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LEACHING OF SMALL GOLD AND SILVER DEPOSITS

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INTRODUCTION

In spite of a long-term decline in small-scale mining in the United States, there has been a recent dramatic surge in the number of small gold and silver mining operations.

The increased activity can be attributed to the development of a technique called heap leaching. The idea behind the technic is nearly as old as mining – piling up heaps of copper ore and irrigating them with leach solution has been practiced for over 500 years. The "revolution," at least in respect to small-scale mining of precious metal ores, is due to small-scale mining of precious metal ores, is due to two recent developments:

1. Plastic membranes are now available which can be used to make inexpensive, quickly installed, impervious leach pads.
2. The use of granular activated carbon has been perfected for the recovery of gold and silver. The use of carbon, instead of the more traditional zinc precipitation process, allows the design of low-cost circuits with very flexible operating parameters. Such installations may be operated on a one shift per day schedule, and may be shut down for weekends and holidays. They can be operated by one or two men with very limited technical training.

Because capital and operating costs are low, heap leaching is applicable to large low-grade deposits. The largest heap leach operation in the U.S. processes 7,200 tons per day of ore containing 2.2 ppm gold. One operation in Nevada heap leaches, profitably, 1,100 tons per day of ore containing only 1.2 ppm gold; the ore at this mine is ideally suited to the process, it breaks naturally to a fine-grained, permeable sand.

Much smaller tonnages of correspondingly higher grade ore are being mined profitably. At least two operations contain total reserves of less than 150,000 tons, with an ore grade of approximately 5.0 ppm gold. The life of a small operation, from the original decision to proceed until completion of all activity, can be as short as 12 months. A typical small operation might leach 200 tons of un-crushed ore per day, with the ore stacked in heaps containing 10,000 tons of ore each. The total capital cost to begin the initial production from a system this size, including the cost of the chemical charge for the first 10,000 ton heap, would be less than US $200,000. This figure includes all leach costs and "on-site" facilities such as haul roads, but it does not include mining costs and purchase costs of major pieces of construction machinery. Costs are for the year 1978. In the concluding section of this paper, a much smaller operation is discussed, one producing one ton of ore per day, using only manual labor with no mechanical equipment.

The following sections of this paper attempt to identify the technical problems and to describe the mechanical systems which are encountered in a heap leach operation. All the details cannot be covered in a paper this size, but it is hoped that enough information is presented to furnish the reader with a comprehension of how the process works.

As in any technical undertaking, there are pitfalls. The Western U.S. has many examples of "failed" heap leach operations. Nevertheless, the system is basically simple and can be implemented using equipment, manpower, and technical capabilities, which are, for the most part, already available in developing countries.

System Description

Figure 1is a photograph of a heap containing 300 tons of ore, with the ore stacked 4 meters high on top of a plastic pad. During the operation of this heap, solution was pumped from the pond in the foreground (the

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barren pond) to sprinklers spaced every 2.5 meters along pipes to the heap. Total flow rate on this heap was 15 liters per minute. The leach solution contained 0.5 – 1.0 grams sodium cyanide per liter and enough lime to maintain a pH greater than 10.0. The chemicals were added by simply dumping them into the barren pond. The solution flowed down through the heap, then across the plastic to a drain, and from there into the "pregnant" pond on the left side of the photo.

Figure 2 is a photograph of the same heap from a different angle. The solution was pumped form the pregnant pond, in the foreground of this view, through columns filled with activated carbon (four columns, 20 cm diameter and 1.5 meters high), and then was discharged into the barren pond. The same solution was used over and over since the activated carbon removes only the metals (gold and silver) and does not otherwise affect solution chemistry.

This system was usually operated eight hours per day, and was occasionally shut down for periods of two to three days. It could be pointed out that in Figure 2, the entire leach system for treating the 300 ton heap is shown – plastic lined pads and ponds, 2.5 cm diameter pipes to carry solution, two small pumps to pump solution onto the heap and through the columns (the pumps are mounted on the carbon stand), and the adsorption columns. The only equipment not shown is the unit which removes the gold from the carbon and converts it to metallic gold. That unit is similar to, and actually of much simpler design, than the adsorption column unit in the photo. In 80 days of operation, 70% of the fire-assayable gold in the heap of 300 tons was removed and transferred to 100 kg of activated carbon which was contained in the columns.

At one operation, where the heaps contain coarse gold and large rocks, the heaps were operated intermittently for over two years. Leach operation for at least two or three months is practiced in nearly all cases because daily operating costs are very low – the only costs are for labor, power, and make-up chemicals. If other "active" heaps are being run in the same area, the labor cost to oversee an old heap is essentially zero. Make-up sodium cyanide need be added only to replace losses due to oxidation of the cyanide, which costs approximately USD $0.15 per ton of ore per month of leaching. The power requirement and cost is almost negligible – 0.0006 kilowatts per ton.

Leachability, Permeability & Stacking Methods

The rock in the heap shown in Figures 1 and 2 is soft, white kaolinite clay. The heap is in the shield area of Western Australia, where long-term surface weathering has caused intense laterization of the top 40 meters of the surface. The primary rock at this locality was a dense, un-fractured, metamorphic rock containing coarse gold. Since coarse gold dissolves very slowly, and the rock was impermeable, the primary rock could probably not have been heap leached successfully. Weathering caused the re-disposition of much of the gold as fine particles and created an open-structured rock that was quite porous.

Because of the high clay content, two specialized procedures had to be used when the heap was constructed. The first of these involved the method of

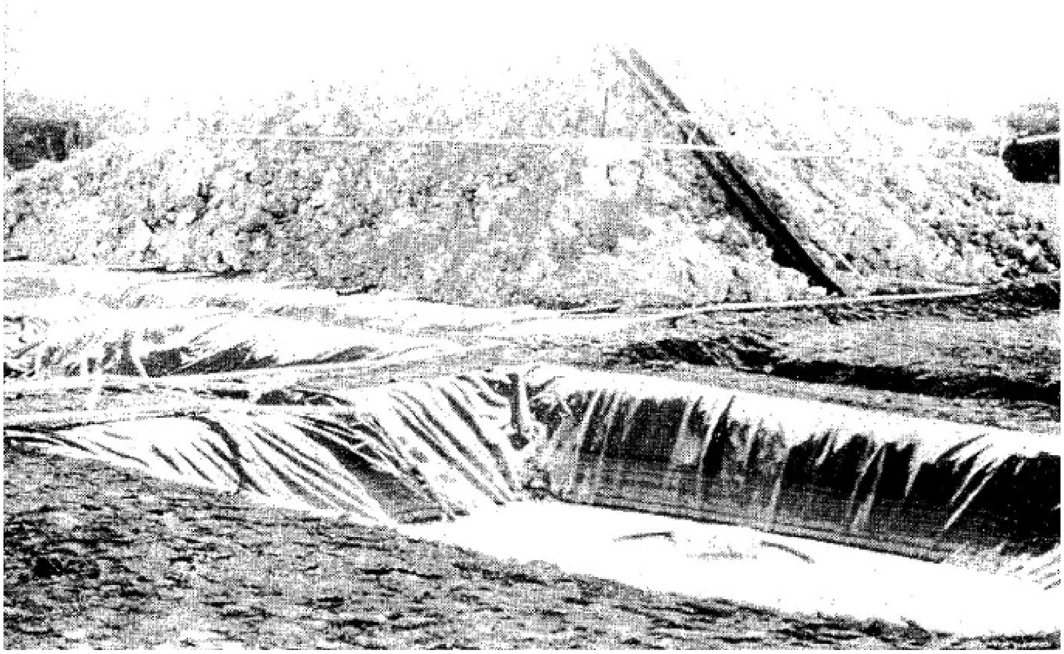

Figure 1. 300 ton heap leach of mine-run ore with a very high clay content.

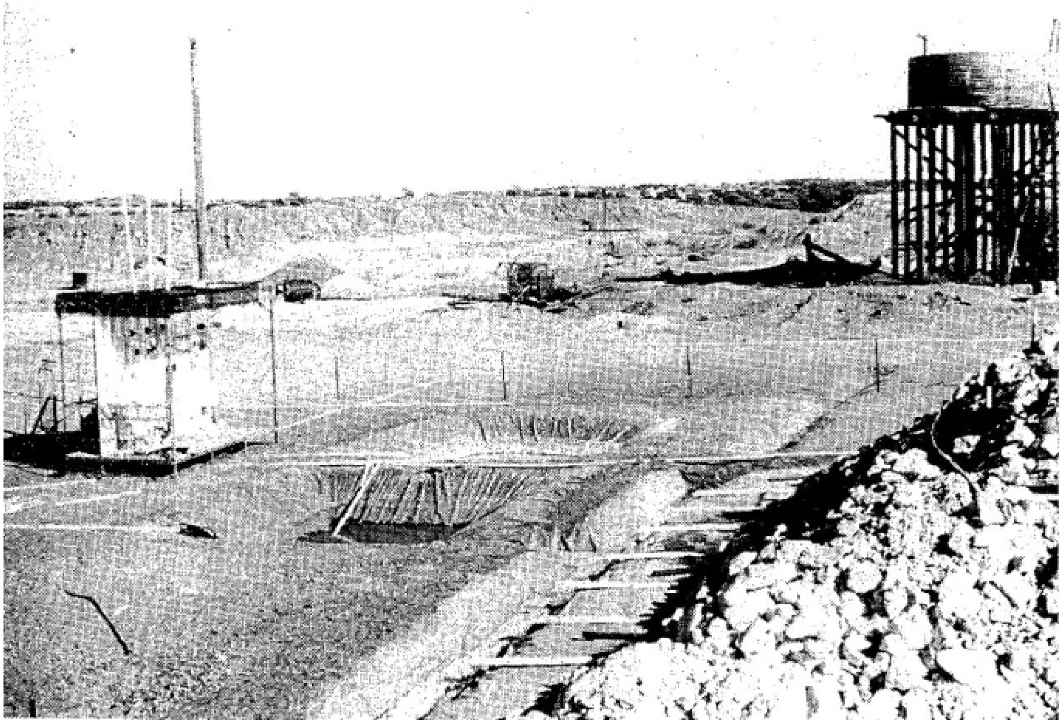

Figure 2. Three hundred ton heap leach showing carbon column and piping layout.

mining. The creation of "fines," or pulverized rock, had to be avoided. Test samples of the ore, ripped with a bulldozer, were found to be impermeable no matter how they were stacked. Successful mining required close-spaced drilling and light blasting, a procedure that resulted in much less fines than ripping while simultaneously limiting the maximum rock dimension to about 0.5 meters.

The second special procedure involved the method of stacking rock onto the heap. A conveyor stacker like that shown in Figures 3 and 4 was used. The stacker can be manipulated to create a series of discrete 1 meter high cones of rock, and a large heap can be built as three or more layers of these cones are stacked on top of one another. The action of the conveyor discharge throws a portion of coarse rocks farther than the fines, and creates a highly permeable shell of coarse rock around each cone. By changing the conveyor movement, the permeability of the heap can be "adjusted" to insure good leachability of problem ores.

The capital cost of a completely mobile, gasoline-driven conveyor (the tip of one is shown in Figure 4) capable of stacking 10 to 20 tons of ore per hour is USD $12,000.

Suitability of Various Ores

Some other "typical" heap-leachable ores and their special leach problems are discussed in the list below:

Fractured Volcanic and Schists, Near High Grade Veins:

- Gold is often coarse (visible to the unaided eye). This may result in long leach times, up to one or two years for complete recovery.
- Development of at least some ore reserves is sometimes easy, since old mine workings on the veins have often exposed low-grade ore.
- This is the most common occurrence being heap leached in the Western U.S. Typical example: Round Mountain, Nevada, the largest operating leach at 7,200 tons per day.

Gold with Pyrite or Arsenopyrite in Primary Ores or Dense Metamorphic Rocks:

- Successful recovery often requires crushing to 1 cm or even 6 mesh Tyler; therefore, heap leaching can only be justified for very high-grade, small deposits.

Gossans:

- Gold has often been enriched by leaching - removal of sulfur and base metals; this is especially common for gossans on massive sulfide type ore bodies.
- Iron oxides are generally not a problem, but in one case a dense high iron laterite could not be heap leached because the iron oxides mechanically covered the gold particles.

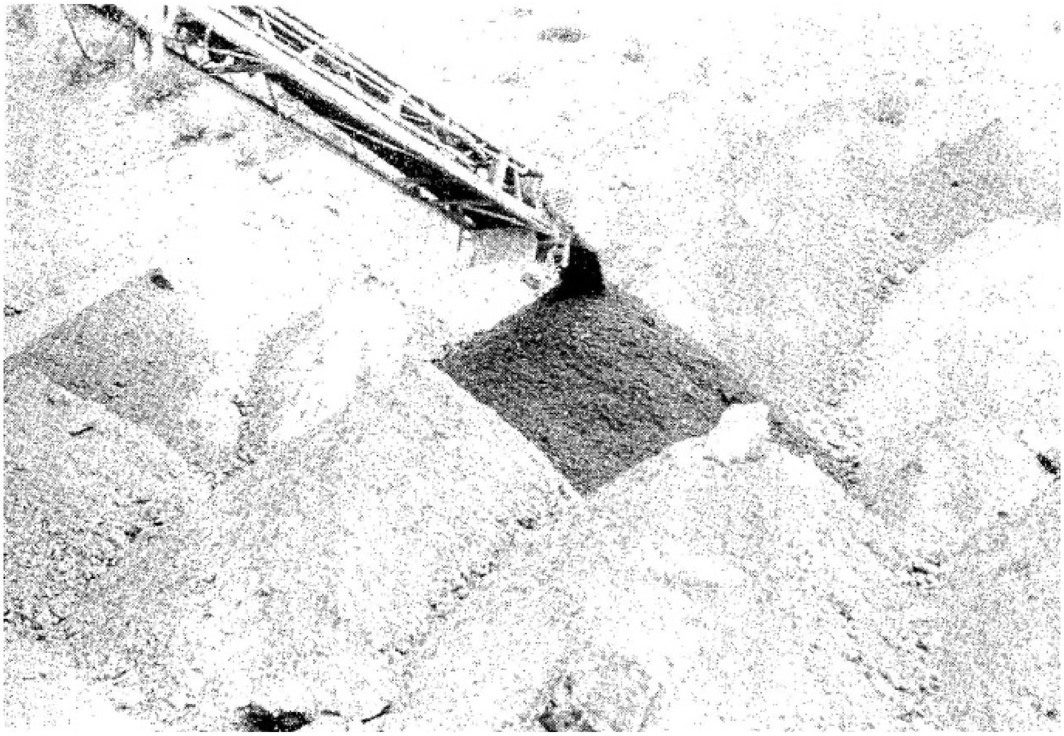

Figure 3. Manual conveyor stacker capable of placing eight tons per hour of mine-run rock.

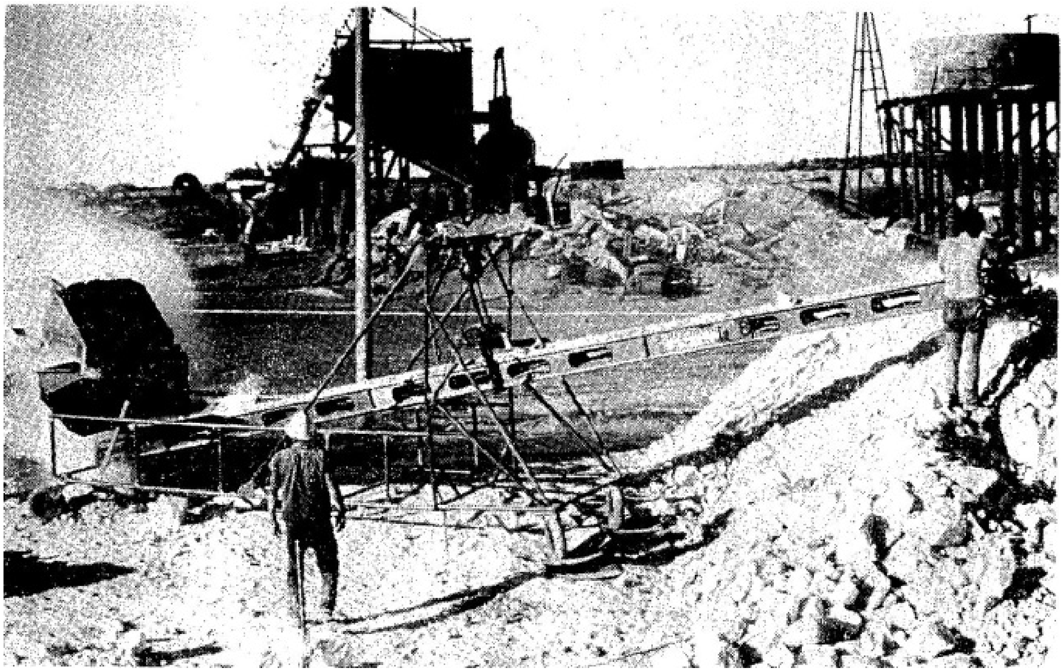

Figure 4. Conveying action builds cones of fine material surrounded by a permeable shell of coarse material. The heap is constructed of several layers of these cones. The conveyor stacker shown here is small, but completely mechanized and capable of stacking.

Gold in Porous Rocks with Sulfides or Soluble Base Metals:

- Below the oxidizing portions of sulfide veins, gold may be deposited on pyrrhotite or marcasite surfaces. Usually the gold leaches well, but cyanide and lime consumption can be high.
- Sulfide veins often oxidize to a mixture of rock fragments and unstable yellow clay. The clay may prevent successful heap percolation, and in fact this has caused the failure of several leach operations.
- Oxidizing copper minerals or base-metal salts may greatly increase apparent cyanide consumption. Chemical control of heap operation becomes more sophisticated.

Disseminated Gold in Dirty or Hydrothermally Altered Limestone:

- These are often very large and relatively high-grade deposits. Typical examples: Carlin (2,000 tons per day, conventional mill); Cortez, Nevada (portion mill and portion heap-leached); Windfall, Nevada (1,100 tons per day heap leach on ore containing 1.0 ppm gold). Gold leaches quickly and thoroughly. Usually there are few chemical problems and the rock is permeable. Carbon already present in the rock is sometimes activated and can prevent leaching.
- Since the gold is sub-microscopic and can be found by assay only, there are often no "ancient" mine workings to serve as guides to ore: ore exploration is based on geologic models.

Silver Ores:

- Generally, these can be leached using exactly the same techniques as for gold ores.
- The "loaded" activated carbon contains a low value of silver per unit of carbon, and a large amount of carbon is needed. An on-site carbon stripping and recovery plant is necessity (for gold leaches, carbon can be shipped elsewhere for stripping or can be even sent directly to a smelter).
- Silver recovery is generally in the 45-60% range, whereas gold recovery is generally in the 65-80% range.

Rock Testing Procedures

Suitability of a deposit for heap leaching depends on the following criteria:

1. Permeability of individual rock fragments – i.e. does the ore have to be crushed to achieve target recovery?
2. Cyanide and lime consumption by chemical reaction over the life of the leach.
3. Total leach time required as a function of the size of gold particles and the size of rock fragments.
4. Permeability of the heap – how high can the rock be stacked? Do special mining or heap loading methods have to be used? Can solution be distributed onto the heap by ponding or is sprinkling necessary?

The hardest question to answer is the last. It is not possible to build a laboratory-size heap that is constructed using the same equipment as a much larger field heap, and compaction and pulverization of the rock during construction can greatly affect permeability. The answer to this question can sometimes be arrived at by comparison with heaps built from similar rock types; but if this is not satisfactory, then it is necessary to build large semi-production field test heaps. The importance of using a correct heap loading method cannot be stressed too highly. Many operations, some with very high-grade ores, have failed because this has been ignored.

The first three questions can all be answered in the laboratory tests. For "typical" property containing one or two "types," lab testing will require 500 pounds of ore sample and cost less than US $3,000 if done by a consulting laboratory. Laboratory apparatus for the most common type of testing is shown in the photograph of Figure 5 and the schematic drawings, Figure 6. The apparatus is simple to build and operate. Generally, the tests are run for two to three months, with the floor tank solution recycled to the head tank once each day. Solutions are assayed for cyanide and lime content and adjusted once every few days. The small bottle of activated carbon shown in Figure 6 adsorbs all the gold and silver as soon as it is dissolved from the rock. The carbon is removed and replaced once per week, and is fire assayed to determine recovery. A test apparatus of this type can be used to examine such parameters as the effect of crushing the rock to various sizes, and changing cyanide strength, pH values, flow rates, etc. The central leach "column" can be replaced with a column up to ten feet or more high where chemical reactivity might be a problem, or with wider/deeper columns for testing very large rock fragments.

Pad Materials

The impermeable pad on which the ore is stacked may be made of many materials including clay, asphalt, concrete, and plastic sheeting. Some heaps have even been placed on an unprepared ground surface, though this almost always results in very low recovery.

In one configuration of the heap leach process, a limited ground area is covered with expensive high-strength pads usually constructed of 20 cm think

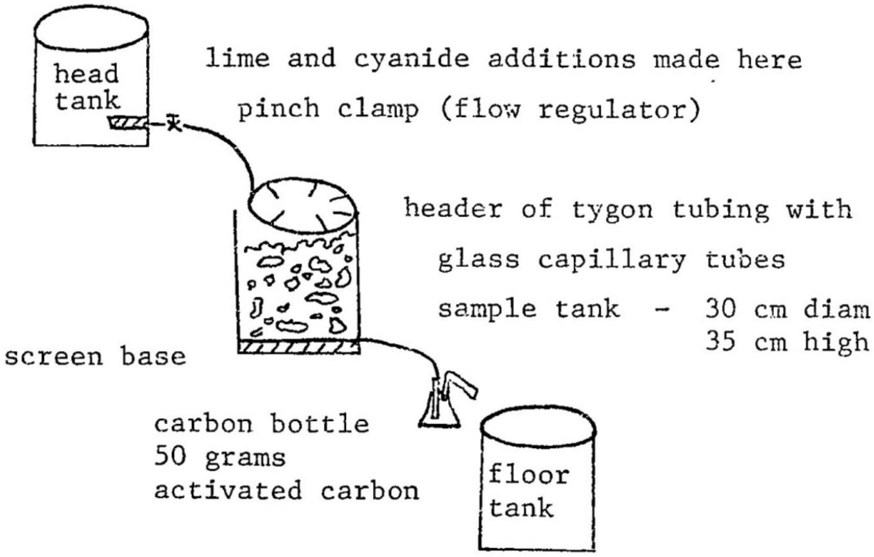

Figure 5. Leach test apparatus diagram.

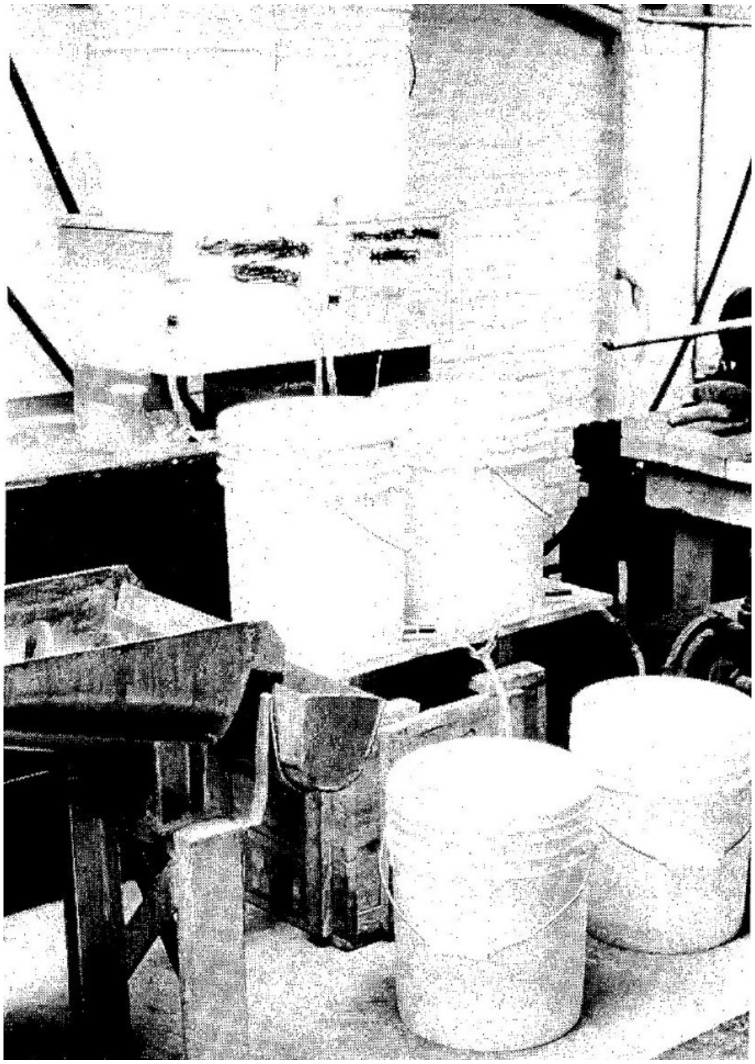

Figure 6. Laboratory leach test apparatus.

asphalt. Ore is stacked onto the pads, leached for a short period (usually less than 60 days), and then removed with a front end loader. The pads are reused for a new ore charge. The biggest disadvantage of this system is that the pads must be cleaned off at predetermined intervals to make room for new ore. With such a rigid time restriction, all the inherent flexibility of the heap leaching process is lost.

A much better procedure is to install inexpensive “single-use” pads, and then to leach the heaps as long as they are returning values in excess of operating costs (in some cases, for longer than a year). New heaps are built alongside the older heaps. In environmentally sensitive areas, the discontinued heaps can be sealed with a clay cover, or contoured and re-vegetated.

Pads made of asphalt, concrete, or clay all share the same problem; to be impermeable, they must be well constructed. Specialized contractors and other equipment are needed, and these are often not available to the small miner.

Single-use pads can be made quickly and inexpensively with plastic membranes. There are several different types available, but all have similar properties. The criteria for selection are:

1. Highest puncture resistance at lowest cost; and
2. The ease at which pieces of the material can be joined together under field conditions to make impermeable splices.

The best materials currently on the market are Hypalon and polyolefins, such as Dupont 3110. Hypalon is more puncture resistant than the polyolefins, but it is more expensive and more difficult to weld.

Typical costs for the pad materials range from U.S. $3.00 to $4.00 per square meter. The maximum amount of ore that will fit onto the pad for a typical 10,000 ton heap is approximately 4 tons of ore per square meter of pad material (including the material used to line the ponds). For very large heaps, the pad loading factor increases to 8 or more tons per square meter.

Preparation of the ground surface under the pad is done by clearing plant growth and roots from a fairly firm, slightly sloping ground surface. If a small bulldozer is available, a three-man crew can prepare the surface for a 10,0000 ton heap, lay the plastic and weld all the seams, and otherwise have the pad ready for loading rock within four days. Another three days are required to excavate and line the solution holding ponds.

Since all plastic pad materials can be punctured by sharp edges of large rocks, the pad is usually covered with a four to eight inch thick layer of fine gravel. The gravel cover also provides a good drainage base under the heap. For a 10,000 ton heap, 500 tons of gravel, screened to 2.0 cm or smaller (and with all the minus 100 mesh fines removed) would be required. The gravel can usually be [produced from crushed ore.

Solution Distribution

Solution is distributed onto the heap for at least eight hours each day, at the rate of six liters per hour per square meter of heap surface. Distribution is accomplished either by ponds or by sprinklers. Ponding is the simplest method and allows the heap to be covered for protection against freezing or excess rainfall; however, it cannot always be used for two reasons:

1. If a heap contains a mixture of coarse and fine rocks with a fairly high percentage of clay, solutions “channel” easily within the heap. The use of ponds results in very inefficient flow.
2. Ponds can only be built on the top (flat) surface of the heap. On small heaps, a large portion of the total tonnage lies under the side slopes, and sprinkling is needed to leach this tonnage.

A system of sprinklers is more complicated and requires more maintenance than ponding, but it guarantees good solution distribution. Sprinklers such as those shown in Figure 7 can be made quite simply by inserting a 25 cm length of rubber tubing over a tapered plastic pipe nipple and forcing this assembly into a small hole drilled into a network of distribution pipes on the heap. Each of the piping systems shown in Figure 8 consists of a network of 2.5 cm diameter PVC pipes for a 2,000 ton heap. Each system, including the sprinkler heads, was installed by two men working two days. Only four days would be required to place an identical system on a 10,000 ton heap. Total cost of materials for the sprinkler heads for the 10,000 ton heap would be US $75.00. Other items needed for the sprinkler system, including 700 meters of 3 cm diameter plastic pipe, and a ¾ hp pump, should cost approximately US $1,500.

Solution Flow & Chemical Control

When solution is first distributed onto a new heap, it may take from three to five days before flow begins to exit from the base. A normal heap will adsorb 50 to 80 liters of solution per ton of rock during this period, and thereafter water need be added only to make up for that lost by evaporation.

The leach solution is a dilute solution of sodium cyanide in which the cyanide is made stable by keeping the solution alkaline. The cyanide strength is 0.5 to 1.0 grams sodium cyanide per liter, and the alkalinity is

Figure 7. "Wobbler" sprinklers are easily fabricated from plastic fittings.

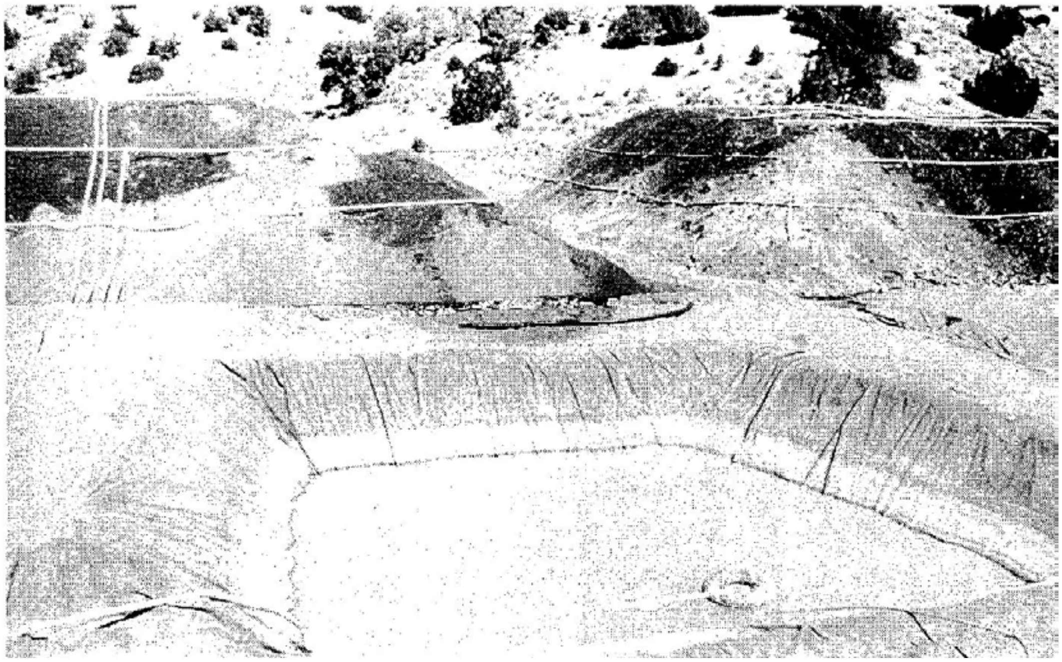

Figure 8. Solution distribution piping for two 2,000 ton heaps.

adjusted to pH 10.0 – 10.5 using calcium hydroxide. For the first several days of operation of a new heap, the exiting solutions are normally depleted in both lime and cyanide, but can contain from 0.3 to 15 or more ppm gold.

In the operation of a "typical" heap, the gold concentration of the solution exiting the heap reaches a peak after five to ten days, and thereafter slowly declines. Operation of a heap is usually discontinued when gold content drops below 0.1 ppm.

The pregnant solution exiting the heap is collected in a surge pond and from there is pumped through tanks or columns filled with enough granular activated carbon to adsorb the gold and silver. Total flow rate for a 10,000 ton heap is approximately 150 liters per minute. The barren solution coming from the adsorption columns, and sufficient fresh water to maintain a convenient working volume of solution, flow into the barren solutions storage pond.

Reagent additions can be made very simply. Calcium hydroxide and sodium cyanide are usually delivered to the project in steel drums or paper bags, and the solid chemicals are added to the circuit by dumping them directly into the barren pond. For a 10,000 ton heap, chemical addition involves the dumping of a maximum of ten 20-liter buckets of chemicals into the pond each day, an operation that takes less than one hour.

Because the ponds and the heap contain a fairly large reservoir of solution, assaying control of pH and cyanide content is not critical. One or two assays per day are usually sufficient. The pH assays can be done quite simply with a battery operated pH meter and assays for cyanide content are performed by a field titration. Total cost of the field assay facilities is US $200.

Assaying for gold and silver content requires more elaborate equipment. An atomic absorption machine or a food fire assay facility is required. The minimum cost for this apparatus and a laboratory to house is it is US $20,000. While it would be nice to have gold assay capabilities on site, it is not absolutely essential. In regard to the adsorption columns, gold and silver assays are needed only to monitor the rate at which carbon must be removed and replaced in the columns. For this purpose, a delay of three to five days between taking the sample and receiving the assay can be tolerated. Efficient operation of the carbon stripping circuit requires closer assay control, but this circuit can be easily overdesigned so that efficient operation is not required.

Design of the Adsorption Columns

When cyanide solution containing gold is placed into contact with activated carbon, the gold cyanide chemical complex is adsorbed onto the surfaces of the

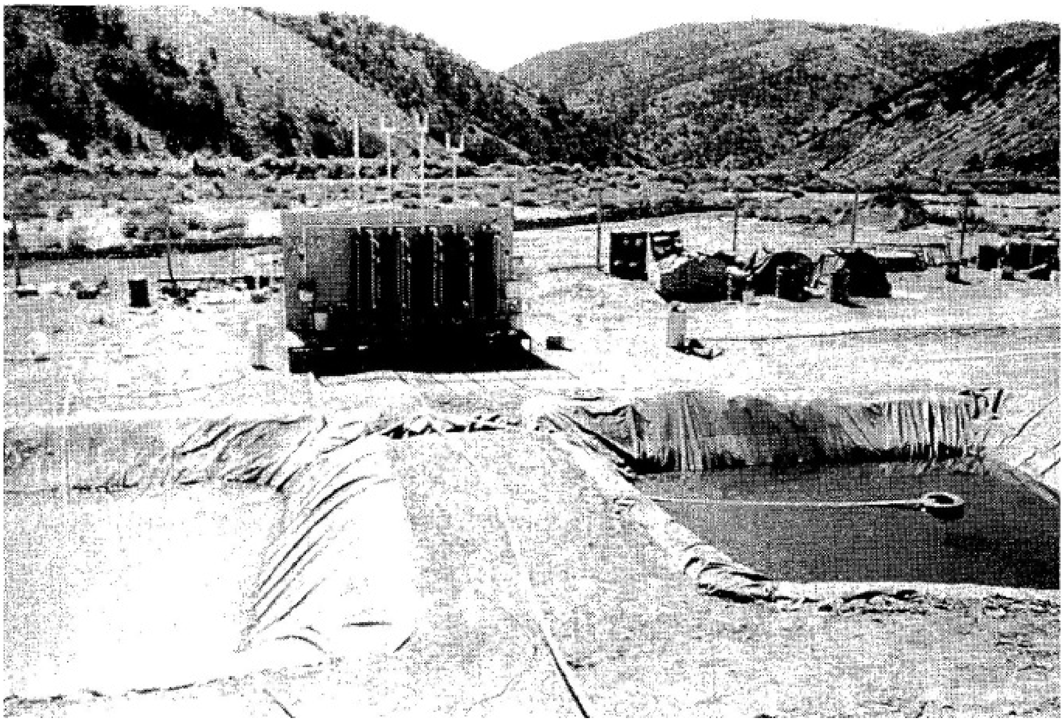

Figure 9. Carbon adsorption columns for a 2000 ton heap. The adsorption system for a 10,000 ton heap would be identical, except that the columns would be a 50 cm diamter instead of 30 cm,

carbon. The reaction is highly efficient – when solution containing 3 ppm gold is pumped continuously though a four-stage column system, five minutes contact time is sufficient to remove 98% of the gold. Simultaneously, the carbon can be "loaded" to 18,000 ppm gold (over 500 ounces per ton). Other than removal of precious metals, the solution is not chemically affected and can be recycled back onto the heap.

For a 10,000 ton heap, the adsorption system is comprised of four columns or tanks 50 cm in diameter and 2 meters high. Auxiliary facilities include an air compressor and a washing column to remove fines from new carbon. The columns are interconnected with a system of 5 cm diameter pipes and two pumps. Figure 9 shows a portable unit containing 30 cm diameter columns which was built for a total cost of US $11,000.

The adsorption system can be built at several levels of sophistication. For a well-engineered, portable circuit that is pre-assembled in an industrial center, and that can be operated safely in the field by totally inexperienced personnel, the capital cost for a 10,000 ton unit would be in the range of US $30,000. At the other extreme, a circuit could be assembled on-site using a maximum of locally available materials. Total cost for the "imported" items for such a circuit, including all pumps, would be less than US $5,000. Four man-weeks of labor by skilled craftsmen would be needed to construct it. This inexpensive "homemade" circuit would require operators with a fair degree of technical skill for the following reason: a 200 ton of ore per day operation (10,000 ton heap), treating or containing 3 ppm gold and 3 ppm silver, would recycle 120 kg of carbon each day; the chance of carbon spillage and gold loss would be quite high if the system was crudely constructed and the operators were unskilled.

Design of the Stripping Circuit

The opening paragraph in the previous section of this paper described the adsorption of gold onto carbon. The reaction is highly reversible. The loaded carbon can be stripped of nearly all its gold by contacting it with a near-boiling solution of 1% sodium hydroxide containing 20% alcohol. Stripping of heavily loaded carbon can be accomplished within 20 hours. The resulting solution from this operation is so heavily loaded with gold (and silver, if it is present in the ore), that the metals can be recovered from it in a simple electrolytic cell. The electrolytic cell is equipped with a cathode of steel wool. After a batch of carbon is stripped, the steel wool is removed from the cell, placed in a smelting furnace with suitable fluxes, and melted to doré bullion. The carbon, now stripped of its gold, is ready to adsorb more gold and can be returned to the field columns.

The stripping circuit is less complicated than the adsorption circuit. It consists of one stripping tank approximately twice as large as the adsorption tanks, a second small solution storage and heating tank with an electric or fuel-fired heater, one small pump, an electrolytic cell and a power supply. Figure 10 shows an extremely crude stripping circuit, fabricated at a cost of less than US $1,500 that was capable of recovering three ounces of gold in per 24 hours.

The stripping solution contains alcohol and is maintained near 90°C, so plastic parts should not be used, but mild steel is quite satisfactory. It is best to fabricate this circuit in an industrial center and transport it to site. The cost of the stripping circuit for a 200 ton per day operation on a gold ore, including the power supply, is approximately $10,000. The cost of the stripping circuit for a similar operation treating silver ores would be much higher, since much more carbon must be recycled per unit value recovered.

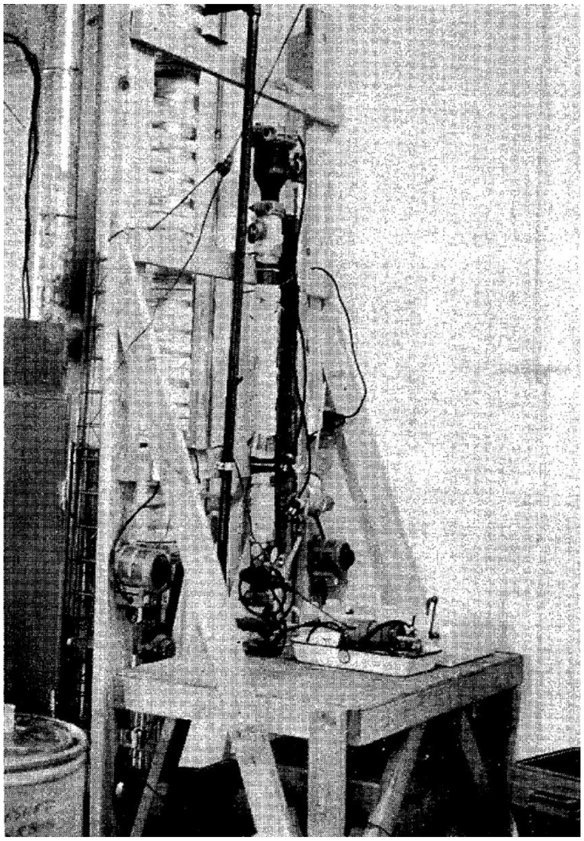

Figure 10. Crude stripping circuit capable of recovering three ounces of gold per day.

Table 1. COST FOR FIRST 10,000 TON HEAP LEACH

Description	Cost, USD
Pad Material	$8,000
Gravel Cover	$2,000
Heavy Equipment Rental for grading pads & ponds, hauling and stacking ore; bulldozer - 5 days; truck, end-loader, stacker - 50 days ore; bulldozer - 5 days; truck, endloader, stacker - 50 days	$40,000
Columns and Stripping Plant	$40,000
Heap Piping	$2,000
Chemicals and Carbon	$15,000
Well, Pump, Generator, Wires, Pipes	$8,000
Misc. Support Items, pickup truck, fences, temporary buildings	$25,000
Consulting Supervision, Engineering Design Fees & Expenses, Assaying	$40,000
Labor, 6 men for 5 months*	$30,000
Total	$210,000

**1978 labor cost in the western US would be higher, perhaps $60,000.*

The product from the stripping circuit is a mass of steel wool which contains more than its own weight of gold plus silver. It can be melted on site, or packaged and sold directly to a smelter.

Summary of a Total Project

This paper provides some details and costs of the major technical items needed for a small heap leach installation, but of course there are many additional items needed such as access roads, housing, fencing to protect the ponds from wild animals, office and storage buildings, a water well and power supply. As earlier indicated, none of the mining facilities have been included. For a 2,000 ton per day operation, the leaching operations would require a well producing 900 liters per hour of water and a total electric generating capacity of approximately 20 kilowatts (energy consumption for pumping of leach solutions is six kilowatts).

Manpower requirements for all of the ore stacking and leaching operations include six laborers, a skilled foreman, and a professional, technically-trained manager. Two additional skilled personnel would be needed part-time for assaying and carbon stripping, but this work can sometimes be contracted out to a commercial laboratory.

In the introduction of this paper, a total cost of US $200,000 was presented as the cost of the first 10,000 ton heap. That figure is probably a little low; estimated values for the individual cost items are shown in Table 1.

Addendum

In the spirit of this conference, I tried to visualize the tiniest heap leach operation which might be reasonably undertaken. Where labor costs are very low, the process could be applied on a very tiny scale. It would be possible to build and operate a heap leach using – as the only piece of mechanical equipment – a bicycle-driven pump.

For example, one man could manually “mine” and haul ore from an old, low-grade mine dump to a nearby heap at a rate of one ton per day. The rock would be leached for a total of 60 days, so at any time there would be an active heap of 60 tons. Sometime during each day, a total of 1,500 liters of solution would have to be pumped from a storage pond onto the heap, a vertical distance of ten meters. The solution could be distributed onto the heap by drip pipes, or by another person spreading it from the end of a garden hose. Pumping onto the heap could probably be done in less than two hours each day.

The solution would slowly run out the base of the heap into a collecting pond. During another two-hour pumping period each day, the solution from the collecting pond would be pumped into the top of the first of a series of three oil drums filled with activated carbon. The drums would be set on a stand, with approximately one-foot elevation differences between them, so the solution would flow by gravity through each of them in turn and then into a second storage pond. New water would have to be supplied to the system at the rate of 100 liters per day.

Using the above system, a one ton per day operation treating ore containing 0.1 ounces gold per ton (3.5 ppm) with a recovery of 70%, would generate US $4,900 worth of gold per year (gold at $200 per ounce). The gold would be recovered onto a total of less than 80 kg of activated carbon (coarse grains of charcoal), which could easily be packaged up and shipped at the rate of 7 kg per month to a conventional base-metal smelter. Total annual operating costs would be US $900 for carbon, sodium cyanide, lime, and plastic pad material. Initial set-up costs would be about US $2,000, including the first six month's supply of plastic and chemicals.

Unfortunately, the above scenario leaves out the most important element – the need for some technical knowledge. Even in fairly educated societies, such as the Western U.S., that knowledge is generally beyond the capability of the individual miner.

To set up the one ton per day operation, two weeks technical assistance would have to be provided. Thereafter, one day's assistance every two weeks would have to be available to keep things operating successfully. Even if several properties were being leached in the same geographic locality, it is doubtful that they could carry the cost of the technical assistance and still show a reasonable profit.

Perhaps in some cases the establishment of a small leaching industry could be justified on government policy grounds and the technical assistance could be provided free of charge to the small miner. The problem may still not be solved, however, an uneducated gold miner working a small labor-intensive mine is usually accustomed to seeing a small pile of glistening yellow metal as his reward for a day's work. It may be difficult to convince him to continue the routine of mining rock and pumping solution, when all he ever sees is unchanging black "charcoal" for which he gets paid according to some mysterious formula.