HEAP LEACH EXPLOITATION IN THE DAWSON RANGE, YUKON, WITH PARTICULAR REFERENCE TO THE NUCLEUS PROPERTY

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January 7, 1985

Introduction

This advisory on possible heap leach application to gold deposits in the Dawson Range, Yukon Territory, is based on field and summary reports provided by Colin Dyson of Chevron. Emphasis is placed on the Nucleus project, but the Mt. Nansen gold occurrence is also considered. It is assumed the reader has access to these reports and is generally familiar with the chemistry of cyanide extraction of gold.

Experience with past heap leach operations has established minimum parameters that should be observed in determining the suitability of any deposit to heap leach technology. Any deposit under consideration should have a minimum of 5,000,000 tons grading at least .032 opt (ounces gold per ton) with gold at $300 per ounce. If the deposit is smaller than this, then the amortization charge climbs to the point where the deposit is not economically attractive. The deposit should be in oxidized or weathered rock so that reagent consumption is minimized. Base metals, particularly copper, should not be importantly present. A copper content above .04% (400 ppm) can result in sufficiently high cyanide consumption so that extraction by weak cyanide solutions is not practical. The presence of some iron sulfide minerals, such as pyrrhotite, marcasite, or very fine grained pyrite can destroy pH control and result in formation of complexes with cyanide. Their presence can raise reagent costs above the break-even point in an operation. Coarsely crystalline arsenopyrite or pyrite, on the other hand, seems to have no effect.

In detail, the mineralogic and physical state of an ore has a bearing on the application of heap leach technology to a specific deposit. However, crushing or chemical pre-treatment can commonly be employed to improve amenability of ores providing the tonnage, grade, and some mineralogic parameters are met. Because the art of accommodating an ore to heap leach exploitation depends on the characteristics of that specific ore, only the Nucleus and Mt. Nansen are further discussed in detailed application. Should either of these be the subject of a heap leach operation, it could be the first in Canada.

Appendix "A" gives the geologic setting of the Nucleus deposit, and Appendix "B" gives the setting of Mt. Nansen. Appendix "C" gives the basis for estimating costs.

Climate

Heap leach exploitation of gold ores requires free movement of the cyanide-bearing leach liquor in the leach dump. Excessive cold or a long winter can reduce the leach season. However, the climate in the Dawson Range is probably comparable to that at Summitville, Colorado. Summitville is located at above 12,000 feet in the southern Rocky Mountains and is mostly above timber line. Summitville has an average annual temperature of 31.4^{o} F, and the mean monthly temperature ranges from 15.1^{o}F in January to 41.0^{o}F in August. Mean monthly temperatures are above 32^{o}F from May through October. Burial of pipes at Summitville extends the leach season from May 1 through December 1 annually. The snowfall at Summitville averages 389.3 inches annually, but because of evaporation and melting, the average spring snow depth is 66 inches. Summitville will be mined at an average annual rate of 3,000,000 tons, and the 1984 test heap program found that the seven-month leach was adequate for an economic operation. It is unlikely that climatic conditions will be economically distinct for the Dawson Range, and for that reason a seven-month leach season should be considered for the Nucleus and Mt. Nansen areas. It is noteworthy that the Pegasus operation in Zortman, Montana, has a climate almost as rigorous as that at Summitville, and their leach season is from March 1 through December 1. Winterizing of the operation permits such an extended leach season.

Costs

Every heap leach operation will have unique characteristics and therefore its own variation of the plant and operating costs. However, all plants include basic piping for carrying leach liquor, a gold recovery facility, and storage ponds. A crushing plant is sometimes also needed, as is also an agglomeration unit.

Capital Costs: Because each deposit has unique characteristics, each operation has its own plant requirements and capital costs. However, Lacana at Relief Canyon, Nevada, has a typical plant for a deposit that contains 9,000,000 tons of .032 opt. The stripping ratio is about 1:1. Lacana has announced that its capital cost to bring Relief Canyon into production will be U.S. $7,000,000, or less than a dollar per ton. Had a crusher also been required, then an additional U.S. $6,200,000 would have been tacked on to the basic plant. On the basis of the descriptions of Nucleus and Mt. Nansen ores, it is assumed that neither crushing nor agglomerating will be required. However, only testing can ultimately decide both questions.

Operating Costs: The standard for unit operating costs for the industry was established by Pegasus at Zortman, Montana. On a per ton basis, their costs, including mining, plant amortization, reagents, pad construction, overhead, taxes, brokerage, marketing, and the various minor costs attendant with any operation, comes to U.S. $6.50. This is for a mine with a 1:1 stripping ratio, but no crushing or agglomerating. Crushing would add about one dollar per ton, and agglomerating would add about U.S. $1.25 per ton. With total costs of U.S. $6.50 per ton, it can easily be calculated that their breakeven with gold at U.S. $300 per oz. and a 70% recovery in leaching comes to a head of .03 opt. Below .03 opt they lose money. Should their recovery rise to 80%, then their breakeven head drops to .027 opt. By constant testing, Pegasus can determine what the breakeven grade is and to adjust its mining accordingly. Other well managed heap leach operations have a similar regime of ore control.

Testing

Metallurgical testing is vital at all stages in the development of a heap leach operation. During exploration, testing can determine if the technology is applicable. If it is, continued testing can show what reagents are likely to be needed and how the heaps can be constructed and treated. If crushing or agglomeration are needed, then tests will disclose their needs at an early date. Tests, including column leach tests, conducted by experienced metallurgists, can fairly accurately forecast recovery rates, reagent consumption and operating costs.

Heap Leach Technology Applied to the Nucleus Project

The Nucleus property (including the adjacent Nitro claims) is located in NTS 115 I/6 at approximately 62°20'N Lat. and 137°20'W Lat. The geology of the area is described in Appendix "A", and only those factors pertinent to a heap leach operation are considered here.

The Nucleus mineralization could be considered to have affinities to a porphyry copper system. The gold occurs in breccias, veins, and veinlets with silica and sulfides, including iron sulfide species and base metal sulfides. Fortunately, oxidation is pervasive at and near the surface, and the exploitable gold occurs within a leached cap.

The host rocks are altered microgranite or breccia of microgranite and schist. Altered quartz-feldspar porphyry dikes are also present. Alteration consists of a hypogene sericitic and argillic core with a peripheral zone of weaker argillization. It is assumed that the gold mineralization coincides with areas of core sericite-clay alteration, and that the silicate minerals developed in the gold zone are feldspar, sericite, illite, and kaolin. If this is correct, then the host rocks should remain chemically inert to the passage of alkaline cyanide solutions. Physically, it remains to be determined if the alteration products will support openings in a leach dump.

Mineralization is described as including "quartz" and "chalcedonic quartz" veins with sulfide. It would be wise at this time to verify the presence of chalcedony petrographically. In many deposits where gold encapsulation is a problem, it is chalcedony and not quartz that protects the gold from attack by cyanide. Quartz, because it is crystalline, rarely prevents entry of cyanide through capillary action. The demonstrable absence of chalcedony would lessen the eventual threat of incomplete gold leaching because of silica encapsulation.

Hypogene sulfides include pyrite, pyrrhotite, sphalerite, arsenopyrite, galena, and chalcopyrite. Their oxidation products include limonite and traces of malachite, azurite, and probably copper oxide not visually detectable in the limonite. These copper minerals are readily soluble in dilute cyanide solutions, but assay data available suggest that the gold-rich oxide zones carry less than .04% Cu. Cyanide loss due to copper complexing should therefore remain at tolerable levels. The copper content in all future drilling should be carefully monitored. Both zinc and lead contents seem to average less than 100 ppm and neither therefore poses a problem. The pyrrhotite may be forgotten because we are considering only oxide ore. The original pyrite content is assumed to have averaged 3-5% of the rock volume. If this is true, then the limonites developed probably carry only minor jarosite or other basic sulfates. It is therefore predictable that pH control for tests and an eventual operation will not be a problem. The normal "poisons" accumulated by cyanide and found in this type of deposit do not appear to be excessive. The mercury, bismuth and antimony levels are low and the arsenic is not a threat. In summary, the mineralogy of the gold-bearing capping suggests no chemical problems for a heap leach operation.

If economic data from Pegasus are applied to the Nucleus deposit, assuming U.S. $6.50 per ton total costs, U.S. $300 gold, and a 70% recovery, the 5.62 million tons averaging .027 opt indicated in the anomaly 1 and anomaly 2 blocks are not economic. At a breakeven grade of .030 opt, only 4.56 million tons are indicated, which is short of the 5.0 million ton minimum. A grade of .036 opt only provides 3.13 million tons. Although that grade may be attractive, the tonnage has declined to the point where no operation could be considered. It is clear that at the current gold price, the tonnage of + .030 opt material is not adequate to provide for an economic operation.

The adjacent Shakwak property appears to have both the geological and geochemical indications of having mineralization identical to that in the Nucleus anomaly 1 and anomaly 2 blocks. Therefore it is clear that no decision should be made on the Nucleus ground until the Shakwak targets can be tested to Chevron's satisfaction.

Further trenching on the Nucleus ground may also expand its tonnage potential. In view of the near economic targets developed to date, it is pertinent for Chevron to complete the exploration of all suspect terranes on their holdings and on adjacent ground. Possibly what remains to be found can be decisive in the evaluation of the project.

Test work on Nucleus bulk samples taken from trenches can indicate leaching rates, ultimate recovery, and the possible need for crushing and agglomeration. Leach tests on core can also provide answers, but bulk samples from trenches, because of the coarser size fraction possible, should be used. Leach tests will also give an indication of reagent consumption. The tests should be carried out by metallurgists experienced in heap leach technology so that the results can be projected to a possible operation.

Heap Leach Technology Applied to Mt. Nansen

The Mt. Nansen gold deposit is described in Appendix "B". Only those factors pertinent to an open pit, heap leach operation are discussed in this section. The gold deposit is located 30 miles west of Carmacks. Mt. Nansen could be considered a zoned district with porphyry copper mineralization in its core. Peripheral to the porphyry are gold-bearing zinc-lead zones and gold deposits. Thus far only the Brown-McDade zone has been investigated, but other zones are known. In view of the results of sampling of the Brown-McDade zone, all of the potential gold-bearing ground at Mt. Nansen should be considered seriously.

The Brown-McDade zone has been trenched, and it is the most intensely studied area at Mt. Nansen. In that area, gold appears to occur in oxidized sheared rock, strongly mineralized rock and in altered wall rock. The sheared rock is comprised of hematized gouge that cuts sericitized mylonitic rocks. The strongly mineralized rock, called the ore zone, is comprised of vuggy silica-sericite-barite replacements and veins. The altered rock is mostly argillized brecciated feldspar porphyry, and it contains feldspar, hematite and quartz. In this setting it can be assumed that the clay alteration is illite and kaolin dominant. The host rocks include granodiorite as well as feldspar porphyry. Only minor schist is exposed in the trenches. It would appear that the host rocks exposed offer no chemical problems for a heap leach operation. Physically, only testing can determine if as-mined muck will make a satisfactory leach dump media. However, the silicification suggests that dump porosity may not be a problem and therefore crushing and agglomeration are not needed.

Hypogene sulfide consists of pyrite, arsenopyrite, sphalerite, chalcopyrite, stibnite, freibergite and ruby silver. However, oxidation persists to at least a 100 foot depth. The gold therefore occurs with limonite and hematite in a silica and barite-bearing gossan. No assay data are available on zinc or copper within the gossan. However, the hypogene sulfide content was described as being as much as 10% by volume, and being mostly pyrite. Oxidation of that amount of pyrite would generate sufficient acid to keep both zinc and copper mobile during weathering. It could be assumed that the copper content of the gossan is less than 400 ppm Cu and that the zinc is not more than 100 ppm Zn. Systematic assays for Cu and Zn are needed for all samples taken in the gold zone. Silver:gold ratios in oxide appear to be in the 5 to 10 range, but unquestionably silver has also been mobile during weathering. The Ag:Au ratio may increase with depth in the oxide zone. In summary, there appears to be no problem (pending complete Cu and Zn assays) for a heap leach operation of the oxidized portion of the Brown-McDade zone at Mt. Nansen.

Sampling has indicated on the order of 1,000,000 tons to be present in the Brown-McDade zone that carries about .1 oz. Au with additional silver. This is assumed to be entirely oxide. Leach tests should be conducted on this material to determine the economics of a heap leach operation (reagent consumption, recovery, recovery rate, operating parameters). It is possible that the Brown-McDade zone is economic on its own.

The tonnage and grade potential indicated thus far at Mt. Nansen is sufficient so that flexability in operating systems is available to Chevron. It is possible that the greatest profitability can be realized by a type of exploitation other than heap leach. Leach test performed at this time can be applied to any cyanide treatment of Mt. Nansen ores and the tests are therefore recommended. However, the encouragement found in sampling of the Brown-McDade zone should also be followed up with aggressive exploration of all of the gold zone at Mt. Nansen.

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Appendix "A"

Geologic Setting of the Nucleus Project

Gold mineralization in the Nucleus project area appears to be part of the porphyry copper complex that occurs in the Mt. Freegold-Yukon Revenue region. In this case the porphyry mineralization is defined by alteration and petrographic affinities rather than metallogenic. The mineralization is characterized by copper, gold, and tungsten, all of which can occur singley or in combination with one another.

The porphyry is related to a Cretaceous igneous complex that includes the following:

(a) Casino Granodiorite (equigranular intrusive that compositionally includes monzonite and quartz-monzonite).

(b) Coffee Creek Granite (equigranular biotite leucogranite).

(c) Mt. Nansen Volcanics (Cretaceous (?) andesitic flows and fragmentals).

(d) Microgranite (small bosses of fine-grained felsic rock).

(e) Quartz-feldspar porphyry (dikes and small plugs of quartz porphyry to feldspar-biotite-hornblende porphyry in composition. Mineralization may be coincident with this unit.)

The Cretaceous igneous complex intrudes rocks of the Yukon Metamorphic Complex. These include granulite, schist, amphibolite, and quartzite. Selwyn Gneiss is also present as is a layered gabbro-diorite pluton.

Within the gold anomaly, numerous breccia zones have been exposed by trenches. The breccias cut microgranite, quartz-feldspar porphyry dikes, and mixtures of microgranite, schist and quartz-feldspar porphyry dikes. The breccias show minimal mixing of fragments, although the feagments are commonly rotated. Clasts and matrix are silicified, especially where microgranite is dominant. Matrix normally consists of quartz, clay, and limonite. Breccia zones often grade along strike into brecciated quartz-feldspar porphyry dikes.

The main gold geochemical anomalies occur in an alteration zone that is 1,100 m long and 300 m wide. The alteration zone includes the breccia and an extensive zone of fine quartz stockworks developed in the microgranite. Pervasive sericite and argillic alteration characterize the alteration zone, and it is surrounded by a peripheral zone of weaker argillization. The mineralogy of the clay alteration is not specified, but illite-kaolin is the suspected type.

Gold mineralization accompanies pyrite, pyrrhotite, arsenopyrite, chalcopyrite and tungsten mineralization. Near the surface oxidation seems to have destroyed all sulfide and converted the iron minerals to limonite. Sulfide appeared to have amounted to 3% of the original rock volume.

The oxide zone contains limonite and hematite as secondary iron minerals and malachite and azurite as secondary copper minerals. The basic sulfates of iron and copper were not identified in the cap.

Gold exposed in the trenches has been also found in three drill holes that tested the trench exposures. The trenching and drilling indicate a potential of 5.62 m.t. of .027 oz. Au to be present in the oxide zone. Possibly .04% Cu accompanies the gold.

Appendix "B"

Geologic Setting of the Mt. Nansen Gold Deposit

Mt. Nansen is an unglaciated zoned district with a porphyry copper core and a peripheral Au-Ag-Zn-Pb zone. The host rocks are Yukon Group gneisses, schists, and amphibolites unconformably overlain by Cretaceous or Tertiary Mt. Nansen andesitic flows, breccias, and agglomerates. Three generations of Cretaceous or Tertiary intrusives cut the older rocks. The oldest are diorite dikes and plugs, and these are feeders for the volcanic rocks. The next are small coarse-grained granodiorite stocks, and the youngest are feldspar porphyry dikes. Mineralization seems to have coincided with the feldspar porphyry stage, because it and all older rocks can be hosts for ore.

Mineralization occurs in complex fault zones that cut all rock types and extend for many thousands of feet along strike. These can be as much as 150 feet wide, including fractured and altered rock in the walls of the main shear. All zones trend northwest to north-northwest and dip steeply west.

In the gold-bearing zones, the wallrocks have an argillic alteration, but this can be assumed to be illite and kaolin dominant. Sericite, clay and silicification accompany stronger sulfide-quartz-barite veining within the shear zones. Sulfide can comprise as much as 10% of the rock by volume.

Hypogene minerals found in the gold zone include pyrite, arsenopyrite, sphalerite, chalcopyrite, stibnite, freibergite, and ruby silver. At and near the surface, oxidation is complete, and it is assumed that most of the Cu, Zn, and Ag have been leached from the weathered rock.

Three areas of gold mineralization are known: the Webber, Huestis, and Brown-McDade zones. Only the Brown-McDade has been investigated to date. Sampling in that zone suggests a minimum potential of at least one million tons carrying in excess of 0.1 opt. Clearly the Mt. Nansen area needs further work.