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SELECTED AREAS OF COPPER MINERALIZATION

During the course of the work, it was decided to study certain areas of obvious copper mineralization. Three areas were selected, different from each other in the minerals present and in host-rock type. The areas chosen were: (a) Menzies Bay Copper, a group of claims where copper mineralization is associated with pillow lava and interlava sediments; (b) Gowland Harbour, where copper mineralization is associated with pillow breccia, flows, sediments and a major zone of shear; (c) Mr. R. Bennett's Copper Roads Mine on Quadra Island (near the intersection of the Deepwater Bay Road and the Granite Bay Road), where mineralization of Cu is associated with a shear in massive flow rocks.

Menzies Bay Copper Deposit

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The Menzies Bay Copper showings on Vancouver Island are about fifteen miles north of Campbell River via the Island Highway. This area was studied by Jambor (1960) who carried out an extensive study of metals, particularly vanadium in these deposits (Figure 42).

In the Menzies Bay area, a bed of close-packed pillow lava dipping eastward about 8° crops out in a large irregular ellipsoid to the west of the Island Highway. This bed is

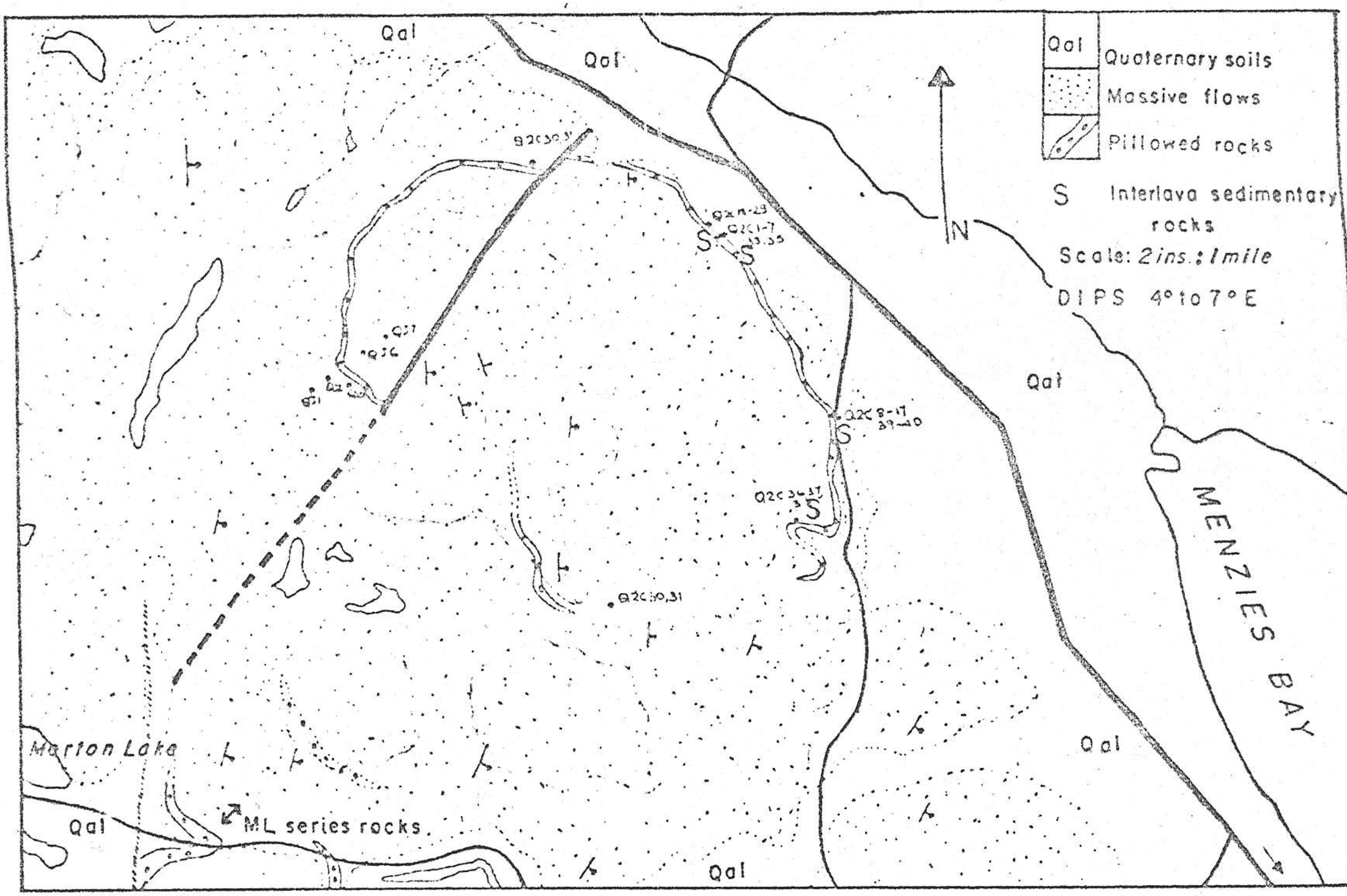

Figure 42.--Menzies Bay area (after Carlisle, unpublished)

overlain by massive basalts and underlain by thin, lenticular sedimentary beds along which much of the mineralization is concentrated. The bed of pillow lava, which averages 20 to 30 feet in thickness, is cut and offset by a northeast trending fault.

The sediments and the pillow lava have been exposed in several trenches and small open cuts. Figures 4, 5 and 6 are diagrams of three of these outcrops. The first, belonging to the Menzies Bay Copper Ltd., lies on Allen 5 claim about one-half mile west of the Kelsey Bay Road. In this exposure only close-packed pillows were exposed. The second, also belonging to Menzies Bay Copper, is about 500 years further west of Allen 5. The third, the Chal-1 excavation, lies off the Mohun Lake Road, and was described in detail by Jambor (1960).

The close-packed pillow lava is about 20 to 30 feet thick, and made up of very close-packed pillows with about 10 to 15 percent interspacial matrix. These interspaces are in part infilled with sediments that have been pushed between pillows. Some tuffaceous matrix, made up largely of rounded globules is found in the second outcrop. In part, the interspaces are also infilled with quartz but to a much lesser extent than in the Kitchener formation.

The pillows are generally well rounded, greenish and very fine-grained. They are elongated horizontally and reach up to 10 feet in length and 3 feet across, but on average the pillows are 4 feet long and 2 feet across. A very thin chilled rim is generally visible. The pillows are non-porphyritic and generally moderately (up to 30 percent) amygdaloidal. These amygdales are typically infilled with quartz (20 percent), pumpellyite (40 percent), prehnite (20 percent) and calcite (20 percent). Toward the sediments, however, epidote replaces the amygdale minerals, and the rock is wholly epidotized near the sediments. In these cases, native copper, bornite chalcocite accompanied by malachite staining are seen throughout the rock. These copper minerals may constitute up to 14 percent of the rock but very locally. The first outcrop, Allen 5, interestingly enough, shows some excellent examples of pipe amygdales in pillows; these pipes are up to 2 inches long, generally straight and vertical and are infilled with either pink prehnite or pumpellyite.

Following Jambor (1960a), the sediments may be divided into four parts from the base up:

1. 0-7 inches of dark grey to black, microcrystalline non-laminated cherty rock containing a few pyroclastic fragments; mineralization of this bed by Cu or V is usually slight.
2. 0-6 inches of very finely laminated vanadiferous black cherty sediment containing a few pyroclastic fragments. This rock is mineralized with abundant vanadium and chalcocite, up to 35 percent, the

deposition of chalcocite apparently having been controlled by the laminations. The laminations are easily apparent due to concentration of malachite. This fissile rock grades downward into the cherty non-fissile rock and upward into the limestone.

3. 0-18 inches of a very dark grey rather impure fossiliferous microcrystalline limestone which weathers into a soft grey crumbly porous rock from which all the fossils have been dissolved. As this rock becomes less cherty upwards, the laminations tend to disappear. In some localities, e.g., Chal-I, the thickness of this bed increases to about 3 feet (Figures 4 and 5). Scattered through this limestone are angular devitrified fragments of porphyritic amygdaloidal flow rock. These fragments range from 4 mm to 8 mm wide, and increase upward in amount, in some cases grading into the matrix of the pillow lava.

4. 0.5 inches of a dark grey, microcrystalline recrystallized cherty rock with a few replaced fossils and up to 40 percent pyroclastic fragments. This layer is overlain by pillow basalts. The pillows immediately in contact with the sediment have chilled rims up to an inch thick and commonly at

the boundary between the chilled rim and the core of the pillow there is found a string of irregular amygdales.

The amygdaloidal metallic mineralization consists of native copper, with traces of bornite and chalcopyrite. Fractures, shears, quartz veinlets and the interstitial quartz of the pillow lavas also contain copper, chalcocite and its alteration products. The one dyke found in this area (Figure 5) contained no copper minerals, and analysis of three samples from this dyke showed Cu contents of 87, 103 and 168 ppm Cu, very similar as compared to the adjacent pillows and sediments.

Epigenetic metallic mineralization in the laminated sileceous sediments consists almost entirely of chalcocite. In the overlying limestone native copper is visible, but even here the sulphide is still predominant.

Oxidation of copper and vanadium produces a variety of colorful supergene minerals, of which brochantite, malachite and azurite are most abundant. Volborthite, a hydrous copper vanadate, is also seen.

Copper Content

The values for Cu content are shown on Figures 4, 5, and 6 and Table II. These values indicate a generally high level of copper in these rocks.

In general, highest values obtained are those from sediments or from rocks in close proximity to these sediments. This region is also coincidental with the zones of strong epidotization (Figures 4 and 5).

The Chal-I exposure is particularly interesting in that the epidotized area occurs around the "syncline" (Figure 4). Ellsworth and Gunning (1932) obtained similar values for the copper content in these rocks.

Mineralogy of Menzies Bay Deposits

Copper has been identified in the following minerals in the Menzies Bay area:

1. Apparently primary minerals

   native copper

   chalcocite, covelite, bornite, chalcopyrite

2. Clearly secondary minerals

   cuprite, tenorite

   malachite, azurite

   brochantite, copper sulphate

   volborthite

Native copper (Cu).--Native copper is found in amygdales of flows, in limestone and in pillow lavas. At Menzies Bay, in one outcrop (Figure 4) the native copper constitutes up to 15 percent of the pillow lava. In polished sections of limestone, some of the mineral is seen to occur as a few disseminated grains, but it is mostly associated with chalcocite, often sharing boundaries with chalcocite or surrounding chalcocite grains.

The native copper occurs in rounded as well as irregular grains, ranging up to 1 cm. across but averaging about 0.25 cm. Under the microscope, it is seen that the copper is disseminated in very fine grains throughout the tuff and pillows at Menzies Bay. It occurs commonly as blebs within prehnite and it has been suggested that the pink color of prehnite is due to inclusion of native copper (Surdam, 1967). Though usually present as blebs within prehnite, crystallographic control of native copper by prehnite has been observed. Native copper also replaces tuff globules. When the copper content decreases to about 5 percent, the tuff matrix is preferentially mineralized.

Chalcocite Cu_2S and Covellite (CuS).--Chalcocite and Covellite are usually intimately associated and are most readily described together.

Chalcocite is distributed throughout the Menzies Bay area. It occurs as amygdale fillings, sometimes by itself but more often associated with covellite, or with pumpellyite and epidote. Very locally it also makes up to 25 percent of the cherty interlava sediments, and is found in veinlets, fractures and shears. Chalcocite grains are amoeboid and irregular in outline, averaging 0.2 mm. but commonly ranging up to 3 to 4 mm.

Alteration of chalcocite to covellite is substantial in some places. Covellite has been observed replacing chalcocite but not as an exsolution mineral.

Bedding and compositional difference in the sedimentary rock exhibit some influence on sulphide deposition, mineralization being concentrated chiefly along the finer laminae. Veinlets for the most part conform to the bedding and their boundaries with the wall rock may be diffuse. The second principal mode of occurrence of chalcocite is as a myriad of closely-spaced blebs (Plate), which tend to be concentrated along the bedding.

Where quartz is abundant as large masses, chalcocite may occur within the quartz. The chalcocite may also partially replace or surround pyroclastic fragments.

<u>Chalcopyrite ($CuFeS_2$) and Bornite (Cu_5FeS_4)</u>.--Both chalcopyrite and bornite are disseminated throughout the rocks, though rarely amounting to more than 0.5 percent, and usually occurring as the odd grain. They tend to occur in amygdaloidal quartz, and have been identified in plagioclase crystals.

<u>The secondary minerals</u>.--The secondary minerals occur as stains and concentrations along fractures and along the laminations as well as stains on the rock face. These include cuprite, tenorite, malachite, azurite, bronchantite and volborthite. These minerals are minute in quantity, and are caused by the oxidation of the copper minerals. They are of no economic importance.

Geologic Control of Mineralization

To the northwest of these deposits is a northeast trending fault which offsets the pillow bed. It is conceivable that hydrothermal fluids ascended this fault perhaps deriving Cu from rocks on either wall of the fault. These fluids may have been tapped by the permeable sediments and pillow lava. However, it should be noted that innumerable faults of similar magnitude occur elsewhere in the region and are not associated with enriched copper mineralization. These faults, however, may not have had access to permeable rock; the very close association of copper enrichment with pillow lava and sedimentary beds enhances the importance of permeability. The only other unusual feature in the area is a thick sill-like basalt layer which overlies the pillow lava. This sill may have acted as a barrier, impermeable to the mineralizing fluids.

Values for Cu content obtained on rocks on the west side of the fault are low, averaging 110 ppm. It is conceivable that during mineralization, the pillow lava bed may have been dipping westward. This would force the fluids to travel eastward in the pillow lava bed resulting in the present distribution of high copper values east of the fault.

It would be appropriate here to mention briefly the world-wide association of copper with pillow lava and interlava sedimentary beds. The best known occurrences of this association are the Troodos Igneous Complex, Cyprus, and the Keewatin basalts, Ontario.

The copper mineralization of the Troodos Complex is restricted to the Troodos Pillow Lava Series (Bear, 1960), which consists of two members. The lower member has been partly albitized and silicified, but the upper member has neither been albitized nor silicified. Both these members have been heavily mineralized by sulfides and Bear (1960: 88-89) attributes this to the fact that they were favorable host rocks. The mode of emplacement appears to have been a volcanic-exhalative process at or near surface (Bear, 1960; Hutchinson, 1965).

The copper deposits associated with the Keewatin basalts are largely limited to the interlava sedimentary beds and pillow lava (Moorhouse, 1965). Large sulfide veins are the producers of copper; these, Hutchinson (1965) suggests were emplaced by the same process as in Cyprus but later metamorphism caused limited mobilization of the sulfides.

These pillow lavas are not considered to be similar to the pillow lava of the Karmutsen Group they have a long history of metasomatism and metamorphism. In all the three cases, however, there is preferential copper mineralization of permeable beds.

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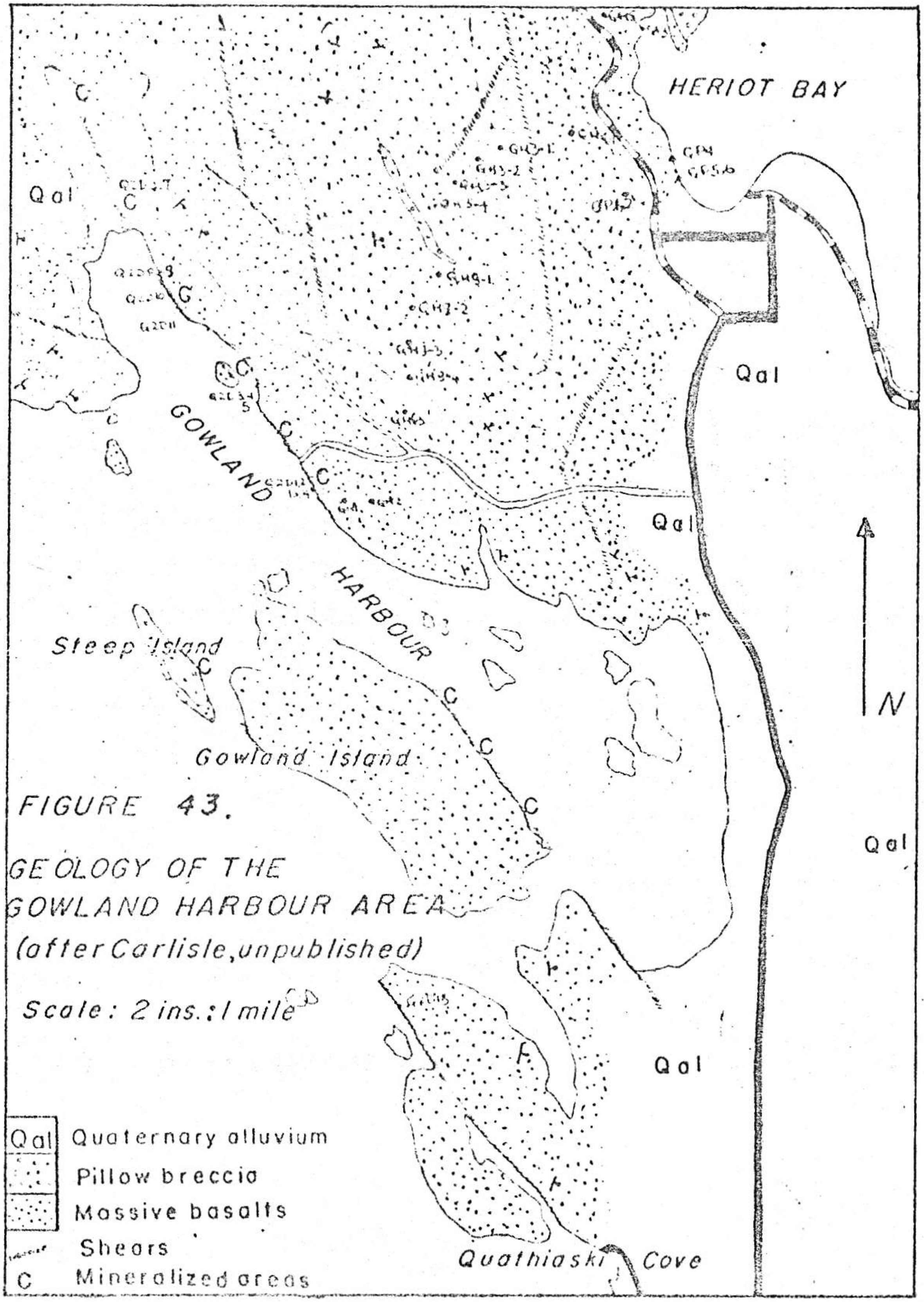
Gowland Harbour Area--Pomeroy Showings

On Quadra Island some of the Upper Menzies Formation flows contain small amounts of sulfides, in particular chalcocite, in vesicles and along fractures and shears. In addition, however, a black vanadiferous sediment essentially identical with that at Menzies Copper, bearing Cu minerals occurs at the north end of the Gowland Harbour area associated with pillowed volcanics also enriched locally in copper (Figure 43). The sediment, seldom more than 6 inches thick, is an irregular, finely laminated black or grey seam occurring between flows. In the middle the seam appears crenulated due to squashing between pillows. Only one of these beds was seen, though Carlisle and Gunning (1944) described three of these in presently infilled open cuts. The open cuts were also studied by Jambor (1960).

The layers of black sediment are about one to two inches thick in general and appear to have been rolled and squeezed into cracks and into interstices of overlying pillows. Jambor (1960a) found volcanic breccia (pillow breccia) below the sediment in two pits, and in the third the sediment was present as a matrix between pillows.

The vanadiferous sediment is a dense, hard dark grey to black rock which is generally found as discontinuous irregular coatings interlayered between lavas. Although fine laminations are conspicuous in thin sections of the sediment, they are difficult to discern in most hand specimens. Occasionally these laminations may be highlighted by concentrations of malachite. They are also apparent in strongly weathered surfaces. The sediments are generally fissile.


HERIOT BAY
Qal
GOWLAND
HARBOUR
Steep Island
Gowland Island
Quathiaski Cove
N
FIGURE 43.
GEOLOGY OF THE
GOWLAND HARBOUR AREA
(after Carlisle, unpublished)
Scale: 2 ins.: 1 mile
Qal Quaternary alluvium
Pillow breccia
Massive basalts
Shears
C Mineralized areas

In polished thin sections, quartz and a brownish substance, possibly organic are seen to be major components of this sedimentary unit. Chalcocite is sparse compared to its occurrence in the beds at Menzies Bay Copper but it is the dominant copper mineral, making up to 15 percent of the rock. Chalcopyrite and occasional bornite are present, and amount to a further 2 to 3 percent of the rock. Since the sediment contains copper minerals, the surfaces of these rocks are stained by malachite, and lesser volborthite and azurite. Similar sediment has been described on Steep Island (Jambor, 1960:24).

The dominant feature of the Gowland Harbour copper-bearing area is a long shear zone trending northwest, whose average width is about 10 feet (Figure 43).

The mineralogy of the Gowland Harbour deposits is similar to that of the Menzies Bay Copper and will not be repeated. High values obtained in the sheared and fractured epidotized rocks fall off rapidly away from the shear and it appears that the copper in the basalt next to the shear may have been leached. Cu content of these leached rocks has decreased to about 60 ppm while the Cu content of the sheared rocks has increased in some places to between 5,850 and 19,500 ppm, i.e., 0.5 to 1.9 percent Cu.

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Copper Roads Claims (Bennett's Mine)

The only producer at this time in the area studied is the Copper Roads Mine. This mine is located along an east-westerly trending shear about 15 feet wide in which the rocks have been highly fractured and epidotized (Figure 44). The shear extends for about 5000 feet, the mineralization being invariably associated with it. However, the mineralization is not continuous, occurring in pods about 15 feet wide and about 50 to 100 feet long. Much of the shear is not mineralized enough for economic mining.

The minerals found in this shear were chalcopyrite, bornite, chalcocite, covellite, tetrahedrite, native copper, magnetite and pyrite. Secondary copper minerals--malachite, azurite, and some tenorite--were also observed. The gangue minerals are quartz, calcite and epidote, the textures, mineral relations, and the copper minerals suggesting a mesothermal origin.

Chalcopyrite, $CuFeS_2$, occurs closely associated with quartz. It usually appears as large irregular grains but is found also as encrustations on quartz and calcite, and often closely associated with bornite as intergrowths. Chalcopyrite mineralization accounts for about 25 to 30 percent of the ore mined. Some chalcopyrite also was found outside the main shear zones as infillings in veins associated with calcite and epidote.

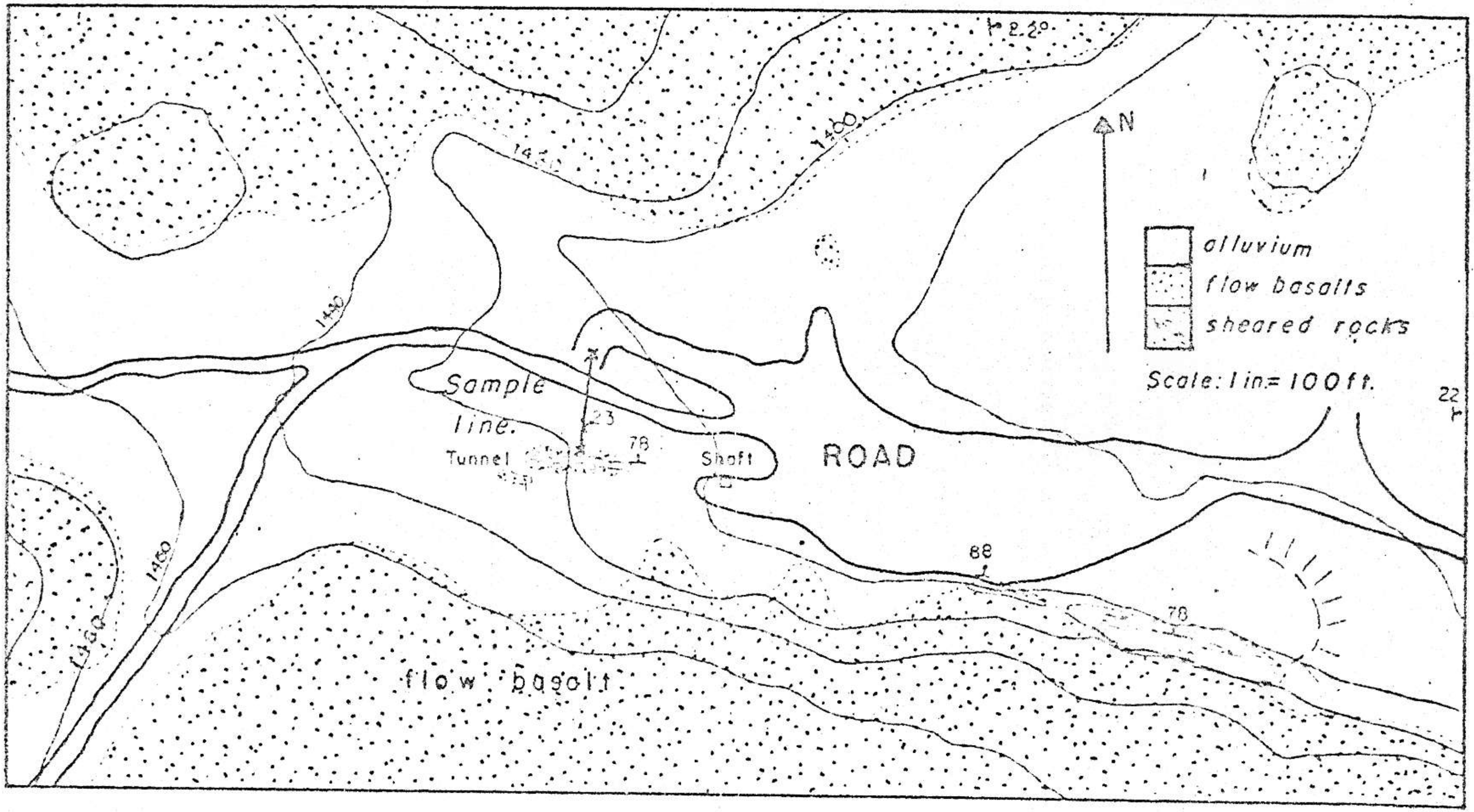

Figure 44.--Geology of the Copper Roads Area, Quadra Island

Bornite, Cu_5FeS_4, is the most abundant copper mineral. It is generally closely associated with chalcopyrite when massive and with calcite when disseminated. Bornite is weathered very extensively and generally is coated with an encrustation of covellite, malachite, and azurite. It alters to covellite along fractures and cracks. Bornite is found in veins up to 4 inches thick in the shear zone, generally with 10 to 15 percent calcite. Bornite mineralization accounts for 50 to 60 percent of the ore mined.

Chalcocite, Cu_2S, is found disseminated with chalcopyrite and generally tends to form a zone at the edges of the shear. It is rarely found in well developed crystals and tends to be associated with epidotized sheared rock. Chalcocite mineralization accounts for 5 to 10 percent of the ore mined. Usually, it is mixed with some covellite.

On the outside of the chalcocite zone, there is a narrow zone containing tetrahedrite $(Cu,Fe)_{12}Sb_4S_{13}$. This zone is 2 to 3 inches thick and usually impersistent. It is of interest for it shows the presence of antimony. Minor tetrahedrite has also been observed in polished sections.

Native copper has been observed in the outermost zone of the shear. It is very minor and is of no economic importance. Although a rough zoning of copper minerals as described above exists, intimate mixtures of the several minerals also are common, caused perhaps by repeated stopping and starting of fluid migration.

Analyses for Cu were carried out on a series of samples taken along the central part of a single flow at 5-foot intervals measured at right angles to the shear northward up to a distance of 120 feet away from the edge of the shear (Figure 45). The copper content at first decreases very rapidly to below a 100 ppm except near subsidiary fractures. The copper content then increases to about 120 ppm which is the regional mode. The samples were all medium grained porphyritic and amygdaloidal rocks. The degree of epidotization decreases rapidly away from the shear. There is little epidotization 100 feet from the shear.

It is an inviting conclusion that the basalts up to a hundred feet from the shear have been leached, and that the copper thus leached has been reprecipitated within the shear zone. The minor fractures and flow boundaries would permit a reasonable quantity of fluid to circulate through the basalts. A calculation of the chemical budget for copper, however, reveals that the copper originally present in the leached area could not account for all the copper present in the shears at the same elevation along the shear (Figure 45). Nevertheless, much of the copper could have been derived from greater depths; at high enough temperatures deeper along the shear, the rising hydrothermal fluids might have only leached the rocks, carrying away the leached copper until the physical conditions were ideal for deposition.

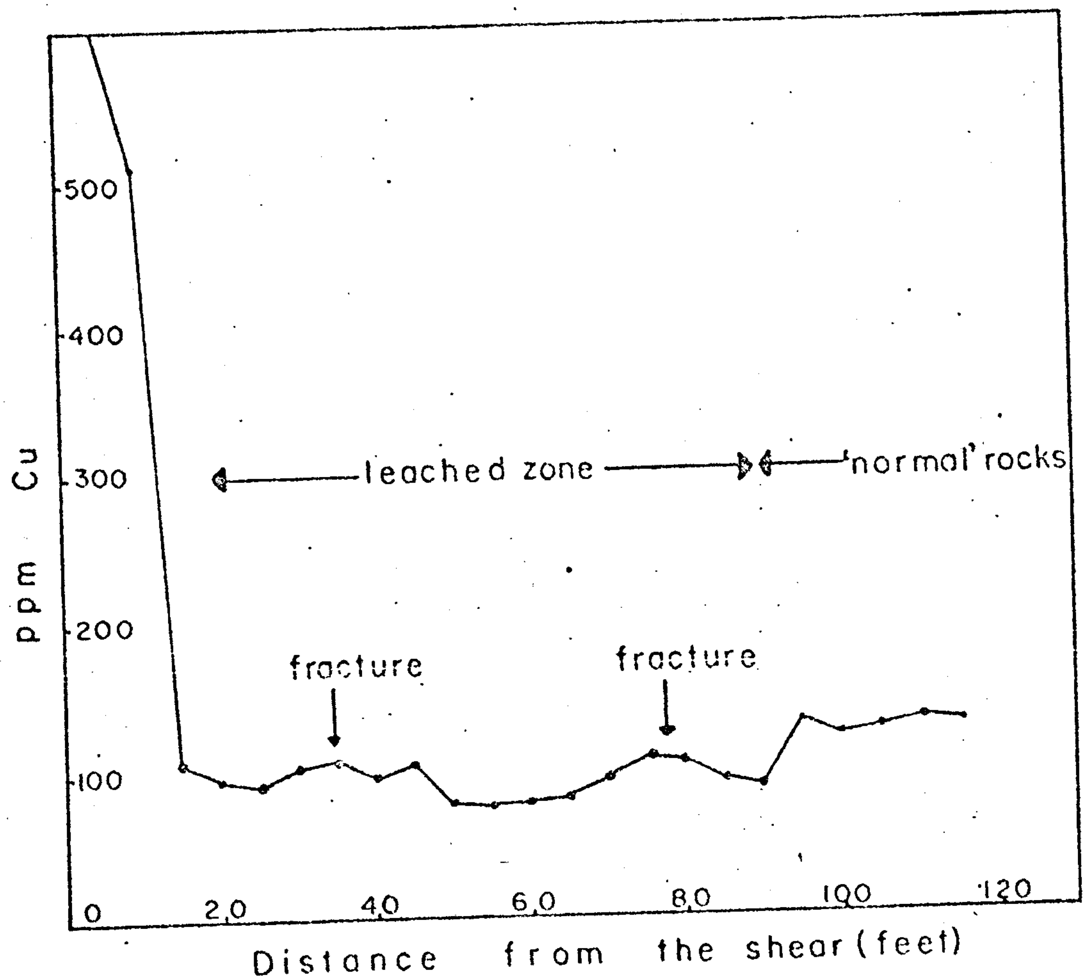

Figure 45.--Distribution of copper away from the shear at Copper Roads Mine

Conclusions

Several factors control the occurrence of the very few highly enriched Cu deposits in the Karmutsen rocks. These copper showings all share certain similarities which are:

1. They are all near or within shear zones. In those cases where the deposits are at a distance from a shear zone, as in the Menzies Bay area, a permeable bed allows the mineralizing fluids to travel great distances. This factor, too, is of importance in the Pomeroy Copper showings at the north end of Gowland Harbour. In the absence of a permeable bed near a fault zone, the copper mineralization is restricted to the shear zone.
2. The copper mineralization is hydrothermal in origin. It appears that copper is mobile only in the presence of hydrothermal fluids and that the fluids associated with the low grade metamorphism of the basalts did neither segregate nor concentrate the copper present in basalts on an appreciable scale. For example, it has been shown earlier that in spite of a large amount of mobile fluid in the Kitchener Formation, no gradational variation of any kind in the content of Cu was found.
3. Bennett's mine represents a higher temperature of mineralization than the Menzies Bay Copper, and

hence the difference in the ratios of minerals of Cu present. Alteration and epidotization of mineralized rocks at Bennett's mine is much greater, and is believed to be due to the higher temperature involved.