PORPHYRIES, BRECCIAS, AND COPPER MINERALIZATION

in Highland Valley, B. C.

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HIGHLAND Valley is 20 miles southeast of Ashcroft in southern British Columbia. The area is on the Interior Plateau at elevations ranging from 4,000 feet to 6,000 feet. Glaciation has covered the country with a prevalent mantle of till. Fluvio-glacial deposits fill the main valleys to depths of as much as 850 feet. The percentage of bedrock exposed is probably less than three per cent, although on the higher ground this amount is greatly exceeded. Rock weathering is confined to places immediately beneath an existing or previously existing cover of Tertiary lava flows. Copper deposits at such places are partly oxidized to shallow depths, and slight secondary enrichment may occur in fault zones.

The copper deposits of Highland Valley are mainly of two related types, namely, bornite-chalcopyrite lodes of small tonnage and chalcopyrite-bornite disseminations of large tonnage. Early production from bornite-rich lodes amounted to several thousand tons of milling ore and a small tonnage of higher grade material. Early attempts to develop one of the large disseminated deposits on what is now Bethlehem property were considered discouraging, and it was not until the boom in copper price of 1955-56 that determined efforts were made to explore this kind of deposit in Highland Valley. Extensive trenching and surface bulk sampling by Bethlehem Copper Corporation in 1955 led to an agreement with American Smelting and Refining Company. From 1956 to 1958 over 50,000 feet of drilling was done and two unsuspected zones of mineralization were discovered. Four sub-commercial copper deposits were found on other properties in Highland Valley. Subsequently, Bethlehem Copper Corporation on their own conducted a tunnelling and underground bulk sampling programme of the two most promising deposits on Bethlehem property. The company is now planning production at an initial scale of 3,000 tons per day from a deposit containing about one per cent copper.

Highland Valley is in the centre of the Guichon batholith. This batholith is about 40 miles long in a northerly direction and about 16 miles wide. It is firmly dated as early Mesozoic. It consists principally of a rather uniform, massive quartz diorite, termed the older quartz diorite, which has been repeatedly intruded by later igneous rocks. Several sizeable bodies of younger quartz diorite were first emplaced in various parts of the batholith. All the bodies of younger quartz diorite are increasingly porphyritic toward their margins, and some consist partly of granodiorite or quartz monzonite.

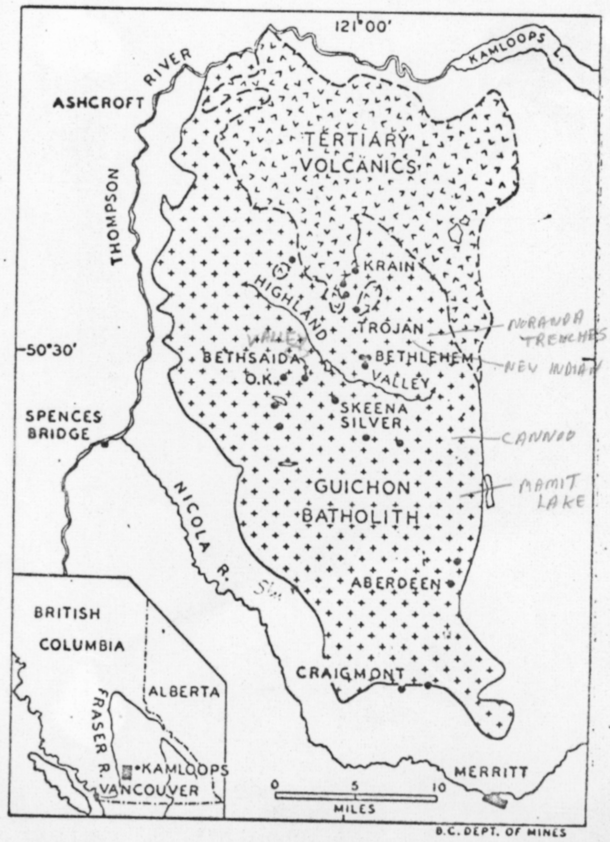

Figure 1. Copper deposits in the Guichon batholith.

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The geology and mineral deposits of Highland Valley were described in 1956 by White, Thompson, and McTaggart.* They were the first to note the structural association of the copper deposits with porphyry intrusions and explosion breccias. At Highland Valley younger quartz diorite extends well beyond the limits of the known important copper mineralization. Probably a single large body of younger quartz diorite extends northward through the Gnawed Mountain area to a highly irregular contact against older quartz diorite on Bethlehem property. More or less tongue-like bodies may extend from this mass to the northwest, north, and northeast, as far as the limits of the map-area.

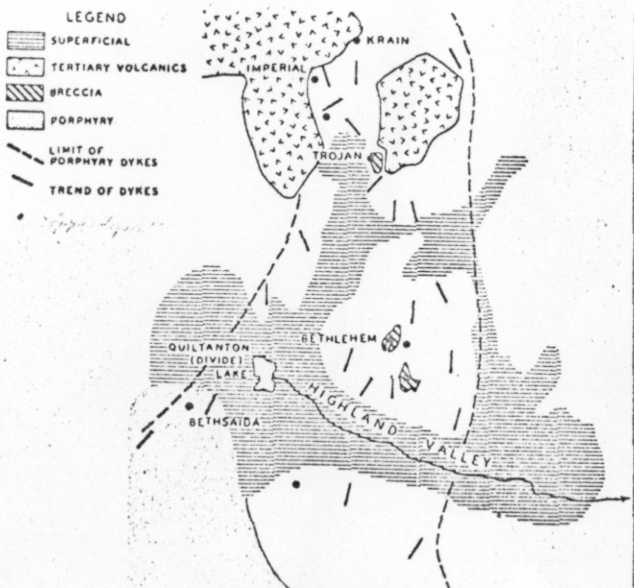
Porphyry intrusions are later than the younger quartz diorite. The porphyries constitute a stock and a dyke swarm which together occupy an area embracing all the principal copper deposits of Highland Valley. The porphyry stock is at least six miles long in a northerly direction and has a maximum width of four to five miles. It consists of uniform granodiorite porphyry which is marginally chilled to an aphanitic porphyry. At Gnawed Mountain the contact is very irregular and breccia has developed adjacent to it.

The dyke swarm comprises numerous porphyry dykes some of which cut the porphyry stock. The swarm has a known length of about 10 miles and a width which decreases northward from about five miles to less than three miles. Porphyry dykes are spaced across the swarm at irregular intervals averaging one dyke every 300 feet to 1,000 feet. The density of the swarm is highly variable; on Bethlehem property and elsewhere, dykes occur very close together. Their prevailing trend varies from place to place as shown, and at some localities there are dykes of more than one trend. They dip generally within 20 degrees of vertical. Individual dykes seldom exceed 100 feet wide and most are less than 60 feet wide. They tend to die out within, at most, a few thousand feet along strike, although one conspicuous dyke persists for at least one mile. Most dykes are of dacite porphyry, but some are quartz latite in composition. The dykes are of more than one age. Correlation of certain dykes with the porphyry stock have been made but cannot yet be considered final.

Breccia is associated with porphyry at three places, namely, Gnawed Mountain, Bethlehem, and Trojan. The composition, fabric, and field relationships leave little doubt as to the manner of origin of the breccia. At Bethlehem it forms inclined, tabular bodies as much as 50 feet wide and extending as deep as 800 feet. Some of the bodies have well-defined contacts, whilst others grade into veined and fractured wallrock. The breccia is a dense, tough rock without voids. It consists of rock fragments in an abundant matrix, which is plentiful enough to prevent almost all contact between the fragments. The fragments are of porphyry together with one, or occasionally both, of the quartz diorites. Porphyry fragments are mostly angular; those of younger quartz diorite are angular or subangular and those of older quartz diorite subangular or rounded.

Fragments of one rock type generally far exceed

*C.I.M. Trans., LX, 1957, pp. 273-289.



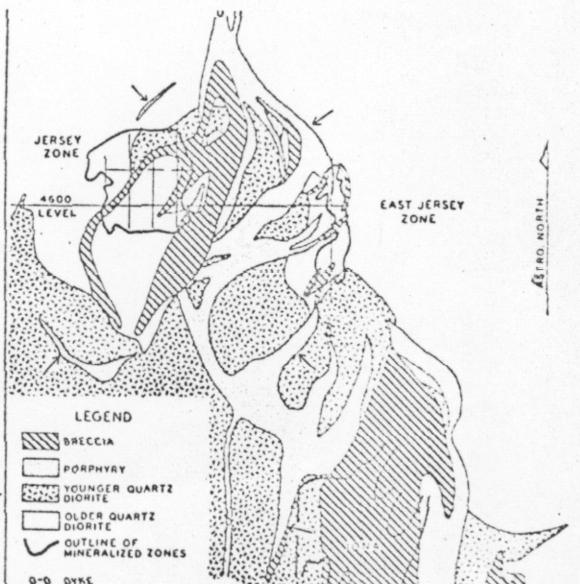


Figure 2. (Left). Distribution of porphyries and breccia in Highland Valley. Figure 3. (Right). Simplified geological map of Bethlehem property.

the others in volume. Although a size-sorting is not always apparent, most fragments commonly range from one-half inch to two inches in size. Porphyry fragments seldom exceed 6 inches, whereas those of older quartz diorite are often from six inches to two feet in size. Still larger blocks occur but they probably represent virtually undisplaced wallrock. In places, the porphyry fragments represent narrow veins in quartz diorite, the whole having been fragmented and injected by matrix without much rotation or separation of the fragments. Tabular, platy fragments of porphyry and younger quartz diorite are common, suggesting that these rocks were well jointed prior to incorporation in the breccia. Such fragments may be sub-parallel over distances of a foot or two; in general, however, the breccia lacks foliation. Ignoring changes due to processes of rock alteration, the matrix of the breccia shows little variation. It is a welded mosaic of sand- and silt-size particles mainly of quartz and feldspar with some chlorite, together with larger, partly broken crystals of feldspar which resemble porphyry phenocrysts. It is concluded that the matrix is mostly porphyry which exploded during its final stage of crystallization. The explosion resulted from intrusion of porphyry under special conditions. The magma entered cold, fractured rock at relatively shallow depths. It split into numerous connected veins which were at once chilled and therefore crystallized. This crystallization was accompanied by a drastic increase in the vapour pressure, which then exceeded the confining pressure. The sudden expansion of volatiles contained in the porphyry caused explosion and the development of breccia.

At Bethlehem, mineralization followed at least two later phases of porphyry intrusion, neither of which are known to cause breccias. The latest porphyry was a quartz latite which forms narrow, irregular dykes and veins, mainly in the East Jersey zone. This porphyry caused introduction of orthoclase into the rocks, including the breccia. Rock alteration of other kinds occurred partly at about this time, and includes silicification, sericitization, and argillitic alteration, as well as the development of tourmaline, fibrous amphiboles, biotite, sodic feldspar, epidote, chlorite, calcite, and zeolites.

At Bethlehem three principal mineralized zones have so far been discovered. They are situated in

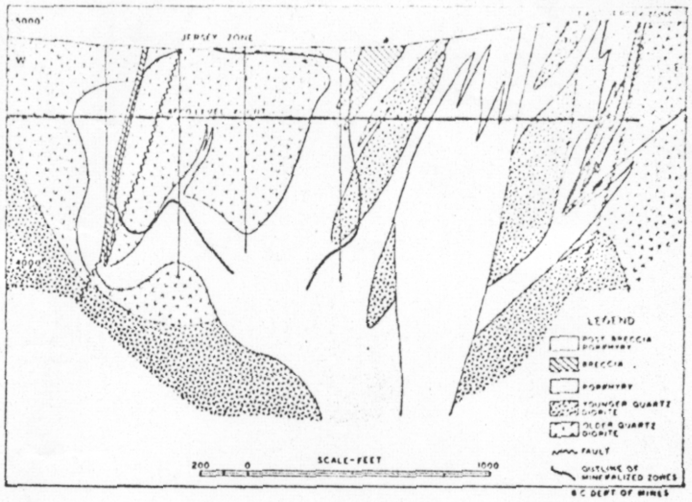


Figure 4. Simplified vertical geological section of Bethlehem property. Not all drill holes are shown.

embayments of the younger quartz diorite, whose irregularly shaped margin played a large part in localizing the mineralized structures. Thus, not only was the older quartz diorite considerably fractured by intrusive pressure from the younger quartz diorite mass, but in addition the younger rock developed a complex system of cooling-joints adjacent to the contact. A porphyry dyke (D-D on the map(intersected this weak zone and was caused to swell and branch, producing a multiple intrusion. The branching sheets dip toward the feeder dyke, and breccia is developed along them or at their terminations. The wider masses of breccia shown on the map, for example at the Iona zone, probably represent a number of breccia bodies separated by screens of less broken rock. Figure 4 illustrates the branching form adopted by the porphyry intrusion. The subsequent mineralization chiefly occurred in places previously subject to repeated fracturing, intrusion, and brecciation. It was preceded, and partly controlled, by faulting. Where the faults intersect previously shattered rock the latter is mineralized for some distance. Thus, the mineralization of the Jersey zone conforms in shape roughly with the enclosing porphyry and younger quartz-diorite, indicating that these masses localized the intense fracturing which allowed sulphide dissemination.

Space Geology Programme

The U.S.A. Department of the Interior announced recently that the Geological Survey has embarked on a $205,000 research programme in Astrogeology financed by the National Aeronautics and Space Administration. This will not entail manned flight by geologists to the moon, but will be limited to geologic analysis of photographs of selected areas on the moon, terrestrial crater studies, studies of material of impact origin such as meteorites, and studies of the mechanics of impacting objects.

In the new studies to be undertaken certain geologic features of the moon will be examined more closely and larger scale diagrams will be prepared of specific areas in the vicinity of landing sites selected for instrument-loaded space vehicles. In order to gain all possible geologic information available in single as well as stereoscopic photographs, existing lunar photographic methods will be supplemented by several lines of investigation.