AN INVESTIGATION OF THE GOOD HOPE MINE

HEDLEY B.C.

by

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A thesis submitted to the Faculty of Graduate Studies and Research of McGill University in partial fulfilment of the requirements for the degree of Master of Science

Montreal, Quebec

April 1948

CONTENTS

FOREWORD

The regional structure and stratigraphy of the Hedley area have been studied by Camsell (1) , Bostock (2) , and McNaughton (3) , of the Geological Survey of Canada . Studies of the ore deposits of Nickel Plate mountain have been carried on by the mine staffs as well as by Camsell , Bostock , Billingsley and Hume (4) , Dolmage and Brown (5) , and others . Since the Nickel Plate deposits resemble in many ways those at the Good Hope , the framework of ore controls established in Nickel Plate mountain and used there with remarkable success has been used as a guide for the study of the Good Hope controls .

The Good Hope has been producing gold for three years . A set of orebodies has been found and mined . In places exploration by drillholes and trenches has been intensive . Through these activities an appreciable amount of information has been acquired concerning the stratigraphy , the characteristics of orebodies , and the structural relations . Some ore controls are known ; the value of other features of the geology as ore controllers has yet to be proved .

ACKNOWLEDGMENTS

As consulting geologist , Dr. Victor Dolmage has supervised geological work at the Good Hope mine since the beginning of major development . Exploration programs suggested by him have been carried out by C.W.S. Tremaine , Resident Manager of Hedley Mascot Gold Mines , assisted by A.R. Allen , J. DeLeen , the writer , and the staff of the Hedley Mascot mine . Geological and mine working maps were made by engineers of the company ; these were revised and extended by the writer in the summer of 1947 .

The writer wishes to thank the mine management for permission to use the property as a thesis topic , Dr. Dolmage for guidance in field work , and members of the mine staff for printing plans and sections to accompany the report . McGill University provided laboratory facilities . Faculty members , especially Dr. J.J. O'Neill , Dr. C.H. Stockwell , and Dr. J.E. Gill were lavish with guidance , advice , and assistance both in laboratory work and in the preparation of the report .

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ABSTRACT

The Good Hope mine at Hedley , British Columbia , was discovered four years ago . Since then , a few thousand tons of gold ore have been mined . The purpose of this paper is to present the evidence that has been assembled indicating the controls that resulted in the formation of the known orebodies .

The ore occurs as irregular bodies of skarn within the limestone members of an assemblage of volcanic rocks and limestone lenses . The writer concludes that the skarn bodies were produced by alteration of limestone , that the gold was introduced during this alteration , and that a set of vertical fractures in underlying rocks were probably the channels by which replacing solutions entered the limestone . A nearby dioritic stock may have been the source of the solutions .

The report was planned as a preliminary study , to be revised and expanded following further work at the property .

REGIONAL GEOLOGY

1. POSITION AND TOPOGRAPHY OF AREA

" The Hedley district , which is 210 miles due east of Vancouver , is situated in the Okanagan range of southern British Columbia , where this rather gentle uplift is deeply dissected by the canyons of the Similkameen and its tributaries . The region is essentially part of the Interior Plateau of the Province , but is adjacent to easterly elements of the Coast Range .

The Similkameen canyon , 4000 feet in depth and frequently less than 4 miles from rim to rim , traverses the district from northwest to southeast . ... At Hedley , an important tributary , Twenty Mile creek , enters from the north in a bold canyon , making a focus of unusually rugged topography . Nickel Plate mountain occupies the sector to the east of this junction .... The elevation of Hedley is 1,700 feet ; the summit of Nickel Plate mountain is 6,200 feet ; and the general average of the plateau is about 6,000 feet . " (Reference 5 , page 525) .

Just downstream from Hedley the valley of Sixteen Mile or Winters creek enters from the north . The Good Hope mine lies on the top of the ridge forming the west wall of the valley , at an elevation of 5,000 feet .

2. STRATIGRAPHY

Sedimentary and volcanic rocks of Triassic age and later are underlain and intruded by stocks and batholiths .

The stratigraphic succession , based on Geological Survey of Canada mapping (References 1, 2, 3) is given in the table on the next page . Formations from Redtop to Henry are prominent around Hedley . The Independence and Bradshaw formations appear toward the southeast and extend several miles down the valley of the Similkameen River . Their importance to this paper lies in the hints they give of the regional structure . Cenozoic rocks are found in the area but as they do not figure in the mine geology are not considered further .

Granodiorite outcrops at Hedley in the bottom of the Similkameen valley and is spread widely over areas to the northwest . Granite forms a small stock just north of Nickel Plate mountain . Earlier intrusive rocks of a diorite - gabbro complex form stocks , sills , and dykes , best exposed on Nickel Plate mountain but present elsewhere too .

There is some dispute as to the age of the intrusive rocks . They may have been formed in post-Triassic , pre-Tertiary time . Some investigators refer them to post-Oligocene time , however . The writer has no opinion to offer , having had no opportunity to examine the field evidence .

In the following table quartzite is listed as a component of the Hedley formation . These quartz-rich rocks may be volcanic in origin . Thicknesses of individual formations are not given , because there is some doubt as to some correlations of outcrops . The total thickness of the Mesozoic rocks has been given as 10,000 feet. (Reference 4 , page 34)

Table of Formations

CENOZOIC

Modern : alluvium

Pleistocene : drift

Tertiary : basalt , andesite , tuff , breccia . conglomerate , sandstone .

MESOZOIC

Jurassic and/or younger :

granite
granodiorite
diorite-gabbro complex

Triassic: ?
Wolfe Creek formation

andesite , basalt , breccia , tuff , minor sediments .

Triassic:
Henry formation

argillite , tuff , limestone .

Hedley formation

limestone , quartzite , argillite , conglomerate , breccia , tuff .

Sunnyside formation

limestone

Redtop formation

limestone , quartzite , argillite , tuff , breccia .

Triassic and/or older:

Independence formation

chert , breccia , quartzite , argillite , basalt , andesite .

Bradshaw formation

argillite , tuff , quartzite , limestone , andesite .

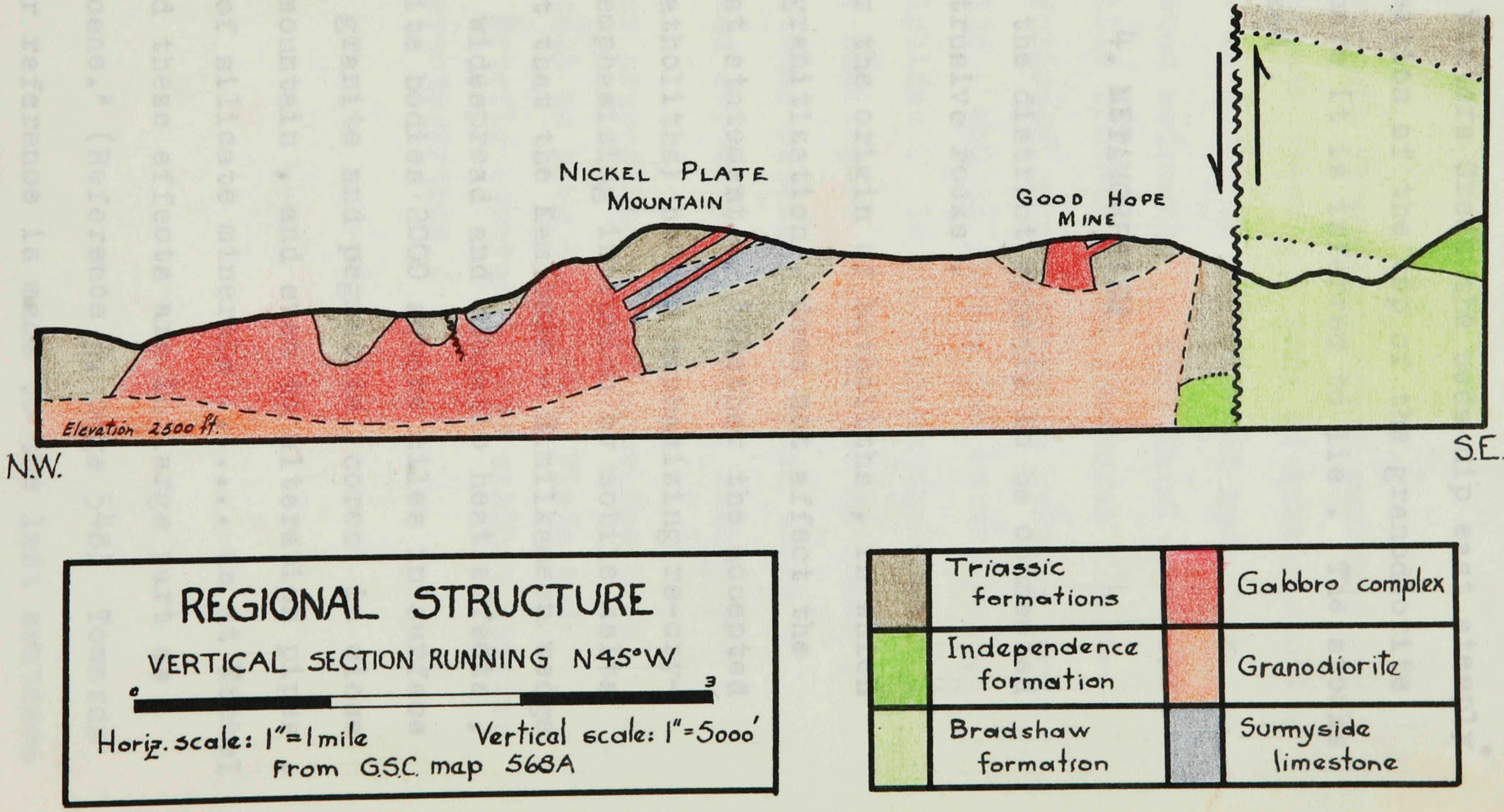
3. STRUCTURE

The position of the Hedley area with respect to the intrusion , thrusting and folding of the western part of the continent has been analysed by Billingsley and Hume :

" Together with the Tulameen platinum belt and Copper mountain , it (the Hedley area) is in a crotch caught between the southeast trending front of the Coast range and the northeast trending 'crust' of the Shuswap shield , a major re - entrant or 'syntaxis' of the Cordilleran plutonic arc . This re-entrant we may call the Kamloops - Similkameen wedge " . (Reference 5 , page 546)

A narrower view of the structure is given by their concept of the Triassic rocks as " a corrugated slice eighteen miles wide caught between eastward thrust zones at either edge " . (Reference 5 , page 548) In addition to thrusts on the boundaries of the Triassic assemblage Billingsley and Hume postulate thrusts from the west as the explanation of peculiar breccias and the repetition of strata in Nickel Plate mountain .

For the area immediately surrounding Hedley and extending southeast down the valley Bostock gives the structure as " a large broken anticline the eastern limb of which has been lifted up relatively to the western limb ". (Reference 3) The fault along the broken crest would run up the valley of Winters Creek , a tributary of the Similkameen River entering from the north . The section on the opposite page , adapted from G.S.C. map 568 A shows the beds west of Winters Creek


Nickel Plate
Mountain
Good Hope
Mine
Elevation 2500 ft.
N.W.
S.E.
REGIONAL STRUCTURE
VERTICAL SECTION RUNNING N45°W
0
3
Horiz. scale: 1"=1 mile
Vertical scale: 1"=5000'
From G.S.C. map 568A
Triassic formations
Independence formation
Bradshaw formation
Gabbro complex
Granodiorite
Sunnyside limestone

dipping moderately west under the Good Hope and the Nickel Plate mines . Particular formations above the Independence beds have not yet been correlated across the valley between the mines . East of Winters Creek the beds dip east steeply . In the sketch the position of the top of the granodiorite batholith is shown where it is inferred to lie . The stocks and sills are idealized .

4. METAMORPHISM

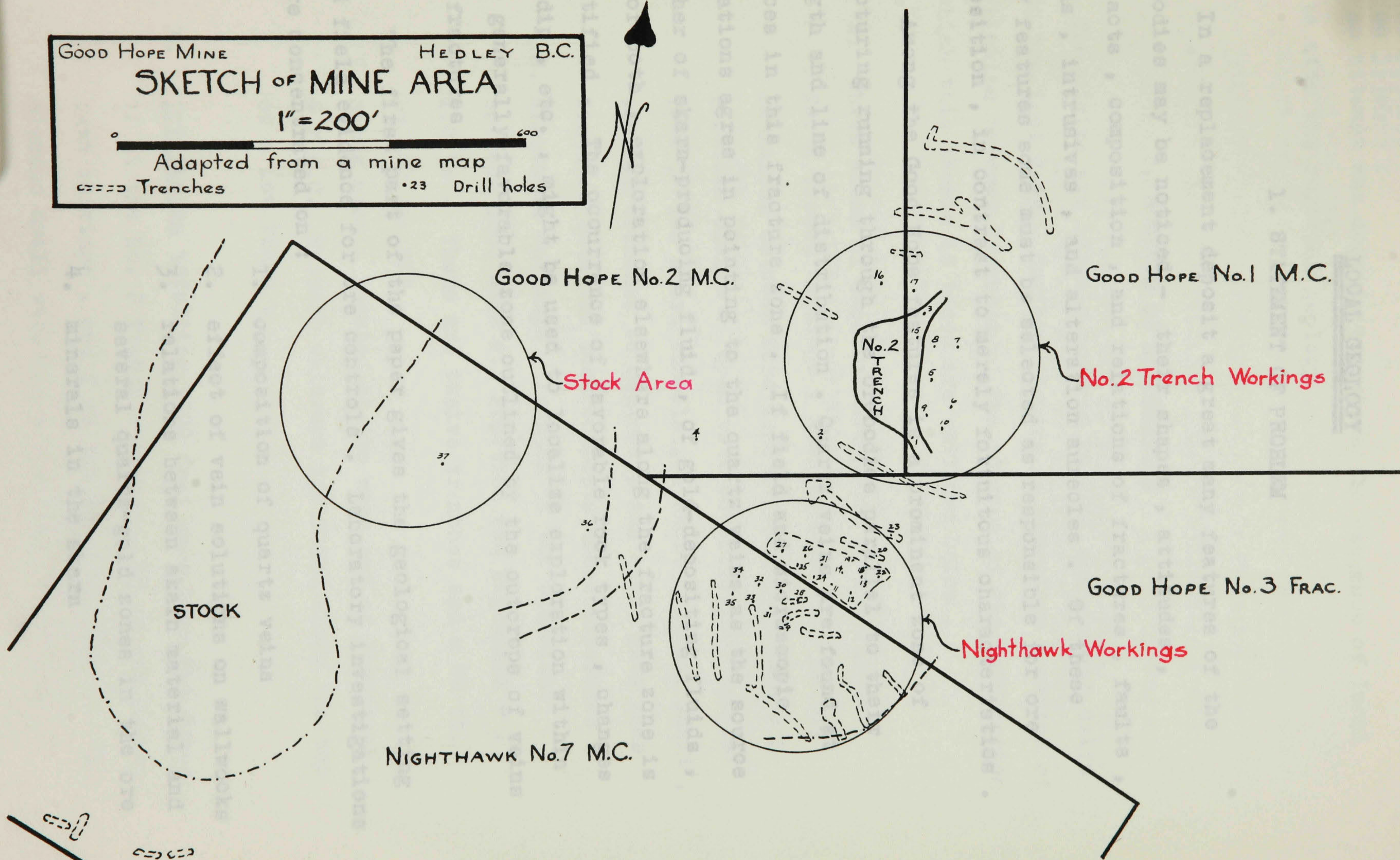
Metamorphism in the district appears to be connected directly with the intrusive rocks .

The dispute over the origin of batholiths , in which Billingsley favours granitization , does not affect the validity of that first statement . "Whether the accepted interpretation (of batholiths) be one emphasizing re-crystallization or one emphasizing intrusion by mobile melts there can be no doubt that the Kamloops - Similkameen wedge has been the seat of widespread and emphatic heat effects , which vary from granite bodies 2000 square miles in surface area .... down to granite and pegmatite 'cores' in close folds , like Copper mountain , and even to alteration pipes , funnels and spreads of silicate minerals .... as at Nickel Plate mountain . And these effects are in large part as recent as post-Oligocene." (Reference 5, page 548) Towards the end of this paper reference is made to the last sentence of the quotation .

Ore deposits of the area have been assigned to the contact - metamorphic class . Lime - rich rocks have been altered to skarn by the development of garnet , pyroxene , amphibole , wollastonite , epidote , axinite and many other minerals .

At Nickel Plate mountain alteration zones surround and were governed by the Toronto stock , a body of quartz diorite (differentiated) . Ore is found in the altered rock near its boundary against unaltered sediments . Structural controls appear to be folds , sills , dykes , and fractures . Apparently late solutions followed up fractures in brittle rocks such as skarn , quartzite , and in places the intrusives , depositing gold and sulphides . In limestones the openings had been closed by self-healing so there no ore is found . Folds and dyke intersections provided structural traps resulting in concentrated deposition of gold , making ore .

None of the smaller properties of the area has been studied in as great detail as have the Nickel Plate and Hedley Mascot mines . Briefly however , they exhibit similar contact metamorphic characteristics .



Good Hope Mine
Hedley B.C.
SKETCH of MINE AREA
1"=200'
0
600
Adapted from a mine map
Trenches
•23 Drill holes
Good Hope No.1 M.C.
Good Hope No.2 M.C.
Good Hope No.3 Frac.
Nighthawk No.7 M.C.
No.2 Trench Workings
No.2 TRENCH
Stock Area
Nighthawk Workings
STOCK

LOCAL GEOLOGY

1. STATEMENT OF PROBLEM

In a replacement deposit a great many features of the orebodies may be noticed - their shapes , attitudes , contacts , composition , and relations of fractures , faults , folds , intrusives , and alteration aureoles . Of these many features some must be selected as responsible for ore deposition , in contrast to merely fortuitous characteristics .

Among the Good Hope features is a prominent zone of fracturing running through the orebodies parallel to their length and line of distribution . Quartz veins are found at places in this fracture zone . If field and microscopic relations agree in pointing to the quartz veins as the source either of skarn-producing fluid , of gold-depositing fluids , or of both , exploration elsewhere along the fracture zone is justified . The occurrence of favorable rock types , changes in dip , etc. , might be used to localize exploration within the generally-favorable zone outlined by the outcrops of veins or fractures .

The first part of the paper gives the geological setting and field evidence for ore controls . Laboratory investigations were concentrated on :

1. composition of quartz veins
2. effect of vein solutions on wallwocks
3. relations between skarn material and several quartz-gold zones in the ore
4. minerals in the skarn

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2. effect of vein solutions on wallwocks
3. relations between skarn material and several quartz-gold zones in the ore
4. minerals in the skarn

An attempt was made to correlate the sequence of local events with the regional geology .

2. SOURCES OF INFORMATION

The claims are largely covered by soil and glacial drift up to ten feet deep . Surface mapping is therefore a matter of correlation between trenches . The sources of the information on which this thesis is based are outlined below .

A. Three areas of exposure are found on the claims :

1. No. 2 Trench workings , located centrally on the claimline between Good Hope # 1 and Good Hope # 2 Fraction claims . Open pits cover 140,000 square feet . Two short tunnels , a short vertical shaft , several trenches to bedrock , and seven pits some distance into the rock complete these exposures .
2. Nighthawk workings , located on the claimline between Good Hope # 3 Fraction and Nighthawk # 7 M.C.'s . There are twelve trenches and a 40 ft. by 100 ft. pit .
3. Stock area , located at the west end of Nighthawk # 7 M.C. Natural outcrops are found along the top of a low ridge .

B. Drillholes totalling 1300 feet have been put down: 12 at the No. 2 Trench workings , 23 at the Nighthawk workings , and 2 at the Stock workings . The diamond drill core has a diameter of 7/8 inch .

C. Notes and maps . A.R. Allen and J. DeLeen are responsible for most of the geological mapping . They and engineers of the Hedley Mascot staff surveyed the area , locating transit stations , claim boundaries , contours , and outlines of workings . A grid of vertical sections was established to supplement plans . Gordon Brown inspected the mine and produced an estimate of tonnage .

D. Personal communication. Dr. Dolmage and members of the Hedley Mascot staff supplied valuable information regarding past years' observations .

E. The writer spent five months in the summer of 1947 as geologist at the mine .

3. STRATIGRAPHY

Regional mapping has not been complete enough to provide a correlation of Good Hope formations with particular ones of the Nickel Plate succession . Both groups are assigned to the Triassic period , however .

Owing to erosion , the two uppermost divisions of the sequence are not present everywhere in the mine area . The section known to the end of 1947 is divided as shown on the next page .

Notes on rock types

1. Marble members . These are coarsely-crystalline marble , in part finely bedded , containing a few discontinuous lenses of volcanic rock . In places the members are massive , elsewhere they may consist of discontinuous lenses of marble enclosed by volcanic rocks . Parts of the massive type consist of a marble breccia of partly rounded fragments of marble up to 1½ inches across set in a fine grained scanty matrix of marble , skarn minerals , and sulphides . Pyrite and pyrrhotite are the only metallics identified . The skarn is barren of gold .

2. Breccias . These occur in great variety . Some are merely angular-fragment aggregates similar to the volcanic rocks enclosing them - thinly-bedded brown tuffs or brown and green tuffs commonly . Others have been called chert because of their fine grained to aphanitic appearance and pale green to grey color . Most of the cherty types are however composed of angular fragments of volcanic rock and show the primary banding to be

Local Stratigraphy

Name	Thickness	Description
Overburden	0' - 10'	Glacial boulders , soil , gravel
Volcanic rocks	0 - 100	Hornblende-feldspar porphyry , thinly-bedded tuff .
Upper Marble	0 - 65	coarsely-crystalline white marble , thin lenses of green volcanic rock . Parts altered to skarn , wollastonite etc.
Volcanic rocks	50	Hornblende porphyry , hornblende-feldspar porphyry , brown tuffs , various breccia cherty volcanic rocks . Sill found near center .
Lower Marble	65 - 90	White marble , marble breccia , skarn
Volcanic Rocks	60	Many types : massive green, breccias , thinly-bedded tuffs .

Two feet of marble and skarn at the bottom of one drillhole may be part of another lower thick lens of marble .

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drillholes is difficult.

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blende-feldspar porphyry " or " feldspar porphyry " . It is
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feldspar phenocrysts up to 3/8 - inch long . Hornblende may
be present , similarly in phenocrysts .

From megascopic examination the groundmass appears fine-
rained to aphanitic , colored a dark grey that weathers to

expected in fragments of tuff . Individual beds are not of great extent or thickness so correlation between drillholes is difficult.

3. Skarn . The many varieties of skarn are fully described in the section on the characteristics of skarn and ore .

4. Tuffs . The term tuffs has been used loosely as a general term for volcanic rocks . Rocks showing good bedding fit the term well . Others , more massive , may be flows or even intrusives . Pillows are absent . Amygdules are absent . Crystals of feldspar or hornblende are common .

5. Volcanic rocks inside the limestone members are preserved as bands of little-altered waste inside the orebodies . Some of the bodies seem to be discontinuous , presumably because of primary lensing . Those that lie parallel to bedding planes are probably water-lain tuffs . Those that crosscut bedding in the limestone may be dykes , but of this there is no proof . The field relations suggest that deposition of volcanic material and limestone alternated irregularly . Initial lensing-out of either rock might produce the observed features . On the other hand, the limestone may have flowed under pressure , buckling originally flat beds of volcanic rock .

6. One peculiar rock of wide distribution is the " hornblende-feldspar porphyry " or " feldspar porphyry " . It is characterized by lack of bedding and the presence of many feldspar phenocrysts up to 3/8 - inch long . Hornblende may be present , similarly in phenocrysts .

From megascopic examination the groundmass appears fine-grained to aphanitic , colored a dark grey that weathers to

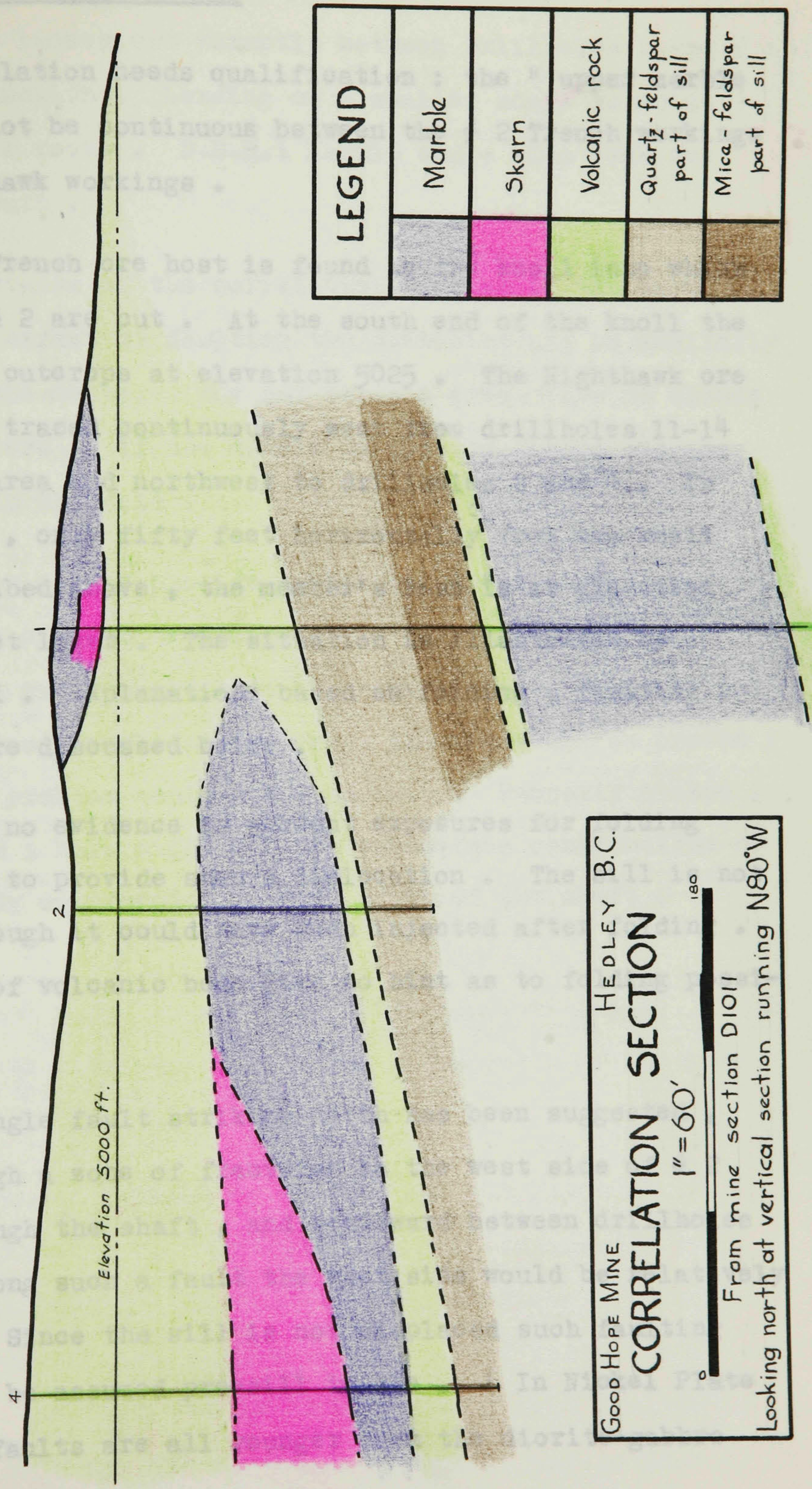
A problem in the stratigraphy

One correlation needs qualification : the " upper marble member " may not be continuous between the # 2 Trench [illegible] and the Nighthawk workings .

The # 2 Trench ore host is found at the knoll [illegible] where Trenches 1 and 2 are cut . At the south end of the knoll the member's base outcrops at elevation 5025 . The Nighthawk ore host has been traced continuously [illegible] drillholes 11-14 to the stock area [illegible] northwest [illegible] drillhole # 2 , [illegible] fifty feet [illegible] outcrop described above , the member's base [illegible] 4915 , 110 feet lower . The situation [illegible] section D 1011 . Explanations based [illegible] and lensing are discussed below.

There is no evidence [illegible] for folding abrupt enough to provide such a dislocation . The sill is not folded , although it could have been intruded after folding . Correlations of volcanic beds [illegible] as to folding possibilities .

A high-angle fault [illegible] has been suggested, running through a zone of [illegible] the west side of the Trench , through the shaft [illegible] between drillholes 1 and 2 . Along such a fault the east side would be relatively downthrown . Since the sill is not displaced such faulting would have to be [illegible] In Nickel Plate mountain the faults are all [illegible] the diorite-gabbro complex.)



A problem in the stratigraphy

One correlation needs qualification : the " upper marble member " may not be continuous between the # 2 Trench workings and the Nighthawk workings .

The # 2 Trench ore host is found in the knoll into which Trenches 1 and 2 are cut . At the south end of the knoll the member's base outcrops at elevation 5025 . The Nighthawk ore host has been traced continuously west from drillholes 11-14 to the stock area and northwest to drillholes 2 and 4 . In drillhole # 2 , only fifty feet horizontally from the knoll outcrop described above , the member's base is at elevation 4915 , 110 feet lower . The situation is illustrated by section D 1011 . Explanations based on folding , faulting , and lensing are discussed below .

There is no evidence in present exposures for folding abrupt enough to provide such a dislocation . The sill is not folded , although it could have been injected after folding . Correlations of volcanic beds give no hint as to folding possibilities .

A high-angle fault striking north has been suggested , running through a zone of fractures on the west side of # 2 Trench , through the shaft , and southward between drillholes 1 and 2 . Along such a fault the west side would be relatively downthrown . Since the sill is not displaced such faulting would have to be assumed pre-sill in age . (In Nickel Plate mountain the faults are all younger than the diorite-gabbro complex.)

Another possible explanation is that the D.D.H.2 - D.D.H.4 marble lenses out abruptly between Drillholes 1 and 2 : see sketched section . Lensing on a smaller scale is quite common in these rocks . D.D.H.1 Marble would also lens out towards the south .

The importance of the correlation is that if the marble horizons were offset by faulting the orebodies may be similarly offset . If the members lens out certain areas have no chance of containing ore . If the marble is tightly folded ore may be localized in the fold .

A solution of the problem cannot be expected until more of the surface is exposed by stripping . A vertical drillhole between Nos. 1 and 2 might hint at an explanation . If it cut a thin section of marble at 60 feet , lensing would be proved ; otherwise the problem would still be open . Properly placed , however , such a hole might cut the subsurface continuation of a small orebody outcropping 50 feet south of the shaft .

4. INTRUSIVE IGNEOUS ROCKS

In view of the dominance of intrusive rocks in ore control in Nickel Plate mountain the local bodies merit lengthy discussion .

Stock

Along the west boundary of Nighthawk # 7 M.C. mica diorite is exposed over an area 300 feet by 700 feet . Judging from its manner of crossing contours the body has steep walls . All the exposures are uniform in composition and texture . A few rounded , sharply-defined inclusions of fine- to medium-grained dark green rock are visible , their diameters predominantly one or two inches although ranging up to one foot . Apparently the country rock was not greatly disturbed during the intrusion , for west of the stock thinly-bedded tuffs have shallow dips to the east , and at the contact retain this attitude . Beds east of the stock show more complex folding that may not be related to the intrusion .

At only one place is a tuff-diorite contact exposed . The contact is sharp , the tuff unaltered , the grain of the mica diorite a little finer than normal .

The west contact is known only by its outcrop down the hillside - apparently it dips steeply . The east contact has been investigated by drillhole 37 which , starting within 150 feet of the nearest mica diorite outcrop , hit similar rock at 200 feet . As the intersection may be with a sill instead of with the main body the dip of the east contact may be stated merely as 50 degrees or more to the east .

Contact metamorphism of marble members of the stratigraphic sequence is suggested by skarn inside marble , as cut by drillhole 37 , within 50 feet of the stock . Trenches south of the stock expose skarn in marble similarly close to mica diorite . It is suggested that these skarn bodies form an aureole about the stock . Proof of such a relationship may be supplied by further drilling and trenching .

<u>Sill</u>

About fifty feet under the orebodies , drillholes run into an intrusive sheet apparently continuous under all the prospected area . Being thick and barren , the sheet was a convenient base for early exploratory drilling . As a result , before 1947 , knowledge of lower horizons was limited to that given by drillhole # 1 . During 1947 drillholes 35 36 37 were continued into rocks lower in the succession and twelve shorter holes were bottomed in the upper few feet of the sill . These drillholes and three trenches are the only sources of information about the sill .

The body appears in general to occupy one stratigraphic osition , the center of a layer of volcanic rocks separating wo marble members . This habit justifies the use of the term sill" . Although general conformability is proved , minor runcation of bedding is suggested by closely-spaced drillole correlations . Contouring based on several drillholes n 25-foot centers shows humps and hollows in the upper surace . No explanation of these irregularities can be given et .

The general attitude is : strike N35°E , dip 14°NW , but locally great variations occur . In thickness the sill ranges from 100 feet (D.D.H.36) to 63 feet (D.D.H.35). It is made of two layers of different composition . The lower layer , 20 to 60 feet thick , consists of mica diorite similar in all respects to the stock . The upper layer , 45 feet thick , consists of a finer-grained aggregate of quartz and white feldspar , provisionally named the " white diorite " because dark minerals are absent . The contact between the layers is in most places gradational , with grain size and content of dark minerals increasing irregularly across a transition zone up to 8 feet thick . Sharp contacts are found too .

No inclusions have been discovered in the white ~~granite~~ diorite . Inclusions are fairly common in the mica diorite . Their dimensions do not commonly exceed three inches . Borders are sharp and partly rounded , though irregular . In composition the inclusions are mostly hornblende-feldspar mixture ranging in texture from aphanitic to fine-grained . No quartz-rich or marble inclusions are found . None show the fine bedding or mottling common in the immediate country rocks .

Little is known of the effect of the sill on its enclosing rocks . Trench exposures of white ~~granite~~ diorite-marble and white ~~granite~~ diorite-tuff contacts show no perceptible alteration of country rock . Drillhole cores are mostly broken and somewhat ground at the contact . Volcanic rocks show no changes . Marble is not found in contact with intrusive although drillhole # 32 cut a mixture of marble and skarn a foot above the sill . Similar mixtures are found in limestone much farther from the sill however . No crumpling of beds near the intrusive contact has been identified . In drillhole # 35 a contact between mica diorite and volcanic rock shows the sill to have a fine-grained border in which dark minerals are scarce .

The junction of sill and stock is not exposed . In Nickel Plate mountain the sills are apophyses from stocks.

Dykes

Dyke outcrops in the sketch:

The sketch opposite page 25 shows the outcrops , the attitudes , and the positions of the outcrops relative to the ore-bodies .

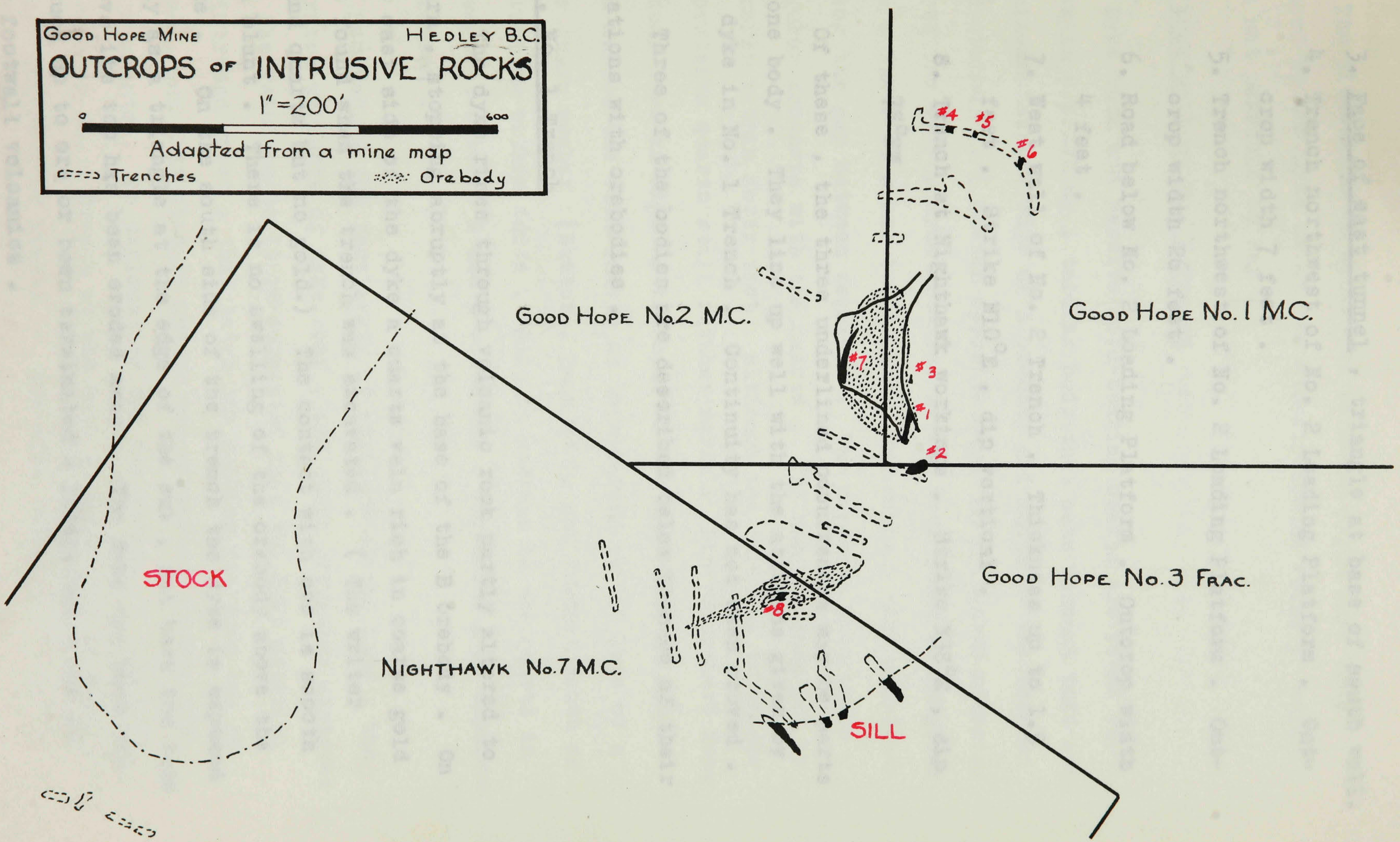
Although the given positions are not open to question , the attitudes are . Most of the dykes are poorly exposed . The contacts may be sharp but they are also irregular . With the short exposures possible in trenches , (generally less than four feet) and only a two-dimensional view , the attitudes given on the sketch are more suggestions than measurements .

Descriptions :

Dykes are found in drill cores , trenches , and open pits . All known have the same composition : they are quartz-feldspar aggregates identical with the upper part of the sill . One or two dykes contain a small percentage of biotite as well .

Surface exposures :

1. East end of No. 1 Trench . Thickness 3 feet . Strike N5°E . Dip steep E.
2. Under No. 1 Loading Platform . Attitude and thickness unknown .



GOOD HOPE MINE
HEDLEY B.C.
OUTCROPS OF INTRUSIVE ROCKS
1" = 200'
0
600
Adapted from a mine map
Trenches
Orebody
GOOD HOPE No. 1 M.C.
GOOD HOPE No. 2 M.C.
GOOD HOPE No. 3 FRAC.
NIGHTHAWK No. 7 M.C.
STOCK
SILL
#1
#2
#3
#4
#5
#6
#7
#8

3. Face of east tunnel , triangle at base of south wall.
4. Trench northwest of No. 2 Loading Platform . Outcrop width 7 feet .
5. Trench northwest of No. 2 Loading Platform . Outcrop width 26 feet .
6. Road below No. 2 Loading Platform . Outcrop width 4 feet .
7. West wall of No. 2 Trench . Thickness up to 1.5 feet . Strike N10^{o}E , dip vertical .
8. Trench at Nighthawk workings . Strike N38^{o}E , dip 78^{o}NW .

Of these , the three underlined occurrences may be parts of one body . They line up well with the attitude given by the dyke in No. 1 Trench . Continuity has not been proved .

Three of the bodies are described below because of their relations with orebodies .

1. No. 1 Trench

The dyke rises through volcanic rock partly altered to skarn , stopping abruptly at the base of the B orebody . On the east side of the dyke a quartz vein rich in coarse gold was found when the trench was excavated . (The writer found quartz but no gold.) The contact with ore is smooth and blunt . There is no swelling of the orebody above the dyke . On the south side of the trench the dyke is exposed only as a triangle at the edge of the cut , and here the rock above its top has been eroded away . The dyke may have continued up to ore or been terminated a little below ore in the footwall volcanics .

The alteration of wallrocks to skarn might have been produced by the dyke or by the closely-spaced veins ; which , it is not possible to say .

2. West wall of No. 2 Trench

Dyke rock and massive gold-bearing quartz are found together in a pinching , tabular body that cuts through tuff and the six-inch-thick edge of A orebody and stops at the base of the B orebody . (Sketch opposite page 42) Quartz makes up most of the body , dyke material having been found at only one place . There it seems to lie along the walls , with quartz filling the gap between segments . The segments have sharp irregular contacts with the quartz . The body pinches out to the north within forty feet , although the fracture continues and contains quartz still farther north . Not everywhere does the body rise as high as the base of the B orebody : A.R. Allen mapped the vein-quartz as terminating at the base of a lower skarn member (Sketch , page 42), and further south as terminating within tuffs . Gold is present in the quartz in the segment between B and A orebodies , but below A is apparently barren .

Because of the regularity of attitude of the body , the separated segments of dyke rock , and their irregular contacts with the vein quartz it is suggested that the dyke material was intruded first , that later the guiding fracture was reopened , and that finally quartz was deposited between the dyke segments . An explanation for the ending of this body and that in No. 1 Trench at the base of orebodies is suggested under " Sequence of Events - Ore-dyke relations ". (Page 76)

3. Dyke in Nighthawk trench

In the trench running east from the collar of drillhole 29 a 6-foot dyke has been mapped with a strike of N38°E , a dip 78°NW . Assays of altered rock on either side show gold assays up to 0.37 ounces a ton .

Owing to the small area of exposure no genetic connection can be proved yet . Drilling suggests that the vertical extent of the orebodies is controlled by flat-lying primary bedding , with tuff remaining waste and parts of marble members becoming ore . The dyke might still govern the horizontal extent of the ore zone .

It is expected that the orebodies here will be mined in the summer of 1948 . More information will be garnered then .

Drillcore intersections

Dykes are found in drillcores as well as on the surface . The intersections recognized so far are tabulated below.

Drillhole	Length of intersection in feet
1	3
5	2
6	1 , 1.5
20	1.5
23	4.5
31	1
35	1

True thicknesses of these dykes are not known . The contacts with the walls are sharp but irregular , and make angles with the horizontal of as little as 30° . All the above-noted stringers are enclosed by volcanic rocks . None is found in skarn or in marble . In composition and texture these thinner dykes resemble the upper segment of the sill in being simple quartz-feldspar mixtures . Oil immersion tests on crushed fragments gave a minimum index between 1.53 and 1.54 , which by Tsuboi's curve gives a composition within the oligoclase feldspars .

One intrusive body has not yet been mentioned . Drill-hole 35 cut forty feet of light-colored biotite diorite at a point 110 feet below the sill . Drillholes 1 and 36 , some distance away , are the only other holes deep enough to cut that stratigraphic horizon : they did not intersect diorite below the main sill . If a sill , therefore , this body does not have as great an extent as the upper sill . If a dyke , it may be much thinner than forty feet .

Relations between Intrusives

Sill , stock , and dykes are considered offshoots of one magma . The basis for such a conclusion is

1. similarity of stock to lower part of sill
2. similarity of dykes to upper part of sill
3. common lack of alteration of volcanic rocks in contact with intrusive rocks
4. unusual composition of the rocks
5. similar composition of feldspars in stock , sill , and dykes .

No contradictory evidence is known .

Age of the Intrusives

Regional correlation is of little help . The unusual composition of the stock and its similarity to intrusives of Nickel Plate mountain suggest a similar source and time of intrusion . The authorities differ however , Bostock attributing the diorite-gabbro complex to post-Triassic and pre-Eocene time , and Billingsley believing the heat effects to be mainly post-Oligocene .

Local evidence of the age is limited to the bodies' intrusive relations with Triassic rocks . Post-Triassic is the most definite time stateable .

The time of intrusion with respect to periods of fracturing and veining are not known because the dykes , veins , and main fractures are all parallel . The intersection of this set of openings with the sill is nowhere exposed . The time of conversion of marble to ore relative to the time of intrusion is not known either . By the argument developed at the end of this paper under " Sequence of Events" the dykes probably preceded the ore . If this is so , and the sill is contemporaneous with the dykes , since both would be pre-ore there is as good a chance for ore under the sill as above it .

Proof of Intrusive Nature

The diorite-gabbro complex in Nickel Plate mountain has been variously described as a normal intrusive and as a product of granitization .

Local intrusives are considered consolidations of mobile magmas because of :

1. Sharp contacts between leucodiorite and country rock
2. Sharp borders on inclusions
3. Angularity of some inclusions .

5. LOCAL STRUCTURE

General

Drilling and mapping corroborate locally the regional westerly dip. Intersections in drillholes 2, 4, 35, 36 give the strike as about N35°E, the dip 14° NW.

Towards the west edge of the mine area lies a small stock of light-colored biotite diorite. The beds therefore dip into the stock. A thick sill, probably an offshoot from the stock, underlies the ore-host formations at shallow-depth. Of the dykes found so far, most are vertical and all lie in a narrow north-south zone 800 feet east of or up-dip from the stock. Fractures, veins, and orebodies are found within this zone, the veins and fractures mainly vertical and parallel to the length of the zone, the orebodies as long flat-lying pods in limestone horizons.

Since little work has been done outside of this zone the veins, fractures, dykes, and orebodies may be of wider distribution than indicated above, and there may be no genetic correlation between their occurrences.

Appreciable minor folding is seen wherever exposures or drillholes permit a detailed study of the beds. What part of the contortion of surfaces is due to secondary folding and what to lensing, primary irregularities, uncertain correlations, faulting, and irregular limits of metamorphism is not known. The axes of the best-exposed folds strike north and plunge gently north.

Apparently the rocks have not been affected by much local faulting . A discussion of known and inferred faults is given on a following page .

Folding

The following are the recognized folds within the mapped area:

1. On the ridge beside the stock is found a well-defined syncline trending N15°W and plunging gently north . The width as exposed is about 150 feet . To the west the syncline dies out in crumples near the contact of the stock . To the east the fold is interrupted by a presumably-crosscutting mass of porphyry , and beyond this the beds have the normal westerly dip .

2. At the Nighthawk workings the upper contact of an ore-body swings abruptly from N65°E to S75°E . Because of lack of continuous exposures no more than this can be said . Lensing rather than superimposed folding may be the explanation of the change in strike .

3. At the No. 2 Trench workings the beds appear to form a bowl , dipping inwards on three sides of a small knoll . The structure may be a shallow syncline plunging gently north . The fold has not been traced away from the immediate vicinity of the open pit .

In addition to these folds there are humps in the surface

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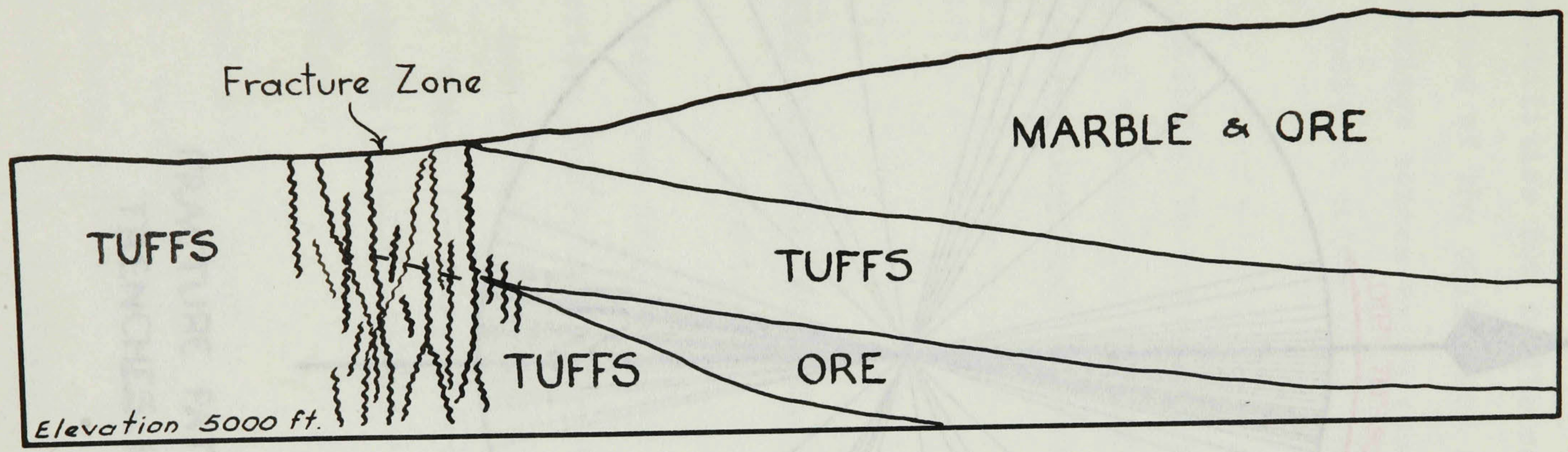
In addition to these folds there are humps in the surface of the sill that may represent minor crumples , and there is the pronounced change in attitude in the feldspar porphyry , which may be an intrusive feature .

No formation has been traced with certainty of correlation from north to south across the mine area . Folding may therefore be much more complex than inferred at present .

Faulting

Only one fault has been found on the Good Hope claims . It lies across the middle of No. 2 Trench with strike N5°E and a vertical dip . The west side was upthrown 1.5 feet relative to the east side , but the actual slip is not known . The fault was traced 30 feet horizontally and 7 feet vertically . No slickensides were seen . No trace remains of this fault , for the displaced rocks have been mined out .

A fault was suggested as the explanation of the limestone dislocation between drillholes # 1 and # 2 . A strong fracture zone is exposed in the shaft . Along the west side of No. 2 Trench , in line with the fractures in the shaft , a massive volcanic rock is cut by a multitude of closely - spaced north-striking fractures , mainly vertical . The fractured zone is at least six feet wide and has been traced on surface for about 100 feet . Excavation during the summer of 1947 showed that bedding planes cross the eastern part of the zone without displacement , and the termination of one orebody now appears to be a result of primary lensing of a host bed rather than offsetting by a fault . See sketch on



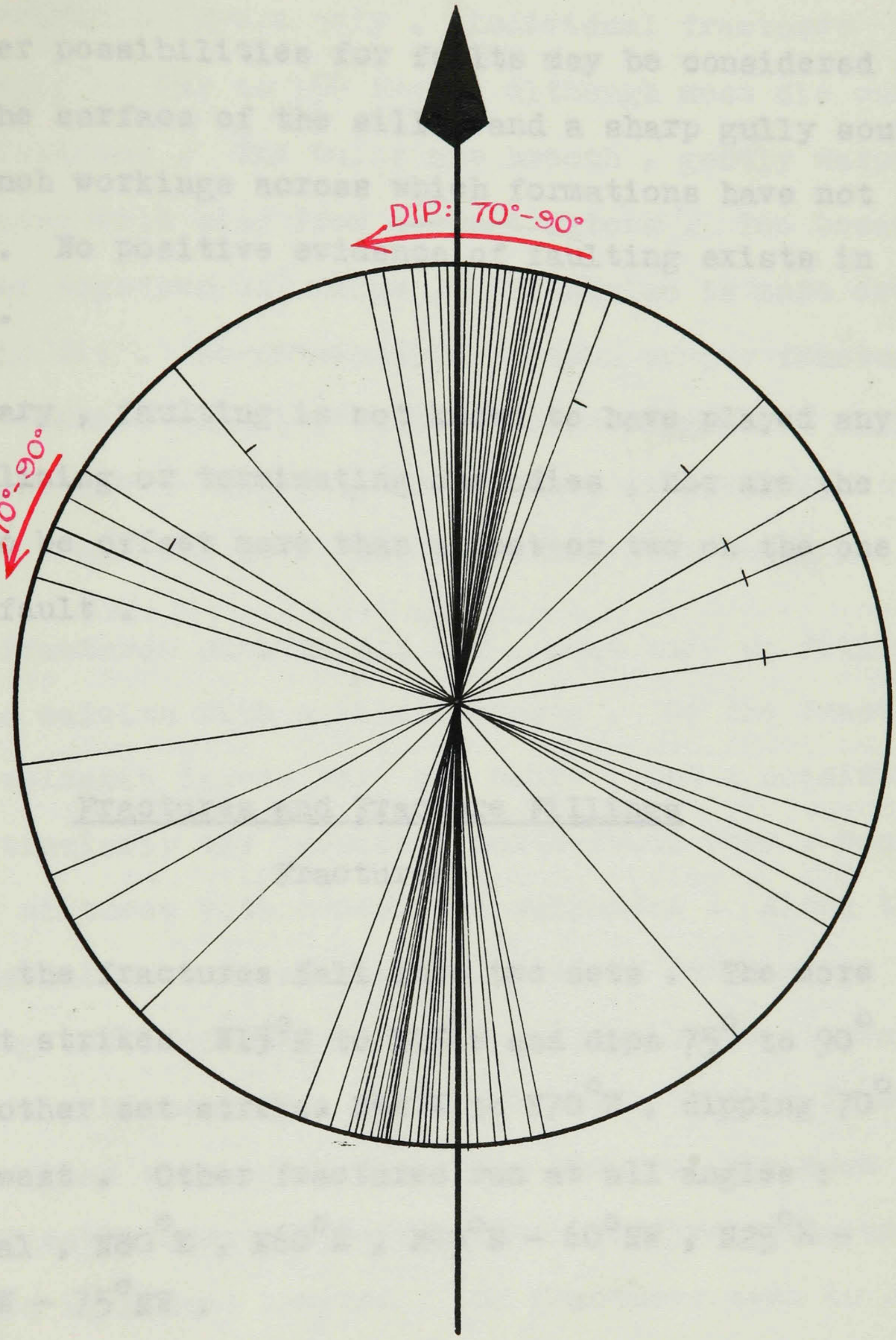
Good Hope Mine — Hedley B.C.

SKETCH of FRACTURE ZONE

1″=10′

0 — 30

Vertical section, looking north



FRACTURE PATTERN
TRENCHES 1 & 2

page 33a. There is, accordingly, little evidence in favour of a fault through this fracture zone.

Two other possibilities for faults may be considered: hollows in the surface of the sill, and a sharp gully south of No. 2 Trench workings across which formations have not been traced. No positive evidence of faulting exists in either case.

In summary, faulting is not known to have played any part in localizing or terminating orebodies, nor are the beds known to be offset more than a foot or two on the one established fault.

Fractures and Fracture Fillings

Fractures

Most of the fractures fall into two sets. The more prominent set strikes N15°E to N15°W and dips 75° to 90° west. The other set strikes N40°W to N70°W, dipping 70° to 90° southwest. Other fractures run at all angles: N85°E vertical, N80°E, N60°E, N45°E - 60°NW, N25°E - 75°SE, N45°W - 75°NW.

The north-south set is found in a band 120 feet wide and 450 feet long, extending from the north edge of No. 2 Trench to the Nighthawk workings. (This is the main area of exposures; fractures may be abundant elsewhere.) The northwest-striking set is best developed in Trenches 1 and 2.

The openings are closely spaced - from ½ inch to 4 feet apart . Strong ones cut through all the rocks , weaker ones through the volcanic layers only . Individual fractures have been traced as far as 150 feet , although most die out in shorter distances . The walls are smooth , gently warped , in places coated with clay from seepage waters . Two breaks that lie close together may merge . The strike is more constant than the dip . No movement is evident on any fracture ; nowhere is a contact offset . A small percentage have fillings of foreign minerals . Veins up to 4 inches in width are fairly common , and one 18 inches thick has been found .

Of the fractures seen to cut ore , most have no fillings , a few contain calcite with a little quartz . Of the fractures seen to cut volcanic layers many are empty , but a considerable number , particularly the prominent north-south ones , contain quartz-skarn mixtures with occasional sulphides . Along these fractures the wallrock is commonly altered to dense green skarn . Along unfilled fractures the only wallrock alteration is a slight thin bleaching . Where two skarn-bearing fracture sets occur , close spacing of fractures results in a more or less complete replacement of tuff by skarn , simulating an orebody ; gold is absent however . Of fractures seen to cut the marble , few fit into either of the two prominent sets . One or two of the more persistent north-south fractures continue through the marble layers . Most inter-marble fractures however show no uniformity in attitude . Some are vertical , striking due west . Others dip 45° to the north . Irregular twisting breaks are the most common . In all fractures within marble the fillings are absent, quartz - calcite type as well as quartz-skarn type.

A more complete description of the fracture fillings is given under " Veins".

The age of the fractures is not easy to specify. Fractures vary in the rocks cut, in attitude, and in the type of filling. If we may assume that all openings available at the time of introduction of new minerals would be filled with them we may specify several periods of fracturing. Thus some fractures were open when the dykes were intruded, others when the quartz-skarn veins were deposited, others (presumably after the orebodies were formed) when calcite - quartz mixtures were introduced, and finally some much later ones that are at present open. It is suggested that fracturing took place at several times or over a long period. The persistence of the north-south axis suggests a dominant regional control; possibly the major anticline near the crest of which the mine rocks lie induces crestal tension cracks in response to any regional stresses that may develop.

Fracture Fillings

A. Veins in No. 2 Trench area

Here the veins fall into three groups:

1. Calcite + minor quartz + minor siderite
2. Quartz + calcite, garnet, pyroxene, and metallic minerals.

3. Quartz + skarn minerals + metallic minerals + gold .

An essential distinction between the distribution of these types is that Type 1. is found in both ore and volcanic rocks , Type 2 in volcanic rocks only , and Type 3 in the ore only . No veins are found in marble , which is the third rock type within the mine workings .

Type 1 .

The calcite veins are rare . Their thickness ranges from 1 inch to 6 inches . In attitude they parallel the most prominent fracture system , striking within a few degrees of north . Most are simply coarsely-crystalline white to creamy calcite . Some have calcite along the walls and coarse well-crystallized quartz as a central filling . In places the calcite has been crushed to angular fragments , then cemented with siderite . No high-temperature minerals are present . Gold content is nil .

Since the ore is a replacement of marble , these veins must have been deposited after the ore had been formed , as they are found cutting the ore formation but are not themselves affected by the ore-forming solutions .

Type 2 .

Quartz and quartz-skarn veins are more common than type 1. The subdivision of this type is made because some are rich in skarn minerals such as pyroxene and garnet while others are predominantly massive quartz . They are grouped together because the wallrocks are altered to skarn .

In attitude all of these veins fall into two sets. By far the best developed are those parallel to the main north-south fracture system. These range in thickness up to $1\frac{1}{2}$ feet. Veins in the northwest-striking fractures are seldom more than $\frac{1}{4}$ inch thick.

Quartz forms a large proportion of the filling. At the edges of the thicker veins and throughout the thinner ones are seen the following minerals: pyroxene, garnet, diopside, calcite. A few veins are simply coarsely-crystalline reddish garnets. The minerals are well-crystallized: pyroxene up to $1\frac{1}{2}$" long, calcite masses 2" across, quartz crystals $\frac{1}{2}$" by 1", molybdenite 3/8" across. Gold is erratically distributed, and in general the veins are barren of it. The mere presence of closely-spaced veins does not make ore out of otherwise barren rock. Arsenopyrite, pyrrhotite, molybdenite are fairly common, tellurides rare but where present may be coarsely crystalline.

The thickness of altered rock along the vein walls does not increase with the thickness of the vein. A $\frac{1}{2}$" vein had 5" of skarn on each wall and a 12" vein only $\frac{1}{4}$". Some vein fillings merge with the wall skarn; others are separated from their walls by open fractures or clay deposited by circulating groundwater.

Some specimens of partly altered volcanic rock exhibit a system of ~~their~~ thin fractures filled with massive brown garnetite. The walls of such veins are not altered. Most of the quartz-skarn type cut across the garnetite veins.

B. Veins at the Nighthawk workings

Here quartz-calcite veins are absent . Quartz-skarn veins are not so common as in the No. 2 Trench workings , their place being taken by thin straight-walled cracks filled with hornblende , pyroxene , calcite , minor quartz , and sulphides . Along these veins the tuff wallrocks have been altered as have the wallrocks at the No. 2 Trench workings .

The vein fillings correspond with the ore type , for in contrast to the quartz-rich skarn in No. 2 Trench the Nighthawk ore is virtually quartz-free . Gold is still present , however , so if the veins are a major ore control the content of gold does not vary with the content of quartz in the ores .

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6. ORE DEPOSITS

The section on ore deposits is divided into five parts as outlined here :

Shape of the orebodies

Position of the orebodies

Characteristics of skarn and ore

Relations of orebodies to veins , dykes , folds , etc .

Conclusions as to host rock and source of fluids .

A certain amount of descriptive matter is placed with the section on microscope work , in order to set out more clearly the problems investigated there .

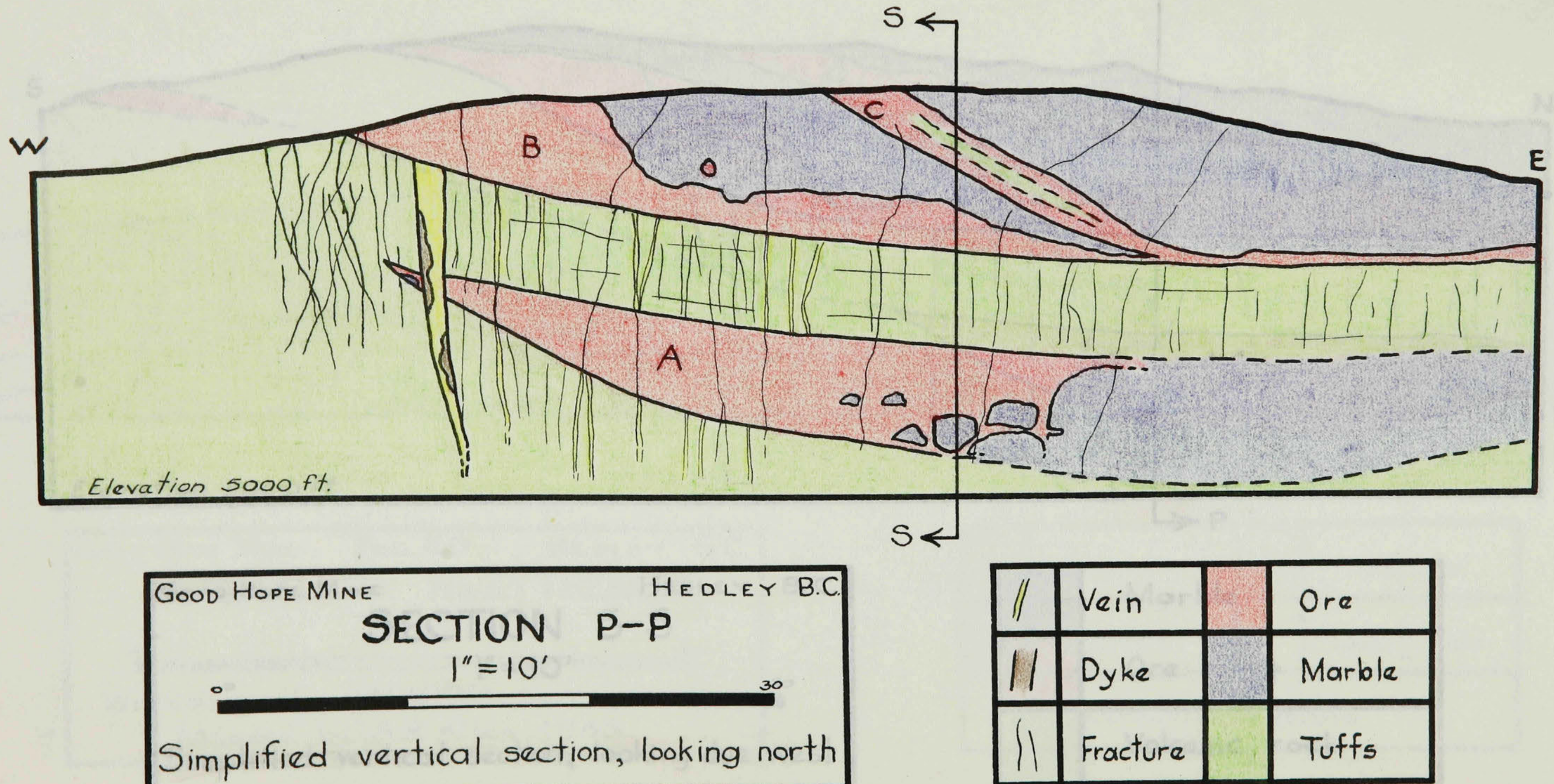
Shape of the OreBodies

A. No. 2 Trench area

In this paper no attempt is made to describe the many irregularities in the shape of orebodies . Such details as affect theories of ore controls are the only ones dealt with at length .

The orebodies are gently-dipping elongated lenses with approximate measurements - length 130 ' width 60 ' thickness 5 ' . They lie one above the other with long directions parallel and running almost due north . The dip varies from 35^{o} east to horizontal .

Section PP illustrates the space relations . It is taken at right angles to the length .



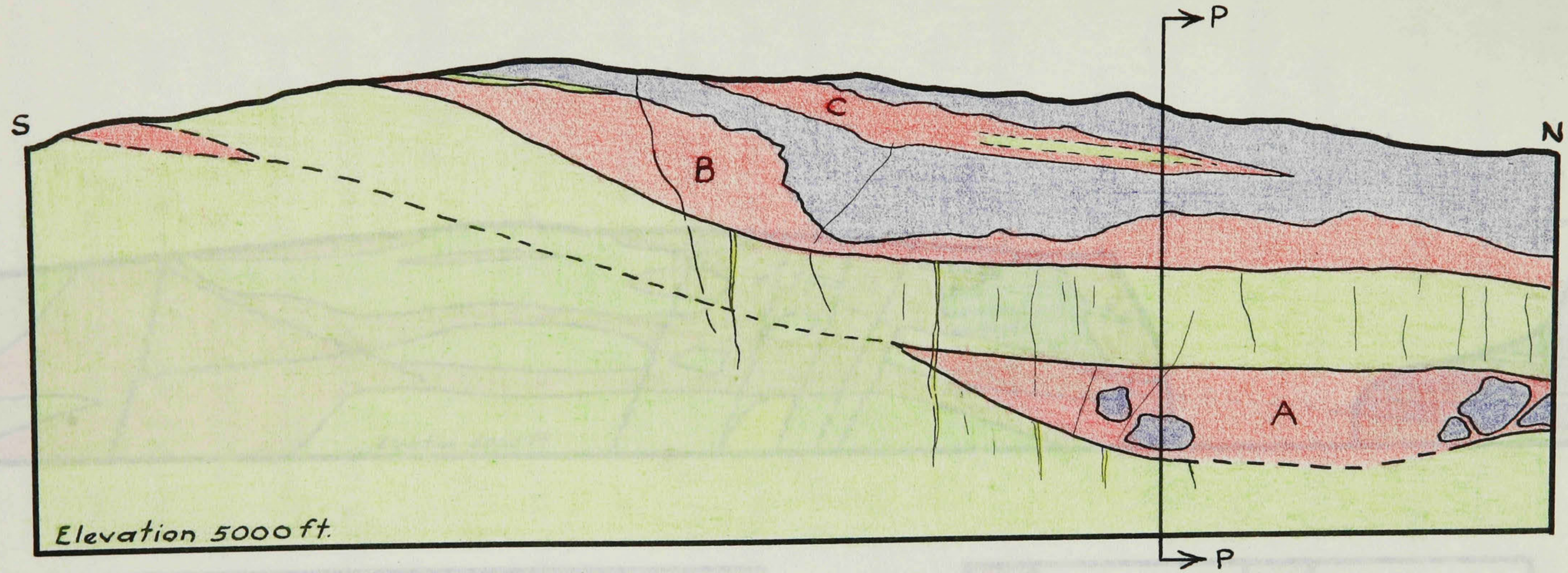
GOOD HOPE MINE HEDLEY B.C.

SECTION P–P

1" = 10'

0 30

Simplified vertical section, looking north



Good Hope Mine Hedley B.C.

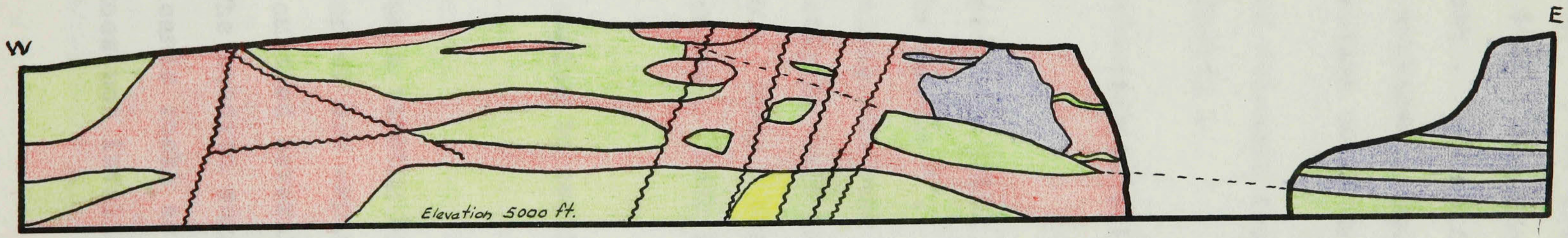
SECTION S-S

1" = 10'

0 30

Simplified vertical section, looking due west

	Marble
	Ore
	Volcanic rock



Good Hope Mine Sec. CD Hedley B.C.

ALTERATION No. 2 TRENCH

1" = 10'

0 — 30

Vertical section N80°W, looking north

Mapped by A.R. Allen 1945

Skarn | Tuff, etc. | Marble | Quartz vein | Fracture

Body A is seen to be lowest in the succession . As shown , it lenses out to the west . Similar thinning is observed to the north and south . As the face of the cut was pushed east blocks of marble appeared , enclosed by ore . The marble increased in percentage until no ore was present .

Below A lies a variety of volcanic rocks , including a thinly-sheared hornblende porphyry .

Above A lies a 5-foot thickness of mixed tuff and massive volcanic rock .

The line XY marks the base of a thick marble member , hereafter referred to as " the marble " . It contains two orebodies B and C . B lies along the base of the member , with a smooth contact against underlying tuff and an irregular contact against overlying marble . Body C branches up from B and divides the marble into two parts . Both B and C are truncated by the erosion surface .

Section SS is at right angles to section PP .

Note on Section CD .

Section CD , copied from a tracing by A.R. Allen is included to show his correlation of ore expansions with fractures . Unfortunately , he omitted several small quartz stringers from his map . The section suggests that ore was formed by replacement of volcanic rocks as well as of limestone . Such a phenomenon does not invalidate the writer's conclusions because :

1. Much of the rock mapped as ore is instead skarn with a gold content from trace to 0.10 oz. a ton , which is not ore in the sense of being mineable . The writer has described elsewhere skarns produced by alteration of volcanic rocks .

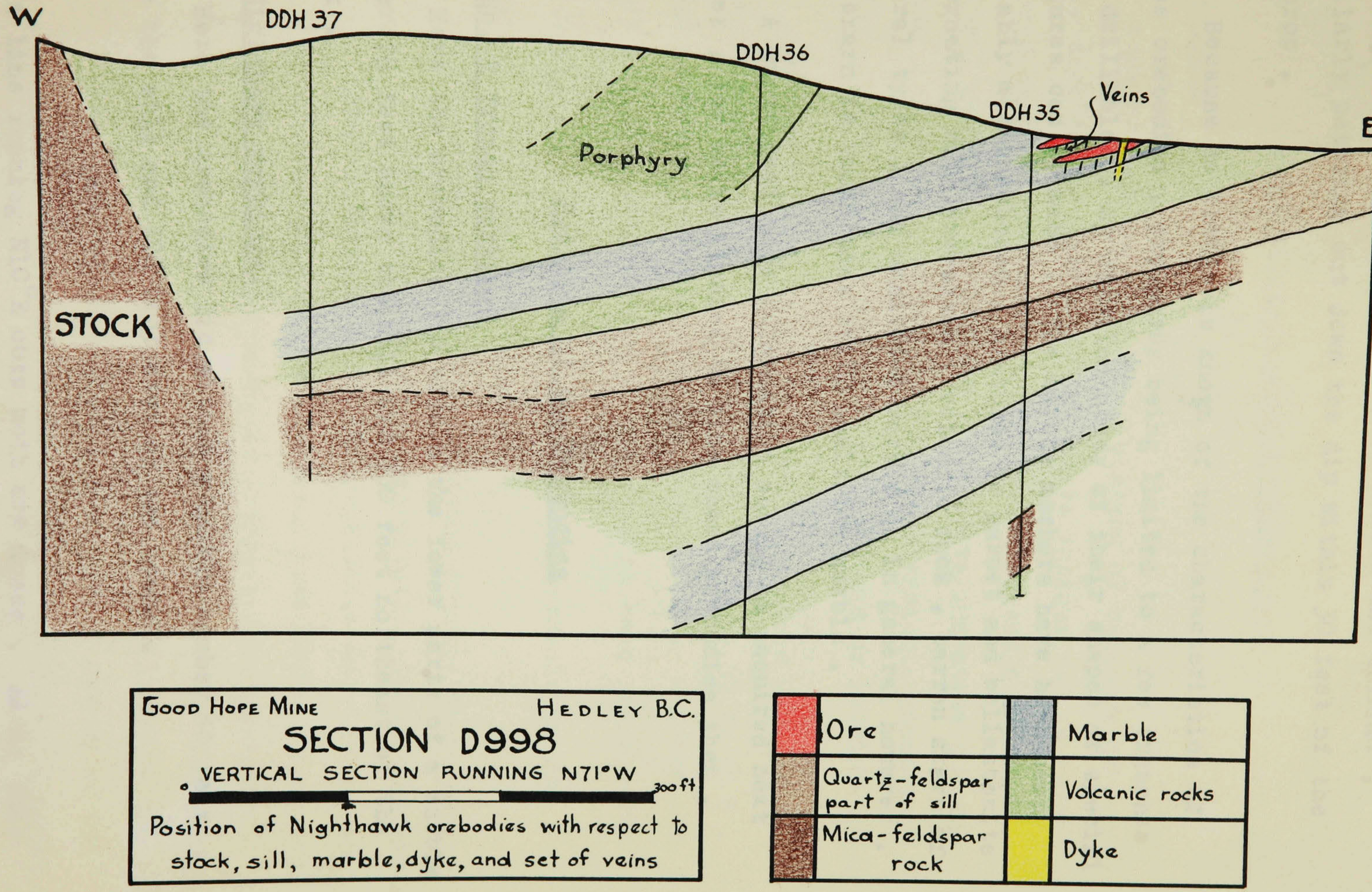
2. There is no reason why parts of the volcanic rocks could not be converted into ore . It is observed , however , that in most places such a conversion did not take place .

3. The writer mapped the same face and concluded that the skarn was confined predominantly to two irregular , almost horizontal bands separated by volcanic rock . These bands could well be the continuation of two thin limestone lenses . It is conceded that the face at that time was obscured as a result of slumping and that information was obtained mainly from trenches dug through the debris at five- or ten-foot intervals . A.R. Allen's map was made when the face was fresh and bare .

B. Nighthawk orebodies .

In the Nighthawk workings two district orebodies are known . In addition , two smaller zones with some gold have been found that may not be connected with the main orebodies .

The upper body is most extensive , being traced on the surface for 200 feet . It is a gently dipping lens of skarn lying within a marble member . The thickness , as shown by drillholes , ranges up to ten feet . Down-dip from the outcrop the body does not continue more than 30 feet or so , judging by drilling results .


W
DDH 37
DDH 36
DDH 35
Veins
E
Porphyry
STOCK
Good Hope Mine
Hedley B.C.
SECTION D998
VERTICAL SECTION RUNNING N71°W
0
300 ft
Position of Nighthawk orebodies with respect to stock, sill, marble, dyke, and set of veins
Ore
Quartz-feldspar part of sill
Mica-feldspar rock
Marble
Volcanic rocks
Dyke

The lower body , separated from the upper one by four feet of volcanic rock , is less extensive and thinner , similarly petering out down the dip within 30 feet of the outcrop .

Because so little is known of the characteristics of these orebodies , exposures being limited to a few trenches and drillholes , no detailed study of their shapes or special features can be made . The marble members have here been variably metamorphosed , mixtures of garnet and wollastonite alternating with ore-skarn , volcanic rock , barren skarn of several types , and unaltered marble . In general however , ore skarn is found near still-unaltered marble .

A great deal more information should be acquired next summer , for it is planned to mine these orebodies then .

Position of the Orebodies

A. No. 2 Trench workings .

Here the orebodies lie within the lower parts of a marble member 75 feet above the sill and 700 feet northeast of the stock .

B. Nighthawk workings.

Here the orebodies lie within a marble member 40 feet above the sill and 700 feet east of the stock .

Note

A line running N10°E cuts both ore zones . Along this line fracturing , veining , and intrusion have taken place .

Folds in the area strike roughly in the same direction .

Characteristics of Skarn and Ore

Rock types

"Skarn" here is used for a mixture of metamorphic minerals such as is commonly found where igneous bodies have altered calcium-rich rocks . Minerals present : calcite , augite , garnets , actinolite , tremolite , apatite , hornblende , diopside , scheelite etc. with variable amounts of quartz . The color ranges from green to red or reddish-brown .

The most typical skarn is a medium-grained mass of well-crystallized minerals of which quartz makes up 50 to 75 % . A high pyroxene content gives green coloring . Calcite and garnet are less conspicuous . The rock is hard and brittle .

Variations of texture and composition result in the different types outlined below :

1. Commonly the pyroxene crystals average four inches in length and are developed parallel to one another . Such a texture is a fairly-reliable accompaniement of rich gold values , although two bodies of this type were found to be of extremely low grade .
2. In parts of the ore pyroxene crystals have a radiating habit . Near overlying unaltered marble the skarn may consist almost entirely of masses of radiating augite crystals up to a foot long . Between such crystals a small amount of quartz may be

found . This "pyroxenite" type shows a tendency towards a lower gold content , sometimes as little as 0.15 oz./ton being reported . By the shape of the orebodies (see sketch in "Shape of Orebodies") alteration from marble into skarn proceeded upward from the base of the marble bed . Two explanations of the pyroxenite are suggested ; neither can be proved .

a) the metamorphism advances by a preliminary replacement of marble by augite . Behind this front a further progressive replacement of augite by other skarn minerals and quartz takes place , with recrystallization of pyroxene material .

b) Components suitable for the production of augite were present in the metamorphosing fluids in excess of the amount required to form the normal percentage of augite in the skarn . When all other constituents were expended the last residues of introduced matter reacted with additional marble to produce a pyroxenite capping .

The laboratory work offers nothing for criteria to aid in choosing between these alternatives .

3. A peculiar variation shows alternate thin layers of quartz and pyroxene , simulating bedding . The orientation of layers does not appear to be governed by vein walls , contacts , or initial bedding planes of the replaced marble .

4. A mass in No. 1 Trench has irregularly banded aphan-

itic green brown and reddish matter with calcite and quartz .

5. Finegrained skarn containing 80-90% quartz is present in small amounts .
6. Coarse crystals of garnet mingled with finer-grained skarn rich in garnet forms large bodies in No. 1 Trench . The gold content is relatively low . Tuff is in places altered to brown garnetite , also barren .
7. A fine-grained green and brown skarn accompanies marble members as cappings of variable thickness and as thinner basal zones . Gold is uniformly absent . Exposures at the Nighthawk workings suggest that such skarn may be produced by alteration of the volcanic rock as well as of marble . There , irregular patches are found entirely enclosed by volcanic rocks .

The above variations are independent of the presence or absence of large masses of quartz that are scattered at random through the orebodies . Other segregations of quartz may be described as "irregular veins" . These branch , twist , swell , and fade out haphazardly , fitting no pattern of attitude . See " Veins , Type 3 " .

Metallic constituents

In order of descending abundance such minerals identified so far are :

tellurides

native bismuth

here and there , and crystals up to $\frac{1}{4}$ inch across have been found beside telluride clusters . Along quartz veins under the orebodies molybdenite is locally abundant .

Pyrrhotite forms small irregular clusters and scatterings in medium-grained green skarn , in places strung out between long pyroxene crystals . Drillhole # 20 intersected pyrrhotite-rich skarn over a length of 2 feet . Gold does not accompany pyrrhotite . (In the Mascot Mine pyrrhotite is found where orebodies lens out .) Pyrrhotite does not appear to be replacing the skarn minerals .

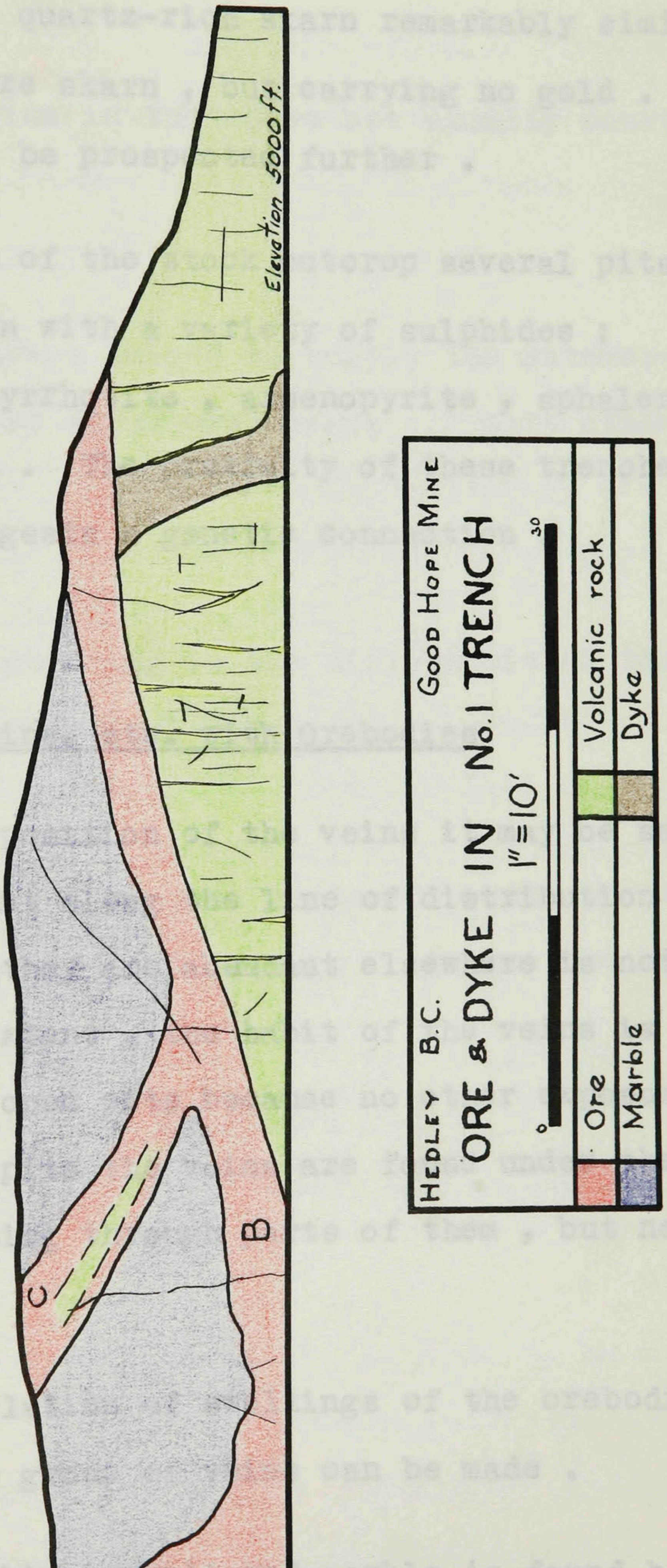
Pyrite has been noticed in a few specimens , generally as tiny crystals .

Chalcopyrite occurs as solitary specks ; only two copper-bearing specimens were found by the writer . A small amount of copper is associated with pyrrhotite in Drillhole # 20 .

Garnet-rich skarns are deficient in metallic minerals .

Nighthawk orebodies

The Nighthawk orebodies differ from those at the No. 2 Trench area by containing very little quartz . Abundant pyroxene and calcite are accompanied by wollastonite , brown garnets , and minor sulphides . Tellurides , pyrrhotite , pyrite , coarse arsenopyrite and gold are the known metallics .. Wollastonite - garnet mixtures are common in many drillholes there , unfortunately without appreciable gold .



HEDLEY B.C. GOOD HOPE MINE
ORE & DYKE IN No.1 TRENCH
1"=10'
0
30
Ore
Marble
Volcanic rock
Dyke
Elevation 5000 ft.
B
C

A long drillhole in the stock area , planned to intersect a marble member near its contact with the intrusive , cut several feet of green quartz-rich skarn remarkably similar to the No. 2 Trench ore skarn , but carrying no gold . This alteration zone will be prospected further .

Beyond the south end of the stock outcrop several pits have exposed similar skarn with a variety of sulphides : pyrite , chalcopyrite , pyrrhotite , arsenopyrite , sphalerite , but no tellurides or gold . The proximity of these trenches to the intrusive body suggests a genetic connection .

Relations of Veins, etc. with Orebodies

With respect to the position of the veins it may be said that the veins are abundant along the line of distribution of the orebodies . Whether they are abundant elsewhere is not known . As to vertical extent , the habit of the veins is not known outside of the open pits because no other exposures exist . Within the open pits the veins are found under the orebodies , possibly cutting through parts of them , but not in overlying rock .

No small-scale correlation of swellings of the orebodies above particular veins or group of veins can be made .

At the Nighthawk workings unaltered marble is found below certain orebodies , whereas if vertical veins produced ore along their walls all the marble cut by veins should be converted to ore . Possibly structural traps or caprocks are needed before the alteration can spread far from the veins . Variations in the composition of limestone layers might affect the alteration .

A close spacing of veins in tuff does not usually convert the tuff into ore .

Dykes

It is possible that dykes helped to supply the metamorphosing fluids , or provided structural traps . More exposures are required .

Sill

There is no evidence pointing to the sill as either the source of fluids or as a structural trap .

Stock

An aureole of skarn may have been produced by the stock where lime-rich formations were cut through . No ore has been found there yet .

7. CONCLUSIONS

1. Ore Type

By the minerals forming the skarn the deposits are identified as belonging to the class called contact metamorphic deposits , formed by replacement of pre-existing rocks near intrusive bodies .

2. Host Rock

Field relationships point consistently to one rock type as the ore host . This is the marble . Mineralogical evidence is supported by the shapes and positions of the orebodies . The facts are summarized below .

Orebody A . The top and base of a marble layer are projected west as the hangingwall and footwall of the ore . Where overlying and underlying volcanic beds converge the ore pinches out , and a bit of marble is found in the extreme tip of the lens . Blocks of marble are surrounded by skarn ; the blocks become larger towards the east until almost no ore is present , the little remaining forming a cement between marble blocks .

Orebody B . The base of the marble is seen to be a flat surface . The base of the orebody continues this surface towards the west and south . The upper contact of the orebody is rough and irregular with crystals of pyroxene projecting upwards into marble .

Orebody C. The ore cuts diagonally through marble apparently following the top and base of a thin layer of volcanic rock . The hangingwall is in places irregular , with tongues of ore projecting upward between fragments of marble .

Corroboratory evidence is given by many exposures of ore faces that contain thin unaltered lenses of volcanic rock . A.R. Allen's section along the north face of No. 2 Trench shows two contorted bands of tuff enclosed by an orebody that , by its position , must be a replacement of limestone . In No. 1 Trench the upper limit of alteration within the marble was controlled for some distance by a bed of volcanic rock that forms the top of the ore . The apparent selective replacement of marble suggests the presence of marble as a major ore control .

3. <u>Aureole</u>

The orebodies do not lie within a metamorphic aureole about the stock . Unaltered marble intervenes , although a narrow aureole seems to be present , and alteration seems to have spread in places along the replaceable layers in the stratigraphic succession .

A contrast between the Good Hope orebodies and the Nickel Plate orebodies is evident here , for in Nickel Plate mountain the ore is found close to the edge of the aureole , but inside it . The Good Hope orebodies are apparently isolated . A means of access for solutions to the marble is required . This topic is discussed later .

4. Ore

Ore consists of skarn and gold . No mineable concentrations of gold have been found in fresh tuffs , in marble , or , in general , in veins . Not all skarn carries gold however . Mixtures of wollastonite and red garnets are uniformly barren . The finegrained green skarn found as capping on many limestone layers is barren . Even sulphide-rich skarn within the stock's aureole is barren . Some general rule must be sought that explains both the variations in skarn and the variations in gold content of the skarn .

5. Vein minerals

Minerals in the veins are the same ones as make up the bulk of the orebodies . This correlation is subject to change as microscope work progresses .

6. Field relations

Field relations do not prove a genetic connection between the orebodies and the veins or the dykes , but they strongly suggest that the veins were a major control of deposition .

o. LABORATORY WORK

Basis of the Investigation

Knowing that limestone was replaced by ore we must examine the following possibilities :

1. Gold was in the limestone before it was replaced by skarn . This alternative is discarded because marble is everywhere barren .

2. Gold and skarn are contemporaneous .

3. Gold came later . (The gold and the sulphides , etc. , seem contemporaneous .)

Criteria to decide between 2. and 3. could take the form of general field relations or of microscopic relations .

Field relations ~~are~~ as criteria :

a) The position and extent of skarn bodies produced by the action of fugitive constituents from a cooling magma are governed mainly by the contacts of the magma body . If the Good Hope orebodies were produced by direct action of the main intrusive body they should lie within the metamorphic aureole . Since the orebodies lie some distance from the aureole , local agencies are apt to have played a major role.

If all the skarn plainly belonged to the aureole , and skarn production was contemporaneous with gold deposition , gold should be found in all the skarn . Since all the skarn is not in the aureole the criterion is of no value .

b) The relations of veins and dykes to ore zones are confused and cannot be interpreted without much more field work over increased exposures .

c) Veining within the orebodies seems to be the only indisputable criterion of age relations . If it could be proved that gold was confined to veins in the ore , such veins being obviously younger than skarn , the age relation would be solved . Unfortunately no simple veining is found . Quartz-rich zones are found in the skarn , however , and it is these that were investigated in the laboratory .

Outline of Microscopic Work

1. A preliminary examination of the wall alteration beside quartz veins was made , to compare the composition of the rocks before alteration with that after alteration and so find out what materials were added during the formation of the veins . Examination of skarn from the orebodies would suggest what was added to the marble . No quantitative data could be expected , first because of the diversity of skarn types and second because the original composition of the marble is not known . Then too , some difference in wall rock alteration might be expected owing to the differences in composition between marble and tuff . Nevertheless , if vein compositions and tuff alteration shows that matter was added there similar to that added to make skarn out of marble , this correspondence would be strong evidence that the orebodies could have been produced by solutions entering through the quartz veins .

2. The gold-rich zones of quartz inside the No. 2 Trench orebodies were examined to find if there was any evidence that these were later than the enclosing skarn . Such evidence might take one of three forms :

a) veining of quartz through cracks in early crystals, and localization of gold in cracks .

b) differences in mineral content .

c) replacement of skarn minerals by vein minerals . This criterion must be applied with care because , although late veins could induce replacement , similar effects could be produced by segregations of fluids during skarn production .

Thin sections were cut across the contacts of quartz zones with skarn . No polished sections were made because of lack of money to pay for them and time to study them .

3. Skarn near the stock was examined to see whether anything was lacking there that was present in the orebodies , other than gold .

4. The intrusive bodies were examined for feldspar composition . A correlation of these intrusives with the diorite-gabbro complex of Nickel Plate mountain would justify more exploration around them .

Intrusive Rocks

A preliminary examination of the intrusive rocks was carried out using oil immersion of crushed crystals for the determination of the lowest and intermediate indices .

Stock

Specimen E104 from outcrop of stock on crest of ridge . Lowest index lies between 1.54 and 1.55 . Albite twinning on one fragment gave an extinction angle of 19 degrees on both sides of the twinning plane . The feldspar thus lies between An 36 and An 42 , andesine .

The remaining components of the rock were estimated by inspection under the hand lens . Quartz forms about 5% of the rock , biotite about 15% . A few grains of hornblende are present , too . For a rock name , diorite , quartz diorite , or biotite leucodiorite might be used . For a field name , mica diorite is most convenient .

Sill

1. The lower part of the sill was examined by oil immersion of feldspar fragments , giving a feldspar composition of andesine . As in its content of mica and quartz the lower layer is similar to the stock the same rock names apply .
2. The upper part of the sill is different . Mica is absent . Quartz makes up 30% of the rock . The remainder is feldspar , similarly determined as andesine , its index lying between 1.54 and 1.55 . None of the common terms of classification fits this rock particularly well . "White diorite" is good enough for field use , pending further examination by thin sections .

Dyke

Specimen E 108 , from the 3-foot dyke in No. 1 Trench , consists of 30% quartz , 70% feldspar , and a few flakes of biotite . Oil immersion shows the minimum feldspar index to lie between 1.53 and 1.54 , suggesting a composition of oligoclase . "Aplite" or simply "dyke rock" will suffice for field terms pending thin-section study . All the dykes on the property have this composition , although the biotite is commonly absent .

Volcanic Rocks and their Alteration

This description of the volcanic rocks and their alteration has to be given in two sections : rocks at the Nighthawk showing , and rocks under the No. 2 Trench orebodies . The reason is that in the thin section from the rocks under the No. 2 Trench ore no fresh volcanic matter is left . Only at the Nighthawk showing can an approximation of the original composition of the rock be made . There it is possible to say what has been added during alteration . Elsewhere the added materials must be inferred from vein contents alone .

1. Nighthawk showing

The specimen selected for study was a massive aphanitic pale green rock cut by two parallel 1/8-inch veinlets . The veinlets contain calcite , hornblende , and minor quartz , telluride , and molybdenite . An alteration band parallels each wall .

Under the microscope fresh rock far from either vein appears to be composed mainly of quartz , feldspar , and augite . The grains are extremely fine , those of feldspar and quartz averaging 0.05 mm in diameter , those of the augite partly that and partly up to 0.2 mm. The coarser grains of augite are clustered mainly in small clots . By polarized light the rock is seen to be composed of small angular fragments set in a finegrained matrix . With crossed nicols the fragments are seen to be composed of tiny grains of quartz and feldspar , without the abundant augite of the matrix . No banding or streaking was seen .

The feldspar is coarsely twinned . Interference figures could not be obtained owing to the small size of the grains . The composition was determined by the maximum extinction angle in sections normal to 010 . The maximum angle found was 24 degrees . As the index is greater than balsam the feldspar is andesine , about An 45 .

The pyroxene was called augite . The mineral is biaxial , positive , with a high index , pyroxene cleavage , moderate 2 V , and a Z to c extinction angle of 46 degrees . The birefringence is high , however , 0.037 if , as the color of quartz indicates , the slide is of normal thickness . Hornblende gives a first order greenish yellow maximum interference color suggesting that the slide is 0.04 mm thick . The corresponding adjustment would lower the pyroxene index to 0.028 , close to augite's 0.025 .

Thin seams of hornblende spread out from the edge of the alteration band into otherwise unaltered rock . Where the band begins , calcite appears in fine irregular masses , and abundant hornblende takes the place of augite . Further inside the altered layer the calcite and hornblende masses are coarser and make up 90% of the rock , the remaining 10% consisting of partly-altered feldspar and quartz . Near the edge of the source veinlet itself a few clear irregular grains of quartz appear .

The following estimates of compositions were made :

unaltered volcanic rock	:	augite 25%
		feldspar 50% or more
		quartz 25% or less
alteration zone	:	hornblende 50%
		calcite 40%
		quartz 5%
		feldspar 5%

It therefore appears that a large amount of calcite was added , and smaller amounts of iron , magnesium , and aluminum , as well as considerable hydroxyl . By the metallic minerals in the veins , sulphur , molybdenum , bismuth , and tellurium were added too .

2. No. 2 Trench workings

The least altered part of the thin section consists of minute feldspar grains enmeshed with calcite . Shreds of chlorite are common . Hornblende is dotted through the rock . Twinning in the feldspar gave a maximum angle of extinction of 32^{o} , suggesting a composition An 60 , labradorite . No confidence is felt for this measurement as the grains were too small to afford means of checking it . Some quartz may be present , but no augite is .

Seams of calcite , hornblende , and quartz cut through the rock , their walls gradational in that large crystals of these minerals enclose many small grains of the invaded rock .

By inspection of the veins it is obvious that large amounts of quartz have been introduced . Without some idea of the original mafic content of the volcanic rock no estimate of the amounts of added iron , calcium , and magnesium can be made . Presumably however , hydroxyl was added .

Skarn of the Orebodies

The following description is based on a study of four slides representing three varieties of ore . Two slides were cut across the contact of green skarn with a quartz-rich zone inside the B orebody . One slide was made of the garnet-rich skarn . The fourth slide was cut across the grain of typical ore skarn in which the pyroxene crystals occur in long laths with the long dimensions parallel .

The composition of the orebody as a whole cannot be estimated from a study of thin sections because of the diversity of types and the coarse grains . Slides are obviously inadequate samples where crystal masses are up to a foot across . The selection was planned to provide identification of the main and accessory minerals and to search for evidence of veining or alteration .

The main minerals were known from field examinations - quartz , calcite , an amphibole , a pyroxene , and a garnet . Several minor constituents had been observed here and there but not identified with any certainty - diopside,actinolite , and wollastonite or tremolite . The metallic minerals were known partly by field study and partly by earlier polished - section work by H.V. Warren and R.M. Thompson . Thin sections could not be expected to aid in identifying these opaque minerals , but might show them to be localized in fractures cutting skarn minerals . Polished section work is planned for a following year .

Microscopic examination

In general appearance the skarn is a mosaic of approximately equigranular euhedral to anhedral crystals of many minerals . Quartz and augite , respectively 50% and 30% , make up the bulk of the rock . Apparently , any mineral can enclose perfectly formed crystals of any other mineral or of the same mineral . Quartz , because it is most abundant , is the most prominent host .

Quartz , mainly in euhedral grains 1 to 2 mm. across , forms about 50% of the skarn , but this percentage varies greatly from place to place . Commonly the grain boundaries are straight , but in places are sutured . No preferred orientation was noticed . Crystals of all other minerals are scattered throughout the quartz generally at random but in places grouped at the boundaries between quartz grains . Augite is notably idiomorphic towards quartz .

Euhedral augite is abundant , its percentage of the total composition ranging up to 90% in the pyroxene border of the orebodies . In the general skarn however its percentage is more commonly around 30% . In composition the augite is presumed to approach diopside , for the Z to c extinction angle lies within the overlap of ranges . Most of the augite is quite fresh . In three slides however thin alteration rims and seams of hornblende were found and in part hornblende seems to replace large portions of augite crystals . Particularly along one contact of a quartz-rich zone this latter effect is noticeable . Tiny , clear twisted crystals , hornblende or possibly tremolite , lie across or project from some augite clusters and may represent partial alteration .

Hornblende is found as a sparse dissemination commonest beside augite , as a rim along a quartz zone contact , and as irregular seams and patches inside augite . Some grains are as much as 2 mm across .

The garnet could not be identified with any precision . The least index , as measured by oil immersion of fragments , is greater than 1-77 . By this index the garnet would be andradite Ca_3Fe_2 $(SiO_4)_3$ rather than grossularite Ca_3 Al_2 $(SiO_4)_3$, these being the two common garnets in contact metamorphic deposits . The index cannot be relied upon however for the oils are old . The garnet is zoned and twinned . Under crossed nicols most sections show a light gray color indicating considerable birefringence . Large masses of unidentified impurities contaminate the centers of many of the larger crystals . Small inclusions of quartz , calcite , and augite are abundant . Garnet seems to be of unequal distribution , some specimens being garnet-rich and others totally garnet - deficient .

Of the accessory minerals scheelite is the most interesting . It forms a few well-shaped crystals inside skarn and inside the quartz-rich zones . Apatite is clustered mainly in the quartz , as the usual tiny crystals .

Notes

1. Veining
2. Peculiarities of quartz-rich zones .

1. The only definite veining consists of a few tiny cracks filled with calcite that cut through all the skarn minerals . Inside quartz these veinlets have irregular fuzzy edges as if replacing quartz a little . The metallic minerals show no signs of crosscutting or replacing skarn minerals .

2. Microscopic examination of the quartz-rich zones of B orebody adds little to what was known previously . Quartz is coarser , the grains averaging four to eight times the area of quartz grains in the green skarn . Grain boundaries are commonly sutured . The crystals show uneven extinction , its cause unknown . Scheelite and apatite seem to be present in about the same proportions as in the skarn . Vugs lined with very fine crystals of quartz and filled with coarser quartz , calcite , and metallic minerals are fairly common . The edges of the zones appear to be

gradational in that augite increases in percentage up to the normal 30% of the rock across a band a few millimeters wide . The mosaics of coarse and fine quartz grains abut sharply however .

Matter added to limestone

Quartz was added in large quantities , enough to form 50% of the orebodies . Iron , magnesium , and aluminum must have been introduced too . Without a bulk analysis of the marble it is impossible to tell how much lime and magnesia was added during the production of skarn . Gold , tellurium , bismuth , sulphur , arsenic , molybdenum , copper , phosphorus , fluorine , tungsten ,,and hydroxyl were introduced too in small amounts .

Stock skarn

One slide was cut from the skarn intersected by drill-hole 37 . The skarn body lies within a marble member close to its intersection with the stock .

Minerals identified are :

quartz	35%	
calcite	35%	
hornblende	15%	
pyroxene	15%	probably augite
apatite		
pyrrhotite		

Quartz forms a sort of background mosaic of equidimensional subhedral grains . Augite is typically finer-grained than the quartz , being somewhat less than 1 mm across , and forms well-shaped stubby crystals . Calcite occurs as large irregular masses enclosing other minerals . Hornblende is mainly coarse-grained , segregated into clots of euhedral crystals . Pyrrhotite is found as irregular blebs with smooth outlines fitting around and between quartz grains . The apatite is in the common tiny crystals .

Mineral identification

Quartz : uniaxial , (+) , low positive index .

Calcite : uniaxial , (-) , twinned , high birefringence .

Garnet : isotropic to biaxial , crystal outlines , high positive index .

Augite : biaxial ,(+) , 2 V moderate , Z to c is 46 degrees .

Hornblende : biaxial , (-) , pleochroic green to brown , Z to c is 20 degrees .

Apatite : hexagonal cross-section , parallel extinction .

Scheelite : uniaxial ,(+) , very high index , birefringence 0.017 .

Tremolite (suspected) : all crystals length - slow .

Possibilities of Replacement

The apparent replacement of augite by hornblende in parts of the skarn can be compared with the alteration in volcanic rocks beside quartz veins , where hornblende near the vein takes the place of fine-grained augite of less-altered rock far from the vein . In the vein wallrocks the alteration can with certainty be attributed to addition of heat and materials from the veins , because the space relations are definite . In the orebodies the space relations are more complex .

Two alternatives must be considered in any attempt to explain the replacement in the skarn . First , alteration could have been caused by solutions , possibly from veins under the skarn , introduced after the skarn had been produced. These solutions would have greatest effect along the walls of their channels but might spread out along tiny cracks or cleavage planes to cause alteration some distance from the channels . Second , the mineral first produced when solutions attacked the original limestone could have been augite . As replacement of limestone went on the increasing percentages of silica and volatiles might have caused slight alteration of augite , giving the effects now visible . In conclusion , then , the alteration of augite offers no proof for or against the contemporaneity of the skarn and of the quartz-telluride zones .

Veining

For evidence of veining inside the orebodies thin section work seems similarly inconclusive . Certainly , some thin calcite stringers post-date skarn , but this was known from field observations , calcite veins having been found to cut through the B orebody .

The other possible veins , the quartz-telluride zones , could be explained in two ways . First , they could be late veins , post-dating the skarn . This would explain their sharp walls . The similarity of rock-making minerals could be a coincidence or might reflect a common or similar source magma below for both the skarn-making and the vein -making solutions . Second , they could be segregations formed as the skarn was made from limestone , made up of excesses of various constituents of the solutions remaining fluid until the bulk of the skarn had been produced , deposited in openings or zones of lower pressure produced by volume changes of the rock during bulk replacement . Beside such segregations the hydroxyl-bearing hornblende might form in preference to augite . Such a mode of formation of the zones would explain the coarse grain , irregularity of walls , branching , and the apparent lack of connection with underlying veins . By this hypothesis , zones and skarn were produced at the same time from the same fluids . The means of entry of these fluids is not discussed here .

(As a final alternative the zones could represent the fractures through which solutions entered limestone and from which replacement worked outwards . This possibility is a variation of the segregation idea and entails similarly the contemporaneity of the zones and the skarn .)

Position of metallic minerals

In the outline of the microscope work at the beginning of this section of the report it was suggested that thin section work might show gold and sulphides to vein skarn minerals .

Such a relationship was not found . Nowhere are the crystals of augite or quartz fractured and veined by sulphides or tellurides . On the contrary , where metallic and non-metallic minerals are in contact the relations are similar to those between any other two skarn minerals , with the slight difference that quartz is idioblastic towards the metallic minerals .

Metallic minerals are most abundant and most coarsely - crystalline in the centers of quartz-rich zones . They are present in smaller amounts throughout the skarn , however .

Age Relations

As the laboratory work did not disclose the age relations between the skarn and the quartz-telluride zones inside B orebody we have to resort to field relations . In the opinion of the writer the irregularity and discontinuity of the zones is strong evidence for a common time of formation .

Assume then that all the components of the skarn were added to the original limestone at one time . The possibilities for entry of the required fluids are discussed under "Access" . The most satisfactory method seems to be by movement through fissures , either with magmas that solidified to form dykes or as high-temperature solutions of the usual vein-depositing variety . Although the dykes cannot be discarded , the vein-filled fractures fit the requirements best because of the alteration along their walls and the similarity of vein matter to skarn . The extreme alteration of volcanic rocks suggests that had the vein solutions entered limestone they would have made it over into skarn . When , as a consequence , it is seen that had skarn been present above the tuff when fractures in them were opened the brittle skarn should have been similarly fractured , allowing the solutions access to overlying unaltered limestone and resulting in a further production of skarn , it seems more quibbling than caution to hesitate to attribute to the veins the formation of the skarn orebodies known at present .

9. CONSIDERATIONS OF ACCESS

Disregarding the conclusions from field and microscopic examination we may approach the problem of ore controls by the avenue of access . If gold and skarn were contemporaneous one source and means of access is required . If skarn preceded the gold two channelways are needed .

Laboratory work shows that iron and silica as well as tungsten , gold , arsenic , and tellurium were added to the marble . A transfer of matter is required , not a mere transfer of heat . According to geological dogma such matter could come only from an intrusive body somewhere near. In the Hedley area the concept is substantiated by the close association of skarn and orebodies with intrusive rocks . For the Good Hope mine , a reasonable assumption is that the added matter came from the diorite stock or from the granodiorite batholith .

New constituents could reach marble by the following ways :

1. Diffusion through minute openings in the rock .
2. Migration along bedding planes
3. Progressive replacement
4. Introduction through fissures by fluids
5. Transportation by intrusive magmas .

Of these , diffusion and progressive replacement can be discarded because the orebodies are surrounded by unreplaced rock . Most of the marble is unaltered . The great mass of tuffs below the orebodies is not replaced by skarn .

That they can be so metamorphosed is shown by the alteration zones along vein walls . That they were not permeated by fluids is proved by their general lack of alteration .

In support of the second process , migration along bedding planes , is the wide occurrence of a peculiar skarn at the top and bottom of marble members . This skarn differs in many ways from that of the orebodies however , and the complete absence of gold in it even directly above orebodies encourages the belief that the two types have different origins . The skarn capping of the marble members might well have been produced by fluids migrating along bedding surfaces . The localized nature of the ore skarn suggests a more localized source for it . The possibility of migration and concentration in traps cannot be discarded however .

As methods of entry for new materials , the last two processes seem to offer most hope . Fissures to depth are proved by the presence of many veins and dykes , and the veins contain minerals similar to those in the orebodies . Intrusive magmas , as dykes , might just as well have been the transporting medium . At this stage it is impossible to choose between dykes and veins because so little is known of the dykes .

Fortunately both lie parallel , so exploration guided by one enters territory affected by the other .

Since means of access are available we may look further into the relations of gold and skarn to the veins and dykes and bedding surfaces . If skarn and gold are contemporaneous the problem of origin is simply one of which means of entry was used . If gold was deposited after the skarn was formed a separate gold provider is needed . Here again diffusion , progressive replacement , and migration along bedding surfaces are discarded because of the general lack of gold outside of the orebodies . In dykes no gold has yet been found . In quartz veins gold is found in a few places , so veins are the best bet .

... SEQUENCE OF EVENTS

The sequence of events of interest in ore control entails the relative ages of dyke-sill intrusion , vein deposition , and ore formation . The local evidence is given below .

1. Calcite-quartz veins cut through orebodies . Since the orebodies were formed by alteration of limestone these veins must have been deposited following the conversion of limestone to skarn , or the calcite of the veins would have been similarly altered .
2. Dykes and quartz veins have not been traced as continuous from underlying volcanic rocks into ore . The relations are therefore in doubt .
3. If , as much evidence indicates , the quartz veins are responsible for changing marble into skarn and producing ore , the only problem is that of the relative ages of ore and dykes or veins and dykes .

   a) Vein-dyke relations .

   The body along the west wall of # 2 Trench contains both quartz and dyke material . Since quartz fills the gap between masses of dyke rock the quartz probably entered after the dyke material .

   b) Ore-dyke relations .

   That dykes stop at the base of skarn bodies may have some significance . The skarn is massive and brittle ; fractures through it are continuous and fairly widely-spaced . Tuff layers are of softer material , cut by a multitude of shorter , thinner joints in addition to the through-going ones . Since the dykes do not spread out along any of these fractures the intrusion must have preceded their formation . Similarly for the quartz veins , which are found in some but not all of the main fractures . Since all the foreign bodies follow the same trend an axis of fracturing must have been established early in the sequence of events . Probably fracturing and the first major folding are related .

If marble had been converted to skarn before the dyke intrusion the brittle skarn would have been fractured when dyke channels were opened , and dykes would now crosscut skarn . If however the intrusion-guiding fracturing took place while the limestone was still unaltered the limestone , being plastic , might close the fissures . Then when later the dyke material followed up fractures through volcanic rock it could have been stopped at the base of the limestone by termination of the opening . The crosscutting of a six-inch thickness of the "A" orebody may be explained on the basis that the limestone there was not thick enough to flow plastically , so closing the fracture . Alternatively the dyke might develop sufficient pressure to re-rupture such a thin layer , but not one several tens of feet thick .

It is presumed therefore that the dykes are earlier than the ore .

The validity of the following sequence depends on the validity of assumptions , rather than on uncontestable observations . It is therefore open to drastic revision .

1. Folding .
2. Fracturing on north-south axis .
3. Intrusion of sill , stock , and dykes .
4. Fracturing on north-south axis and on N.W.-S.E. axis .
5. Deposition of quartz veins : perhaps with conversion of marble into skarn .
6. Fracturing : persistent , widely spaced .
7. Quartz-calcite veins deposited .
8. Fracturing : to form those fractures still open .

The regional sequence may be :

		Correlation with local sequence
Pleistocene	glaciation and weathering	
Tertiary	vulcanism followed by erosion.	
Post-Laramie	granodiorite batholith	
Laramide	orogeny , faulting	4 - 8 not known
	stock , sills , dykes of diorite - gabbro complex	3
Close of Jurassic	orogeny , establishment of major anticline	1 , 2
Triassic	deposition of volcanic rocks and associated limestone	

Perhaps the initial folding , the establishment of the anticline , provided a dominant structural axis along which all later regional stresses would be resolved . Thus crestal tension cracks , striking north parallel to the axial plane , might be re-opened at various times .

The structural feature not included in the above sequence is thrust faulting , proposed by Billingsley as the explanation for various repetitions of stratigraphy and for unique breccias in Nickel Plate mountain . No such faults have been identified in the Good Hope map-area .

If Billingsley and Hume are correct in assigning all the "heat effects" , including the resulting diorite-gabbro complex , to post-Oligocene time all the local sequence younger than the initial folding and fracturing must be compressed into post-Oligocene time too .

11. LINES OF EVIDENCE

The investigation of ore controls has followed several lines :

1. Ore was made from limestone .
2. Gold and skarn-materials were added to the limestone at the same time . Microscope work being inconclusive , field relations were relied on for this assumption .
3. The solutions that deposited the veins could have produced skarn from limestone . The materials added in each case are about the same .
4. Veins or dykes offer the best means of access for the solutions .
5. In space , the zone containing ore corresponds with the zone containing fractures , veins , and dykes . This conclusion may be discarded when more bedrock has been exposed , however .
6. Quartz veins have not been found in unaltered marble .
7. Other structures are missing or not yet recognized owing to incompleteness of surface mapping .

The writer considers it probable that the fractures now filled by veins controlled the formation of the orebodies in suitable host rocks . Some contrary evidence is presented below :

1. Skarn near the stock does not contain gold .
   Further drilling may find ore here , possibly towards the outer edge of the aureole . Alternatively ,

12. ORE CONTROLS

The first and most obvious ore control is the presence of rocks suitable for replacement . In this mine the best rocks seem to be the marble members . Given suitable traps to concentrate the action of magmatic fluids it might be possible to have ore produced from volcanic rocks as well , but such traps are not recognized at present . Quartz veins by themselves have not been found to be of ore grade . As in the past , so in the future the marble members will be the main guide in exploration .

For secondary ore controls there are a lot of possibilities , the best of which is the set of quartz veins . The zone of guiding fractures merits exploration at depth , where veins might intersect the lower marble horizons . No reason is known why the veins should not persist below the sill , for there is no evidence that the veins originated in the sill .

Dykes , since they provide a means of access for magmatic fluids , must be examined and traced on surface . A uniform association of orebodies with contacts of lime layers and dykes would turn exploration towards other possible intersections .

Folds and faults , if pre-ore , might localize ore , but since no faults and few folds are known well such structures cannot help in ore-hunting . Until enough trenches are put in to permit tracing of formations across the mine area no general picture of the folding can be developed .

The intersections of several sets of fractures might control ore by concentrating the effects of fluids from below . This may have happened at No. 2 Trench , although the secondary set of fractures is almost lacking in fillings .

The stock itself may be an ore control , for ore could be developed in the aureole . If it was , exploration in the outer zones of the aureole has the best chance of finding ore , judging from experience at the Nickel Plate mine .