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NEW DEVELOPMENTS IN HEAP LECHING

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In the 1550's, Agricola wrote a convincing description of heap leaching for (strangely enough) aluminum. The ancients did not like aluminum cookware, but they used a lot of alum.

In its current reincarnation, heap leach technology is now 20 years old, and is showing encouraging signs of coming into adulthood.

The simplistic approaches of the early years are now being supplemented by new sophistication in areas such as the control of scale formation, systems for water balance control, conveyor stacking, and countercurrent leach techniques.

In the western U.S., heap leaching is alive and well and is beginning to be applied elsewhere. Significant studies on actual gold leaching operations have been undertaken on every continent except Asia (and maybe there also) and in most significant gold producing nations. Leaching of copper and uranium ores have developed in parallel, though to a lesser extent.

Where do we go now? The ultimate goal is low costs per ounce, which requires a combination of low operating costs and high gold recoveries.

Table 1 shows the typical operating costs of a 2000 ton per day heap leach.

Emphasis is often placed on lowering operating cost factors by building high heaps. While this is admirable, the primary emphasis must be maintained on that final factor: recovery. A small percentage change in recovery more than offsets a change in any other cost category.

The factors which affect recovery are still not well understood. Major developments are still needed in several areas, including the following list.

Understanding the nature of chemical reactions and flow mechanisms:

- Why do tall heaps behave slower than short heaps?
- Are there chemical additives that can enhance recoveries?

Management of water balance:

- Solution application systems to conserve water.
- Solution application systems to conserve heat.
- Systems to minimize rainfall intake.

Methods of handling and preparing difficult ores:

- Crushing and agglomeration methods for damp ores.
- Development of efficient stacking systems.

Table 1 - Typical Operating Costs for a 2000 Ton Per Day Heap Leach

Mining	$4.00	/ton
Crushing & Stacking	$1.00	
Leach Pads	$0.80	
Ponds & Pipes	$0.20	
Operating Labor	$0.70	
Gold recovery	$0.40	
Cyanide & Lime	$0.60	
G & A	$1.00	
TOTAL OPERATIONS	**$8.70**	/ton
CAPITAL	**$2.70**	
GOLD NOT RECOVERED	**$6.70**	*****

**35% loss of 0.06 oz/ton in ore*

Thickness of Heaps – False Economics?

A major question which always affects costs is the heap height. Higher heaps require less management and are much less of a problem than shallow heaps.

Operations like Landusky-Zortman and Candelaria provide models of heaps 60 and 100 feet high which

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are tempting to duplicate. Many operations are stacking new heaps atop old ones.

The cost tradeoffs are not very straightforward, however. Lab column data indicates that increases in column height can lower recovery rate or total recovery percentage. Where does this stop? There is some recent data which indicates the development of "roll fronts" – gold moving slowly downward through the heap. Some multi-lift heaps show definite signs of delayed or lower recovery.

Raising the heap height to 60 feet from 20 feet decreases costs by $0.75 per ton. A recovery drop of five percent wipes out the advantage.

<u>Can Solution Movement Within Rocks Be Made More Effective?</u>

An interesting question is: How does solution move through the grain boundaries of the rock to get the gold?

In a lot of ores, the gold is on fractures that appear too fine to permit solution movement.

The near-surface ore at the Sterling Mine in Beatty, Nevada, provides an interesting example. Here, ore microscopy established that gold occurs as one micron particles which form "necklaces" around calcite grains in a calcite-rich shale. The grain boundaries are tight, yet recovery from ore containing 0.30 ounces gold per ton – at a three inch crushed size – was 90 percent in three weeks.

Evidence for grain-boundary gold which can be recovered by heap leaching exists in other deposits.

Interesting work is being done on chemical additives to enhance leach rates and recovery. Faster-leaching heaps, or high heaps with low-heap performance characteristics, should result.

<u>New Geographic Frontiers Require Novel Systems for Solution Application</u>

The western U.S. is an ideal location for leaching: moderate rainfall, moderate temperatures, and remote, but still accessible. In some areas of the world, improvement in techniques is necessary for heap leaching to be undertaken.

Heap leach field tests have proceeded in the high desert areas of South America at altitudes of 14000 feet (4300 meters). Ice forms on the heaps every night during the SUMMER. Modified solution distribution methods are key to the operation:

For seasonal ice in the western U.S., buried pipes and drip points are used, but this is an ineffective method of solution distribution. Tests conducted several years ago at Windfall, Nevada, indicate that the angle of the wetting cone is only 10 degrees. In a 30-ft high heap with drip points on 8 foot centers, only 45 percent of the heap is effectively leached.

Alternatives for conventional sprinkling are needed for conditions exactly opposite to those in freezing environments. Sprinkling in hot desert conditions uses up scarce water resources.

<u>Permanent Vat Leaching May be a Useful Technique</u>

We have recently evaluated heap leaching in extreme desert environments in North Africa. One modification, leaching in permanent vats, shows promise of eliminating evaporation problems.

The use of permanent vat leaching has also been proposed for high mountain areas. Permanent vats – large, plastic-lined heap leaches with plastic-lined sidewalls – offer the advantage of self-containment for winter shutdown and the ability to leach below ice cover.

It is possible that we may see several installations of the permanent vat leaching technique in the near future. The main roadblock to permanent vat leaching has been that small vats incur high containment costs – the containment for a 50000 ton vat costs $1.50 per ton – but this can be overcome by the use of ore to build temporary internal dikes. Evaluation indicates that a 2000 ton per day permanent vat leach will incur containment costs only $0.40 per ton higher than heap leaches.

<u>Rainfall Cycle is as Important as Rainfall Amount</u>

For heap leaching in high rainfall areas, the annual cycle of rainfall can be more important than the total rainfall. In Costa Rica, the annual rainfall is 5 meters (200 inches), but for six months of the year the country is dry.

Here, high clay ores have to be dried and then agglomerated. Fortunately, during the dry season, the ores can be dried by solar heat and stockpiled for treatment during the rainy season.

In tropical climates during the dry season or in northern high-desert climates, the solar drying area required to dry clays is roughly 10 square meters (100 square feet) per ton per day. Capital and operating costs of a solar drying system are comparable to crushing costs.

Different conditions apply on the northern coast of South America. Rainfall is less than in Costa Rica, but is spread uniformly throughout the year. Drying in the open air is not possible, and field drying tests indicate that a 1000 ton per day operation will require a rather impractical drying area – an area under canopies of ten acres (four hectares).

Investigations here are centering on the use of log washers to mix and agglomerate the high clay ore in its wet condition. Pinson Mining Company has applied similar equipment for agglomeration at the Preble ore body in Nevada.

Solution Discharge is Usually Not Necessary

Water imbalance, the need to discharge excess water, is usually not a problem in tropical climates. Tropical jungle areas show high humidity near ground levels under forest canopy, but cleared areas show low humidity during most days. Under such conditions, evaporation of sprinkled leach solution is rapid. Typical daily average evaporation levels are shown in Table 2.

Table 2 - Typical Average Daily Evaporation

CLIMATE CONDITIONS	% EVAPORATION IN 24 HOURS*
High Desert, Summer	20%
High Desert, Winter	5%
Tropical Jungle, Dry Season	20%
Tropical Jungle, Wet Season	10%
Cool, Rainy Climates	0%

**Percent of solution evaporated when being applied through sprinklers*

Because of the high rates at which solutions are applied to the heap leaches, it doesn't take much evaporation to keep the systems in water balance.

Our experience at a heap leach operation in Costa Rica was that the systems are in balance during months with 15 inches of rain or less. Table 3 shows the typical relationship between sprinkling rate and rainfall.

The worst conditions in the world for heap leaching are cold, damp climates. Engineering was just completed for a heap leach in western France, which will employ covered shortage ponds, solution neutralization, and discharge. Witteck Development Corporation recently announced that they're installing a neutralization system at the Gordex Mining Company in eastern Canada.

Covered Ponds or Heaps Should be Considered

Where rainfall is heavy, solution balance can be greatly improved by covering the ponds, which may have a surface area equal to half that of the active heap area.

Either for heavy rainfall or for cold weather leaching, roofs have been considered but not applied. The cost of inflatable buildings or suspended/supported membrane roofs is $4.00 per square foot. A "modular" roof covering a two month active leaching segment, that moves continuously across the top of the heap on a series of steel runners, should cost less than $0.50 per ton of ore leached.

Table 3 - Typical Relationship Between Sprinkling Rate & Rainfall

Sprinkling Rate:	5	gallons / day / sq ft
	0.0035	gallons / minute / sq ft
	10	liters / hour / sq meter
Equals:	7.5	inches of rain per day
	19	feet of rain per month
	6.0	meters of rain per month
10% Evaporation:	22	inches of rain per month
	0.6	meters of rain per month

Conveyor Stacking Systems Are Being Proven In Practice

Conveyor stacking is now becoming established as an important heap construction method. Conveyor stacking allows complete flexibility to create internal structures (controlled channels) within the heap where this is necessary, or to build the heap as a thoroughly homogenous mass of agglomerated material.

Since no heavy equipment needs to drive on top of the heap, a conveyor stacking system for any heap of crushed ore results in lower heap construction costs per ton and improved percolation characteristics.

Ortiz uses a permanently mounted bridge conveyor stacking system. Portable bridge conveyors mounted on tires have been used by the construction industry and appear feasible for heap leaching.

Falcon Exploration Company at their Tonopah Divide mine in Nevada pioneered the use of extension conveyors for building heaps, which permit efficient working surfaces on the heaps.

Sectional conveyor systems have been used at Amboy in California and at Getchell, Little Bald Mountain, and Buckhorn in Nevada. These systems permit direct stacking with almost no manpower needs beyond the crushing plant discharge.

Typical installations involve between three and ten short sectional conveyors between the preparation systems and the heaps, but we've recently evaluated systems with up to 3000 feet of fixed conveyor leading to telescopic conveyors at the heap construction site.

These systems appear to be feasible and simple extensions of technology already proven in other industries.

Simple Low-Cost Heap Leaching Is Alive and Well

Conveyor systems and other heap leach systems need not be expensive. The Little Bald Mountain operation of Northern Dynasty Explorations Ltd., used a custom-designed stacking system, contract mining and crushing, and portable recovery plant in a first-phase leach this past summer. Total capital and operating costs for this 600 ton per day installation were less than $1,000,000 and payback occurred in less than five months. Performance like that, of course, is exceptional, and requires a combination of good ore and simple production systems with something that hasn't changed at all since Agricola's time: a team of professional managers with common sense and the dedication to work long and hard hours.