HEAP LEACHING

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Editor's Note: This article was summarized by the editor from two papers (Trexler, 1987 and 1990) published in Geothermal Resources Council Transactions, Vols. 11 and 14.

INTRODUCTION

Heap leaching for gold and silver recovery is a fairly simple process that eliminates many complicated steps needed in conventional milling. A "typical" precious metal heap leaching operation consists of placing crushed ore on an impervious pad. A dilute sodium cyanide solution is delivered to the heap, usually by sprinkling or drip irrigation. The solution trickles through the material, dissolving the gold and silver in the rock. The pregnant (gold bearing) solution drains from the heap and is collected in a large plastic-lined pond (Figure 1).

Pregnant solution is then pumped through tanks containing activated charcoal at the process plant, which absorbs the gold and silver. The now barren cyanide solution is pumped to a holding basin, where lime and cyanide are added to repeat the leaching process. Gold bearing charcoal is chemically treated to release the gold and is reactivated by heating for future use. The resultant gold bearing strip solution, more concentrated than the original pregnant cyanide solution, is treated at the process plant to produce a doré, or bar of impure gold. The doré is then sold or shipped to a smelter for refining. Figure 2 is a process flow diagram for the operation.

One of the problems associated with heap leaching is low gold recovery. Commonly untreated ore will yield about 70 percent or less of the contained gold. Crushing the ore will increase recovery, but it also increases production costs. At

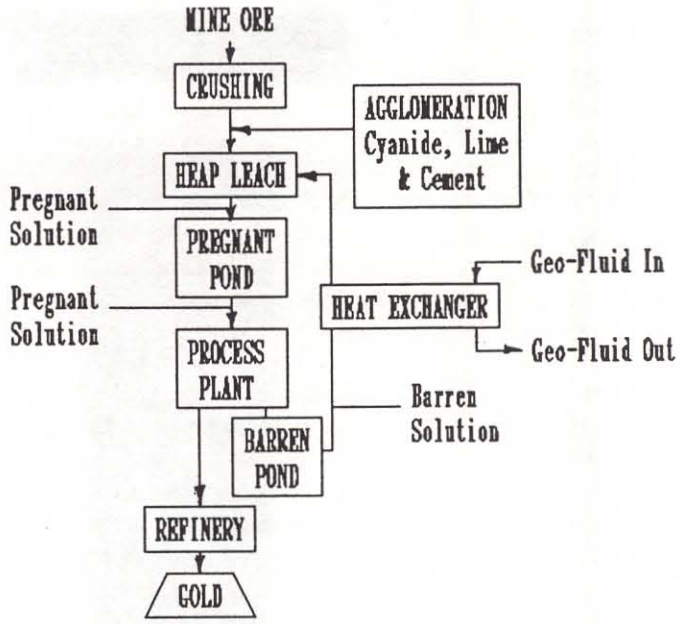

Figure 2. Heap leach process flow.

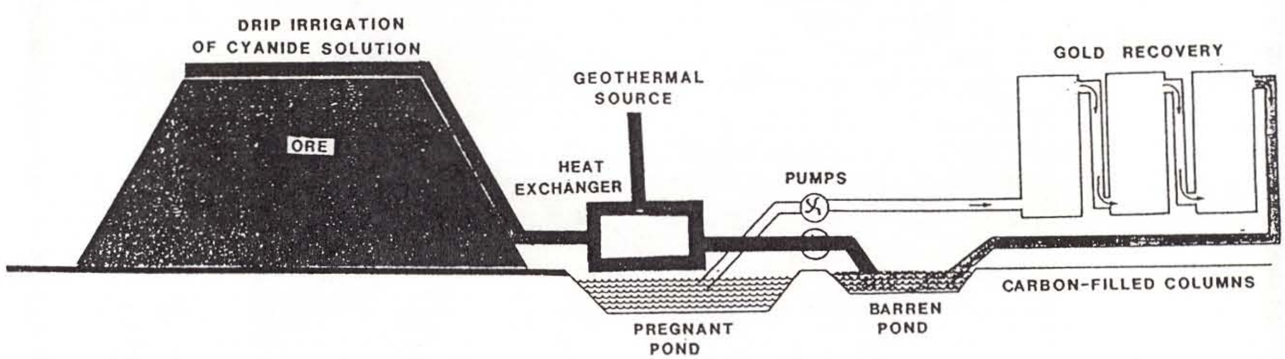

Figure 1. Idealized thermally enhanced heap leach (Trexler, 1990).

some mines, the ore must be agglomerated, or roasted to increase recovery. Gold recovery can be usually increased by crushing, grinding, vat leaching, agglomeration, roasting, chemical pretreatment, or wetting, depending on the ore. Gold recoveries of over 95 percent are possible with cyanide leaching. The value of the additional gold recovered must be compared with the increased processing costs to determine the most cost effective method.

Trexler (1987) reported 32 producing gold, silver or gold/silver mines in operation in Nevada. A collocation study of geothermal resources with these mines identified 10 mines that have geothermal resources on mine property or in close proximity to the leaching operation. It was this study that initiated further research into the utilization of geothermal energy in the leaching process.

GEOTHERMAL UTILIZATION

Using geothermal energy is another method of increasing gold recovery. Heating of cyanide leach solutions with geothermal energy provide for year-round operation and increases precious metal recovery.

It is known that the addition of heat to the cyanide dissolution process accelerates the chemical reaction. Trexler, et al. (1987) determined that gold and silver recovery could be enhanced by 5 to 17 percent in an experiment that simulated the use of geothermal heating of cyanide solutions.

Perhaps the most important aspect of using geothermal energy is that geothermally enhanced heap-leaching operations can provide year-round production, independent of the prevailing weather conditions. Figure 3 illustrates a cyanide heap leach "production window" that may be expected in central Nevada. This curve is provided for illustration purposes only and has not been substantiated by actual production data. If the production window opens at a minimum temperature of 40°F, then leaching operations may begin in mid-March and continue through late October. This has been the historical practice at Nevada mines. Since enhanced recovery of gold from heated cyanide solutions has already been established, maximum production would be restricted to June, July and August. Using geothermal fluids would substantially increase the size of the production window (shadowed area, Figure 3) and would provide for enhanced extraction rates on a year-round basis. The benefits include increased revenue to the mine operator, year-round employment for the labor force, and increased royalty payments for mineral leases to both federal and state governments.

Mines that incorporate geothermal fluids directly in heap leaching operations need to consider the chemical as well as the physical nature of the resource. Two aspects that must be addressed during elevated temperature leaching are the compatibility of geothermal fluids with leach solution chemistry and the susceptibility of the heap to mineral deposit formation from high total dissolved solids (TDS) geothermal fluids.

Cyanide reacts chemically with gold and oxygen to form a soluble gold cyanate ($Na\ Au\ (CN)_2$). Silver and platinum group metals are also dissolved by cyanide in similar reactions. Non-precious metals, such as iron, copper, manganese,

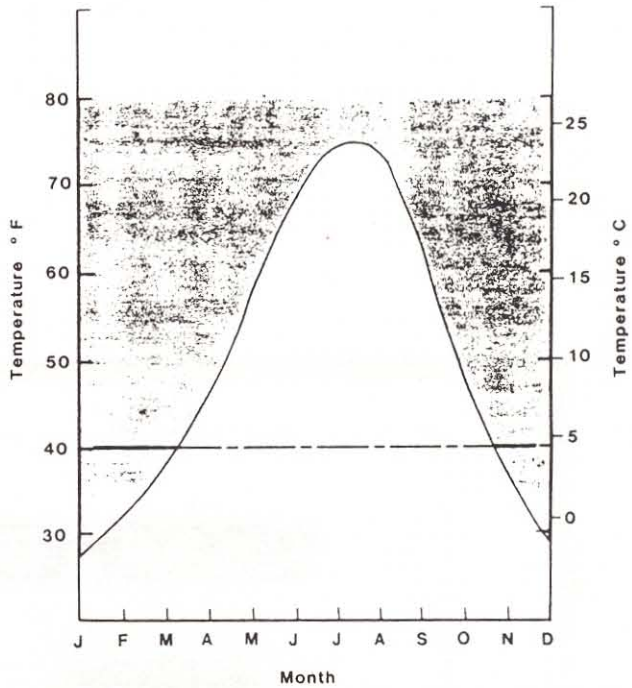

Figure 3. Soil temperature at a depth of 10 cm (4 inches) at Central Nevada Field Laboratory near Austin, NV (elevation 5,950 ft)(Trexler, 1987).

calcium and zinc, along with the non-metals carbon, sulfur, arsenic and antimony also react with cyanide. Undesirable elements and chemical compounds, other than precious metals, that react with cyanide are called cyanocides.

Since cyanocides consume cyanide, high concentrations may interfere with the economic recovery of precious metals. To determine the compatibility of geothermal fluid chemistry with cyanide solutions, a series of consumption tests were conducted by Division of Earth Sciences, UNLV on a variety of geothermal waters from Nevada. Three major types of geothermal fluids are present in Nevada: $NaCl$, $NaSO_4$ and $Na/CaCo_3$.

Experimental leach columns were used by the Division of Earth Science, UNLV to analyze compatibility of geothermal fluid chemistry with cyanide solutions and to determine the effects of geothermal fluid chemistry on ore permeability. Preliminary results from this work indicate that:

1. Geothermal fluids do not cause plugging of the leach columns by precipitation of minerals.

2. The percent of recovery of gold is not significantly affected by concentration of the geothermal fluids in the process stream.

3. Geothermal fluids with high TDS do not contain significant concentrations of cyanocides.

MINES USING GEOTHERMAL ENERGY

Two mines in Nevada use geothermal fluids in their heap leaching operations, Round Mountain Gold and the Florida Canyon Mine.

Round Mountain Gold currently (1990) mines 40,000 tons of ore per day. Estimated gold reserves are 42 million tons of Type I ore at a grade of 0.043 oz/ton and 111 million tons of Type II ore at 0.039 oz/ton. In 1989, 286,200 ounces of gold were produced.

Geothermal fluids are produced from two shallow wells (~ 1,000 ft) which penetrate fractured ashflow tuffs. The wells produce fluid at a temperature of 180°F at an average flow rate of 1100 gpm. Heat from the geothermal fluids is transferred to the cyanide leach solution via a flat-plate, counter flow heat exchanger. Geothermal fluids enter the heat exchanger at 180°F and exit at 80°F. Typical monthly heat production is approximately 40 x 10^9 Btu.

All produced geothermal fluids are injected into a 1,055 ft deep well located 4,000 ft north-northwest of the production wells. At a flow rate of 1100 gpm, and assuming operation of the geothermal system for 180 days each year, a total of 6,545 acre-feet of cooled geothermal fluid will be injected back into the reservoir.

Geothermal fluids are not used directly as process water at Round Mountain Gold. Process water is pumped to the mine from cold water wells located 8 miles to the west. The major element chemistry of the geothermal fluids is presented in Table 1.

Table 1. Geothermal Fluid Chemistry

Constituent	Round Mountain Gold (ppm)	Florida Canyon Mine (ppm)
HCO_3	121	202
Cl	10	2250
SO_4	26	18
Na	110	1350
K	2	240
Ca	2	120
Mg	<0.1	4
SiO_2	75	340
F	21	6
TDS	340	4530

One concern that has been expressed by the metallurgical staff at the mine is that the geothermal fluids contain 110 ppm sodium which amy interfere with gold recovery if these fluids are used as process water. Currently, make-up water is added to the process stream at a rate of 300 gpm, during the flushing phase of the leach operation.

At the Florida Canyon Mine currently (1990) 14,000 tons per day of ore are loaded on the heap. The ore is crushed to 0.5 inches and agglomerated with Portland cement and dry sodium cyanide prior to transportation to the 1,500 ft long radial-arm stacker. With an average grade of 0.025 oz/ton, the mine is estimated to produce 350 ounces of gold per day.

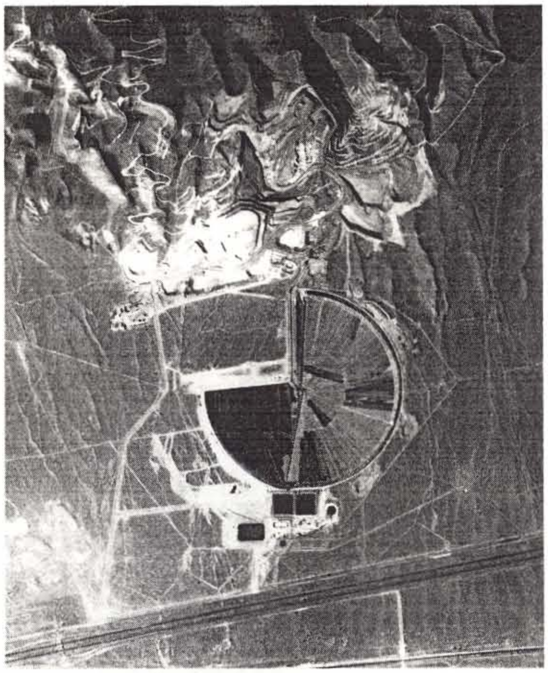

Figure 4. Aerial view of the Florida Canyon Mine.

The mine is located in the Ryepatch KGRA and geothermal fluids are produced from a 580 ft deep, 12-3/4 in. cased well. Maximum temperature in the well is 238°F and fluids are produced at 210°F. The geothermal fluids are piped to a tube-in-shell heat exchanger where heat is transferred to the barren cyanide solution. Since geothermal fluids are the only source of water at the mine site, they are used as process feed. The amount of make-up water required varies with the local meteorological conditions and the time of year. After the geothermal fluids pass through the heat exchanger they are stored in an open cooling pond.

The exact amount of geothermal energy used at the Florida Canyon Mine is difficult to determine, since data on flow rate and temperature drop are not routinely reported. It has been estimated that annual heat consumption is 40 billion Btu/y (Lienau, et al., 1988). During January 1988, heated barren solution was applied to the heap at a temperature of 55°F. The system was modified from spray to drip application to reduce heat loss to the atmosphere.

The chemical composition of the geothermal fluids is presented in Table 1. Scaling in the production well and surface facilities is common. To alleviate problems associated with precipitation of calcium carbonate, chemical inhibitors are added to the cooling pond.

CONCLUSIONS

Preliminary results of experiments using geothermal fluids directly in the leaching process demonstrate fluid compatibility with cyanide solutions. In addition, no loss of permeability or porosity has been observed as a result of using geothermal

Experiments planned for the future by the Division of Earth Science, UNLV include: 1) examination of temperature differences between paired columns, 2) the effect of above ambient temperature on gold recovery, 3) cyanide consumption by geothermal fluids of various chemistries and concentrations, and 4) further investigate the potential for adversely affecting the permeability by precipitation of foreign minerals.
fluids in the process stream.

ACKNOWLEDGEMENTS

The authors wish to thank personnel from Round Mountain Gold Company, without whose assistance this investigation could not have been undertaken. Special thanks are extended to Andre Douchane, Manager; Doug Barto, Environmental Engineer,; Richard Crowell, Leach Supervisor, and Richard Fenstress, Metallurgist. Personnel from Florida Canyon Mine that have provided invaluable assistance are Robert N. Wiley, Mining Manager; John Rice, Manager and John Pickerel, Metallurgist. To all of the above as well as many other members of the geothermal community in Nevada who allowed us to collect samples from their operations, we are indebted.

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