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DOLLY VARDEN MINES

GEOLOGY

MAUDE MCPHEE
DOLLY VARDEN
N. STAR
TORBRIT
TIGER
KITSOL
S. MUSKATAWA
MITCHELL
DART
WOCK
SURPRISE

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Rec'd. 4/73

REGIONAL GEOLOGY

The Dolly Varden property is located approximately in the center of a panel of Hazelton group rocks that extends in a south-east direction from north of Stewart, B.C. to Alice Arm, B.C.

This panel, perhaps 40 miles long and 15 miles wide, is bounded on the west by the coastal plutonic complex of Tertiary age and on the east and south by Cretaceous sediments of the Bowser assemblage. The latter apparently covered the whole area at one time but have been eroded away by glaciation exposing the older Hazelton group of Jurassic age.

The Hazelton group within the panel consists of intercalated marine sediments, pyroclastics and volcanic epiclastics, the products of vulcanism and sedimentation in an unstable, paralic environment, and typically shows wedging, lensing and mixing of formations. The exact age of the rocks within the panel has not been definitely determined but work by Carter and Grove, 1971, indicates that they are slightly younger than the main Hazelton sequence to the south and may be the correlatives of the Mid-Jurassic fine grained marine sediments to the north. If this is true, the rocks in the panel probably represent marine sedimentation of Mid-Upper-Jurassic times near the west margin of the Successor Bowser Basin, the sedimentation being interrupted by two or more periods of late marine-terrestrial vulcanism.

LOCAL GEOLOGY - Hazelton Group

Black, 1951, has divided the Hazelton assemblage in the Dolly

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Varden property area into four formations based on gross lithologic aspect. They consist of two marine sedimentary formations "A" and "C", and two volcanic -- volcanic epiclastic formations "B" and "D". Formation "A" is the basal unit and is a typical euxinic, thin-bedded black shale with occasional littoral, sandy or conglomeratic facies present. A measured thickness is not recorded but the unit is presumed to be between 500 and 1000 feet thick. Formation "B" overlies formation "A" conformably and consists of a complex pile of pyroclastic material intercalated with and grading laterally into volcanic epiclastic material. The formation is intruded by contemporaneous "feeder" dike complexes and volcanic plugs often intergradational with much of the volcanic pyro-epiclastic material surrounding them. Much of the formation is typically massive exhibiting little or no bedding and grades from purple or brown to green in colour with no apparent reason for colour changes. Although the volcanic section has never been measured and a true thickness would be hard to obtain due to the distortion of folding and the irregularity of the formation, it is believed that the formation may locally be more than 3000 feet thick. While the bulk of the formation is notable for its lack of marker horizons, one such horizon does exist near the top of the formation. This horizon consists of a bright red to purple pyroclastic unit, rich in hematite. Its thickness is estimated as being 100 to 300 feet and it locally appears to be the oxidized pyroclastic equivalent of a magnetite-hematite rich phase of dike complex found within the formation. This horizon appears to overlay the lower part of the volcanics formation unconformably and is generally found capping many of the hills in the area. The horizon is in turn overlain by a green volcanic sandstone unit which conformably grades into the basal littoral facies of the marine sediments of formation "C".

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Formation "C" has a thickness of perhaps as much as 500+ feet but is highly contorted so that accurate measurements are not possible. This formation consists of a littoral basal section, with fossiliferrous sandstones, conglomerates, greywackes, and limy shales grading to a deeper, euxinic environment black shale upper section and represents sedimentation within a restricted marine basin probably with low volcanic highlands of formation, "B" in part being the topographic restrictions.

Formation "D" overlies formation "C" unconformably and occurs just north of the Dolly Vardenproperty area. The formation consists of volcanic rocks similar to formation "B" grading into gritty tuffs and fossiliferrous marine sediments. The lower portion of the formation appears to represent the youngest period of vulcanism in the area, immediately preceding the continental-marine sediments of the Cretaceous Bowser Assemblage.

LOCAL GEOLOGY - INTRUSIVES

Intrusive bodies in the panel of Hazelton assemblage rocks have been mapped by Carter, 1971, as belonging to three ages. These are:

1. Jurassic - Feldspar porphyry, Augite porphyry, and hornblende diorite.
2. Eocene - Granodiorite and quartz monzonite.
3. Oligocene and Younger - Lamprophyre, basalt and andesite dike swarms and small plugs.

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Jurassic plutonism is represented within the panel by intrusive bodies up to four miles long, elongate parallel to the long direction of the panel and the eastern margin of the coast plutonic complex (i.e. northwest-southeast). Perhaps most significantly, the largest of these bodies is found on the western part of the Dolly Property and the bulk of economic mineralization discovered to date is in the area immediately south and east of the intrusive.

The gradational nature of the contacts of the above intrusive body with the surrounding and overlying volcanic formations "B" and "D" indicates that the intrusive represents the volcanic feeder complex for the two formations. The intrusive, composed of numerous northwest-striking - easterly dipping "sill"-like masses has, on its west side, a gradational contact with the pyroclastics of formation "B" but intrudes and cuts sedimentary formation "C" on its east side and grades into the pyroclastic units of formation "D" to the north indicating that the volcanic vent was a periodically active fissure zone.

The intrusive contains numerous elongate roof pendants of shaly material, probably from formation "C" which are construed as being intersill remnants of that formation. The pendants are found at a much higher elevation than the main sequence of formation "C" which is found in the center of the valley (to the east) indicating that the latter now occupies a zone of subsidence to the east of the intrusive. The gradational nature of the intrusive/volcanic contact to the west and the sharp intrusive/shale contact to the east suggests a migration of the volcanic vent system from west to east. This migration was probably accomplished by each of the series of "sills" intruding caldera

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subsidence fissures along the hanging wall of its immediate predecessor.

The caldera-subsidence intrusive relationship is readily apparent to the south east of the intrusive where the red and purple pyroclastics of the upper part of formation "B" have been down faulted into contact with the magnetite-hematite rich dike complex that was the "feeder" for the pyroclastics. The contact consists of a normal fault zone extending in an arc from the southeast end of the volcanic vent system through a circumfrential distance of 7500 feet to a position perhaps originally 4500 feet east north east of the southeast end of the volcanic vent system. The fault structure, an extension of the main subsidence structure, dips toward the center of the arc, steeply north east at its west end, moderately north in its central protion and steeply north west to vertical at its eastern extremity and appears to be later than the dike complex. The dike material, where not capped by the purple-red pyroclastic unit has been found immediately in the footwall of the arcuate subsidence structure for about one half of its length; south of the Dolly Varden, North Star and Torbrit mines and also northeast of the Torbrit mine. To this date, the dike complex has not been completely mapped but it is suspected that its configuration is that of a ring dike complex related in age and structure to the main volcanic vent system with a common magma chamber to the east (down dip) of the main vent system and a similar mode of emplacement.

One other Jurassic intrusive has been found on the Dolly Varden property. It consists of a sill-like body with an attitude and composition similar to the main intrusive complex. This body intrudes formation "C" in the center of the valley adjacent to the Wolf mine and is thought to be either a cupola of intrusive exposed by glaciation or

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faulted off section of the main vent system. The body is 2200 feet long by perhaps 500 feet wide and is bounded by black shale on all sides.

Oligocene intrusives within the Dolly Varden property are represented by north easterly trending, high angle dike swarms. These dike swarms are ubiquitous throughout the property and their generally weatherable nature serves to form the basis for many of the prominent lineaments that cross the Kitsault River Valley. The dikes generally have a basaltic composition with diabase and lamprophyre textures common, but locally they may have a diorite or microdiorite composition. None of the major deposits in the area are free of these dikes which are post ore and have the effect of complexing the ore structures or rendering unmineable parts of the deposits. Where encountered in mining operations, these dikes commonly show a ribbon or braided structure that may lens in or out over distances of a few feet. Geologic sections of the deposits show that the dikes occupy near vertical dip-slip faults with the south east blocks down thrown relative to the north west blocks.

The above cupola? of Jurassic intrusive has a small plug of oligocene dacite contiguous with its southeast end. This plug is located some 900 feet south of the Wolf Mine and has been classified as an oligocene intrusive because it not only cuts formations "B" and "C" but because a carbonatized dike equivalent cuts the mineralization at the Wolf Mine.

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STRUCTURE - REGIONAL

The panel of Hazelton group rocks extending from Stewart to Alice Arm, B.C. appears to have undergone more or less continuous tectonic activity from their Jurassic deposition up to the present. Mapping by Carter, 1971, shows that the rocks have been folded and faulted against the eastern margin of the coastal plutonic complex so that the panel shows a marked linearity of belts of sedimentary and volcanic rocks oriented in a north west direction. These belts are, then, the remnants of numerous partially eroded anticlines and synclines whose axes are oriented in a northwest-southeast direction, parallel to the eastern margin of the coastal plutonic complex. Numerous fault zones, likewise oriented, have complicated the structure of the area and it is to be suspected that some of these faults, in an area impinging on a major plutonic complex are thrust faults which may cause the overriding of older stratigraphic successions upon younger with the local folding of these strata.

Another set of structural trends that occur throughout the area, in fact, one that occurs along the coastal region from Prince Rupert, north through the Stewart area is well represented in the above panel of Hazelton assemblage rocks. These trends consist of sets of northeast trending lineaments which presumably are major fault dislocations. Typically, many of the rivers and creeks, such as the Dak River, East Creek, Evindsen Creek and the west fork of the Kitsault River follow these lineaments for much of their lengths.

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STRUCTURE - LOCAL

The structure within the Dolly Varden map area has been interpreted by Black, 1951, as consisting of a fairly tightly folded north westerly plunging syncline, the axis of which runs approximately up the center of the Kitsault River Valley. More recent mapping of the area confirms this interpretation but with the proviso that while the thin bedded sediments of formations "A" and "C" are clearly folded and indicate the general "horseshoe" shaped surface trace of the syncline, the volcanics of formation "B" are highly competent and show little if any traces of folding, and should be assumed to have been at least partially faulted into their present position along the limbs of the syncline. Analysis of the fault and fracture patterns within the synclinal structure shows that north east faults such as the Evindsen Creek and Barite Creek faults have a right handed displacement while north west faults like the Dolly Varden-North Star, Moose-Lamb, and Musketeer Hill faults, have a left hand displacement. These two directions of faulting then, conform to the two principal shear planes caused by compression at Az 70^{o} which created the synclinal structure. The areas of possible tension fracturing are marked by the course of Trout Creek and the lower course of Evindsen-Tiger Creeks. The effect of this faulting has been to displace triangular blocks within the trough of the syncline to the south and to infault broad wedges of formation "A" along the east limb of the syncline at Tiger and Trout creeks elongating and thinning formation "B" along this limb, and making its contact with formation "A" jagged. It is considered however, that this compression, folding and faulting occur in tertiary times, a result of intrusion of the coast plutonic complex and that a

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pre-synclinal trough was formed along the axis of the syncline in Jurassic times due to volcano tectonic subsidence.

The shape and size of the trough probably changed several times due to the periodic nature of the vulcanism in the area with heretofore unexplained north westerly trending lineaments in the valley and the sub-arcuate cataclasite zone in Homestead Creek possibly representing the subsidence zones of the now faulted and deformed trough in some stage of its evolution.

Repeated movement along many of the faults in the valley seems to be the rule rather than the exception with renewed shearing along old faults often crossing younger faults to give a quasi-contemporaneous pattern of fault displacement. This effect is particularly noticeable in the trough part of the syncline where the arcuate south-east extension of the subsidence structure has been dislocated into many segments similar to the effect produced by cutting a pie into pieces and then pulling the pieces on one side of the pie out varying distances from their common center.

Finally, the high angle Oligocene faults that often have basalt dikes associated with them have further complicated the fault patterns in the property area, often reversing pre-existing fault displacements and exaggerating the outlines, and outcrop areas of the vein structures.

MINERALIZATION AND ORE DEPOSITS

The mineralization on the Dolly Varden property appears to be directly related in size, shape, and location to structures formed during the latter stages of Jurassic vulcanism in the area.

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The mineralization may also be genetically related to the Jurassic vulcanism although later stages of mineralization occupy structures that could have been formed as late as Tertiary times. Although the mineralization is younger than formation "C" it is rarely found in this formation, but rather, is found in formation "B" or in the intrusive bodies. This effect is attributable to:

(a) Formation "C" being a poor host rock for mineralization because it deforms rather than brecciates or shears under stress.

(b) The erosion of the parts of formation "C" that could have contained mineralization.

In general configuration, the mineralization takes the form of two large northwest striking, east dipping zones of quartz-carbonate-pyrite veining with associated silicification and carbonatization, each zone having a thin arcuate, tail-like quartz-carbonate replacement zone or vein to the south east.

The main zones of mineralization occur along the eastern margin or hangingwall side of the main intrusive bodies and plainly represent the hydrothermal replacement of parts of the main volcanic vent system along either structures related to caldera subsidence above a magma chamber or in a diatreme related breccia structure. The positioning and widespread mineralization in these zones suggests a proximity to the source,and rock textrues found in the zones suggest that the host rock was highly brecciated prior to mineralization either through the mechanism of explosion or collapse. The vein "tails" on the other hand, represent the same mineralization in a less violent, more structurally controlled environment farther away from the hydrothermal source with less surrounding alteration and a more regular form.

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The structural control for this part of the mineralization is a subsidence structure consisting of a normal fault or faults dipping toward the magmatic source of the main intrusive bodies. Like the two main zones to the north-west, the veins occur to the hangingwall side, or along the hangingwall contact of intrusive bodies; in this instance the suspected ring dikes within formation "B".

The southernmost "tail" of mineralization is reasonably well defined but is cut and displaced by crossfaults into segments known, from west to east, as the Maud McPhee, Dolly Varden, North Star, Torbrit, Tiger, and Kitsol-South Musketeer veins. These segments when replaced in their original positions represent a vein structure over 7,500 feet long and encompassing 180° of arc connected to the south main zone at the Maud McPhee vein and apparently fingering out at the north east end of the South Musketeer vein.

The northern "tail" of mineralization is rather poorly defined due to faulting, oligocene intrusion, masking of formation "B" by formation "C", and local thick overburden and river gravels. It does, however, appear that the northwest striking east dipping Surprise showing represents the north silicified zone or west end of the tail and that the Wolf vein segments, northeast striking dipping steeply, represent the east end of the "tail". The central portion of the "tail" is probably represented by structures like the Mitchell-Dart veins. Silver, lead, zinc geochemical anomalies to the west of the Mitchell vein, and on Wolverine and Trout creeks indicate that there are other mineralized structures (yet to be discovered) in the area. The Surprise showing is found within and along the margins of the feldspar porphyry sill west of the Wolf mine and the Wolf vein itself has what appears

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to be a heavily carbonatized porphyry along its east wall showing an intrusive-mineralization relationship similar to that found in the southern "tail" of mineralization.

The ore deposits on the Dolly Varden property occur along the main caldera subsidence structures in zones where the original quartz-carbonate mineralization has been brecciated, crossfaulted and fractured allowing re-mineralization by two or more phases of silver, lead, and zinc bearing hydrothermal solutions.

The crossfaulting of the main structure appears to be in response to a different set of stress conditions than those found during the main thrust of Tertiary compression. Displacements along these fault zones are commonly found to be the reverse of displacements found in the Tertiary faulting and offsets are generally less. The faults are thought to precede the major Tertiary faulting and could be classified as occurring in the late Jurassic or during the Cretaceous.

As yet, the mechanics of ore control due to the faulting and brecciation are not completely understood but it appears that the faulting must be at a high angle to the original structure with breccia zones within the structure being formed by a combination of flexure of the structure, deflection of the fault into the structure, and the formation of feather joints within the structure close to the faults. In many instances the crossfaults are themselves well mineralized in proximity to the original structure, the Torbrit mine being a fine example of this with the bulk of the mineralization occurring as lenses in and replacements of a shear zone to the hangingwall of the original structure.

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As may be expected, the thickness of the orebodies varies with proximity to the zones of crossfaulting the thicker portions being immediately adjacent to the fault zones with widths of 40 or 50 feet tapering down to 5 to 20 feet within a few hundred feet along strike from the faults. The Wolf and North Star Mines contain notable examples of this effect. The orebodies may occur within the original structure either to the hangingwall or footwall of the crosscutting fault zones and in some instances may straddle them as at the Dolly Varden Mine where the crosscutting structures are spaced closely enough that the brecciation and re-mineralization has achieved a "bridging" effect from fault to fault. In general, the shape, and plunge of the orebodies are controlled by the attitude of the cross-faulting and the size by the displacement along the fault; for example, the Dolly Varden has 100,000 + tons with 50 ft. displacement, the North Star 250,000 + tons with 250 ft. displacement, and the Torbrit 2,000,000 + tons with 600 ft. displacement.

The first generation of mineralization, occupying the original structure, consists of mainly quartz-carbonate-pyrite and occasionally chalcopyrite and is notable for its local wholesale replacement of wall rock and its tendency to have well developed propyllitized alteration zones adjacent to it wherever it is found. Textures within the mineralization are simple with little or no brecciation present and the mineralization is apparently mesothermal in character.

The second and succeeding generations of mineralization however, are epithermal in character and consist of a quartz-calcite and barite gangue with marcasite, galena, sphalerite, pyrargyrite, and native silver ore minerals. Colliform textures and crustification are

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quite common within the ore body and indicate the brecciated nature of the material replaced. Jasper, jasperiod minerals, and siderite, are usually quite common and the hematite therein is thought to be derived from metasomatism of the wall rock. Barite is generally only present where there are good values in galena, lead and sphalerite, although galena and sphalerite may occur without associated barite. The alteration effects of these later phases of mineralization on the wall rocks are considerably less than the early phase, the area above and in the hanging wall. The Torbrit replacement bodies, for example, shows little alteration except a little bleaching and occasional calcite veining.

The orebodies are typical of epithermal deposits inasmuch as their silver content may bottom abruptly. The maximum vertical range through which economic values in silver have been found to date is 750 ft., however the lead, zinc and copper content increases with depth, and may more than replace, in dollar value per ton, the value of the above lying silver ore body.

In conclusion, the salient factors controlling the location, size, shape and grade of the Dolly Varden Mines' orebodies are:

(1) The orebodies are along main subsidence structures adjacent to a jurassic Volcanic Vent.

(2) The orebodies are localized within the subsidence structure by cross faults at a high angle to the structure which have created breccia zones within the structure.

(3) The mineralization consists of two or more phases:

(a) original quartz-carbonate veining along the subsidence structure apparently mesothermal

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(b) later phases containing silver minerals, lead and zinc minerals obviously epithermal, along the cross fractures and within the breccia zones.

(4) Many of the orebodies are associated with an intrusive/pyroclastic-epiclastic contact.

(5) The size and shape of the orebodies depends upon the attitude of and displacement along the crossfaults.

(6) The grade of the mineralization depends upon the part of the epithermal zone which it is in.

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