THE ECONOMIC GEOLOGY OF THE POLARIS-TAKU MINE, TULSEQUAH, B.C.

by

William Russell Bacon

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R. V. KIRKHAM

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INTRODUCTION

The Polaris-Taku Mine is a gold property situated in the far northwestern corner of British Columbia. In a straight line it is approximately thirty-eight miles north-east of Juneau, Alaska and six miles northwest of Tulsequah, B. C. The International Boundary separating British Columbia from Alaska is five miles to the west. The mine camp and townsite lie at an elevation of seventy-five feet above sea-level in the valley of the Tulsequah River, six miles north of its confluence with the Taku River. The mine workings, consisting of eight levels, are opened from four adits at elevations between 135 feet and 575 feet on the steep, east slope of the northwesterly trending mountain range forming the west side of Tulsequah valley.

ACKNOWLEDGMENTS

The writer is greatly indebted to Dr. Alex Smith, mine geologist at Polaris-Taku, for making available two representative suites of altered material. Special thanks are due Dr. H. C. Gunning of the University of British Columbia for advice and guidance given throughout the work.

HISTORY

The first important interest in the Taku River district resulted from the discovery of two promising zinc, copper, lead, gold, silver prospects from 1923 to 1925. One of these, the Big Bull, located about two miles from Tulsequah, was extensively prospected and developed by the Alaska Juneau Gold Mining Company, while the other, the Tulsequah Chief, located along the east bank of the Tulsequah River, approximately nine miles above its confluence with the Taku River, was first prospected by the Alaska Juneau Gold Mining Company, and later extensively developed by the United Eastern Mining Company. Both these operations ceased in 1929.

In 1929, three men, freighting up the Tulsequah River to the United Eastern Mine, discovered the Whitewater property, now known as the Polaris-Taku. In 1931, the N. A. Timmins Corporation examined the showings and secured an option on the claims. From subsequent drilling and trenching they reached the conclusion that the veins were extremely erratic, lenticular, and restricted replacements. Consequently, the option was dropped in the fall of 1932.

Immediately upon Timmins dropping their option the property was taken over by the Alaska Juneau Gold Mining Company. In the fall of 1934 they relinquished their option for the twofold reason that:

1. Vein structures seemed too complicated and

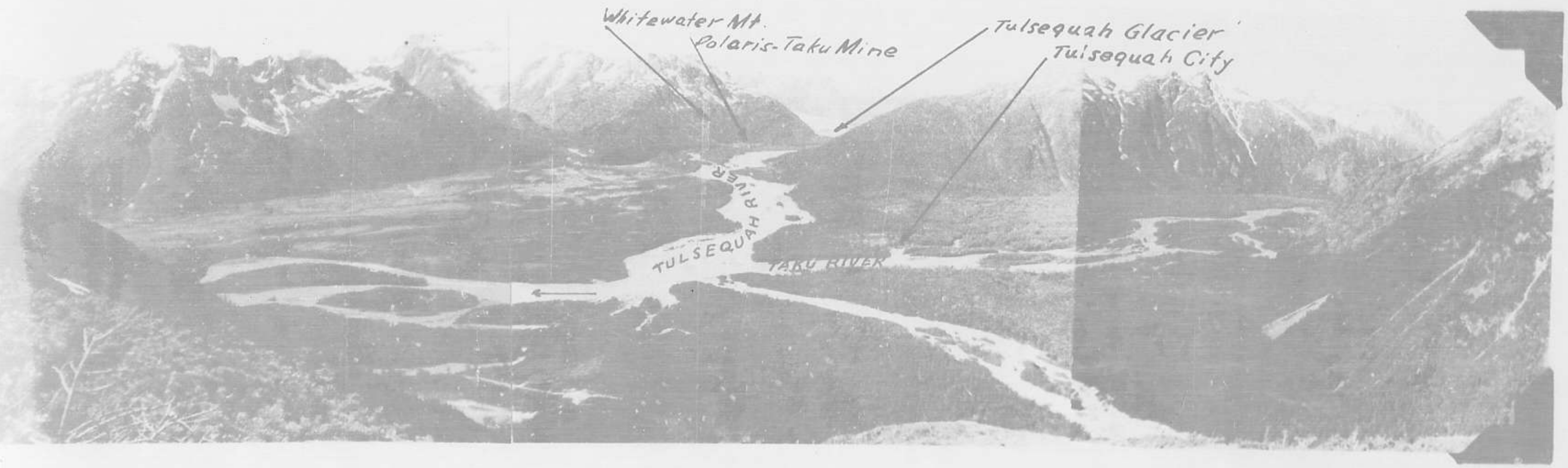
2. Tests indicated a complex metallurgical problem and poor gold recovery.

Late in 1934 an option on the property was obtained by Edward C. Congdon and associates, of Duluth, Minnesota. Work was started in May, 1935 and, by February, 1937, sufficient ore had been developed to warrant construction of a 150 ton mill. Production officially started November 1st., 1937 and was increased in the summer of 1940 to 225 tons daily.

In April, 1942, because of increased transportation difficulties, labour shortage, and inability to obtain necessary equipment, the Company decided to discontinue operation for the duration of the war.

PHYSICAL FEATURES

The Taku River area, lying on the steep, rugged, Coast Range mountains, is one of extreme relief, with elevations ranging from sea-level to 8500 feet. Extensive glaciation has been the dominant factor in the development of the physiographic features. The Taku and Tulsequah Rivers, which dissect the area, provide its most striking features with their broad valleys bounded by steep, sheer mountains. Numerous tributary streams emanate from U-shaped and sometimes hanging valleys, many of which are filled with glaciers. The majority of the glaciers are fingers branching from the extensive Muir Ice Cap lying to the northwest of the Taku River, but some are of alpine type, occurring as



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PANORAMIC VIEW OF PART OF THE TAKU RIVER DISTRICT individual units.

Heavy overburden, consisting of glacial boulders and clay, covers the surface of the claims to a depth of from two to fifteen feet.

GENERAL GEOLOGY

The oldest rocks on the west side of Tulsequah Valley are of Paleozoic age. They differ greatly in character and include crystalline limestone, quartzites, schists, slates, argillites, and some volcanics. The crystalline limestone, usually light grey in colour, occurs almost entirely in one group at the top of the series. These Paleozoic sediments are the most abundant rocks in the area and, as yet, have not been found favourable for mineralization.

Unconformably overlying the Paleozoic rocks is a series of metamorphosed volcanics and associated rocks, consisting mainly of pyroclastics which were probably originally of andesitic composition. Included as pyroclastics are coarse fragmentals and intimately associated, fine-grained, well banded tuffs. Soft phyllite, intrusive serpentine bodies, and minor interbeds of limestone also occur. Of Mesozoic age, probably Triassic, this series is the host rock for the Polaris-Taku ore-bodies.

The main geological feature of the area, as in the Stikine and other better known areas to the south, is the Coast Range batholith which, here as elsewhere, occupies the core of the Coast Range. The most common rock types vary from granite to granodiorite. Diorite, gabbro, syenite, and rocks of intermediate composition occur locally in relatively small amounts. The eastern contact of the batholith strikes in a north-westerly direction across the Taku River and appears to follow this course about five miles to the west of the mine.

STRUCTURE

The structure of the rocks is complex as is fairly well shown by their distribution as indicated in Fig. 1. In the main the west side of Tulsequah Valley conforms to the same side of a synclinorium which has a general plunge to the south. The volcanics present, though fairly extensive, are more or less in the form of a shell on the valley wall. Owing to the innumerable small and complex folds the shell shows a wide range in thickness; in synclines it may be carried to a considerable depth, whereas over the crests of anticlines it may be entirely absent, as is the case at the base of Whitewater Mountain on the east side, not far south of Whitewater Creek. Wilms Creek (See Fig. 1) has cut completely through the shell; it is not believed that there is any connecting band between the volcanics on either side of this creek. There is thus indicated a maximum possible thickness for the Mesozoic volcanics of about twenty-seven thousand feet. Over most of the area it is probably much less than this.

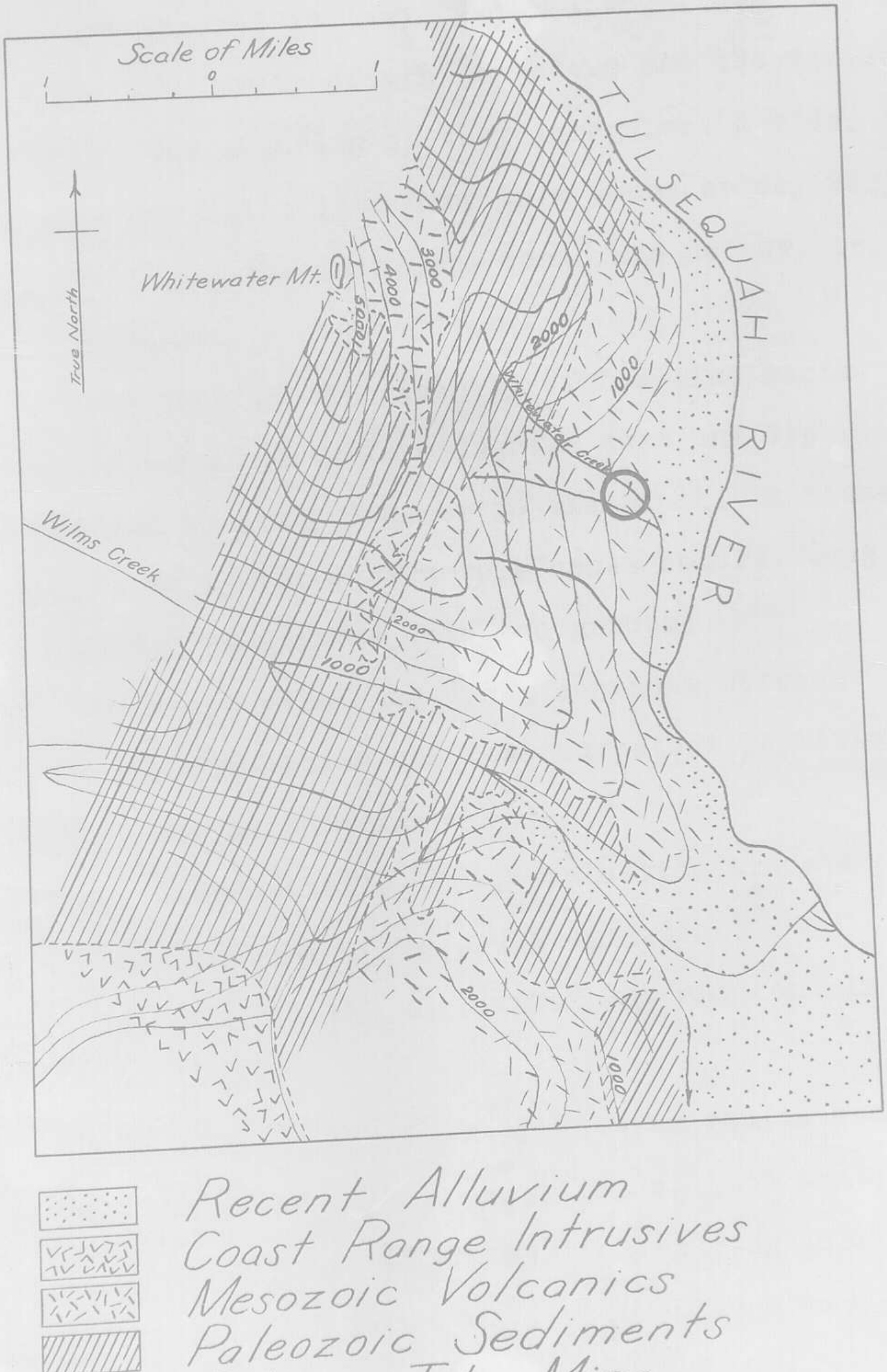

Scale of Miles
0
1
1
True North
Whitewater Mt.
5000
4000
3000
2000
1000
Whitewater Creek
TULSEQUAH RIVER
Wilms Creek
2000
1000
2000
1000
Recent Alluvium
Coast Range Intrusives
Mesozoic Volcanics
Paleozoic Sediments
Polaris-Taku Mine

Fig. 1

Because of the intensity of the folding, the volcanics are sheared in many places along minor structures. Owing to the complexity of the structure and the variability of the rocks, the shearing is very irregular. A wide, well-sheared zone may split into many thin zones or may vary in almost any way. In the main, the zones are narrow, irregular, and discontinuous.

The beds in the vicinity of the mine strike from east-west to north forty-five degrees west and dip from ninety degrees to sixty degrees to the south. In these rocks a complex system of fracture zones occurs. Roughly these zones can be divided into two groups:

1. Those occurring along contacts between pyroclastics and less competent phyllite and serpentine.
2. Those cutting the pyroclastics transversely. i.e. in a north-south direction.

These zones are of similar age and contain similar minerals.

In the mine a series of reverse faults occur which strike generally about north ten degrees west, and dip sixty to thirty-five degrees east. Faulting is both pre- and post-mineral and may indicate a continuous period of adjustments which began before mineralization and continued after mineralization had ceased.

ECONOMIC GEOLOGY

General Statement

The Polaris-Taku ore bodies are probably best described as metasomatic replacement zones. This term is applied to properly emphasize the role played by metasomatism in the formation of these deposits. In many cases the fissures were not opened to any noteworthy extent, but only so much as to admit the passage of the mineral-bearing fluid. The latter attacked the rock on either side of the fissures, depositing ores in the place of the simultaneously dissolved rock-constituents. The typical metasomatic replacement zone consists of a network of quartz-carbonate veins, stringers, and veinlets with intervening partial or complete alteration of the rock formation.

The main sulphides are arsenopyrite, pyrite, and, with locally important exceptions, minor amounts of stibnite. The arsenopyrite and pyrite occur so finely disseminated that it is often very difficult underground to distinguish between good ore and country rock.

All of the deposits are marked by an alteration of the green volcanics to dark grey, light grey, and, where the alteration has been most intense, to cream-coloured material. These altered zones may grade into the normal volcanics or may end abruptly against them. The zones are irregular in shape and their size does not usually give any indication as to whether an economically important concentration of sulphides may be present. Often a large altered zone may contain pyrite as the only sulphide. A good example of this occurs on 6 Drift-C Level where the greyish zone extends over a width of one hundred feet yet, pyrite, with very small amounts of gold, is the only mineralization. Many zones, however, carry sufficient concentrations of sulphides and associated gold to make mining quite profitable.

Materials of the Altered Zones

With a view towards determining more exactly the nature of the materials comprising the metasomatic replacement zones, a number of thin sections and corresponding hand specimens were studied in detail. The results of this study, as well as some methods used in obtaining these results, will now be discussed.

Specimens P1 - P13 Suite taken from foot wall to hanging wall (6" intervals) across 224 Drift zone - 300 Level. It is a north-south zone.

Megascopically Specimen P1 is a soft, dirty green, fine grained chloritic rock showing considerable foliation. There occurs throughout the rock a general alignment of lenticular patches of darker green material. Late calcite stringers traverse the rock in a winding manner.

Under the microscope this rock is seen to be highly carbonatized. In fact, at least seventy-five per cent of the thin section consists of very fine anhedral grains of carbonate. The remaining twenty-five per cent is mainly chloritic material.

In order to determine the carbonate, a small sample of this rock was taken and ground very fine. The rock flour was given a cold, dilute hydrochloric acid leach for only one minute. A short, weak leach was insurance against decomposing any chlorite. On filtering and testing the filtrate, large amounts of calcium and magnesium and a slight amount of iron were obtained. Thus the carbonate is a ferriferous dolomite.

The chloritic material occurs as lenticular masses of fine, slender shreds. Its mode of origin is a question. The constituents necessary for its formation may have been derived from the original rock which, it is believed, was andesitic in composition. Dynamic metamorphism could have altered this andesite to a chlorite schist. Certainly the parallel arrangement of lenticular patches of chlorite suggests this origin. It is also possible, however, that some of it is of hydrothermal origin.

Under the microscope two distinct types of chlorite can be seen. They are very intimately associated. In attempting to name these chlorites the writer encountered two difficulties. The first was how to isolate the two types in order to do qualitative chemical analyses of them. The second was, after establishing certain criteria distinguishing each type, what to call them. There is a decided lack of unanimity among recognized petrographers pertaining to the naming of the chlorite minerals and also to the number of different minerals included in the chlorite group.

The writer found that in grinding the rock sufficiently fine to unlock the two chlorites, it became almost impossible under the microscope to separate enough of each to run worth while qualitative analyses. A test run on the combined minerals showed substantially more magnesium and aluminum than iron.

Finally, use was made of three optical properties to classify these chlorites.

Interference Colour	Orientation of Cleavage Traces	Index of Refraction	Name
First-order white	Length Slow	1.55	Antigorite
First-order grey	Length Fast	1.59-	Clinochlore (?)

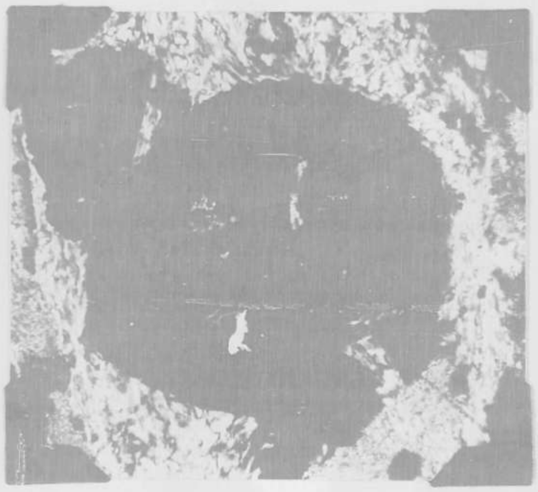
The indices of refraction were obtained by removing the cover glass from the thin slice, removing all the balsam with xylene, and applying directly to the slice oils whose indices of refraction were known. The various oils were likewise thoroughly removed by applying xylene to the slice with a paint brush.

In Specimen P1 there also are very small amounts of chromite and a few grains of pyrite and magnetite. The chromite occurs both as anhedral grains and as minute octahedra.

This whole slide is dusted with a white, opaque, amorphous-looking substance which may be leucoxene. The common associates of this alteration product, ilmenite and sphene, however, are not in evidence.

Specimens P2 and P3 are very similar microscopically to P1. A late quartz-carbonate stringer is present in the thin section P3. The hand Specimen P3 has a lighter green appearance caused partly by bleaching of the chloritic material. It is the chlorite in these rocks that is largely responsible for their colour and, by its masking effect, makes all the rocks, despite considerable differences in composition, appear very similar megascopically.

Specimen P4 represents a decided change in the mineralization of the altered zone. The originally dark green chlorite has been bleached to a nondescript grey colour. Mica, colourless in thin section, is developed as fine, wavy shreds. Very often it surrounds corroded crystals of chromite which are relatively abundant in this specimen. In many places the mica seems to be replacing the chromite. This idea is substantiated in the hand specimen where the mica has a bright green colour, suggesting it is a chrome-mica which obtained its chrome from the chromite. On closer examination of the thin section, however, some complications arise to this simple theory. Some chromite occurs surrounded by carbonate and some mica occurs without any identifiable chromite. Thus, what seems to be an obvious relationship between the chromite and the mica, cannot be proved definitely.



From Specimen P4. 245 X.
Chromite surrounded and invaded by mica.

In spite of the bright green colour of the mica in the hand Specimen, it well might be asked if there is proof that any of the mica is chromiferous. In order to prove that some of the mica does contain chromium, the writer ground some very fine, screened it, and superpanned the minus 200 mesh material to remove the chromite present. The product was examined under the Ultrapak microscope and found to be very pure. Many borax and phosphorous bead tests were run on this mica but no really conclusive results were obtained. Spectrographic tests, however, revealed that a small but definite amount of chromium is present in some of the mica.

Whether the mica is chromiferous where it is not directly associated with the chromite remains a question. It would be impossible to scrape some mica from the hand Specimen and be sure that it came from a place in which not even microscopic grains of chromite were present. Therefore, it is probably wise to consider the mica as a light green sericite where a definite relationship with the chromite is not visible.

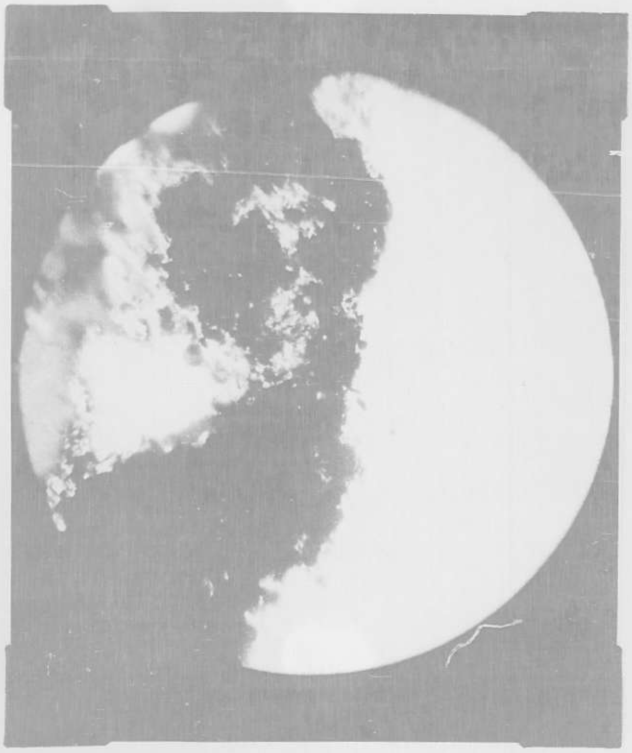
Pyrite in irregular disseminated grains is relatively abundant.

Specimen P5 is very similar to P4 but contains less green mica. It is approximately eighty-five per cent carbonate, ten per cent chlorite, and five per cent green mica.

P6 is taken within six inches of the foot wall of the ore zone. It is approximately ninety per cent carbonate, seven per cent green mica, and three per cent chlorite. The metallics, which occupy less than one per cent of the section, are, in order of their abundance, pyrite, chromite, arsenopyrite, and magnetite.

Specimen P7 is in the foot wall of the ore zone. There are remnants of wall rock that have been completely altered to green mica, carbonate, and fine granular quartz (.03 mm.). The green mica and, to a lesser extent, the carbonate are well mineralized with arsenopyrite and pyrite. The character of the later solutions varied considerably as quartz and dolomite are found veining each other as well as earlier quartz and dolomite. The late carbonate was identified as dolomite by specific gravity tests. The later gangue minerals are much more coarsely crystalline, (quartz = .6 mm., dolomite = .8 mm.) suggesting deposition in more or less open spaces. A relatively small amount of arsenopyrite and pyrite are found associated with the later gangue minerals, mostly along fractures in the dolomite.

Specimen P8 is vein material from the foot wall of the ore zone. In the hand Specimen there is hard, dark grey altered rock separated sharply in most places from the later, dull greyish-white quartz-carbonate material by a very thin line of sulphides. There are also small patches of mineralized wall rock in the lighter material. The sulphides are in sufficient concentration along the boundary of the two types of material to give the aspect in the hand Specimen of a massive, tiny stringer or cement. Close examination of these sulphides under the microscope, however, reveals that they are intimately associated with the small amount of mica present. Clearly the altered wall rock was first mineralized with arsenopyrite and pyrite, later quartz-carbonate solutions replacing practically all the altered wall rock except that which was closely associated with and protected by the metallics. Following the same line of reasoning, the writer believes that where the metallics are not visibly associated with any altered wall rock, the latter may have been completely replaced as it quite evidently has been in sections free of sulphides.



From Specimen P8. 162 X.
Sulphides associated with mica.
Replacement quartz on the left.
Vein quartz on the right.

Under the microscope the dark grey material is seen to be almost completely silicified. This replacement quartz is much finer grained (.02 mm.) than the lighter material (.7 mm.) which obviously was deposited in more open spaces. The latter is barren of sulphides. Here, as in the previous Specimen, quartz and carbonate vein each other as well as earlier quartz and carbonate. Evidently shattering must have recurred a number of times during mineralization or alternated with it to give such a series of veinlets, one crossing the other. The large crystals of quartz exhibit wavy extinction and even the later carbonates are not altogether free from the effects of deformation.

Specimen P9 is fairly typical of the ore found in the less silicified zones. The rock has been completely altered to a dark grey aggregate consisting of eighty-five per cent dolomitic carbonate, ten per cent sericite, and very small quantities of quartz and leucoxene. It is mineralized with arsenopyrite and pyrite. The metallics, which occupy about two per cent of the section are finely disseminated throughout the rock. The arsenopyrite is the more abundant, occurring as fine needle-shaped and diamond-shaped crystals. The pyrite occurs as irregular, rounded grains, as skeleton crystals, and as massive irregular patches. In the Polaris-Taku ore the average size of the pyrite grains is .15 mm. to .2 mm. while the size of the arsenopyrite crystals varies from .03 to .07 mm. In some cases the sulphides are intimately associated with a little fine granular quartz as well as with the carbonate and sericite. A peculiar feature of P9 is noticed on examining the thin section under crossed nicols. Many definitely lath-shaped forms occur suggestive of feldspar. In most cases, whatever was the original mineral has been more or less completely altered to sericite.

Specimen P10, on the hanging wall of the ore zone, is well mineralized with arsenopyrite and, to a lesser extent, with pyrite. The sulphides occupy at least five per cent of the section. The original material has been highly carbonatized. Sericite is present, sometimes occurring in forms suggestive of the alteration of larger individuals of feldspar. Late calcite stringers occur in which there are very few grains of metallics.

Specimens P11, P12, P13 are typically greyish altered material showing slight mineralization, mainly pyrite. All contain over ninety per cent dolomite and emphasize the fact that a slight change in the amount of carbonatization suffered by the rock results in a very considerable change in its colour.

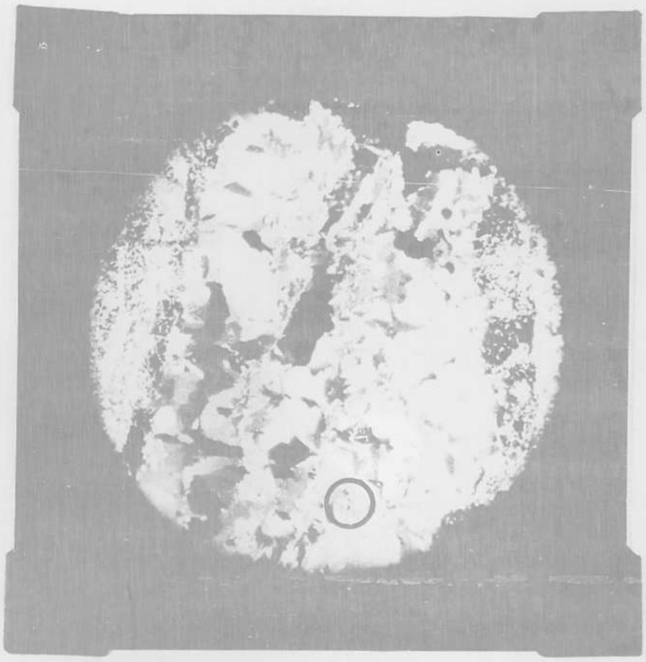
A stringer in P12 illustrates the changing character of the late solutions. A typical comb structure is developed with calcite, quartz, and calcite having been deposited in that order. Only a very little pyrite is associated with the late stringers.

Specimens P14 - P17 Suite taken from "unaltered rocks" to ore (4" intervals) across 17 Drift-B Level. It is a north-south vertical zone.

Specimen P14 is far less carbonatized than any rock previously described. Eighty per cent of the rock is an intergrowth of antigorite and clinochlore (?). In two places, clinochlore (?) also occurs veining the groundmass. Carbonate occurs all along the middle of one of these clinochlore(?) veinlets. The rest of the rock is made up of biotite which is more or less altered to negative penninite. The latter was determined mainly on the basis of its "ultra blue" interference colours. The thin section shows sharp contacts between these biotite-penninite areas and the rest of the groundmass, suggesting in places a breccia. Again, a few sharply defined, rounded areas of sericite give the impression that they might have resulted from the complete alteration of feldspar phenocrysts. Irregular grains (.02 mm.) of quartz and possible feldspar are scattered throughout the groundmass. A few scattered grains of pyrite and magnetite and the ubiquitous leucoxene are also present. A number of late calcite stringers cut the rock.

Specimen P15, only 4inches nearer the ore than P14, is an entirely different rock. It is light coloured due to its high carbonate content (70%). The chloritic material, patches of which are still visible in the hand Specimen, is now a light grey colour. Wavy shreds of light green sericite occur throughout the Specimen. Small, disseminated grains of pyrite are relatively abundant.

P16 and P17 are similar specimens from the ore zone. The rock is much like P15 but is well mineralized with arsenopyrite and pyrite. Fine-grained quartz (.02 mm.) is associated with these sulphides. It is plainly evident, from the concentration of sulphides around the small quartz-carbonate filled fissures, that these fissures, before the quartz and carbonate were deposited, served as the channels for the early mineralizing solutions, and, from these channels, the arsenopyrite, pyrite, and fine-grained quartz invaded the altered wall rock.



From Specimen P17. 9 X.
Sulphides on either side of late quartz-carbonate stringer which is barren except for a little stibnite (in circle).

These late stringers, sometimes exhibiting comb structure, are practically barren of sulphide mineralization. In P17, however, a little stibnite veins the late carbonate. Associated with this stibnite is a very small amount of bright red mineral which may be cinnabar.

The type of alteration represented by these two suites of rock is quite typical of Lindgren's mesothermal deposits. He says, "Sericitization, with or without carbonates but always with pyrite, is the principal process of alteration in igneous rocks.........The alteration of the country rock is usually very intense next to the ore but seldom yields coarsely crystalline products as in some high-temperature deposits. In feldspathic and ferromagnesian rocks the principal product is sericite, the fine-grained foliated form of muscovite; in many deposits carbonates, such as calcite, dolomite, and ankerite, develop in large amounts. The dark minerals are first altered, their iron being usually recombined as pyrite. The feldspars are also rather easily altered; even quartz grains are attacked and partly, at least, converted to an aggregate of sericite and carbonates."

Warm aqueous solutions containing arsenic, lime, potassium, carbon dioxide, and hydrogen sulphide would be quite competent to effect the changes noted in these rocks. It would seem probable that, in most cases, the added material has more than balanced losses.

Description of the Ore Zones

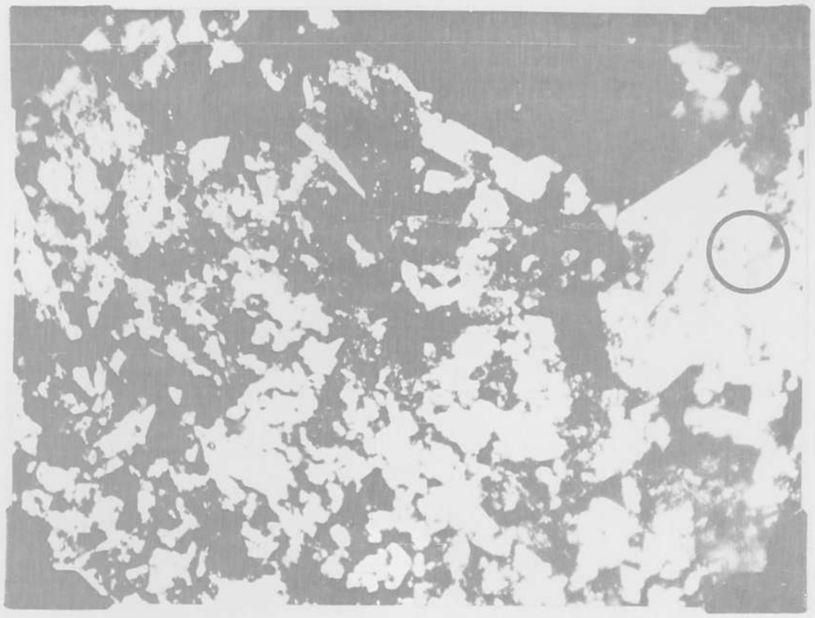
As will be remembered from the description of the structure, there are two types of mineralized fracture zones, contact and transverse.

The largest and most persistent zone developed is of the contact type. It is known as "A" zone and generally follows the contact between pyroclastics on the foot wall and phyllite on the hanging wall. In places, however, it diverges either into the phyllite or into the pyroclastics. The strike of "A" zone is north 55 degrees west and the dip is from 55 degrees south to nearly vertical. The zone varies from two to thirty-five feet in width and averages about ten feet. Five ore shoots have been stoped along this zone. The horizontal distance from the 1A orebody to the 5A orebody is approximately one thousand feet. The actual zone persists past the 5A orebody but has not been found productive. This zone has been extensively worked from the surface (Elev. = 500 feet) down to the 150 level (Elev. = - 13 feet). It has also been cut on the 450 level (Elev. = - 313 feet) but has not been explored at this depth.

The shape of "A" zone is roughly tabular except in one place. Thirty feet above B level the pyroclastics on the foot wall of the 5A orebody have been extensively replaced, resulting in a large irregular body of ore extending vertically to thirty feet above C level. This one orebody yielded fifty thousand tons of ore.

The ore minerals are practically the same throughout the horizontal and vertical range of "A" zone. Arsenopyrite is the most abundant and is the main gold carrier. Pyrite is next in abundance but is not important economically. Stibnite, in very minor quantities occurs in the late quartz-carbonate stringers. Small quantities of a grey mineral occur as inclusions in and veining the pyrite.

This mineral was only visible under oil immersion and hence could not be determined by etch reactions.



Disseminated Arsenopyrite and Pyrite. 675 X.
Note grey mineral veining pyrite. (In circle)

There has been greater movement and more continuous movement along "A" zone than along any of the transverse zones. Consequently the full mineral sequence is best developed in "A" zone. In places the later quartz and carbonate have completely replaced the wall rock, giving the zone somewhat the appearance of an irregular fissure vein.

The transverse zones strike from north 10 degrees west to north 20 degrees east and dip very steeply. Zones of this type are abundant, but are smaller than the contact type. They all lie in the foot wall and to the north of "A" zone. The zones occur solely in the competent pyroclastics, dying out where they intersect a phyllite band. However, not infrequently, what appears to be a continuation of the zone is found on the other side of a phyllite band. Several of the zones have been found to branch from "A" zone but none cross it and continue beyond on the hanging wall side.

The longest transverse zone developed is approximately five hundred feet long. These zones are usually much narrower than the "A" zone. "Y" zone on the 300 level, however, reached a width of over twenty feet.

18 Zone and 23 Zone are two of the richer transverse zones which have been mined right to the overburden. They vary from six feet to six inches in width. Within the upper one hundred feet of these zones stibnite is by far the most abundant ore mineral. In places arsenopyrite and pyrite are practically absent. This stibnite has run from six to fifteen times as much in gold as the average ore from "A" zone. In spite of this no gold was seen in even the richest polished sections of stibnite from this zone. In six sections examined only two small pieces of gold were found and they were in quartz, not stibnite. Extremely small quantities of a grey mineral were seen in two of the polished stibnite sections. Upon testing this mineral the following characteristics were noted.

Colour - Grey

Hardness - C to D

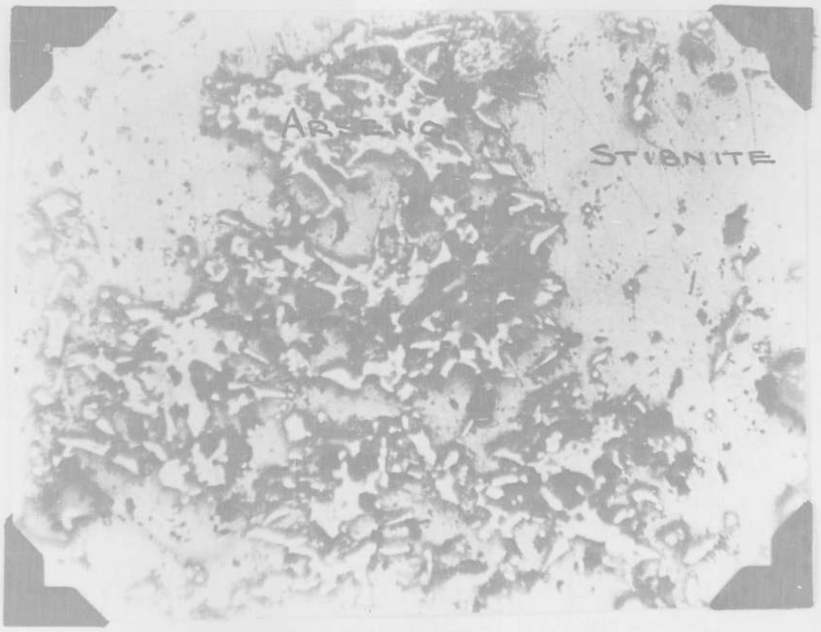
Crossed nicols- Isotropic

Etch tests -

HNO_3 - Fumes tarnish

HCl, KCN, $FeCl_3$, KOH, $HgCl_2$ - Negative

Spectrographic analysis of the stibnite showed medium to weak copper and silver lines. The evidence thus suggests that this mineral might be tetrahedrite.



Arsenopyrite and Stibnite, 1-23 Stope. 165 X.

The vertical range of this type of ore zone is not known. However, as a typical transverse zone is smaller in length and width than "A" zone, it seems reasonable to expect that it will be smaller than "A" zone in the third dimension, depth.

CONCLUSION

The Polaris-Taku mine lies within the eastern contact-belt of the Coast Range batholith. The solutions responsible for this deposit may have been genetically connected either with the batholithic intrusion or with some later, deeper-seated, igneous source. The Paleozoic sediments were apparently unfavourable for replacement by the mineralizing solutions which deposited ores in the Mesozoic volcanics. These solutions showed a considerable range of composition over a period of time. The following sequence of events is suggested for the emplacement of the orebodies:

1. Dynamic metamorphism, resulting in shearing and alteration of the original rock to one high in chlorite.
2. Penetration along narrow fissures of the rock by warm aqueous solutions, resulting in alteration of the wall rock to an aggregate of chlorite and dolomite.
3. Further carbonatization; bleaching of the chlorite; development of greenish sericite (chromiferous in places), pyrite, and some fine-grained quartz.
4. Replacement of the altered wall rock by abundant arsenopyrite, pyrite, and some fine-grained quartz. Most of the gold was introduced with this arsenopyrite.
5. Fracturing, alternating with vein introductions of quartz and carbonate, and a very little arsenopyrite and pyrite.
6. Continued fracturing; introduction of stibnite, often with important amounts of gold.

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