEX AERIAL EXPLORATION LTD.

Don Rotherham discussed the Endako project from the point of view of 1. a sampling project; 2. a geological aspect.

Physical properties given for MoS_2 were: very soft, hardness 1-1.5, specific gravity 4.7-4.8, flaky, flexible, sectile, crumbly and floats easily with an affinity for grease. D.R. emphasized great care is necessary for 0.2% MoS_2 can be analagous to 1/4" of mineral over a width of 10 feet. Therefore good core recovery is essential. Molybdenite is the only economic mineral at Endako. There is less than 1% pyrite; a trace of hematite and magnetite; and very rare chalcopyrite.

The molybdenite occurs 94% in narrow, 1/64" - 1/8" quartz veins that have a banded appearance due to ribbons of molybdenite, one on each side of the vein and one in the middle frequently. Not all the ribbons are parallel however, and microscopic work revealed oblique mineralized fractures in the quartz. An affinity of molybdenite for calcite was also recognized microscopically. An additional 5% molybdenite occurs as free molybdenite in fractures and about 1% as disseminated rosettes.

There are no surface exposures at Endako consequently diamond drilling is necessary. There was some previous drilling by Andrew Robertson and Associates. With an ore of this type one could theoretically have 98% core recovery and still lose all the molybdenite. Drilling with conventional AX and BX equipment was unsatisfactory. Core recovery was poor owing to intermittent hard and soft intersections and correlation between core and sludge was poor. Canex resorted to wireline equipment with hydraulic heads, and Transmission type pumps with pressure gauges. Core recovery at once improved from 68% to 89%, however the sludge correlation was still poor. Initially the sludge values were always higher and sludges were collected in large tanks from which the water was decanted and the residue dried and weighed. The over flow from these tanks contained molybdenite, magnetite and drill cuttings at times, also it was found that at least one drill crew was using molybdenum grease on the drill rods. By switching to a rotary (Ray) type sludge splitter with baffles and an added floculant, a fair correlation between core and sludge was obtained.

Conventional diamond drill logs were used initially but a graphic type log soon proved far more useful and ore fractures were shown graphically. The core was sampled on even 10 foot intervals starting from the collar but the staff feel that sampling of vertical holes on an even 10 feet of elevation might have been a better system. The core was weighed in 10 foot sections and for the first 30,000 feet of drilling the specific gravity of a typical section was determined, then the core was split and assayed. A similar technique was used in handling the sludge. The sludge was dried, bagged and weighed. The following formula was used to weight the core and sludge using theoretical recovery figures:

$$\frac{(\%\ \text{core recovery} \times \text{core assay}) + (\%\ \text{sludge recovery} \times \text{sludge assay})}{\%\ \text{core recovery} + \%\ \text{sludge recovery}}$$

Underground exploration was used in advanced studies.

In all, 2750' of underground work was done of which 1500' consisted of raises on drill holes. All rock thus removed formed mill samples. It was first crushed to 1" size then 1/40 was taken and split into 2 parts by a Jones riffle. One part representing 1/80 of the total was kept and the other part was reduced in a cone crusher to 1/8" size and split to a 10 lb. sample weight for assay. Three assays were obtained from each round and then one composite sample from the three was taken as a check. Channel sampling was tried with raises sampled every 10 feet and drifts and crosscuts every 5 feet. Results were "pretty wild" and not in agreement with drill core or bulk sample results. However, there was a better comparison after "treating and adjusting". Direction of fracturing was a significant factor in sampling errors.

The geology at Endako is based primarily on diamond drilling. A total of
82,877 83,000 feet was completed with the average hole depth about 500 feet and the deepest 1200" feet. The host rock is a red porphyritic granite containing dikes of aplite, rhyolite porphyry ~~and quartz feldspar porphyry~~ and quartz feldspar porphyry. There are also some biotite lamprophyre dikes that are not mineralized. The ore body is strongly faulted and fractured. There is a general relationship between molybdenite and potash feldspar. There are three types of alteration at Endako: 1. Red potash metasomatism which shows up very well underground; 2. hydro mica - like chloritization except that no chlorite is present; 3. Kaolinization. Types 1 and 2 are commonly found in proximity to faulting. The best mineralization values are found where the alteration is changing rapidly. On the north side of the ore body the molybdenite stops along an east west line but the quartz seams persist beyond.

A central north-south fault divides the deposit into two zones of mineralization. The west zone is an area of old workings and is characterized by larger quartz veins from 6" up to 4 feet wide fractured and well mineralized on the footwalls and hanging walls but poorly mineralized between veins. This zone contains the best mineralization and mining will probably be initiated in this zone. On the east of the northsouth fault the quartz veins are all under 1 foot wide with the majority about 1/4" and smaller. This zone is not as strongly faulted but the mineralization is deeper and plunges about 15° to the west. An eastwest fault inferred from drilling marks the south border of this zone. It is pre-mineral and is believed to be a thrust fault that is responsible for a great deal of fracturing.

The ore body is elongated in a slightly north west-south east direction and on the north side dips 50 degrees southward, flattens in the middle, and dips at 30 degrees to the north along the south side making a canoe shaped body ideal for an open pit. In reply to a question, Don stated the body is 5,000 feet long, 600 to 1000 feet wide and deep drilling ran out of mineralization, at 650 feet depth, into progressively less altered rock that approaches the periphery rock in appearance.

Geochemistry was a great help in outlining target areas for diamond drilling. There is only 1% sulphides inthe ore body and although Canex was advised that I.P. would work the geochemical techniques were so successful that the entire ore body was delineated this way. Initially the soil samples were processed by X Ray Laboratories of Toronto at a cost of $1.00 per sample but later on Canex established their own lab.

In answer to questions Don stated there was little salting in the bulk sampling equipment and the equipment was cleaned between samples.

Clive Ball's microscopic work showed that pyrite was later than molybdenite, also that molybdenite was probably low temperature and is frequently associated with calcite. Apparently there are at least 3 ages of quartz each with molybdenite and there is a close relationship of pyrite and molybdenite over the 3 ages.

The quartz veins are very persistent. Don described one flat vein that has been traced 750 feet and is still going.

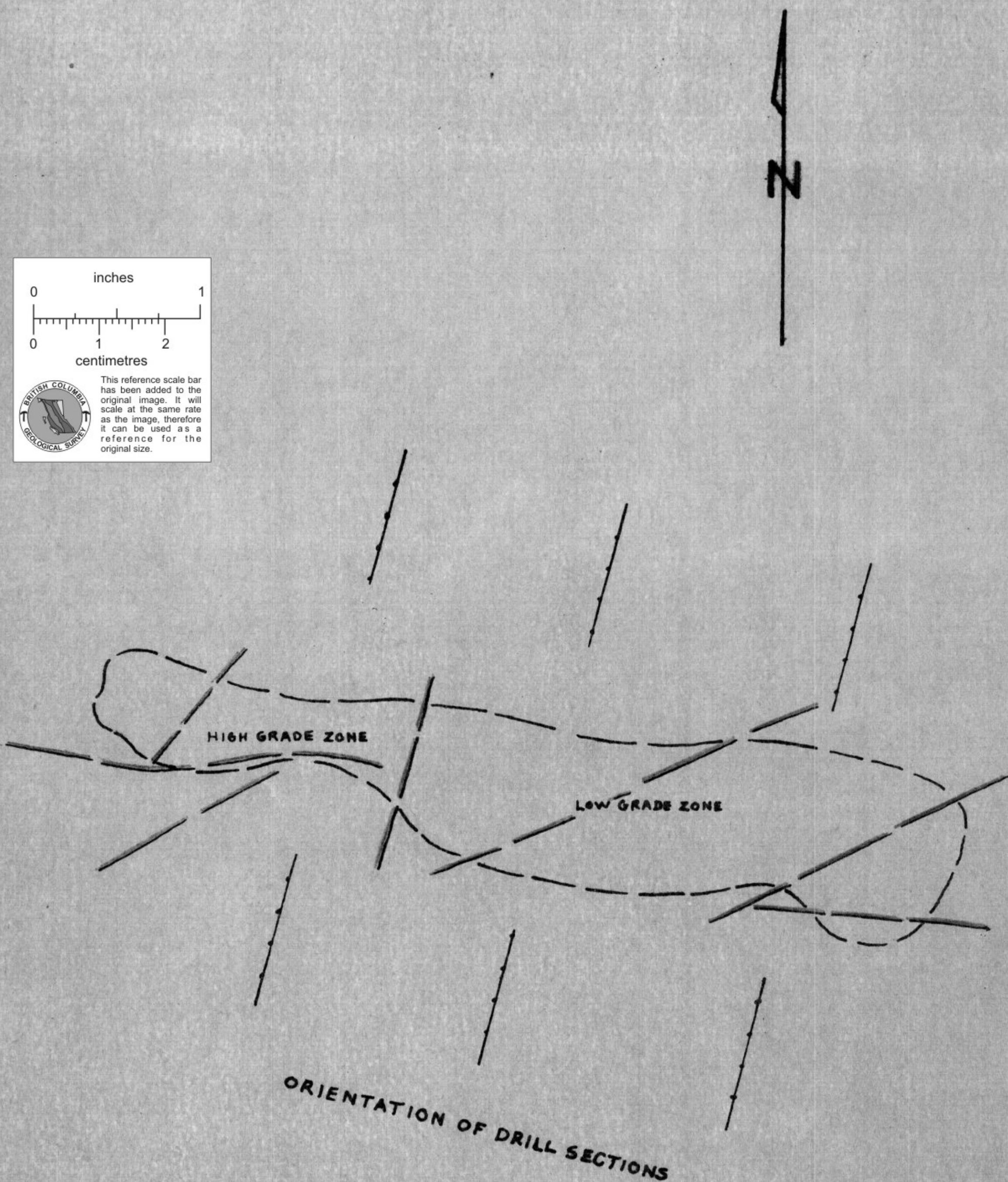
C. A. Aird

C.A. AIRD,
Geologist.

A. G. Humphrey

A.G. HUMPHREY,
Geologist.

APRIL 27, 1964
Vancouver, B.C.



SKETCH MAP
OF
ENDAKO MOLYBDENITE ORE BODY

Scale: approx. 1" = 1000 feet

C.A.A. & A.G.H. April 27, 1964

Source: M.E.G. Meeting April 21, 1964

93K/35

File: Endako 9-2.

GEOLOGY OF ENDAKO MINE

(A SUMMARY)

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January 1971.

700 BURRARD BUILDING

ENDAKO MINE

INTRODUCTION

Endako mine is the largest molybdenum producer in Canada and second largest in the world after Climax, Colorado. The deposit is an elongate stockwork of quartz-molybdenite veins developed within the Endako quartz monzonite phase of Topley Intrusions. In comparison with other Cordilleran porphyry-type copper and molybdenum deposits, Endako is notable for the paramagmatic affiliations of hydrothermal alteration and mineralization, the well-defined sequence of potassic, sericitic and argillic alteration stages, and the lack of ore-controlling breccias and minor intrusions.

Endako mine is located 100 miles west of Prince George, British Columbia, within the glaciated uplands of the Nechako Plateau.

HISTORY AND DEVELOPMENT

The original Stella vein was discovered in 1927, but the large-tonnage potential of the deposit was not recognized until 1962, when a small but encouraging drilling program was initiated by R and P Metals Corp.Ltd. Canadian Exploration Ltd. examined, optioned and commenced drilling the property in late 1962. The decision to develop the deposit for production was announced in March 1964, and the mine was officially opened on June 8, 1965.

Production is currently being maintained at 27,500 tons per day at an average ore grade of 0.16% MoS_2. Reserves are estimated at 209 million tons of ore averaging 0.15% MoS_2, calculated at a cut-off grade of 0.08% MoS_2 (1971 figures).

REGIONAL GEOLOGY

Geologic knowledge of Endako area is based primarily upon mapping by Armstrong (1949), Tipper (1963), Carr (1966) and the writer (Dawson, 1971).

The Topley batholith, of Jurassic age, extends west-northwestward from Quesnel to Babine Lake, a distance of some 180 miles. The batholith flanks and intrudes the southwestern margin of a flexure in the Stuart Lake High, an elongate, fault-bounded belt of Cache Creek metamorphic rocks in central British Columbia. This belt of Carboniferous-Permian rocks was uplifted in Late Triassic time along steeply-dipping peripheral faults which subsequently provided conduits for rising Topley magma. South and west of Stuart Lake High, Topley batholith intrudes volcanic and sedimentary rocks of the Takla-Hazelton Assemblage that were laid down intermittently in Late Triassic to Middle Jurassic time.

The oldest and most extensive Topley unit, the Middle Jurassic Simon Bay diorite complex, is a concordant mesozonal pluton whose prominent foliation parallels the northwest batholithic trend and probably reflects pre-existing structural controls upon its emplacement. In Endako area, Simon Bay rocks are intruded by Late Jurassic Topley phases (Endako, Nithi, Glenannan, Casey and Francois plutons) of discordant, epizonal type and west-northwest elongation. The predominantly quartz monzonitic plutons are closely grouped in radiometric age (137-141 m.y.) and represent a relatively short period of differentiation of the parental Topley magma, with enrichment in silica and alkalies in youngest phases.

Youngest Late Jurassic to Early Cretaceous Topley units in Endako area (Stellako and Fraser plutons) are more granodioritic in composition and divergent from the regional northwest trend.

Topley Intrusions are overlain by extensive, flat-lying andesitic and basaltic Endako Group flows of Eocene age. Related dykes intrude post-ore fractures in Endako area.

MINE GEOLOGY

Geology of the Endako deposit is drawn, in part, from the more comprehensive description by Kimura and Drummond (1969). Potassium-argon ages of Endako area rocks are drawn from White, et al (1970).

1. Rock Types

Ages and descriptions of rock units in Endako area are summarized in Table 1. Endako quartz monzonite and three types of acidic pre-ore dykes form the host for the mineralized stockwork. Endako quartz monzonite is a subporphyritic to equigranular rock with average mode: microperthitic pink orthoclase 44.5%; quartz 22.6%; gray zoned oligoclase (An_{19}) 26.3%; brown biotite 4.6%; hornblende 0.6%; accessory minerals 2.0%. Aplite, porphyritic granite and quartz-feldspar porphyry dykes occur in two swarms in the central pit area. Post-ore basalt and andesite dykes cross-cut thr quartz monzonite, pre-ore dykes and mineralized stockwork.

2. Structure

Endako orebody is an elongated elliptically-shaped zone of stockwork that occurs wholly within Endako quartz monzonite. The orebody may be considered as a series of major east-west veins oriented en echelon to form a zone elongated in a northwesterly direction. The orebody, including the Denak zone, is 11,000 feet long by 1,200 feet wide. The average dip of mineralized stockwork is a consistent 50° south over the orebody length, but depth of economic mineralization varies from a minimum of 100 feet at the east end to over 1,000 feet at the west end.

The development of Endako orebody was influenced by three related igneous events: emplacement and crystallization of Endako quartz monzonite; intrusion of residual granitic magma as pre-ore dykes; and ascent of hydrothermal fluids through the localized zone of intense fracturing.

Early compressional stresses, active during emplacement and cooling of Endako pluton, apparently generated localized doming and fracturing in the vicinity of the mine, an area occupying the intersection of regional east-west, northwest and northeast fracture systems. Intrusion of pre-ore dykes accompanied the principal structural adjustment of the pluton: wrench faulting along principal orebody faults and secondary shears; doming of the orebody area; and antithetic faulting along conjugate southward and northwestward-dipping fractures. Many large veins and smaller stockwork veinlets follow the predominant east-west and northeast fracture directions.

Localization and development of Endako stockwork is summarized in Figure 1, and schematic plan and sections of the orebody are given in Figure 2.

3. Alteration and Vein Mineralogy

A. Alteration Mineralogy

Three distinct alteration phases are recognized by Drummond and Kimura (1969) within the Endako ore zone: (1) envelopes with K-feldspar; (2) envelopes with sericite; and (3) pervasive kaolinization.

Envelopes 1/8-inch to 2 feet wide containing principally salmon-pink orthoclase are developed around Stage 1 (oldest) quartz, quartz-molybdenite and quartz-magnetite (all $\pm$ pyrite) veins. K-feldspar envelopes may be of three types: 100% orthoclase; 90% orthoclase and 10% biotite; and 60% orthoclase, 30% quartz, 5% biotite, 5% altered plagioclase. Grey envelopes 1/8-inch to 2 inches wide containing 55-60% quartz, 30-35% sericite, and 1-5% finely disseminated pyrite are developed around Stage 2 quartz-molybdenite

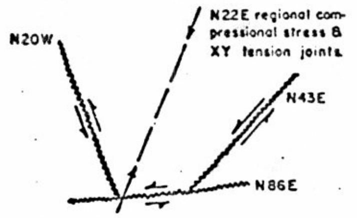


FIGURE 1 a.

Pre-doming stress and early fractures.

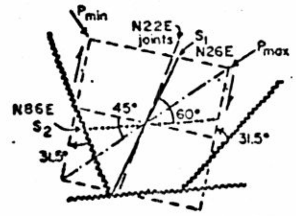


FIGURE 1 b.

Shear stress orientation in the fault-bounded orebody block. Shear S_1 augments existing N22E fractures. Shear S_2 develops after S_1 is intruded by pre-ore dykes.

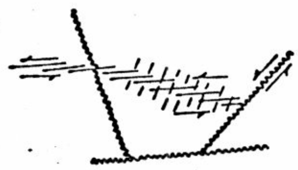


FIGURE 1 c.

Doming occurs over the weakened zone of intersecting S_2 shears and NNE dykes and fractures. S_2 shears first become YZ tension fractures under release of lateral NNE stress then become normal faults during domal uplift and subsidence.

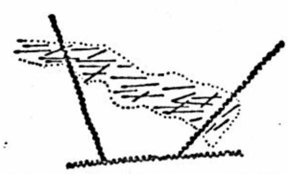
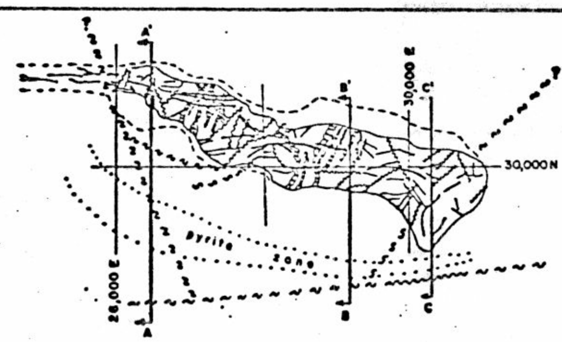


FIGURE 1 d.

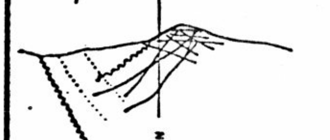
Schematic plan of orebody showing en echelon array of E-W veins, with antithetic NE veins.

FIGURE 1. Localization and development of Endako stockwork.



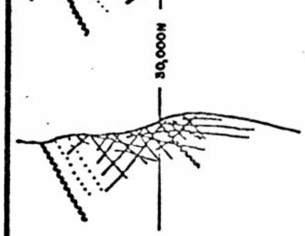
SECTION AA' : West Pit

The orebody is a narrow zone of large, mainly south-dipping veins. A few flat and shallow northerly-dipping veins occur. The stockwork is very limited in extent. Post-ore NE fractures are abundant. Orebody is at the maximum distance from S. Boundary fault.



SECTION BB': Central Pit

A combination of vein trends occur. Large EW/45 S veins are predominant. Flat to moderate northerly-dipping veins occur. Stockwork is well-developed. A large NNE zone of dykes occupies the central orebody.



SECTION CC': Southeast Pit

Strongest vein trend is NE/0-30°NW. Flat veins are the largest. EW/50S veins are of secondary importance. Stockwork is most intensely developed here. Apparent shallow south dip of orebody is due to flat veins. South Boundary fault passes close by.

FIGURE 2. Schematic sections showing veins and stockwork.

and/or magnetite, and quartz-pyrite veins. Sericitic envelopes are less abundant than K-feldspar-bearing envelopes. Within the sericitic envelope original K-feldspar, plagioclase and biotite have been replaced by sericite and quartz, and iron from the breakdown of biotite has been sulphidized to form pyrite.

Quartz monzonite may be contemporaneously kaolinized outward from potassic and sericitic-enveloped veins, and is pervasively kaolinized within the stockwork of Stage 3 quartz-molybdenite veins. Degrees of pervasive alteration are arbitrarily defined by the progressive mineralogical change of hard grey plagioclase in fresh rock to a soft greenish mixture of kaolinite and sericite, and the kaolinization of primary K-feldspar under intense argillization. Weak kaolinization is typified by plagioclase grains showing a hard unaltered rim and a soft greenish core of kaolinite, lesser sericite, and locally montmorillonite. Moderately kaolinized rock is characterized by complete replacement of plagioclase by a greenish or white mixture of kaolinite and sericite. K-feldspar is not attacked in either weak or moderate stages of kaolinization and biotite may be either chloritized (primary) or fresh (secondary). Intensely kaolinized quartz monzonite is typified by partial or complete replacement of primary K-feldspar by kaolinite plus a little sericite, and complete breakdown of plagioclase to kaolinite and sericite. Intensely kaolinized rock contains both greenish and white mixtures of clay minerals, but only the white material contains very fine-grained secondary biotite. Ferrous iron that imparts a green colour to kaolinite in one case is fixed in biotite in the other case and consequently the coexisting kaolinite is white.

B. Vein Mineralogy

The most abundant primary metallic minerals are molybdenite, pyrite and magnetite, with minor amounts of chalcopyrite and traces of sphalerite, bornite, specularite and scheelite. A single occurrence of beryl and bismuthinite was found.

Molybdenite occurs in two types of veins: large, 6-inch to 4-feet wide quartz veins containing laminae and fine disseminations of molybdenite; and fine fracture-fillings and veinlets of quartz-molybdenite as stockworks adjacent to major veins. Brecciation of major veins with subsequent quartz-molybdenite healing is common.

Magnetite, pyrite and minor amount of chalcopyrite commonly are associated with molybdenite, but may also form distinct veins. Magnetite in quartz veins has undergone supergene martitization (oxidation to hematite) that progressively decreases in intensity with increasing depth. A pyrite zone that bounds the orebody on the south is a poorly-developed stockwork of veinlets containing quartz, pyrite, minor magnetite and rare molybdenite. Pyrite content of the zone is an estimated 1 percent.

Post-molybdenite veins including relatively abundant calcite, and relatively rare quartz-specularite and chalcedony occur throughout the orebody, and may be either a terminal stage of deposition from ore-bearing fluids, or younger epithermal deposits related to Eocene volcanism.

Secondary minerals include limonite, hematite, ferrimolydite, powellite, pyrolusite and malachite. Depth of oxidation varies from 1 to 5 feet in general, and development of secondary minerals is not extensive.

TABLE 1

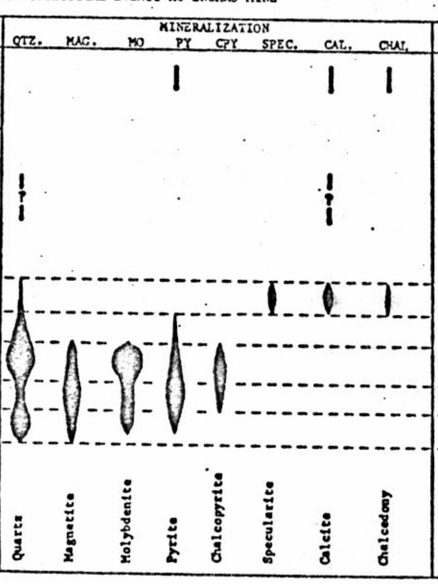
TABLE OF FORMATIONS - ENDAKO AREA

ROCK UNIT	AGE	DESCRIPTION
Endako Group	Eoc.(50±2 m.y.)	Porph.andesite and basalt flows, agglomerate and related dykes.
Fraser qtz.monz.	L.Cret.(112±4 m.y.)	Pink biot.hb qtz.monz. Small circular stock.
Stellako intrusions	U.Jur.(136±5 m.y.)	Pink biot.qtz.monz.,pink-grey hb-biot.granodiorite, Discordant, NNE trend.
Francois granite	U.Jur.(137±5 m.y.)	Red porph.biot.granite.Miarolytic,chilled margins. No Mo deposits.
Casey alaskite	U.Jur.(138±5 m.y.)	Leuco granite and qtz.monz.Discordant stocks and satellitic dykes. Mo deposits at OWL L.,TATIN L.,NITHI MT.,ENDAKO.
Glenannan complex	U.Jur. (134-140±5 m.y.)	Zoned pluton north of Endako.Pink proph.granite,qtz. monz.,granod. No Mo deposits.
Nithi qtz.monz.	U.Jur. (138-141±5 m.y.)	Pink-grey subporph.biot.-hb.qtz.monz.Resembles Endako qtz. monz.and may be equivalent.Mo deposit at NITHI MT.
Qtz.felds porph. Porph. granite aplite	Endako pre-ore dykes (140±5 m.y.)	Brown-pink porphyry dykes up to 150' wide,abundant at mine Porph.pink Kspar granite dykes up to 50' wide. Pink sugary aplite up to 4' wide.
Endako qtz.monz.	U.Jur.(141±5 m.y.)	Pink subporph.biot.-hb.qtz.monz.Host rock at Endako mine.
Simon Bay diorite complex	M.Jur. (155±6 m.y.)	Coarse g'd.,foliated hb.diorite, qtz.diorite,granodiorite, gabbro. Mesozonal,concordant pluton. Oldest Topley unit. No Mo deposits.
Takla Group	U.Trias.	Rhyodacite and andesite stocks,flows and pyroclastics.

TABLE 2

SUMMARY OF GEOLOGICAL EVENTS AT ENDAKO MINE

IGNEOUS EVENT AND AGE	STRUCTURAL EVENT	ALTERATION
Tertiary volcanism; emplacement of plagioclase porphyry and basalt dykes (50 ± 5 m.y.).	Minor movements parallel to dykes.	Deuteric chlorite-calcite-epidote propylitization.
Emplacement of Stellako pluton (136 ± 5 m.y.).	Movement on EW and NE faults.	
Emplacement of younger Stage II plutons: Glenannan, Casey, Francois (140-137 ± 5 m.y.).	Post ore fracturing and faulting (Stage 6)	
Termination of cooling of Endako pluton.		
	Stage 5 veins	None
	Stage 4 veins	Minor bleaching
Hydrothermal alteration and mineralization (140 ± 5 m.y.)	Stage 3 veins	Weak to intense pervasive kaolinization.
	Stage 2 veins	Quartz-sericite-pyrite envelopes.
	Stage 1 veins	Kspar,Kspar-biot.,qtz-Kspar-biot.envelopes.
Emplacement of acidic mine dykes (140 ± 5 m.y.)	Doming, antithetic stockwork fracturing	
Onset of cooling and crystallization of pluton	NNE compression, NNE and EW secondary shearing	
Emplacement of Endako quartz monzonite (141 ± 5 m.y.).	NE, NW and EW regional fracturing.	



4. Age Relations of Vein and Alteration Minerals

Age relations of vein and alteration minerals plus corresponding structural and igneous events are given in Table 2.

A sequence of relative ages of vein and alteration assemblages has been determined from observations of cross-cutting relationships. There is no significant correlation between vein mineralogy and a specific type of alteration envelope or intensity of pervasive kaolinization. However, within the orebody, K-feldspar envelopes are more commonly developed around quartz-molybdenite veins, sericitic envelopes commonly enclose quartz-magnetite veins, and weak to moderate kaolinization is the commonest intensity of pervasive alteration.

Five stages of alteration and mineralization have been defined. Stage 1 and 2 veins and envelopes were described previously. The greatest volume of molybdenite was deposited in Stage 3 veins, which may contain quartz-molybdenite, quartz-magnetite, and/or quartz-magnetite-molybdenite (all $\pm$ pyrite, chalcopyrite). Pervasive argillic alteration accompanies Stage 3 mineralization. Stage 4 veins contain quartz and pyrite, and lack associated alteration other than occasional bleaching around the veins. Stage 5 veins contain quartz-specularite, calcite and chalcedony, and lack associated alteration. Post-ore unfilled fractures define Stage 6.

ORE CONTROLS

Three interrelated factors; structural, chemical and thermal effects, combine to control the nature and distribution of vein and alteration minerals at Endako mine.

1. The structure of the orebody has been described previously. Configuration of stockwork is the principal ore-localization factor. From east to west along the length of the orebody, relatively homogeneous stockwork generated by intense domal movement gives way to poorly-developed stockwork adjacent to large shear veins. Homogeneity of ore values varies accordingly. Stockwork fracturing and ore values terminate abruptly along the north side of the orebody, but diminish gradually southward towards the pyrite zone that marks the southern limits of stockwork mineralization.

2. Chemical control of hydrothermal mineralization and alteration is evident from the spatial and temporal relationships between alteration assemblages of Stages 1, 2 and 3. K-feldspar envelopes are intersected by sericitic envelopes, and the rock outward from these envelopes and Stage 3 veins is pervasively kaolinized. The mechanism relating potassic, sericitic and argillic alteration is a progressive ion leaching or migration of Ca^{++}, Na^{+}, Mg^{++}, Fe^{++} and Fe^{+++} toward the vein, with simultaneous outward migration of K+ and H+.

The K+/H+ activity ratio controls outward diffusion of K+ and H+ and varies outward from the vein mainly in response to variations in temperature, K+ and H+ concentration gradients, rate of removal of leached constituents, and pressure. Reaction curves for the system K_2O-Al_2O_3-S_1O_2-H_2O developed by Hemley (1959) show that temperature and K+/H+ activity ratio are the most significant variables in determining stability of phases in the system. Drummond (1969) notes the relative age sequence of K-feldspar-sericite-kaolinite is in agreement with a chemical control based on the activity ratio of K+/H+ in a nearly isothermal environment.

3. Thermal controls are evident in zonation of alteration assemblages from north to south across the orebody. A relative abundance of K-feldspar-bearing envelopes defines a "K-feldspar zone" about 800 feet wide parallel to

the orebody and flanking it on the north. The transition to the orebody proper is marked by a sharp increase in the abundance of molybdenite, sericitic envelopes and intensity of pervasive kaolinization. The transition to the "pyrite zone" is marked by a sharp decrease in abundance of K-feldspar alteration, a gradual diminishment in intensities of molybdenite mineralization, kaolinization and sericitic alteration, and an increase in relative abundance of pyrite.

Alteration zonation suggests decreasing temperature from the ore zone towards the south, implying similar temperature variations for sulphide deposition. Fluid inclusion studies support this trend. Minimum filling temperatures for fluid inclusions in quartz from K-feldspar-enveloped veins are slightly higher than 500°C; those for inclusions in quartz from sericite-enveloped veins center around 480°C; whereas those for quartz veins without envelopes but within pervasively argillized rock range from 380°C to 460°C (Dawson, 1971). These temperatures are in agreement with Hemley's (1959) experimental data for stability fields of the alteration phases.

Minor element content of pyrite shows a similar temperature-dependent trend across the orebody. In Q-Mode factor analysis of 12-element spectrochemical data from 67 orebody pyrites, Mn, Ni and Sn define Factor I which coincides with the ore zone, whereas Factor II (Co and Cu) coincides with the pyrite zone (Dawson,1971). Correlation of Factors I and II to ore and pyrite zone respectively implies that the factors are related to mineralizing processes that gave rise to the two mineralogically distinct zones.

Within a single vein or vein system, thermal gradients may have been less significant than chemical controls in affecting the stability of an alteration or sulphide phase, but on a megascopic scale temperature gradients have controlled the relative abundance of mineral assemblages in the orebody area.

CONCLUSIONS

The Endako stockwork was localized within an early quartz monzonitic phase of Topley batholith by wrench faulting and doming generated by cooling of the batholith and intrusion of pre-ore dykes. Hydrothermal fluids effecting alteration and mineralization of the stockwork were generated contemporaneously with the cooling of the Endako pluton. Abundant early potassic alteration and relatively high fluid inclusion temperatures attest to the paramagmatic affiliation of vein and alteration mineral assemblages. Crosscutting relations indicate a relative age sequence among the alteration stages which is in agreement with a chemical control based primarily on the activity ratio of K^+/H^+. Concurrent north-south zonation of stockwork mineralization, principal alteration types, fluid inclusion temperatures, and minor element content of pyrite indicates thermal gradients diminished southward across the orebody from a "high" centered over the K-feldspar zone.

January, 1971.

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TABLE 1

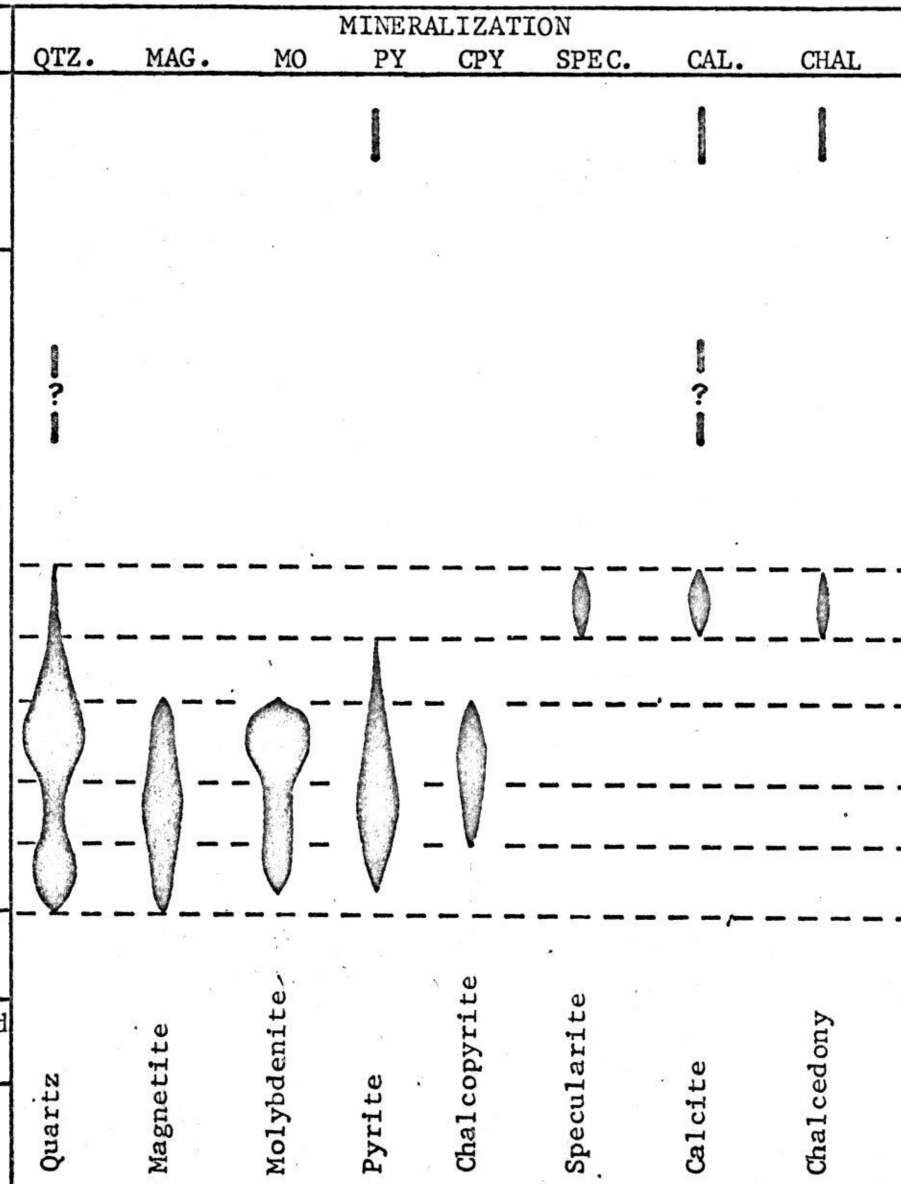
TABLE OF FORMATIONS - ENDAKO AREA

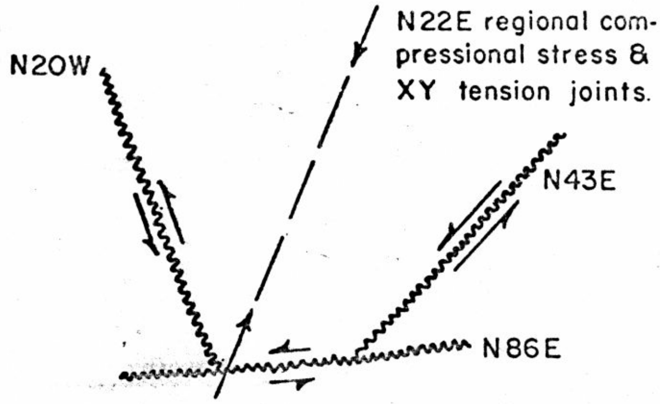
ROCK UNIT	AGE	DESCRIPTION
Endako Group	Eoc.(50$\pm$2 m.y.)	Porph.andesite and basalt flows, agglomerate and related dykes.
Fraser qtz.monz.	L.Cret.(112$\pm$4 m.y.)	Pink biot.hb qtz.monz. Small circular stock.
Stellako intrusions	U.Jur.(136$\pm$5 m.y.)	Pink biot.qtz.monz.,pink-grey hb-biot.granodiorite, Discordant, NNE trend.
Francois granite	U.Jur.(137$\pm$5 m.y.)	Red porph.biot.granite.Miarolytic,chilled margins. No Mo deposits.
Casey alaskite	U.Jur.(138$\pm$5 m.y.)	Leuco granite and qtz.monz.Discordant stocks and satelliti dykes. Mo deposits at OWL L.,TATIN L.,NITHI MT.,ENDAKO.
Glenannan complex	U.Jur. (134-140$\pm$5 m.y.)	Zoned pluton north of Endako.Pink proph.granite,qtz. monz.,granod. No Mo deposits.
Nithi qtz.monz.	U.Jur. (138-141$\pm$5 m.y.)	Pink-grey subporph.biot.-hb.qtz.monz.Resembles Endako qtz. monz.and may be equivalent.Mo deposit at NITHI MT.
Qtz.felds porph. Porph. granite aplite	Endako pre-ore dykes (140$\pm$5 m.y.)	Brown-pink porphyry dykes up to 150' wide,abundant at mine Porph.pink Kspar granite dykes up to 50' wide. Pink sugary aplite up to 4' wide.
Endako qtz.monz.	U.Jur.(141$\pm$5 m.y.)	Pink subporph.biot.-hb.qtz.monz.Host rock at Endako mine.
Simon Bay diorite complex	M.Jur. (155$\pm$6 m.y.)	Coarse g'd.,foliated hb.diorite, qtz.diorite,granodiorite, gabbro. Mesozonal,concordant pluton. Oldest Topley unit. No Mo deposits.
Takla Group	U.Trias.	Rhyodacite and andesite stocks,flows and pyroclastics.

TABLE 2

SUMMARY OF GEOLOGICAL EVENTS AT ENDAKO MINE

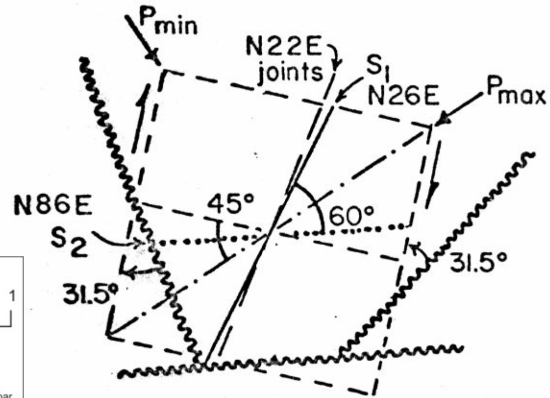
IGNEOUS EVENT AND AGE	STRUCTURAL EVENT	MINERALIZATION	ALTERATION
Tertiary volcanism; emplacement of plagioclase porphyry and basalt dykes (50 ± 5 m.y.).	Minor movements parallel to dykes.		Deuteric chlorite-calcite-epidote propylitization.
Emplacement of Stellako pluton (136 ± 5 m.y.).	Movement on EW and NE faults.		
Emplacement of younger Stage II plutons: Glenannan, Casey, Francois (140-137 ± 5 m.y.).	Post ore fracturing and faulting (Stage 6)		
Termination of cooling of Endako pluton.			
	Stage 5 veins		None
	Stage 4 veins		Minor bleaching
	Stage 3 veins		Weak to intense pervasive kaolinization.
Hydrothermal alteration and mineralization (140 ± 5 m.y.)	Stage 2 veins		Quartz-sericite-pyrit envelopes.
	Stage 1 veins		Kspar,Kspar-biot.,qtz Kspar-biot.envelopes.
Emplacement of acidic mine dykes (140 ± 5 m.y.)	Doming, antithetic stockwork fracturing		
Onset of cooling and crystallization of pluton	NNE compression, NNE and EW secondary shearing		
Emplacement of Endako quartz monzonite (141 ± 5 m.y.).	NE, NW and EW regional fracturing.		





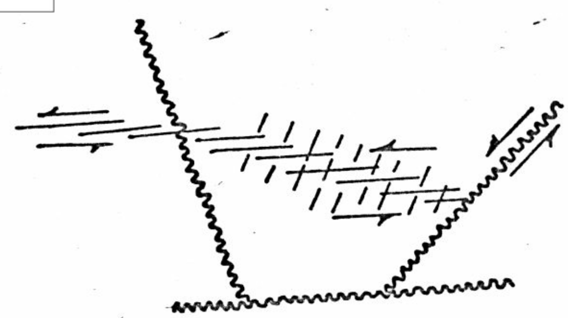
FIGURE

Pre-doming stress and early fractures.



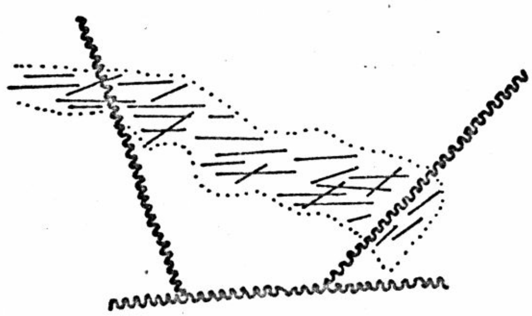
FIGURE

Shear stress orientation in the fault-bounded orebody block. Shear S_1 augments existing N22E fractures. Shear S_2 develops after S_1 is intruded by pre-ore dykes.



FIGURE

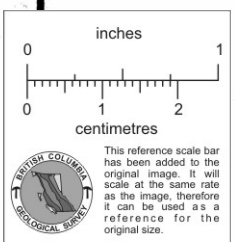
Doming occurs over the weakened zone of intersecting S_2 shears and NNE dykes and fractures. S_2 shears first become YZ tension fractures under release of lateral NNE stress then become normal faults during domal uplift and subsidence.

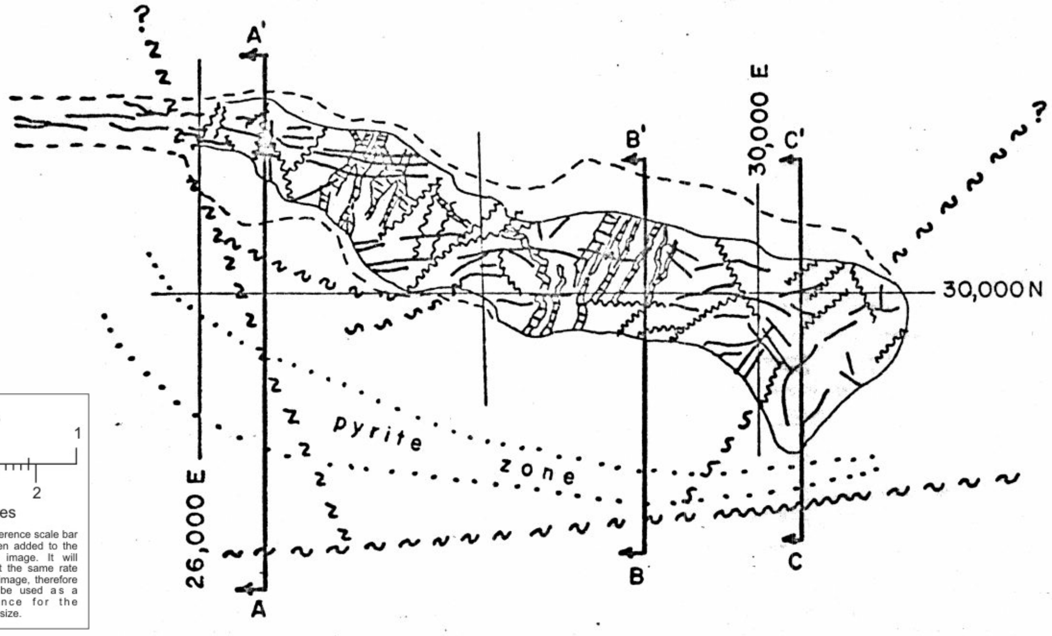


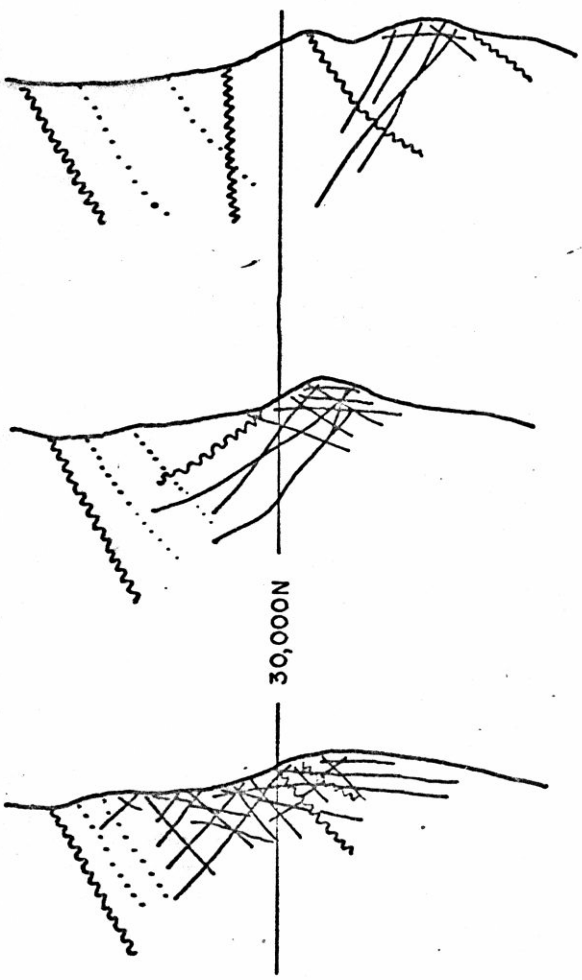
FIGURE

Schematic plan of orebody showing en echelon array of E-W veins, with antithetic NE veins.

FIGURE Localization and development of Endako stockwork.







SECTION AA' : West Pit

The orebody is a narrow zone of large, mainly south-dipping veins. A few flat and shallow northerly-dipping veins occur. The stockwork is very limited in extent. Post-ore NE fractures are abundant. Orebody is at the maximum distance from S. Boundary fault.

SECTION BB' : Central Pit

A combination of vein trends occur. Large EW/45 S veins are predominant. Flat to moderate northerly-dipping veins occur. Stockwork is well-developed. A large NNE zone of dykes occupies the central orebody.

SECTION CC' : Southeast Pit

Strongest vein trend is NE/0-30° NW. Flat veins are the largest. EW/50S veins are of secondary importance. Stockwork is most intensely developed here. Apparent shallow south dip of orebody is due to flat veins. South Boundary fault passes close by.

FIGURE Schematic sections showing veins and stockwork.