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# SCALEUP EXPERIENCE IN GOLD-SILVER HEAP LEACHING

*Presented at the AIME Annual Meeting - Chicago, Illinois, USA - February 1981*

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A precious metals heap leach is a fairly straightforward mechanism. Ore is stacked on an impervious pad and is sprinkled with a pH-controlled cyanide solution. The solution dissolves gold and/or silver from the rock and carries it down and out of the heap. Gold is removed from the solution and the solution is recycled.

The prediction of field behavior from laboratory tests should be relatively straight forward, provided that the laboratory test procedures are faithful mini-heap leaches. Detailed comparisons of field heap behavior versus lab behavior now exist for several ores. They indicate that field heap performance differs significantly, but predictably, from laboratory tests. Specifically, field heaps reach the same level of recovery as lab tests, but they take from three to six times longer to get there.

The data suggests that all production heap leach systems should be designed with flexibility to extend leach times for as long as the ore requires. Fortunately, Aesop's lesson, that slow is not necessarily bad, is one of the guiding principles of heap leaching. The capability for unlimited leach times is inherent in the heap leaching process, both technically and economically. Surprisingly, this capability has been "designed out" of several operations in which the ore is stacked, leached, and removed on regular intervals. The data presented here, and evidence in the literature from other producing heap leaches such as Cortez and Round Mountain[1], suggest that eliminating this flexibility greatly increases investment risk.

**<u>Example 1 – The Extremely Long Delay: A Clayey Ore</u>**

Figure 1 shows recovery curves in the lab and field tests for two ores. Both ores leach quickly in the lab, but in the field they are at the extremes of heap behavior; one leaches very fast, the other very slow.

The laboratory test curves in Figure 1 were developed in typical small laboratory bucket leach tests, containing 20 kg of ore in a 34 cm deep and 28 cm diameter column. A drawing of the test layout and details of the test procedure have been published previously[2].

Ore A is a soft, almost pure kaolinite clay containing fine gold. Ore "lumps" are stable and permeable, but ore "fines" can form clay layers that are almost impermeable. To minimize the fines problem, the ore for the field heap was carefully blasted and was not crushed before leaching. The field heap was intentionally built in a manner that would result in delayed, steady gold recovery by using a conveyor stacker to construct the heap as a series of one meter high cones. Within each cone, the ore fines created an almost stagnant "pocket" about 0.6 meters in diameter. Around each cone the "throwing" action of the conveyor stacker created a layer of coarse rock which allowed free-flow of solutions downward through the heap.

As the curves for ore A in Figure 1 show, 60% recovery was achieved in lab tests in ten days, whereas the same recovery took fifty-five days in the field. It is not too surprising that the field and lab recovery curves for this ore are different since the tests differed in two significant ways:

1. There is no way to take an accurate sample of run-of-mine sized rock for small lab tests (these tests were run on ore crushed to 50 mm).
2. The throwing and segregating actions of the conveyor could not be duplicated in the lab.

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[1] For a good general article and bibliography on heap leaching, see "Design Factors for Heap Leaching Operations" by George M. Potter, Mining Engineering, March 1981, pp 277-281.

2 "Leaching of Small Gold and Silver Deposits" by D.W. Kappes, pp381-388, in THE FUTURE OF SMALL SCALE MINING, edited by R.F. Meyer and J.F. Carmen, McGraw-Hill Publishing Co., 1981, 50 pp.

**Figure 1 - Comparison between Lab & Field Leaches, Two Ores**

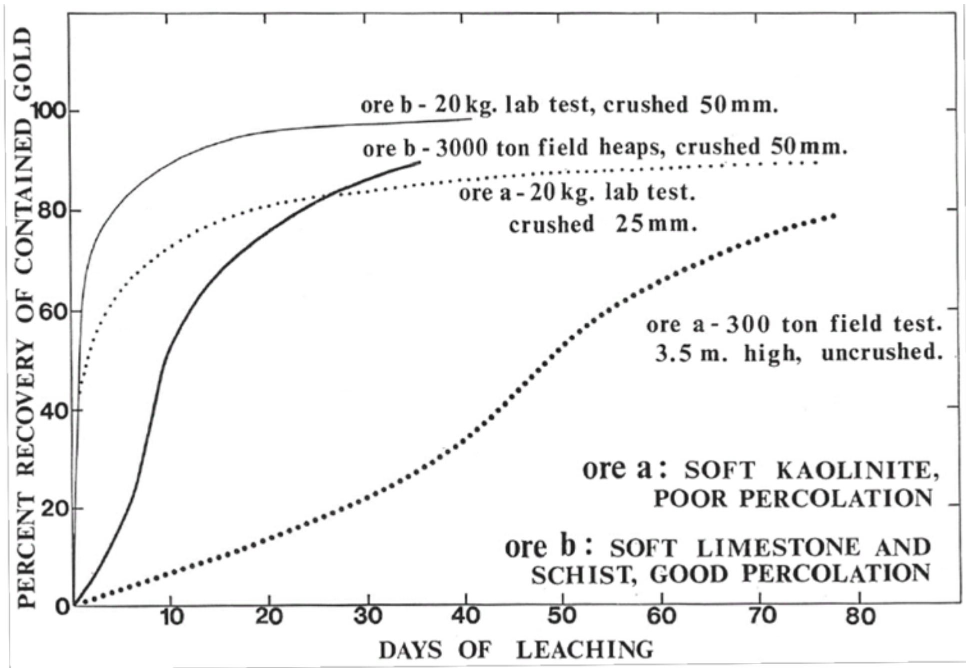
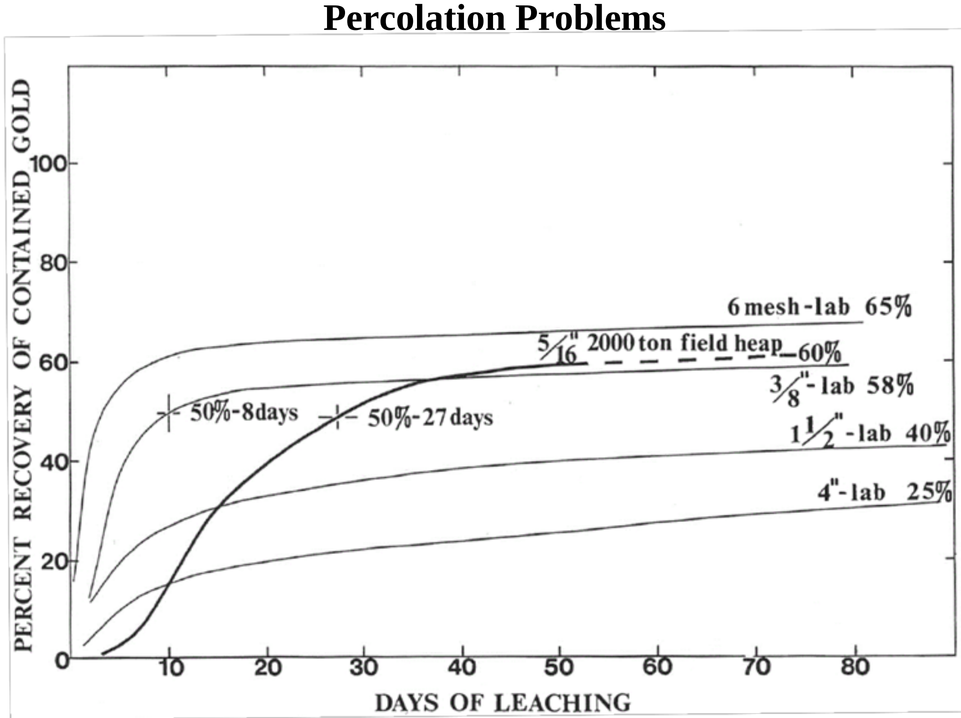



**Figure 2 - Comparisons between Lab & Field Leaches, Crushed Ore, No Percolation Problems**



The first factor appears to have been not too significant for this ore. Large production heaps have since been run on crushed ore with recovery curves that duplicate those from the uncrushed field test heap. The controlling factor appears to be heap permeability, not rock size.

The second factor is part of a problem common to all laboratory test columns, which is that there is no way to duplicate the "structure" that is built into the field heap. Ore cannot be compacted the same way it is in the field, and ore segregation, which results from rocks rolling down the heap slopes, cannot be duplicated.

**Example 2 – The Short Delay**

Ore B in Figure 1 is a mixture of permeable limestone and shale. Both the laboratory tests and the field heap were run on coarse-crushed ore. The ore is hard enough so that ore fines do not clog the heap. As a result, it was possible to build the field heap as a vertical "stack" of 1.9 meter lifts, to a final height of 3.9 meters, using trucks which drove directly on top of each ore lift

Laboratory tests were run in short bucket tests and in 2.5 meter high columns, and no difference in recovery times was noted. As in all other tests reported here, flowrates of leach solution in the lab and field tests were roughly identical.

Like ore A, the laboratory tests on ore B appeared to be faithful "mini-heaps," except for one aspect: the important factor of the inability to duplicate heap structure. As Figure 1 shows, the laboratory tests achieved 85% recovery in eight days. Subsequent production heaps have all behaved identically to the first heap.

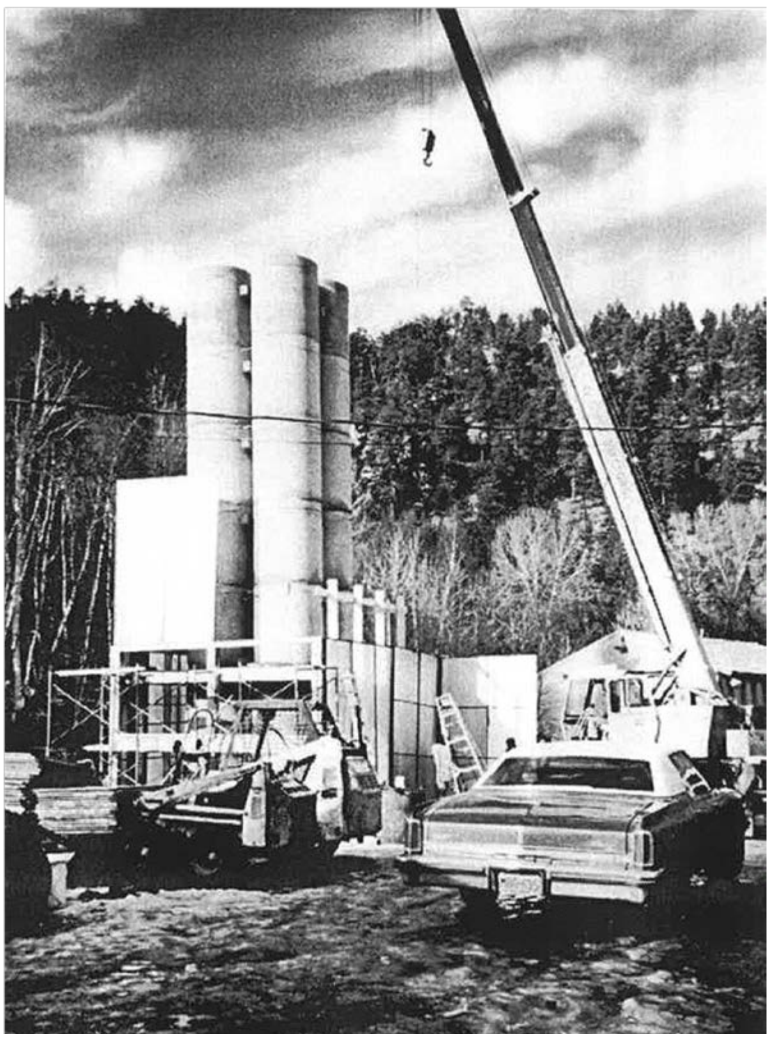
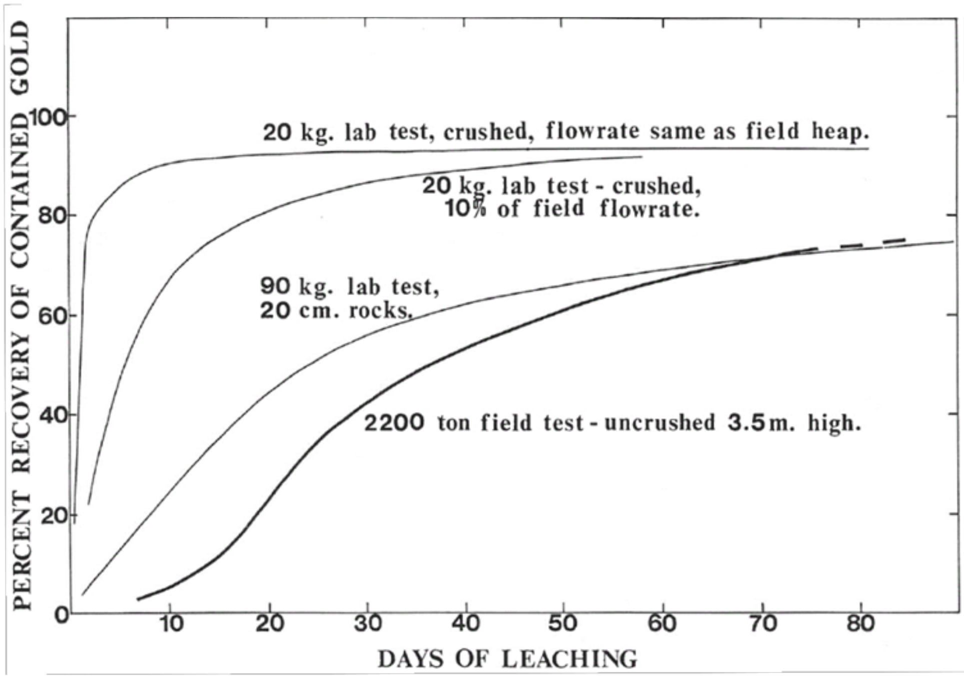


**Figure 3 Tall leach columns can provide data on scale-up of chemically reactive ores. These four leach columns, four stories high, hold 25 tonnes of ore each.**

# Figure 4 - Effects of Lab Test Variations




**Example 3 – Ores That Require Crushing**

The ore presented in Figure 2 is physically very different from either of the ores in Figure 1. This ore is a hard chert or jasperoid, in which very fine gold is apparently well disseminated. Recovery of the gold in the laboratory tests is a straightforward function of the size to which the rock is crushed.

The field test curve shown in Figure 2 was generated from a 3.5 m high field heap, with rock crushed to 8 mm. The ore in this heap was stacked using a conveyor stacker. There was no clay in the ore and no percolation problems could be detected in the field or in tall-column laboratory percolation tests.

As Figure 2 shows, the ultimate field recovery exactly matched the recoveries predicted from 13 cm high laboratory leach columns. However, as with ore B in Figure 1, there was a significant delay in field recoveries. Recovery of 50% was achieved in eight days in the lab, versus twenty-seven days in the field.

The field delay appears to be a function of heap structure, not of heap height. The same ore was leached in a 6 m high, 0.6 m diameter laboratory column located at the USBM Reno Metallurgical Research Center. The recovery curves closely matched the small bucket tests rather than the field leaches.

Figure 3 shows a set of four gigantic columns, measuring 12.3 m high and 1.25 m in diameter. The ore in these tests is "run-of-mine" size volcanic rock, with gold on fracture surfaces. The correlation for both ultimate recoveries and recovery times, between 13 cm high lab tests and these tall columns, has been very close.

**Example 4 – Flowrate and Rock Size Variations**

It is easy, in a paper such as this, to present only the data which clearly makes the author's point. The ore in Figure 4 tends to muddle things a bit.

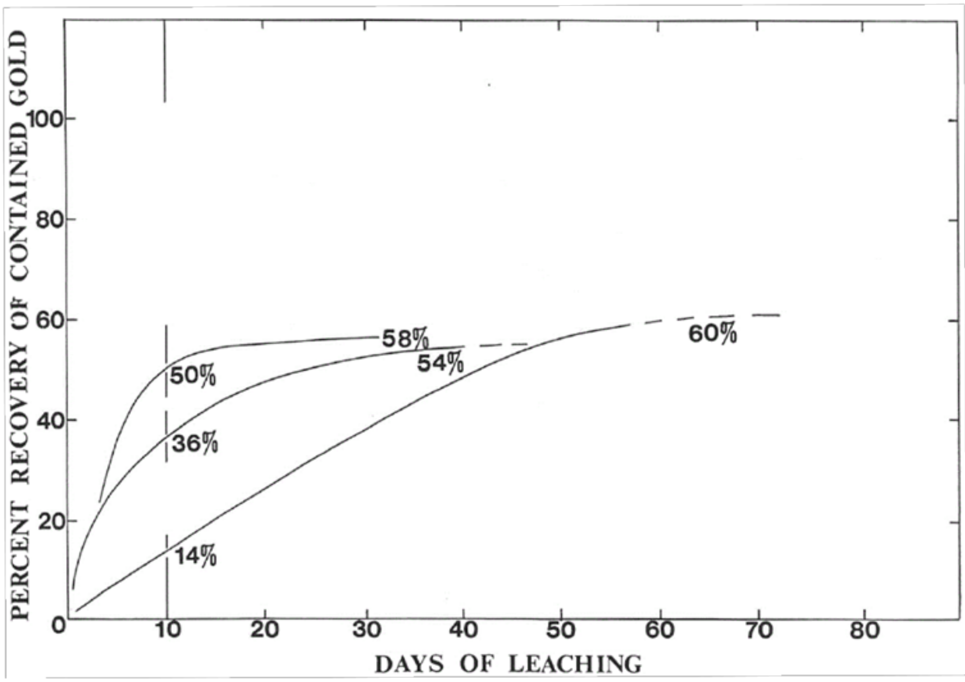
This ore is a soft porous limestone. It is physically similar to ore B in Figure 1, but it breaks differently. Simple bulldozer ripping results in "run-of-mine" ore which is 90% smaller that 1-inch. Because of its fine, earthy appearance, the heap was stacked (with ripped rock) using a conveyor stacker, in 1 meter high cones, to a final depth of 3.5 m. Subsequent laboratory and field percolation tests showed that percolation rates were very satisfactory.

Three laboratory curves are shown in Figure 4. The effect of drastically lowering the flowrate had only a minor effect on recovery. Selected large rocks leached slowly and not very well, but the ore in the field heap was mostly small. The "prediction" from the lab tests would be for a 60% recovery after approximately twelve days of leaching. It took fifty days of leaching to achieve the same recovery from the field heap.

**Example 5 – Time Factors in Testing**

Figure 5 makes a point somewhat removed from the general scheme of this paper. The figure shows laboratory test curves for three different ores. All three ores have approximately the same ultimate recoveries, near 60%. Had only short-term laboratory tests been

**Figure 5 – Leach Time Comparison Laboratory Small Bucket Tests, Three Ores Same Conditions**




run on these ores, however, the apparent picture would have been radically different. Recoveries after ten days ranged from 14% to 50%. A problem commonly faced by every testing laboratory is the "when can I have an answer?" syndrome, and a common response is to shorten the laboratory testing time.

**CONCLUSION**

In production heaps, allowing extra leaching time does more that insure against scale-up errors. At an ongoing project where the heaps are run counter-currently, the cost to leach "old" heaps is roughly $0.07 per ton per month. Significant additional cash flow can be generated from heaps producing only 0.5% additional recovery per month.

It appears that "time" must be added to a heap leach like "reagents" to a conventional mill; the approximate levels can be determined in the lab, but field operators must be given the flexibility to make final adjustments.