R. V. KIRKHAM

H.B. Mtn. Mo Deposit

R. V. K.

GEOLOGY OF
THE HUDSON BAY MOUNTAIN MOLYBDENUM DEPOSIT
SMITHERS, BRITISH COLUMBIA

by

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To accompany a presentation at the Annual Meeting of the Canadian Institute of Mining and Metallurgy, Vancouver, B. C., April 24, 1968

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INTRODUCTION

The Hudson Bay Mountain molybdenum deposit is on the east side of Hudson Bay Mountain, approximately five miles northwest of Smithers, B. C. (fig. 1). The deposit has been explored since 1957 by American Metal Climax, Inc., and a total of 119,051 feet of diamond drilling and 9,074 feet of tunnelling have been completed to-date.

Many geologists have studied the geology of Hudson Bay Mountain in the past and have made significant contributions. E. D. Kindle, W. W. Moorhouse, J. F. Allan, C. L. Smith, and R. V. Kirkham deserve special mention.

REGIONAL GEOLOGY

Physiographically, the area of interest is near the northwestern edge of the Nechako Plateau (a sub-division of the Interior Plateau), and is about 40 miles east of the Coast Mountains (fig. 2). Hudson Bay Mountain (fig. 3) is a prominent feature of the Hudson Bay Range, an isolated group of mountains about 200 square miles in area.

This range lies on the Skeena Arch, a major geological feature that trends northeasterly beneath Mesozoic sedimentary and volcanic rocks, and includes the eastern portion of the Coast Crystalline Belt and the western portion of the Cassiar Crystalline Belt (ref. 4,5). The arch is characterized by granitic apophyses near the eastern edge of the Coast Range intrusive complex, and by numerous small stocks and bosses that occupy a well defined zone between the two major intrusive "belts". The Skeena Arch separates the Bowser Basin on the north from a large area on the south underlain by Tertiary basaltic rocks.

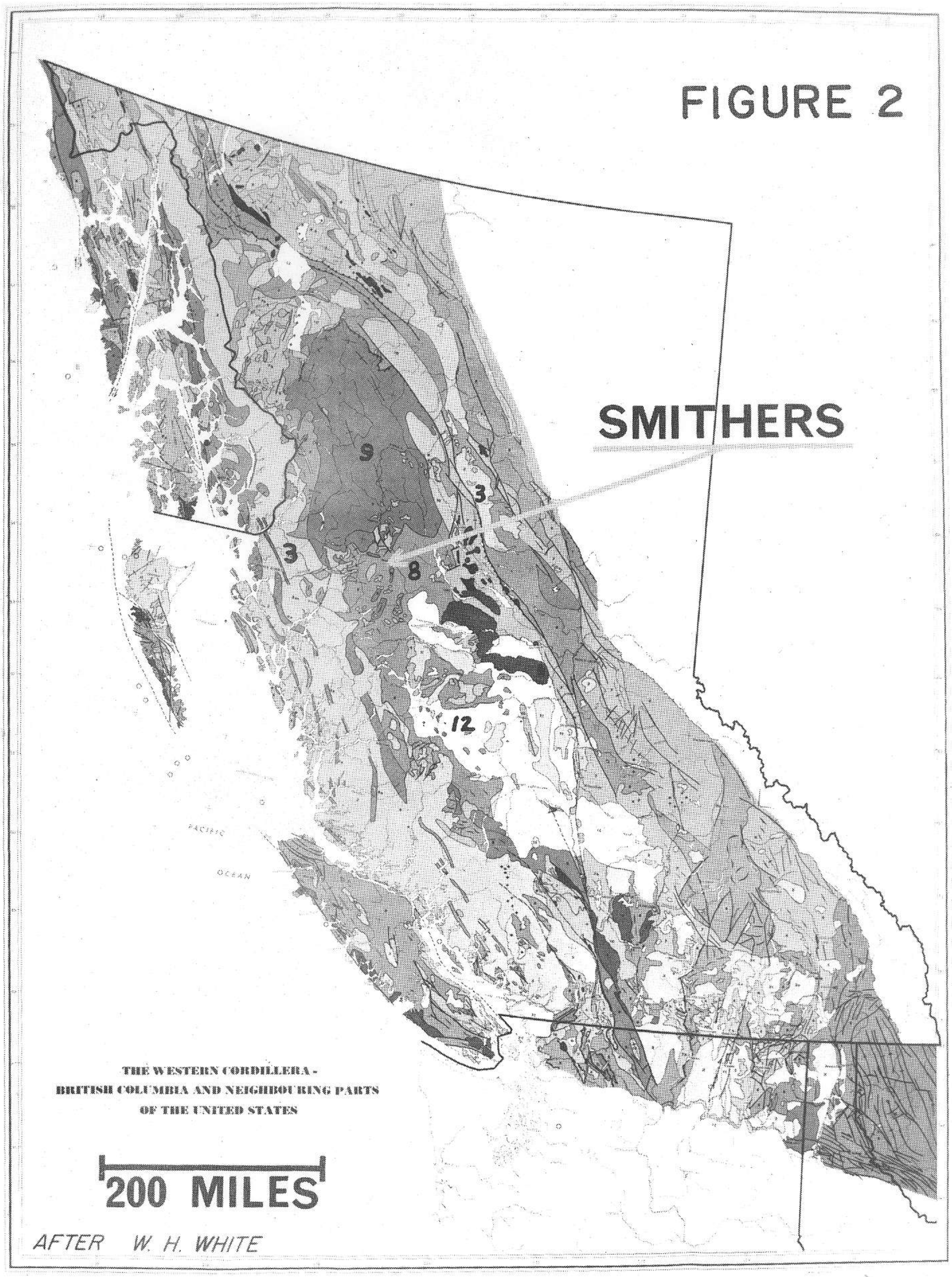
The Hudson Bay Range is underlain mainly by volcanic and sedimentary rooks of the Hazelton Group, and by sedimentary rocks of the Bowser Group. Small bodies of granodiorite and quartz monzonite are exposed in the northern, southern and western parts of the range.

Block faulting, doming and thrust faulting are the dominant structural features in the Hudson Bay Range. Many of the individual mountains appear to be fault block segments separated by steep normal and reverse faults (ref. 1).

FIGURE I


YUKON
N. W. T.
ALASKA
SMITHERS
ALBERTA
PRINCE RUPERT
PRINCE GEORGE
KAMLOOPS
VANCOUVER
U. S. A.
BRITISH COLUMBIA
400 miles

FIGURE 2



THE WESTERN CORDILLERA -
BRITISH COLUMBIA AND NEIGHBOURING PARTS
OF THE UNITED STATES

AFTER W. H. WHITE

LEGEND — WESTERN CORDILLERA MAP

+	Pleistocene and Recent volcanoes.
12	Upper Tertiary, mainly plateau besalt.

MESOZOIC TO MID-TERTIARY OROGENY

Strong uplift, folding and regional faulting. Moderate to intense regional metamorphism of most existing orogens. Successive emplacement of granitic plutons and plutonic complexes from Upper Triassic to Miocene.

11	Lower Tertiary, mainly continental volcanics and sediments. Marine sedimentary basins and marginal troughs along the Pacific Coast.
10	Upper Cretaceous, mainly continental sediments and some volcanics. Marine sedimentary basins marginal to older orogens.
9	Upper Jurassic to Late Lower Cretaceous. Syntectonic deposition of coarse to medium-grained clastics, including much granitic debris, in successor basins and taphrogenic troughs.
8	Upper Triassic to Upper Jurassic. Eugeosynclinal deposition in a complex "Island Arc" environment of abundant andesitic lavas and pyroclastics with thick intercalated beds of muddy and limey sediments. 8a — May be partly or wholly Paleozoic.

LATE PALEOZOIC EPEIROGENY

Uplift and block faulting on a regional scale. Folding with trend related to individual fault blcks.Intrusions of ultramafic plutons.

7	Carboniferous to Permian. Deposition in one or more eugeosynclines of volcanics, chert, siliceous mud and limestone. 7b — Includes rocks as young as Mid-Triassic.

MID-PALEOZOIC OROGENY

Strong uplift, folding, regional metamorphism and granitization. Orogeny may have occurred as early as Mid-Devonian in some parts and as late as Lower Mississipian in other parts of the region.

6	Upper Proterozoic to Lower Paleozoic. Miogeosynclinal deposition of sands and muds with some persistent limestone horizons in upper part of sequence. Sedimentation ceased in main geosyncline in Devonian but continued in marginal troughs and on stable shelves until Mississippian. 6c — Eugeosynclinal deposition of coarse and medium-grained clastics and volcanics from Ordovician through Devonian. 6d — Devonian unconformably overlying gneiss and granitoid rock of unknown age.

LATE PROTEROZOIC EPEIROGENY

Strong uplift, tilting and arching. Intrusion of many small granitic plutons.

5	Early and Middle Proterozoic. Exogeosynclinal deposition of fine-grained clastics with some limey horizons in upper part; minor volcanics. The large metamorphic terranes of the region probably include some rocks of this sequence.

GRANITIC ROCKS

4	Relatively Young. Intrude rocks ranging in age from Lower Cretaceous to Miocene.
3	Intrude Upper Jurassic and older rocks. Large plutonic complexes consist of multiple phases of differing relative age, but for many parts absolute age of any or all phases is unknown. 3n and 3v denote older and younger phases, respectively, of the Nelson plutonic complex. 3m denotes granitoid rock that is probably of metamorphic origin.
2	Relatively Old. Intrude Upper Triassic and/or older rock. 2d is Lower Paleozoic.
1 ●	Ultramafic plutons; mainly intrude Paleozoic rocks.

SYMBOLS

Metamorphic rocks — colour denotes age of original rock, not age of metamorphism. S — denotes rocks probably metamorphosed initially during Mid-Paleozoic orogeny.	▤
Fold trend	⁓
Major fold axis	‡ ‡
Fault — High angle, mainly gravity type	— — —
— Thrust	▲▲▲
— Strike slip	⇄
Epicenters of earthquakes of magnitude 5.3 or higher	○

Compiled by Wm. H. White from published and unpublished sources, with additions by D. A. Brew (Southeastern Alaska), Peter Misch (Northern Cascades), and R. G. Yates (Eastern Washington, Idaho, and Montana).

DETAILED GEOLOGY

ROCK TYPES

Most of the rocks exposed on Hudson Bay Mountain are a bedded sequence of Hazelton volcanic rocks of intermediate composition (fig. 4). Small, irregular felsitic intrusions and a large, lenticular rhyolite sill occur within this pyroclastic pile. All of these rocks are considered to be Jurassic age.

Sedimentary rocks of the Bowser Group unconformably overlie the volcanic strata on the northeastern flank of the mountain. These rocks are of Upper Jurassic to Lower Cretaceous age.

A buried wedge-to lens-shaped body of granodiorite-granodiorite aplite underlies much of the area of economic significance (fig. 6), and is host to much of the molybdenite mineralization. Compositional and textural variations within the sheet are complex. Small, irregular "diabase" dykes cut the granodiorite sheet.

A small plug of quartz porphyry intrudes the volcanic rocks and the lower portion of the granodiorite sheet below 3500 feet elevation (adit level). This rock is mostly of pre-mineral (i.e., premolybdenite) age, but some breccia and texturally and compositionally related dykes exhibit an intermineral relationship.

A large buried stock of porphyritic (feldspar) quartz monzonite was subsequently intruded. This stock is believed to be the source of a distinctive sub-radial dyke swarm that outcrops in upper Glacier Gulch.[1] Relatively late intermineral relationships are exhibited by this unit, which has been dated as Tertiary.

VOLCANIC ROCKS

The Hazelton volcanic rocks exposed in the Glacier Gulch area trend west-northwest and dip at moderate to steep angles to the north. This sequence consists chiefly of lenticular layers of dark green, brown to black, microcrystalline tuff and lapilli tuff of dactio-andesitic composition. Minor amounts of tuff breccia have been observed.

The only marker horizon in the pyroclastic pile has been designated the Quartz Eye unit. This is a quartz-rich crystal-lithic lapilli tuff consisting mostly of subhedral quartz and sodic plagioclase to 3 mm. in diameter, set in a fine-grained to microcrystalline fabric of interlocking quartz and feldspar. Sub-rounded lapilli of dacitic-andesitic volcanic rocks are found in small amounts throughout. Colour tone varies from grey through shades of green and

[1] Glacier Gulch is the steep valley below the toe of Hudson Bay Mountain glacier. See figure 3.

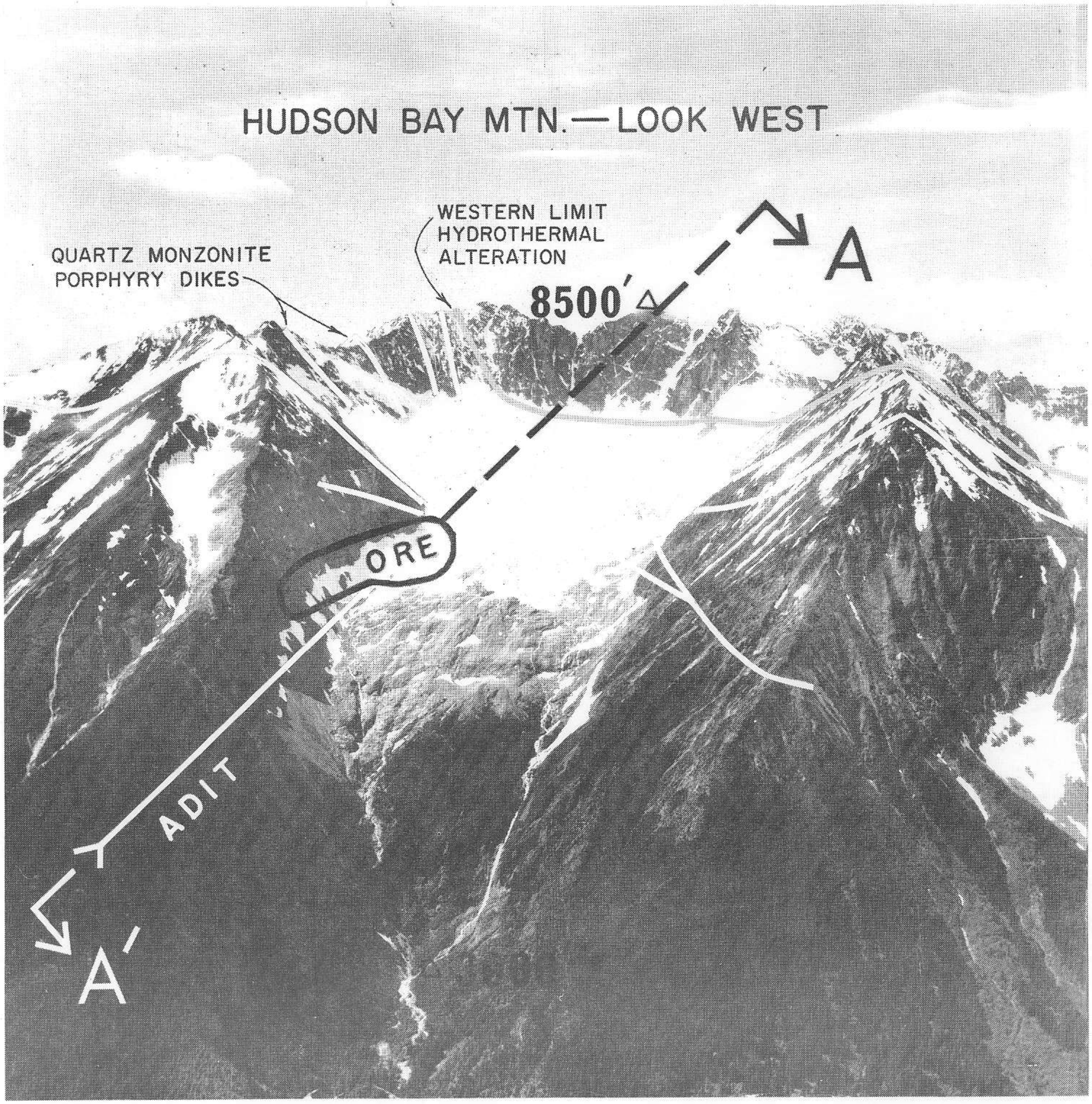

HUDSON BAY MTN.—LOOK WEST
QUARTZ MONZONITE PORPHYRY DIKES
WESTERN LIMIT HYDROTHERMAL ALTERATION
8500'
A
ORE
ADIT
A'

FIGURE 3

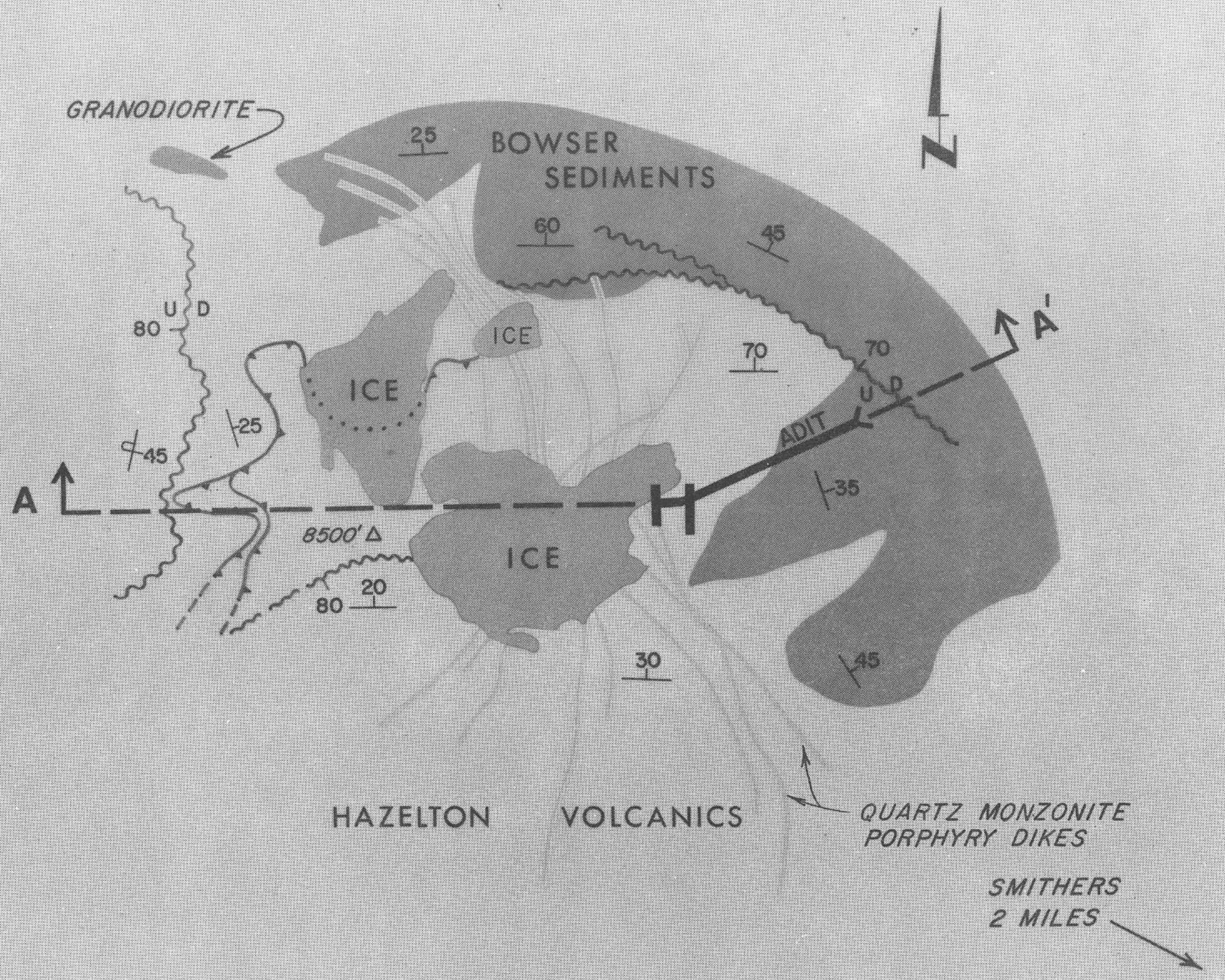


FIGURE 4

SURFACE GEOLOGY OF HUDSON BAY MTN.

brown, and is dependent upon the relative abundance of fine-grained chlorite and/or biotite in the rock fabric.

Locally, the tuffaceous rocks are irregularly and pervasively "bleached", and in some instances there is a vague spatial relationship of lighter colour tones to molybdenite mineralization.

A lenticular sill-like mass of light grey rhyolite 6000 feet long and up to 800 feet wide occurs on the north side of Glacier Gulch. This rock is a glassy to microcrystalline aggregate of quartz and feldspar. Contorted flow banding is well developed, and the unit is locally spherulitic.

The tuffaceous rocks are cut by small, irregular white to grey felsitic intrusions that exhibit both sill-like and dyke-like relationships with the pyroclastics. The felsitic rocks are weakly porphyritic, with small subhedral to euhedral grains of potash feldspar and sodic plagioclase to 1 mm. in diameter set in a microcrystalline matrix of quartz and feldspar.

Rhyolite and felsite are considered to be high-level intrusions related to volcanism. These rocks are not shown on the attached illustrations.

SEDIMENTARY ROCKS

Continental and marine clastic sediments of the Bowser Group unconformably overlie the volcanic rocks on the northeastern portion of Hudson Bay Mountain. In the Glacier Gulch area these rocks trend northerly and dip moderately to the east.

Dark grey to black greywacke is the most abundant rock type in the group. It consists chiefly of grains of feldspar, some quartz and abundant fragments of volcanic rocks. Minor amounts of dark grey argillaceous quartzite, dark grey to black argillite, buff to light grey siltstone, and pebble conglomerate are interbedded with greywacke.

Lenticular layers of contorted and sheared anthracite coal several feet thick were encountered near the portal of the adit. Small amounts of coal have been mined in Glacier Gulch.

Bowser Group rocks contain abundant pyrrhotite in disseminations, thin layers and small elliptical pods. Much of the pyrrhotite is believed to be syngenetic.

INTRUSIVE ROCKS

1. GRANODIORITE

This unit occurs in a wedge- to lens-shaped sheet with a remarkably planar base. The base trends northeast and dips about 30 degrees southeast. Diamond drilling indicates that the sheet is at least 4000 feet wide, has a dip length of at least 6000 feet, and is up to 2000 feet thick. The distribution of the unit to the south and east of the underground workings is unknown, although the wedge appears to thicken and steepen down-dip. To the north and west the sheet thins, and may pinch out. The granodiorite does not outcrop (fig. 6).

The economic significance of this unit will be reiterated here, for although of decided pre-mineral age, the sheet is host to much of the higher-grade molybdenite mineralization.

Textural and compositional variations within the sheet are complex. The major phases have been classified as follows:

a) Normal Granodiorite

This phase constitutes over 80 percent of the sheet. It has a very fine- to medium-grained holocrystalline fabric consisting primarily of interlocking anhedral to subhedral quartz, plagioclase, and potash feldspar. Incipient to moderately well-developed granophyric intergrowths are common, some of which are obviously post-fabric. The normal granodiorite may be weakly to moderately porphyritic. A typical rock of this phase is composed of approximately 30 percent quartz, 18 percent potash feldspar, 42 percent plagioclase (An_{30}), and 10 percent ferromagnesian minerals.

Colour tone is heterogeneous and varies from shades of green-grey through brown-grey, and is dependent upon the relative abundance and type of mafic mineral (mostly chlorite, biotite and actinolite).

Mafic minerals occur mostly in very fine-grained aggregates in microfractures and as replacements in small wisps and clots. Primary ferromagnesian minerals are rarely observed. Macroscopically, the texture of the quartz-feldspar fabric is commonly obscured in the less leucocratic phases.

b) Porphyritic Phase (Quartz monzonite - granodiorite)

A distinctive porphyritic phase occurs in an irregularly shaped core within the central and upper portions of the sheet. The distribution of this unit is not completely known because the texture becomes obscured with increasing amount of secondary mafic minerals. In many cases, the less leucocratic varieties can be identified only in thin section.

This unit is characterized by a very fine-grained (.5 mm.) sugary fabric consisting of equigranular quartz, plagioclase and potash feldspar. Phenocrysts constitute up to 30 percent of the rock, and are mostly euhedral grains of plagioclase with minor subhedral to euhedral quartz grains up to 2.5 mm. in diameter.

These rocks consist of approximately 30 percent quartz, 30 percent potash feldspar, 37 percent plagioclase (An_{30}) and 3 percent ferromagnesian minerals. The ratio of potash feldspar to plagioclase is locally variable.

This phase is generally grey to greenish-grey, but darker shades of green and brown have been observed. Colour tone is largely dependent upon the type and relative abundance of secondary mafic minerals.

c) Aplitic Phase (Granite - quartz monzonite)

Most of the aplitic rocks occur in an irregular 800-foot-wide "slab" that trends west-northwest, dips steeply to the north, and forms the northern edge of the granodiorite sheet. These rocks are characteristically mafic deficient and are light grey.

Composition is relatively uniform throughout the aplite, but textures are varied. The aplite consists of about 33 percent quartz, 27 percent potash feldspar and 40 percent plagioclase (An_{30}). Grain size varies from aplitic through fine-grained granitic, with some varieties approaching medium-grained granitic. Textures vary from equigranular sugary to interlocking, and the unit may or may not be porphyritic. This phase is commonly granophyric. Some granophyric intergrowths are post-fabric and are obviously a product of recrystallization.

A prominently spotted variety of the aplitic phase occurs at the southern edge of the "slab", at, or near, the contact with normal granodiorite. This is characterized by the secondary development of orange-red to green, ovoid spots of replacement garnet-epidote-magnetite-carbonate and/or chlorite-sericite-carbonate up to 2 inches in diameter. These spots locally constitute up to 30 percent of the rock.

Contacts of the aplitic phase with other units in the sheet are generally vague. With increasing amounts of secondary mafic minerals the aplitic rocks may grade imperceptibly into more leucocratic phases of the normal granodiorite. Conversely, in areas of "bleached" normal granodiorite, rocks similar to the aplitic phase are evident. Mafic-deficient types of the porphyritic phase are locally gradational into rocks of the aplitic phase near the edge of the sheet.

The origin of the granodiorite sheet is open to conjecture. As evidenced by locally extensive recrystallization of quartz and feldspar, the remobilization of ferromagnesian minerals, and the widespread clotting and spotting by replacement garnet-epidote-carbonate-magnetite-chlorite-sericite, much of the sheet has undergone varying intensities of metamorphism and metasomatism. Although some phases are totally, or in part, of probable igneous origin, the possibility of metamorphic and metasomatic formation of other portions of the sheet cannot be dismissed.

2. "DIABASE"

Small, irregular "diabase" dykes cut both the Hazelton volcanic rocks and the granodiorite sheet. These are dark green, or dark brown to black, very fine-grained holocrystalline rocks. The "diabase" is highly altered and the original composition is unknown. "Diabase" is not shown on the attached illustrations.

3. QUARTZ PORPHYRY

Diamond drilling has indicated the presence of a small quartz porphyry plug that intrudes the Hazelton rocks and the lower portion of the granodiorite sheet below the southwest extremity of the 3500 Level (fig. 6). Available data indicates that the plug is oval in plan with a maximum width of 1100 feet. The north and west walls are steep, and the relatively flat top is near the 3000 foot elevation.

Typical quartz porphyry is a buff to grey rock with a very fine-grained (.5 mm.) sugary groundmass which consists of equant interlocking grains of quartz, plagioclase and potash feldspar. Phenocrysts up to 3 mm. in diameter constitute 20 percent of the rock and are mostly euhedral to subhedral quartz with minor subhedral plagioclase. Typical quartz porphyry consists of 25 percent quartz, 37 percent potash feldspar, 37 percent sodic plagioclase and 1 percent biotite and/or amphibole.

At the top of the plug, an irregular zone approximately 150 feet thick is characterized by a very fine-grained to microcrystalline weakly porphyritic phase. Phenocrysts increase in size and number with depth. This zone is interpreted as a chilled margin.

The upper portion of the chilled margin is characterized by 1/16-inch-wide fine-grained, contorted quartz seams. The feature is interpreted as flow banding. Quartz phenocrysts are commonly attenuated into the quartz seams. Comb cronulated layering

Numerous 1/8-inch to 2-foot-wide dykes occur above the upper plug contact, and are apparently derived from the quartz porphyry. Dyke textures vary from very fine-grain aplitic, porphyritic with

Any vein dykes?

aphanitic groundmass, to pegmatitic. These dykes are mostly premineral in age.

Immediately above, and in part overlapping, the upper plug contact is a zone averaging 50 feet thick of nearly complete replacement by fine-grained hydrothermal silica. (This silica zone is briefly discussed here because of the overlapping relationship of igneous and hydrothermal events). The "high silica" zone grades upward into a quartz vein stockwork which gradationally terminates upward near 3500 Level (fig. 6).

A breccia occurs within and above the plug (fig. 6). Fragments of volcanic rocks, normal and aplitic granodiorite, flow-banded quartz porphyry, "high silica rock", barren quartz veins and quartz-molybdenite veins occur in a matrix of quartz porphyry in a 500-foot-thick zone straddling the apex of the plug. At depth, within the plug, fragments of quartz veins, quartz-molybdenite veins and flow-banded quartz porphyry are irregularly distributed over a vertical interval of 1300 feet. Quartz-molybdenite vein fragments are crossed by later, post-breccia quartz-molybdenite veins, and the breccia is therefore classed as intermineral. The breccia is truncated at depth by a porphyritic quartz monzonite stock. Although the breccia is shown as pipe-like in Figure 6, the areal extent and cross-sectional shape are conjectural.

Several narrow dykes of very fine-grained quartz porphyry occur within the breccia (fig. 6). Most dykes are later than the breccia but some dyke fragments have been found within the breccia. Dykes both truncate, and are veined by, quartz-molybdenite mineralization and are therefore intermineral in age.

4. PORPHYRITIC QUARTZ MONZONITE

Recent underground drilling has proven the existence of a quartz monzonite stock beneath the Hudson Bay Mountain glacier (hereafter referred to as "the glacier"). This stock is the apparent source of a sub-radial swarm of dykes which extends for at least two miles north and south of the glacier (figs. 4,6). The stock may outcrop beneath the glacier, and its presence has been inferred by several geologists over the last 40 years.

The stock is a pink, medium-to coarse-grained porphyritic granitic rock. Subhedral to euhedral phenocrysts of pink to buff potash feldspar average 1/2 inch in diameter and constitute 20 percent of the rock. These, and smaller phenocrysts of subhedral to euhedral quartz, white to buff plagioclase and potash feldspar, and dark green to black biotite and/or hornblende 3 mm. in diameter, are set in a fine- to medium-grained equigranular matrix of quartz, plagioclase and potash feldspar.

The rock is a quartz monzonite, as shown by modal analyses. A typical specimen is composed of 23 percent quartz, 33 percent potash feldspar, 36 percent plagioclase (An_{32}), and 8 percent biotite and/or amphibole.

A more mafic border zone, approximating quartz diorite in composition, is locally developed along the eastern border of the stock.

The chilled margin between the stock and Hazelton volcanic rocks rarely exceeds 2 inches in width.

Related quartz monzonite porphyry dykes observed on surface have microcrystalline groundmass, and colours are generally shades of buff, grey or greenish grey (fig. 4).

The stock truncates the mineralized quartz porphyry plug and is considered late intermineral relative to the mineralization within the plug. Quartz monzonite porphyry dykes cut the granodiorite sheet and are intermineral relative to molybdenite mineralization on the western side of the ore zone.

A potassium-argon age date of 67± 5 m.y. (Lower Tertiary) was obtained by the Geological Survey of Canada from biotite near the upper stock contact.

STRUCTURAL GEOLOGY

Doming, block faulting and thrusting are the major structural features on Hudson Bay Mountain.

FAULTING

The mountain appears to be bounded by steep normal and reverse faults. Most of these faults occur in sets which form a crude north-south, east-west rectangular pattern. Major faults are uncommon within this fault block.

A northwest-trending normal fault that dips steeply northeast crosses the lower portion of Glacier Gulch immediately below the portal of the adit (fig. 4). This fault shows a minimum apparent dip slip movement of 200 feet, and locally it forms the contact between Bowser sediments and Hazelton volcanics.

A steep, westerly-trending fault forms a prominent notch in the headwall of the cirque above Glacier Gulch. This fault cannot be traced eastward beyond the swarm of quartz monzonite porphyry dykes.

A flat thrust fault that trends northerly and dips at low angles to the east occurs on the northwestern flank of the mountain. The upper block appears to have moved westerly with respect to the lower block. Displacement on this structure is unknown. On the north side of the mountain the thrust fault disappears under a small glacier immediately west of the dyke swarm. It is believed that one of these dykes may occupy a steep fault that has truncated the thrust. On the west side of the mountain the thrust becomes stranded, and it has not been located south of the steep westerly-trending fault that crosses the cirque headwall.

No significant faults have been recognized in the area explored by diamond drilling and underground development.

FOLDING

The Hazelton volcanic rocks were subjected to broad, open regional folding prior to the deposition of Bowser sedimentary rocks. All of these rocks were subsequently uplifted and further deformed by doming that appears related to emplacement of the buried quartz monzonite stock.

The easterly-trending volcanic rocks dip steeply to moderately north in the northern portion of the mountain. Dips progressively flatten to the south.

Bowser sediments wrap around the northeastern side of the mountain and have strikes that are roughly concentric to the stock. These rocks dip moderately to steeply away from the mountain.

Complex, large-scale overturned folds are well-developed in the sole of the thrust on the western side of the mountain. The upper plate is relatively undeformed.

Small-scale, complex drag folds are developed along the fault that crosses lower Glacier Gulch. Fold structures observed near the adit portal are believed to be related to this fault. With this exception, rocks encountered underground and in diamond drilling are remarkably uniform in attitude.

FRACTURES

A well-developed fracture system that is believed related to the intrusion of the quartz monzonite stock and the resultant doming has been mapped on surface. This feature is discussed in more detail under "Vein and Fracture Patterns".

MINERALIZATION

Mineral deposits on Hudson Bay Mountain exhibit a crude mineralogical arrangement in concentric zones, centered by silica-molybdenum-tungsten-copper mineralization (ref. 2,3). This zone is successively surrounded by the Quartz Vein Zone (1½ x 2 miles in area) (fig. 5), the Pyritic Zone (2½ x 4 miles in area, which includes the Quartz Vein Zone), and the Base Metal Zone comprising numerous small vein and replacement deposits distributed over several square miles. The Base Metal Zone has been subdivided by Kirkham (ref. 3) into an inner zinc-gold-copper-arsenic zone and an outer lead-silver-copper-arsenic zone.

The Hudson Bay Mountain molybdenum deposit lies in the central portion of the above zonal arrangement. Here, molybdenite-bearing veins and fractures occur over a vertical interval of 7000 feet. Veins and fractures 2 to 10 feet apart form a rude stockwork in which most of the veins are less than ½-inch wide. These veins grade outward into pyrite-quartz veins, pyrite veins, and pyrite and iron oxide coated fractures spaced 6 inches to 1 foot apart in the Pyritic Zone. Mineralogy, texture and relative ages of the veins and fractures are complex.

Molybdenite, and lesser amounts of scheelite-powellite and chalcopyrite, are the minerals of economic interest. Other metallic minerals in the stockwork include abundant pyrite, pyrrhotite and magnetite, and minor to rare amounts of wolframite, arsenopyrite, galena, sphalerite, bismuthinite and native arsenic. The predominant gangue mineral is quartz, and it may be accompanied by minor amounts of one or more of the following: carbonate, potash feldspar, sericite-muscovite, chlorite, biotite, amphibole, fluorite, and gypsum.

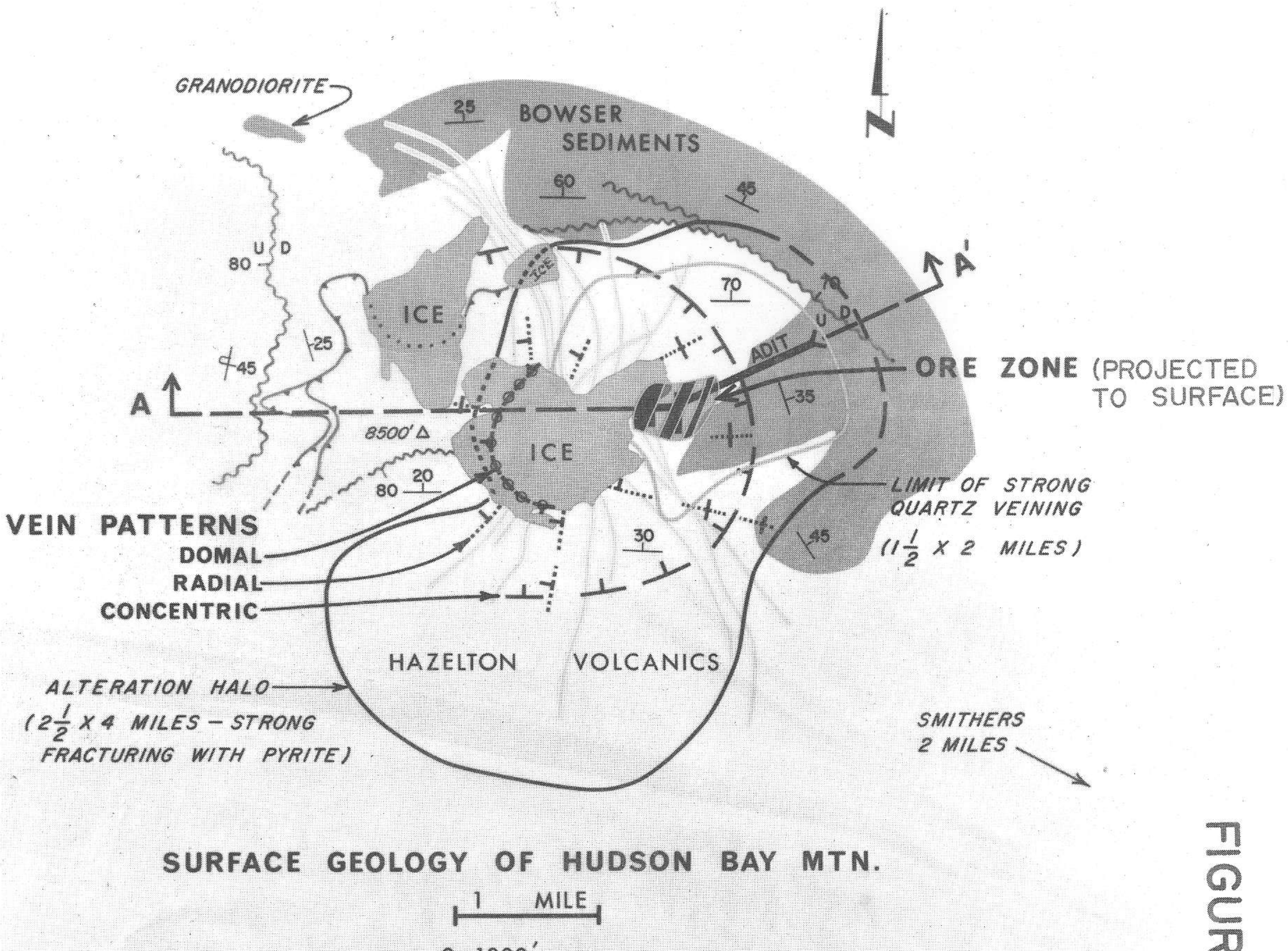
Most molybdenite occurs as:

a) fine-grained disseminations, or in more or less continuous thin layers of fine-grained flakes in a gangue that consists mostly of fine-grained quartz. These veins have been designated as "Type I", and may locally exceed two feet in width.

b) disseminated fine- to coarse-grained flakes, rosettes, or aggregates of flakes in medium to coarse-grained quartz veins up to six inches in width. These veins are designated as "Type II", and in many instances they appear to post-date the Type I veins. Most of the molybdenite-bearing veins within the Quartz Vein Zone on surface are Type II.

c) flakes or thin films on fracture surfaces ("moly paint").

FIGURE 5



SURFACE GEOLOGY OF HUDSON BAY MTN.

The mineralogy of Type I and Type II veins is nearly identical. They are differentiated by the degree of coarseness of the contained minerals. Some veins exhibit textures typical of both Type I and Type II mineralization.

Minor amounts of molybdenite occur as fine-grained disseminations in narrow feldspathized, argillized and sericitized halos adjacent to some veins.

Scheelite-powellite occurs in molybdenum-bearing quartz veins of all types, in some barren quartz veins, on fracture planes, and in one quartz-carbonate-bismuthinite vein crossing Hazelton rocks 1660 feet from the portal of the adit. Most of the tungsten mineralization appears to be spatially related to molybdenite deposition.

Chalcopyrite occurs in some veins associated with molybdenite, and may be present in quartz veins that both pre-date and post-date molybdenum deposition. It is also found as grains and plates on fractures where it is commonly associated with pyrite, and as sparse fine-grained disseminations in the volcanic rocks. There appears to be no well-defined spatial relationship of copper mineralization to molybdenum-tungsten mineralization.

VEIN AND FRACTURE PATTERNS

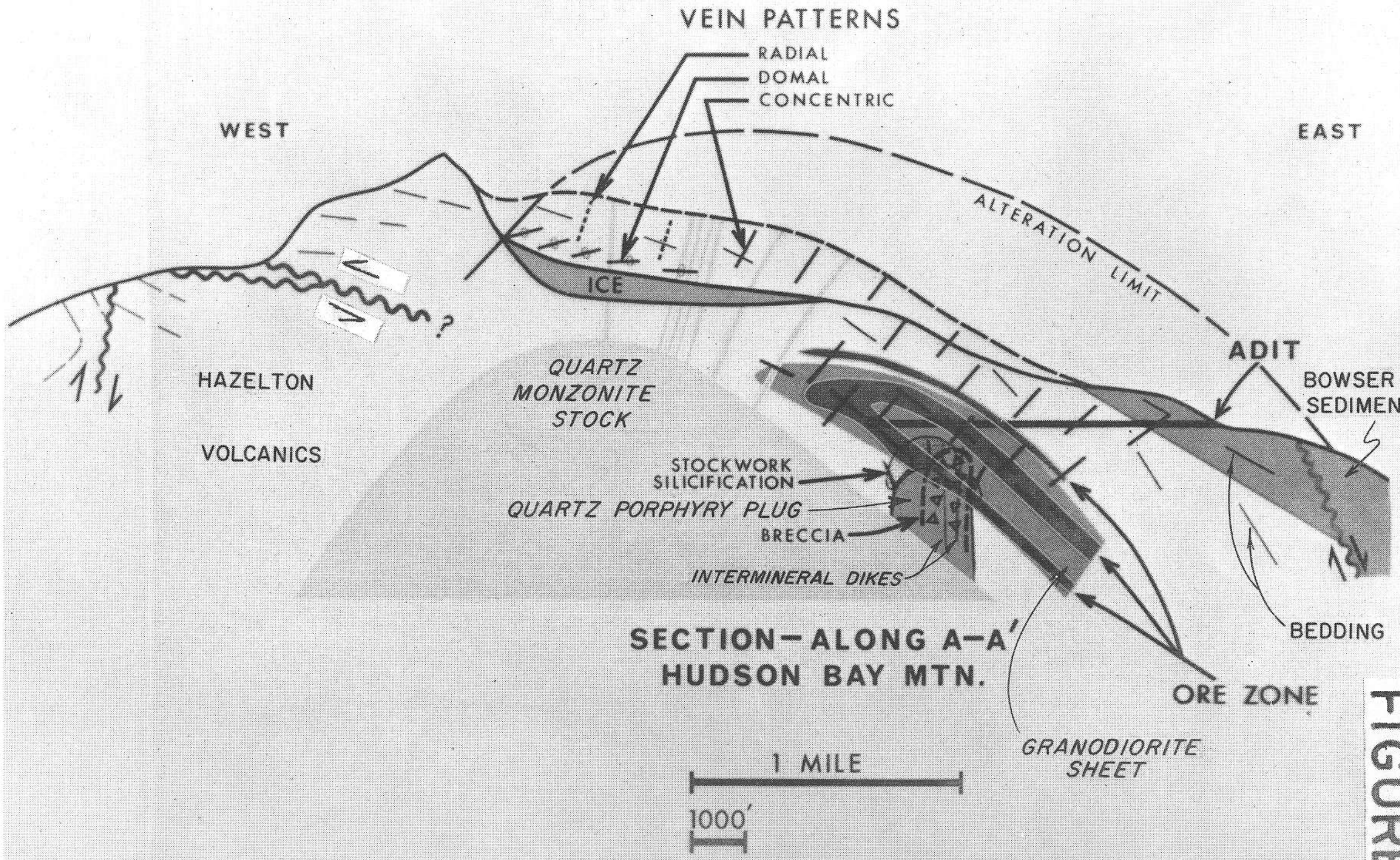
SURFACE PATTERNS

Recent surface mapping has been directed toward understanding the pattern of widely-dispersed fracturing and veining on Hudson Bay Mountain. This work, although incomplete, shows concentric-radial-tangential (domal) patterns (figs. 5,6) that are believed to have been formed during intrusive doming by the quartz monzonite stock which forms the core of the mountain beneath the glacier.

1. CONCENTRIC PATTERN

Most surface veins and fractures form a concentric pattern relative to the glacier. These features dip westerly and steepen from 20 degrees at low elevations to 80 degrees near the top of the mountain. Although diagramatically illustrated as a single arc on figure 5, this pattern has been mapped over several square miles.

In the Quartz Vein Zone, concentric veins form irregular swarms up to 400 feet wide. Individual veins may be traced up to 300 feet along strike and lie en echelon relative to other veins in the swarm.



SECTION—ALONG A–A'
HUDSON BAY MTN.

FIGURE 6

2. RADIAL PATTERN

Most radial veins and fractures are vertical or dip steeply west. The radial pattern is not as extensive as the concentric pattern in the Quartz Vein and Pyritic zones. However, most of the veins in the Base Metal Zone form a radial pattern relative to the Pyritic Zone.

3. TANGENTIAL (DOMAL) PATTERN

These fractures dip gently (10 to 30 degrees) away from the north and south sides of the glacier within the Pyritic Zone. Tangential veins and/or fractures are rare in the Quartz Vein Zone on the east side of the mountain.

4. RELATIONSHIP OF FRACTURE PATTERNS TO THE THRUST FAULT

Fracture and vein patterns diminish gradually away from the glacier in all directions except the west. In this area, fractures and fracture-controlled hydrothermal alteration terminate abruptly a short distance west of the quartz monzonite porphyry dyke swarm. This area is underlain by the thrust fault (figs. 5,6). It is postulated that the sudden termination of the fracture pattern here is due to relief of doming stress by recurrent movement along the thrust plane. This mechanism has been described by Wisser (ref. 6) to explain a similar structural setting in the Goldfield, Nevada, mining district.

SURFACE PATTERNS ABOVE THE ORE ZONE

The top of the ore zone is 1000 feet below the surface near the toe of the glacier (fig. 5). In a 1500 x 2000 foot area of continuous outcrop at the foot of the glacier, which has been named the Grid Area, veinlets average ¼ inch wide and are spaced approximately 4 feet apart. Vein density increases gradually toward the southwest corner of the Grid Area where veins are spaced 1 to 2 feet apart; the ore zone lies directly below this corner of the Grid Area.

As many as six distinct vein sets form a modified stockwork. The stockwork is dominated by gently-inclined concentric veins and near-vertical radial veins.

A set of distinctive "carbonate shears" that strikes northwest and dips moderately southwest post-dates, and in many instances occupies, pre-existing quartz and/or quartz-molybdenite veins. These weak fracture zones average 4 inches in thickness and are filled with calcite, ankerite(?), and minor pyrite. The "shears" are spaced from 200 to 300 feet apart, and are part of the concentric pattern.

Pyrite-filled fractures that strike northeast and dip steeply southeast truncate quartz-molybdenite veins and some of the "carbonate shears". These late fractures are spaced from 300 to 400 feet apart and form part of the radial pattern.

The distribution of quartz veins underground appears to correspond to that mapped on surface. However, there are two notable exceptions:

1). A stockwork of intense barren quartz veining caps the quartz porphyry plug (fig. 6). This zone is 500 feet thick and gradationally terminates upward near 3500 Level. In section, the stockwork has a crescentric shape that is convex upward. It appears to be localized along the top of the quartz porphyry and has not been found along the sides of the plug.

2). Two thick, sheeted swarms of banded, fine-grained quartz-molybdenite veins (Type I) strike northeast and dip gently to moderately southeast. These are mostly contained within, and are roughly parallel to, the granodiorite sheet. Individual banded veins within the set vary in width from ½ inch to 2 feet, and can be traced for several hundred feet along strike.

The above vein set is of major economic significance. Higher grade mineralization occure in two tabular, sub-parallel, gently-inclined zones within the sheeted vein swarms (fig. 6). The mineralized zones merge near the upper, northwest part of the granodiorite sheet. Here, the zone has a width approaching 2000 feet and is up to 700 feet thick. This mineralization has been incompletely explored for a dip-length of over 3000 feet. Exploratory drilling has encountered anomalous mineralization an additional 2000 feet down dip.

A third zone of higher grade mineralization occurs in volcanic rocks above the granodiorite (fig. 6), and although the zone is approximately parallel to the upper contact of the granodiorite, veins within the zone are very steeply inclined and do not parallel the gently-dipping vein swarms which lie below.

Available data indicate that sheeted, southeasterly-dipping vein swarms may be local in areal extent within the mineralized area on the east side of the mountain. Veins of similar attitude are rarely noted on surface above the ore zone, although drill core contains weakly mineralized, gently-inclined quartz veins over a vertical interval of 1500 feet underground; these veins are presumed to dip southeast.

ORE CONTROLS

The main structural control appears to be the sheet-like swarms of large, banded quartz veins which strike northeast and dip gently to moderately southeast. These veins carry a major proportion of the mineralization, and are reinforced where they intersect molybdenite-bearing quartz veins in the more widespread stockwork.

The granodiorite is an apparent lithologic control, and the strong, banded vein sets are developed almost completely within, and parallel to, the sheet. The granodiorite may have been more susceptible to fracturing as compared with surrounding volcanic rocks, or the relationship may be fortuitous.

ALTERATION

HYDROTHERMAL ALTERATION

Hydrothermal alteration within the molybdenite deposit is variable in type and weak to moderate in intensity. Alteration has been controlled by stockwork fracturing, and is strongest near veins and fractures. Distribution of alteration minerals is not uniform, and large areas of the stockwork are only slightly altered.

There are two main associations of hydrothermal alteration minerals:

1). Sericite-carbonate with variable amounts of potash feldspar and pyrite;

2). Amphibole-biotite-chlorite-magnetite.

The first type of alteration appears to be spatially and genetically related to molybdenite mineralization and is commonly accompanied by "bleaching" of wall rocks. Strong sericite-carbonate alteration is associated with "carbonate shears".

The second type of alteration is characterized by a concentration of minerals in tight, hairline fractures which may or may not have bleached halos. This type of alteration is mainly pre-mineral.

A vague zoning is present in the western part of the mineralized area. Quartz veins contain abundant potash feldspar, lesser amounts of magnetite and minor fluorite. This association is rare or absent elsewhere in the mineralized area, and is thought to be related to the quartz monzonite stock.

The quartz porphyry plug is overlain by a zone of "high silica rock", apparently the result of intense silicification by fluids introduced through a stockwork of fractures enveloping the apex of the plug.

REGIONAL AND THERMAL METAMORPHISM

Prior to the intrusion of the quartz porphyry plug and quartz monzonite stock, the Hazelton volcanic rocks and Bowser sediments were subjected to low-grade regional metamorphism. Primary structures and internal relationships in the volcanic rocks have been obscured, and the Bowser sediments have been altered to argillite, meta-greywacke, quartzite, and meta-conglomerate.

The volcanic rocks, sediments, and the granodiorite sheet have been thermally metamorphosed to varying degrees by later igneous activity. Some of the altered rocks are hornfels, while others contain abundant fine-grained garnet and epidote, indicating relatively high-grade thermal metamorphism.

It has not yet been resolved whether many of the secondary minerals are the product of regional metamorphism, thermal metamorphism and metasomatism, or propylitic hydrothermal alteration.

GENESIS OF THE ORE

It is postulated that the mineralization is related to a single, complex intrusive event. Early in this event, a relatively silicic magma was intruded, and a stress environment was set up that subsequently resulted in the observed concentric-radial-tangential fracture patterns. Volatile constituents and a slightly more silicic magma are believed to have been concentrated near the upper portion of the magma chamber. An intrusive pulse that resulted in the emplacement of the quartz porphyry plug and its related capping of "high silica" replacement and intense barren quartz vein stockwork was preceded by barren quartz veining and was closely followed by a complex period of molybdenite mineralization. Intrusive activity continued, as evidenced by the intermineral quartz porphyry breccia and later intermineral dykes. The close spatial relationship of the quartz porphyry plug and the strong southeasterly-dipping banded veins could indicate the development of a localized stress environment.

Continued upward movement of the main intrusive mass resulted in the emplacement of the quartz monzonite stock in its present position. The stock thus truncates fractures, mineralization, hydrothermal alteration and rock types that were indirectly produced by its parent magma.

Quartz-molybdenite mineralization continued after consolidation of the stock. This was followed by barren quartz veining and by late carbonate which filled fractures.

GEOLOGIC HISTORY

The oldest rocks exposed on Hudson Bay Mountain are a thick sequence of Hazelton Group volcanic and sedimentary rocks. These are cut by small bodies of rhyolite, and by small irregular dyke- and sill-like felsitic intrusions which are considered to be effusive and/or high level intrusive rocks that were related to volcanism. All these rocks are of Jurassic age.

The Hazelton rocks were folded and uplifted with the subsequent deposition of marine and continental clastic sediments of the Bowser Group. The Bowser Group has been dated as Upper Jurassic-Lower Cretaceous by fossil evidence from coal seams in Glacier Gulch.

The intrusion of the granodiorite is believed to have taken place during the Cretaceous Period in post-Bowser time. Absolute dating of the granodiorite is inconclusive, but this interpretation best fits the regional evidence. Remobilization and reconstitution of the mafic minerals, and some recrystallization of quartz and feldspar, took place within, and possibly adjacent to, the intrusive portion of the granodiorite following its emplacement.

The "diabase" dykes post-date the granodiorite, but their relative age with respect to metamorphism and metasomatism is uncertain.

Available data indicates at least three pulses of intrusive activity in the emplacement of the quartz porphyry plug. These are closely related in time with molybdenite mineralization.

Most of the plug, and its related "high silica" replacement and intense barren quartz vein stockwork, was emplaced in the first intrusive pulse. Some of the earliest molybdenite mineralization may have occurred slightly before, during, or after this event.

A second pulse of intrusive activity during the later stages of mineralization is evidenced by intermineral breccia with quartz porphyry matrix.

A third intrusive pulse is evidenced by intermineral quartz porphyry dykes that cut the breccia. Late dykes, believed related to the quartz porphyry, cut mineralization.

The quartz porphyry was subsequently intruded by the quartz monzonite stock. This mass truncates the mineralized quartz porphyry plug.

Molybdenite mineralization continued after consolidation of the quartz monzonite stock, both within the stock and also, it is believed, above the stock, but the relative amount of this mineralization is unknown.

Because the quartz porphyry plug and the quartz monzonite stock both exhibit intermineral relationships, and because the quartz monzonite stock has been dated as Tertiary, both the mineralization and the intrusives are considered to be Tertiary, and they are believed to represent phases of a single, complex igneous event.

REFERENCES

(1). Armstrong, J.E., 1944, Smithers, British Columbia, Preliminary Map: Geol. Surv., Canada, Paper 44-23.

(2). Kindle, E. D., 1954, Mineral Resources, Hazelton and Smithers Areas, Cassiar and Coast Districts, British Columbia: Geol. Surv., Canada, Memoir 223 (Revised Edition).

(3). Kirkham, R.V., 1966, Annual Report, Minister of Mines and Petroleum Resources, British Columbia.

(4). Souther, J.G., and Armstrong, J.E., 1966, North Central Belt of the Cordillera of British Columbia: Can. Inst. Min. Met., Special Volume No. 8.

(5). White, W.H., 1966, Tectonic Map of the Western Cordillera, British Columbia and Neighbouring Parts of the United States: Can. Inst. Min. Met., Special Volume No. 8.

(6). Wisser, E., 1960, Relation of Ore Deposition to Doming: Geol. Soc. Amer., Memoir 77.

(7). Geological Staff, 1958-1964, American Metal Climax, Inc., Geological Reports on Hudson Bay Mountain Molybdenum Property.