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OBSERVATIONS ON RECENT SUCCESS & PROBLEMS IN HEAP LEACHING

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ABSTRACT

This paper examines the issue of heap leach cash flow based on some recent operational examples. After the first six months of operation, single-lift continuous heaps produce into salable bullion only 70% of the total recoverable gold stacked. This compares with "batch" heaps and lab columns which achieve 100% in two to three months. Multiple-lift heaps often experience a second cash flow depression as a result of holdup of gold in the heap. Heap leach projects seldom fail based on technical performance, but they often fail in the sense that they generate cash flow at a much slower rate than expected.

INTRODUCTION

In 1979, Dan Kappes presented a paper titled, "Heap Leaching – Simple Why Not Successful?", which surveyed existing precious metal heap projects. The paper concluded that 11 of 22 had been failures. In the 21 years since then, there has been a huge increase in the number of heap leach projects. There are still many failures, but the ratio of successes to failures has probably increased, depending on how you define success.

This last point – the definition of success – often depends on the very critical issue of cash flow scheduling. A heap leach project can be technically functional and nominally profitable from an operations basis, while its parent company is struggling with cash flow problems. This is because projected overall percent recovery is usually used for profitability purposes, with not-yet-produced gold showing up in inventory. Unfortunately, cash flow requires turning the inventory into sales, which may entail a very long delay.

SINGLE-LIFT HEAPS

Figure 1, on the following page, shows the average results from four single-lift African heap leaches. All of these leach operations appear to be highly successful and are expected to achieve their long term target recoveries. The recoverable ounces used in Figure 1 are the field recoverable ounces projected from lab column tests. The percent recovery shown on the graph is the percent recovery of these recoverable ounces. In other words, all of these heaps should eventually achieve 100% recovery.

In the lab columns, 85% of the target recovery was achieved in the first four weeks of leaching. However, the field recovery is only 70% of the total recoverable gold stacked after six months. After 12 months, recovery is 82% with an increase of about 1% per month.

It should be especially noted that Figure 1 is based on projected recoverable gold, not total gold content. Recoverable gold may typically be 65-85% of the fire assayable gold. In the case of an ore with 70% gold recovery, after six months the field heaps will have yielded only 48% of fire assayable gold, and after one year only 57%. This seems like an obvious distinction, but it is often lost on the investment community and even on upper management.

It is very important to factor in both recovery and time delays during the financing process; the numbers sometimes seem too low. A surprising number of projects get into fatal trouble because they have not come to terms with this issue.

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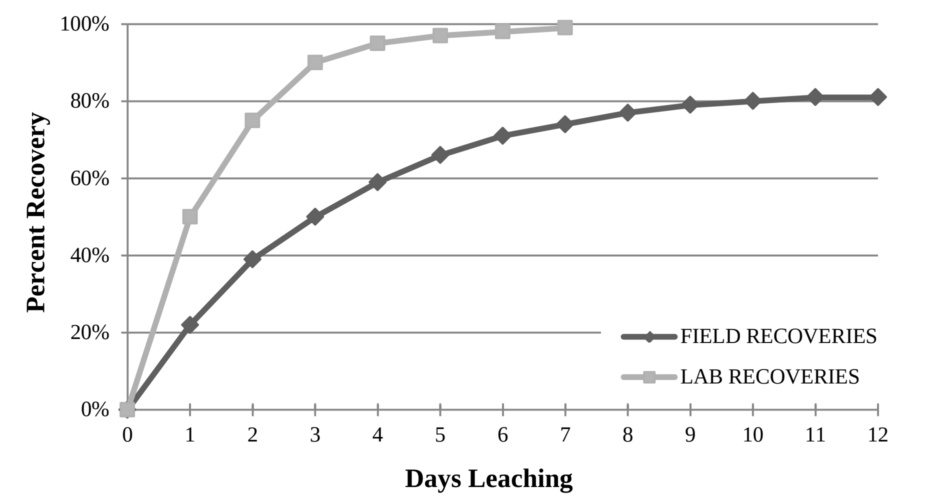
Figure 1. Percent Recovery of Total Gold Stacked



Examples of successful U.S. production heap leaches which achieved recovery rates similar to Figure 1 are Northumberland, Nevada, and Big Springs, Nevada, both of which were truck stacked single-lift heaps (6 meters high) of crushed ore.

Saprolitic heap leaches, such as Ity in the Ivory Coast, generally show predictable, fast leach curves, even though the ore can be characterized as soft clay. These ores break up to relatively small rock sizes and need to be uniformly agglomerated with high cement levels. While the costs are high, the results are good. The recovery curves for a continuously-stacked saprolitic ore may be 5% higher than the Figure 1 curve for the first eight months.

MULTIPLE-LIFT HEAPS

With multiple-lift heaps, the "cash crunch" that develops during startup is often followed by a second cash flow problem resulting from the holdup of gold as the upper lifts are built. This problem is more difficult to predict since it depends on the behavior of the lower lifts as they are put under load. There are two "ideal" situations:

a) **Solution flows in true plug flow down through the lower lifts.** In this situation, the heap would show the same recovery curve as successive upper lifts are stacked. The only difference would be a delay of 7 to 10 days per lift, while the lower solution was displaced.

b) **As the upper lift is loaded, the lower lifts become totally impermeable except for open vertical channels.** In this situation, solution from the upper lift immediately flows through the lower lifts to the collection system. In this case the new lift will show the same recovery curve as a single-lift heap. This situation is the same as putting a secondary plastic liner on top of the lower lifts.

Plug flow is not normally encountered. For homogeneous heaps of hard rock – i.e. ideal permeability – several operations report that it takes about three displacement washes to recover solution (rather than one with plug flow).

Likewise, complete impermeability of the lower lifts is seldom encountered. For most heaps, the lower lifts contain zones of relatively low permeability and channels of relatively high permeability, and permeability decreases gradually with depth. Under these conditions, some of the high grade gold bearing solution from the new upper lift penetrates the low permeability zones and takes a long time to be washed out.

Paradoxically, heaps with poor lower-lift permeability show a high-grade gold spike relatively quickly after a new upper lift is put into operation, but this spike drops off relatively quickly. Overall recovery will be achieved more quickly if the initial spike is low and slow. The exception is if the lower lift becomes totally impermeable under load. This may have been the case when upper lifts were stacked at Goldfields' Mesquite operation, where both rate of recovery and total recovery in the upper lifts seemed to exceed projections (as with most heaps, production variations made the data somewhat difficult to interpret).

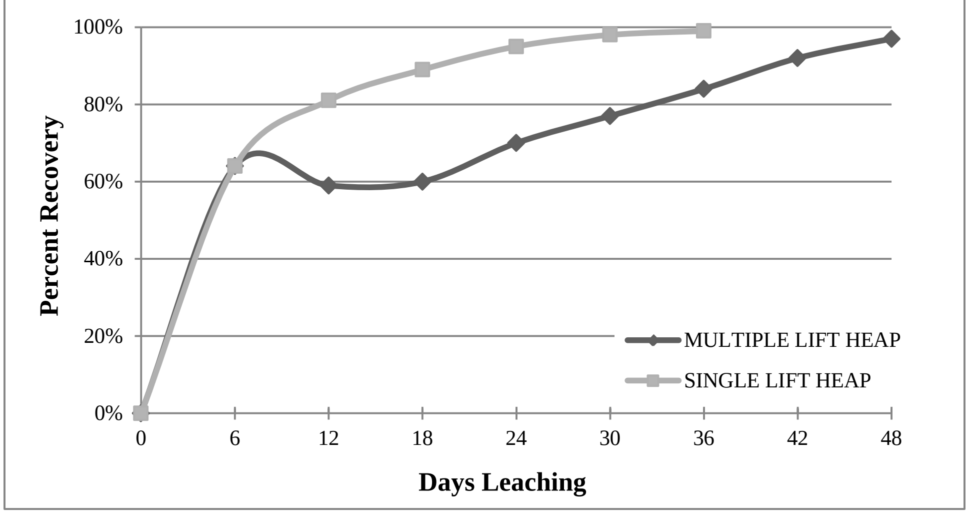


Figure 2. Percent Recovery of Total Gold Stacked

Figure 2, above, reproduces the single-lift curve from Figure 1, but adds a second curve which is a typical curve for percent recovery of gold stacked on a multiple-lift heap. The upper curve is the single-lift heap. The lower multiple-lift curve takes a dip late in year one, as it assumes that the second lift began after six months.

A simplistic, but workable, model for multi-lift heaps is to assume the leach column has three parallel components. Figure 3 shows a symbolic layout of this model. The results can be calculated using a simple spreadsheet.

Figure 3. Multiple Lift Heap Leach Model

	Channels	Permeable Areas	Impermeable Zones
TOP (ACTIVE) LIFT	N/A	N/A	N/A
3rd LIFT	10% 0:1	70% 3:1	20% 8:1
2nd LIFT	10% 0:1	60% 3:1	30% 8:1
BASE LIFT	30% 0:1	20% 3:1	50% 8:1

In this model, the percent number is the percent of total flow which enters each area. The ratio is the dilution, which is experienced during the pass through the lift. For the permeable areas: if the lift contains solution assaying 0.06 ppm gold and the incident solution is 0.60 ppm gold, then the exiting solution is 0.195 ppm gold. For the channels, the solution exiting the lift is the same grade as the solution entering the lift. Solutions exiting each lift are averaged to determine the grade of solution entering the next lower lift.

The model can be run and summarized for the appropriate time periods to determine overall heap performance. The percent flow and dilution ratios that apply to each area of each lift can be varied, hopefully leading to a model that reflects observed field performance.

One inescapable result of the above model is that as each successive lift is added, it takes more solution to achieve the same percent recovery. Gold grade of pregnant solution will naturally decrease (and volume of solution processed will increase) if overall recovery is maintained. Heaps which are operated to maintain a steady gold head grade in pregnant solution will experience a steady decrease in overall recovery.

The majority of heap leaches in both copper and precious metals which have been built in the past few years have been designed (very successfully) as multiple-lift heaps. This is either because the grade of ore is very low, or because physical constraints limit the area available for heaps. If the ore grade is relatively high (above 2 grams gold per tonne), single-lift heaps should be considered because gold recovery is steadier, faster, and washing is more efficient and therefore closure time is shorter. Also, single-lift heaps allow for better water management practices in areas of high rainfall.

The above discussions address the issue of recovery delays caused by normal physical conditions within the lift and delays caused by additional lifts. In practice, recovery (and cash flow) is often further delayed for a variety of operational reasons discussed on the following pages.

Truck Stacking

If the heap is truck stacked, several weeks of ore can be tied up under truck roads and ramps. The "tie-up" of ore under ramps can easily approach $1 million for a 2,000 tonne/day heap leach, and needs to be factored into first year cash flows. In contrast, conveyor stacked heaps can be designed to start leaching ore within three to four days of stacking. When the cost of ore tie-up is considered, conveyor stacking is often the better choice from both a capital and operating cost standpoint.

Solution Application and Drainage

Even with a system of carefully laid out pipes and drip points, it is very difficult to uniformly apply solution. Sideslopes comprise a large percentage of ore heaped and must be efficiently irrigated to achieve target recoveries. Sideslope leaching problems can seriously impact cash flow, especially during the first year of operation.

The drain base below the heap is equally important. Randall Pyper of KCA's Australian office recently provided consulting services to an operation with side-by-side production cells on the same ore: one cell had only drain pipes below a fine, compactable ore, the other had pipes within a gravel drainage base. Recovery was dramatically faster, and overall recovery was higher for the cell with the gravel/drain pipe composite. The large valley-fill Illinois Creek heap leach in Alaska failed in part because drainage pipes were not installed below the heap.

Selection of Crushing Systems

A common cause of early project failures is the choice of open circuit versus closed circuit crushing systems. Especially during startup, open circuit crushers are seldom operated at the designed crush size, and heap recovery is depressed. If open circuit crushing systems are employed for ores which are sensitive to crush size, a significant safety factor should be added to cash flows.

Some ores can be successfully leached at run-of-mine sizes. Yanacocha in northern Peru is a very successful application of run-of-mine heap leaching. Where this works it is the best method, and often a loss in recovery is justified by a much simpler operating system. Run-of-mine leaching can be tested in the laboratory, but a higher safety factor is usually applied to the results because it is difficult to predict the size mix in actual mining conditions.

At the other extreme, some ores need fine crushing. The Comco silver heap leach of Comsur at Potosi, Bolivia, crushes and dry-grinds the ore to 50% minus 20 mesh, before agglomerating and heap leaching. It has been operating successfully for over ten years. An economic review in the fourth year of operation examined the option of conventional agitated tank leaching and concluded the heap leach was more cost effective.

Agglomeration Experience

For high clay ores, especially in high rainfall environments, correct agglomeration of ores is critical. Often the initial operating staff has no previous experience with correct design or operation of agglomerating systems. Santa Rosa in Panama is a good example of a heap which was started up by operators without much experience in handling and agglomerating high clay ores, and as a result the operation was a failure. Lack of quality agglomerates has probably resulted in the largest number of recent heap leach failures.

CONCLUSION

Heap leaching has some unique negative characteristics that can result in failures:

- The low initial capital cost often permits a less rigorous design and cost analysis, leading to cash flow problems.
- Heap leach systems are not easy to change once they are installed. A series of relatively small errors or omissions, all of which can be justified or ignored during design, can develop into a significant long term problem.
- In a conventional mill, performance problems show up quickly and can be addressed. In contrast, heap leach performance cannot be easily evaluated. Operational problems can continue for a long time, and remedies do not have an effect for an equally long time. In one recent example, lack of grade control allowed for the stacking of ore with preg robbing characteristics. Although recovery delays appeared within six months, it took two years to positively identify and correct the problem.

On the other hand, heap leaching can be a very successful method of processing precious and base metal ores. The very low cost heap leaches at Newmont's Yanacocha project and Barrick's Pierna project, both in northern Peru, are testimony to what happens when a very good ore is coupled with a very good system design and good project execution.