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Wm. HARRISON WHITE, Ph.D., P.Eng.
Consulting Geologist

Vancouver, B.C.
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MEMORANDUM

To: Bethlehem Copper Shareholders

From: Wm. H. White, Consulting Geologist

Subject: A Comparison of Porphyry Copper Ore Deposits and the Highland Valley Deposits of Bethlehem Copper Corporation Ltd. (N.P.L.)

Despite the fact that huge very low grade deposits known as "Porphyry Coppers" account for roughly three-quarters of the world production of copper, the Canadian investor and mining engineer alike knows relatively little about them because no deposits of this type are presently being mined in Canada. As exploration at Highland Valley proceeded and it became evident that we were dealing with deposits of the Porphyry Copper type, it seemed advisable to learn more about this type of deposit than can be gleaned from the literature. In consequence, this Spring your President and I visited a number of Porphyry Copper mines in the Southwest United States. Operations visited included Silver Bell; Ajo; San Manuel; Ray; and Morenci in Southern Arizona and Santa Rita in New Mexico. Other deposits of the same general type include Bingham Canyon, Utah; Cananea, Mexico; Braden, Chile: Chuquicamata in Chile; and the great new deposit under development at Toquepala in Peru. Our visits and discussions with the local engineers proved most enlightening and this memo will seek to summarize the salient features of the Porphyry Copper operations and relate them to the Bethlehem Copper operation at Highland Valley, B.C.

THE PORPHYRY COPPER DEPOSITS OF THE SOUTHWESTERN STATES

1. GENERAL GEOLOGY

Porphyry Copper deposits find their homes in and around complex stocks, dykes and sills of porphyritic igneous rock that probably was formed relatively close to the surface in areas of strong crustal disturbance. The rocks probably represent the basement of volcanic edifices long since destroyed by erosion. In some deposits such as Morenci and Santa Rita and also at Cananea, Braden, and Toquepala, evidence of explosive volcanic activity is preserved in irregular pipe-like structures filled with rubble that are referred to as "breccia-pipes". None of the deposits are particularly old geologically; they were apparently formed in either Cretaceous or Tertiary times. A striking feature of the Porphyry Copper deposits is the intensely fractured nature of the rocks. In few places can one find a piece of unfractured rock more than one foot in diameter. This shattering of the rocks was most important to the formation of the deposits because the fractures permitted ingress of the mineralizing fluids.

2. MINERALOGY

Mineral-bearing fluids that probably represent late emanations from the same source as the porphyritic igneous rocks permeated the fractured area strongly altering the rocks and depositing in the myriad fractures quartz, pyrite, chalcopyrite and a little molybdenite. In only a few Porphyry Copper deposits, however, notably Ajo and San Manuel, is this primary mineralization or "protore" of sufficiently high grade to constitute commercial ore. For example, at Morenci the "protore" runs only .17% copper. A typical Porphyry Copper deposit owes its existence to the fact that, long after it was formed and after it had been exposed by erosion, weathering processes operated to redistribute the copper and enrich certain portions of the lean "protore" to commercial grade. This is roughly what happened during the process of weathering and secondary enrichment:

Surface water seeping down into the fractured outcrops reacts with oxygen and pyrite to form sulphuric acid and ferric sulphate. These powerful reagents attack the chalcopyrite and its copper is released as soluble copper snlphate. If a precipitant such as calcite is present the copper may redeposit above the groundwater table as copper carbonates, silicates or oxides. Otherwise, the copper-rich water will seep down below the water table where it reacts with the primary sulphides present there to form secondary copper sulphides, notably the mineral chalcocite. The effect of this weathering process operating for a long period of time is to produce four more or less distinct zones; first, a leached capping that retains no copper; second, an oxidized zone containing copper carbonates and silicates; third, a zone of secondary enrichment in which the copper content may be enriched anywhere from three to ten times that of the primary ore; and fourth, the low grade "protore", unaffected by surface agencies. In most Porphyry Copper mines, therefore, the zone of secondary enrichment, or "chalcocite blanket", ranging from a few feet to a few hundred feet in thickness is the only commercial ore of milling grade. Ajo is an exception. Pyrite is scarce in this deposit and there is in consequence little or no secondary enrichment. Fortunately, the "protore" there is of commercial grade.

3. EXPLORATION AND DEVELOPMENT

Characteristics of the Porphyry Copper deposits outlined above determine the methods used for their exploration and for preparation for mining. The altered and heavily weathered rocks of the ore zones are soft and easily drilled, and the churn drill or rotary drill, similar to the rig used in the oil fields, is the standard machine used in primary exploration. Tonnage and grade estimates are made from holes drilled on a grid pattern at 300 or 400 foot spacings. In a new operation the drill results are usually checked by some form of underground work. The experience in the mines visited was that such tonnage and grade figures were fairly accurate and in some instances the grade of material mined turned out to be about .1% higher than the estimate.

A major item in the development of most Porphyry Copper deposits is the removal of many hundreds of feet of overburden, barren leached capping, low grade oxidized ore and other unmineralized rock material. Many of tens of millions of tons of such material has to be removed before actual open pit mining can be started. This is a large item of expense in the development of such deposits.

4. MINING

Being formed near the surface and of essentially horizontal tabular shape most Porphyry Copper deposits can be mined most economically by open pit methods. The pit is developed as a series of benches about fifty feet high that spiral downwards and inwards to the bottom, the surface of the bench serving as a haulage way for ore and materials. The ore is blasted progressively from the edge of the benches, loaded out below by power shovels, and thus the pit expands outwards in all directions at a more or less uniform rate. As the pit is deepened and widened the upper levels must be cut back progressively to maintain both an even haulage grade and a safe angle repose on the pit walls. In the open pit mines visited the pit walls had slopes that, depending upon the strength of the rock involved, ranged between angles of 30° to a maximum of 56°. This means that even after a pit is in production a great deal of waste has to be mined and hauled out. Thus, the "stripping ratio" is a vital item in the operation of an open pit mine. In the operations visited the ratio of waste to ore mined ranged from 2:1 to 6:1. One of the nightmares of the open pit operator is that he will find himself "boxed in" so that his haulage costs become prohibitive, and in this connection the local topography has a very marked effect on the cost of the operation. For example, at Morenci the ore body lies in the side and bottom of a deep canyon. Although the pit is nearly a thousand feet deep the rail haul out of the pit is less than two miles and only the bottom two benches have adverse grades. In contrast, at Santa Rita where a pit of about the same depth is developed in more or less flat country, the rail haul out of the pit amounts to 13 miles against an adverse grade of 3%.

The very largest equipment is used in these open pit operations. Power shovels have buckets with capacities ranging from 5 to as much as 9-1/2 cubic yards. In the larger pits diesel- or electric-powered trains having a trip capacity of about 500 tons are the preferred methods of ore haulage. In the smaller pits such as the Silver Bell, 30-ton Euclid trucks are used.

San Manuel deserves special mention because it is an example of a successful underground block caving operation. The ore body extends in a crude "U" shape to a vertical depth of 2400 feet below the surface. The main copper-bearing mineral is chalcopyrite and the ore is not enriched. At the present time the main haulage level is 1500 feet below the surface. Ore above this level is caved in blocks about 200 feet square, drawn through chutes into standard gauge railroad cars, and transported to one of two shafts where it is hoisted to the surface. At the time of our visit the rate of production at San Manuel was 27,000 tons per day.

5. TONNAGE AND GRADE

The Porphyry Copper deposits are remarkable for their huge tonnages of commercial grade ore. Reserves range from around 30,000,000 tons divided between two pits at the Silver Bell to nearly half a billion tons at Morenci. Reserves at San Manuel are reported in excess of 300,000,000 tons grading .785% copper. To an outsider it is difficult in a given case to estimate the grade of the ore actually being milled.

It appears to range from a low of .6% copper to a high somewhat less than 1% copper. A figure of .75% copper is probably close to the average for all deposits. However, the grade of the material being mined, against which mining costs must be charged, includes large amounts of waste; consequently, the average over-all grade of material being mined is very much lower, perhaps as low as .3% or .4% copper. A key figure used in all the operations is referred to as the "cut-off grade". This is the grade at which it becomes uneconomical to send the ore through the mill. The cut-off grade varies according to a number of factors such as the mining and milling costs, the price of copper, and so forth. It ranged between a low of .35% copper at Morenci and a high of .5% copper at Santa Rita. In addition, most of the mines recover small amounts of gold, silver, and molybdenite which are simply regarded as a bonus. Last year the value of molybdenite recovered at Morenci amounted to some $3,000,000.00.

6. MILLING, LEACHING AND SMELTING

The Porphyry Copper mills, or to be more exact, concentrators, are extremely simple and efficient. A bulk flotation concentrate is taken off which is recleaned and from the recleaner flotation circuit the molybdenite is recovered as a by-product. At three of the Arizona operations, Silver Bell, Ajo, and Morenci, the mills were conveniently located adjacent to the mines, but at the others the rail haul to the mill for crude ore varied from 8 to 23 miles.

A considerable additional amount of copper is recovered by a process that is known as "heap leaching". The material that is below the cut-off grade or material of higher grade that contains a large proportion of carbonates is put in a separate dump which is sprayed with water. Over a long period of time the water dissolves some copper and is collected in troughs below the dump from which the copper is precipitated. This copper which would otherwise be lost is also regarded as a bonus. It is not figured in the ore reserves.

The modern trend is to have the smelter immediately adjacent to the mill, and all the deposits visited with the exception of Silver Bell either had this arrangement or were in the process of building smelters. Great savings are effected by such a setup in both transportation charges for concentrate and custom smelter charges. The daily tonnages milled at the operations visited are as follows: Silver Bell - 7,500 tons; Ajo - 31,000 tons; San Manuel - 27,000 tons; Santa Rita - 25,000 tons; Ray - 15,000 tons; and Morenci - 52,000 tons.

A problem closely connected with milling and also with the operation as a whole is that of water supply. Water is extremely short in southern Arizona and the necessary supplies are obtained at great expense, mainly from wells. For example, Ajo has two shafts 700 feet deep and a system of galleries that collect seepage from a porous volcanic formation. This water is pumped 6 miles to the mine. At Morenci water is obtained from the Gila River valley, 50 miles away and is pumped over a mountain range. Due to the shortage of water, great economies in its use have been instituted. Despite the great loss of water due to evaporation in the extremely dry southern Arizona climate roughly 80% of the water used is recovered and new water required for the operation amounts to a mere 200 gallons per ton of ore milled.

Now, with the foregoing summary in mind, let us compare the copper deposits in Highland Valley owned by Bethlehem Copper Corporation Ltd. with these Porphyry Copper deposits, and attempt to look a little way into the future.

THE COPPER DEPOSITS OF HIGHLAND VALLEY, B.C.

1. GEOLOGY AND MINERALIZATION

The deposits lie in a complex of igneous rocks that is intrusive into the older granitic rocks of the Guichon Batholith. Much of the rock is fine-grained and porphyritic suggesting a near-surface or subvolcanic origin. A vital element in the geology of the area is the presence of several breccia bodies, composed of angular fragments of all rocks in the area cemented by finely pulverized material. One such body comprises much of the Iona Zone, another is present in the Jersey Zone, and a third is known at the Trojan property some distance to the north. Breccia probably occurs also in the Simons Zone but its limits have not been mapped in detail. These breccias are interpreted as irregular pipe-like bodies formed by subvolcanic explosive activity.

As a result of earth movements that accompanied this subvolcanic activity the rocks within and around the breccia pipes were severely faulted and jointed. Thus the rocks were made permeable and prepared to receive the mineralizing fluids. Minerals deposited in the myriads of fractures and also by replacement in contiguous rock include quartz, tourmaline, specular hematite, chalcopyrite, bornite, molybdenite and only a little pyrite. The presence in these deposits of bornite, a copper-iron sulphide that contains almost twice as much copper as chalcopyrite, is a fortunate circumstance not found in many of the Porphyry Copper deposits.

The Highland Valley deposits have been but slightly affected by surface weathering. In the Jersey Zone virtually fresh sulphides occur almost at the rock surface and in the Iona Zone copper carbonates are prominent to a depth of only about 100 feet below the surface. Due to the scarcity of pyrite there is little or no secondary enrichment and in consequence, there is no leached capping to be removed.

The Highland Valley deposits have all the essential characteristics of the Porphyry Copper type. Mineralogically they most closely resemble Ajo, and structurally they conform to the breccia-pipe type such as that at Cananea, Mexico. As a result of their relationship to breccia-pipes the Highland Valley deposits are comparatively deep in proportion to their lateral extent. For example, in the Jersey Zone mineralization of commercial grade is known to persist throughout a vertical interval of more than 1200'.

2. EXPLORATION AND DEVELOPMENT

Current development is by diamond drilling using machines that drill 3" diameter holes. To date some fifty holes amounting to about 45,000 feet have been drilled. Thus far no churn drilling has been done as it is thought that the rocks are too hard to obtain much progress by this method. However, a churn drill is to be tested on the North Simons development in the near future. Exploration to date is considered to be highly successful, and exploration cost per ton development has amounted to something less than 10¢ per ton.

Preparation of the Iona and Jersey Zones for open pit mining will be comparatively simple and inexpensive. On the Iona Zone a little overburden and about 100 feet of leachable carbonate ore will have to be stripped. Preparation of the Jersey Zone will only involve the removal of less than 60 feet of overburden.

3. TONNAGE AND GRADE

To date the total of Inferred and Indicated ore amounts to about 100,000,000 tons in the Iona and Jersey deposits. For the Jersey Zone I have reported about 58,000,000 tons as Indicated ore, that is, ore that is virtually proven reserve. Of this amount 30,000,000 tons have been separated out as a unified mineable block that will grade about .8% copper. Incomplete results from holes now in the process of drilling suggest that in the near future the indicated reserves of the Jersey Zone will be substantially increased.

The reserves developed to date are certainly cause for satisfaction. Although the reserves do not as yet approach those of the large Porphyry Copper mines that have been under development for the past fifty years they exceed, however, the reserves of the successful Silver Bell Mine of A.S. & R. in Arizona. In addition to copper, the Highland Valley ores contain low but persistent values in molybdenite, gold and silver. Although these metals have not been consistently assayed for, it is reasonable to expect that their recoverable value will amount to about 50¢ per ton.

4. MINING PROBLEMS

The comparative hardness of the rocks at Highland Valley will mean somewhat increased drilling and blasting costs. On the other hand, the stripping ratio for both the Iona and Jersey Zones is apt to be relatively low because of, first, the favourable shapes of the ore bodies, and second, the hardness of the rock that will permit steep pit walls.

A most efficient open strip mining operation could be established on the Iona Zone. Because of the local topography an open pit mine on the Iona Zone would have favourable haulage grades to a vertical depth of about 400 feet.

Mining of the Jersey Zone would be a somewhat different problem because this ore body is relatively deep in comparison to its width.

However, the ore body could be readily mined by open pit methods to a vertical depth of 500 or 600 feet. Skip haulage, or underground haulage might prove to be economical alternatives to surface haulage with steep adverse grades. For the deeper ore the example of San Manuel might well be followed. As the ore is highly fractured it should offer no great difficulty to recovery by underground block caving methods.

5. MILLING

Preliminary tests indicate no great problems in the milling of Highland Valley ore. Both a high percentage recovery and a high grade copper concentrate are indicated. Ample room is available in the area for waste dumps and tailing disposal, and the mill could be located close to the mines.

No great difficulty is anticipated in the matter of a suitable water supply. Although the surface water rights are alienated for agricultural purposes strategically placed dams could suppy sufficient water for all mining and milling purposes. Fuel and power requirements should offer no great difficulty either. Electric power is available at Ashcroft, 30 miles distant, and a natural gas pipe line passes within ten miles of the property. Last, but not least, Highland Valley is a resort area of great beauty and it would be an ideal location for a mining townsite.

The question of a smelter need not be considered in detail at this time. However, it has been pointed out that the trend in the Southwest mining areas is to build smelters close to the mining operations. In the event that the American Smelting & Refining Company remains the chief operator at Highland Valley it is likely that it will wish to ship concentrates to its smelter at Tacoma, Washington, which is now faced by dwindling supplies of domestic concentrates. On the other hand, should other companies attain successful production at Highland Valley, a custom smelter in the area would become a distinct possibility.

6. CONCLUSIONS

From the foregoing it should be evident that the Highland Valley deposits are of the Porphyry Copper type, the first of its kind to be developed in Canada. These deposits compare favourably in all aspects with the operating Porphyry Copper mines of the American Southwest and there appear to be no major difficulties in the way of the establishment of similar large scale mining and milling operations at Highland Valley., British Columbia.