Kappes, Cassiday & Associates

7950 Security Circle, Reno, Nevada USA 89506
Telephone: (775) 972-7575 FAX: (775) 972-4567

THE ASHANTI (GHANA) HEAP LEACH
TREATMENT OF DECOMPOSED SCHIST IN A TROPICAL ENVIRONMENT

Presented at the World Gold Conference, Cairns, Queensland, Australia, 1991

by M. Cassiday[*], T. Cox[†], I. Domfeh[‡], I. Stalker[§], & B. Jaczkowski[**]

ABSTRACT

Mining and treatment of gold ore in the Ashanti region at Obuasi, Ghana has been continuous for more than 100 years. Earlier production from this world-class deposit can be traced far into the history of West Africa's gold trade.

As part of a general development and expansion program, Ashanti Goldfields Corporation (Ghana) recently undertook a program to heap leach oxidized near-surface ore. Kappes, Cassiday & Associates was given a major role in the design, equipment supply, installation, and start-up management of the 3000 tonne per day heap leach. Unusual conditions included a high annual rainfall and an ore which could be characterized as a soft, decomposed, water-saturated schist. Production began in March 1990. Start-up problems and their solutions are discussed.

SUMMARY

On 1 March 1990, Ashanti Goldfields F(Ghana) Ltd. (AGC), began heap leaching high clay ore mined from their recently commissioned Sansu deposit. The first gold bar from the heap leach project was poured on 20 March and by November production was averaging approximately 145 kilograms (4,500 ounces) per month.

The Sansu deposit is located adjacent to Ashanti Goldfields existing mine facilities and concessions in Obuasi, Ghana. Obuasi's climate is tropical, being located approximately 200 kilometers from the coast of Ghana at 4 degrees North latitude. The area receives two meters of precipitation annually which predominately occurs over a seven month rainy season from mid-April through mid-November.

The process involves open circuit crushing the ore to minus 25 millimeters, agglomeration with cement and barren solution, conveyor stacking on HDPE-lined pads, and sprinkling with cyanide solution. Gold is recovered from pregnant solution by carbon adsorption, then stripped from the carbon using an alcohol strip and electroplated.

The project was designed to process ore at the rate of 90,000 tonnes per month for 12 months per year. From the start of operations in March through September 1990, an average of 75,100 tonnes per month was processed with a three month average for July, August, and September of 84,000 tonnes per month. By December, weekly production rates were regularly exceeding 110,000 tonnes per month. The quick start is unusual for heap leaches, especially in remote locations, and is attributed to a system design especially tailored for the ore and the climate.

GEOLOGY

The southwestern portion of Ghana which includes the Obuasi area is comprised of Proterozoic terrain of the West African shield which has an age of two billion years. The area is made up of northeast and north striking belts of volcanic and sedimentary rocks known as the Birimian. All known gold deposits in Ghana, including those of AGC, are hosted by rock of the Birimian or are all in alluvial deposits whose origin is Birimian.

The Obuasi area is near the boundary between the Birimian meta-sediments and meta-volcanics and is part of the Axim-Konogo gold belt. This belt extends over 250 kilometers from Axim-Dixcove on the coast northeast to the Konongo area and is the strongest of the several defined Ghanaian gold belts.

[*] M. Cassiday –Kappes, Cassiday & Associates, Reno, Nevada, USA
[†] T. Cox – Kappes, Cassiday & Associates, Reno, Nevada, USA
[‡] KI. Domfeh – Ashanti Goldfields Corp., Accra, Ghana
[§] I. Stalker – Ashanti Goldfields Corp., Accra, Ghana
[**] B. Jaczkowski – Ashanti Goldfields Corp., Accra, Ghana

The deposits at Obuasi occur in the meta-sediments and are associated with shear zones hosting quartz veins. In the fresh, un-weathered ore, which has been the primary resource treated by AGC, gold occurs as free gold or intimately associated with iron and arsenic sulfides. The primary structure from which ore has been mined to a depth exceeding 1.5 kilometers has a strike length of over 8 kilometers. Average grade of the 30 million tonnes of ore produced from the start of production through 1986 has been 22.4 grams of gold per tonne.

The near surface portion of the ore structure has been highly oxidized. The surface is composed of lateritic clay-rich material containing minor amounts of quartz in thin stringers. Below the laterite surface the material zones to thoroughly oxidized soft schist which still retains its original texture. Sulfides have been completely oxidized, liberating the contained gold. Surface oxidation and partial decomposition continue to a depth of more than 50 meters.

The resource to be treated by heap leaching consists of laterite and oxidized schists. Due to the tropical nature of the area, the in-place ore is quite damp. The ore grade average ranges up to 3.0 grams of gold per tonne with little or no silver or copper present.

TEST WORK

Heap leach testing of the Sansu deposit material was performed by KCA at its Nevada-based laboratory. The material tested can be described as a very earthy and clayey, highly altered schist. This material was considered representative of the ore expected to be encountered throughout the Sansu deposit, although it was realized that the ore would become somewhat more competent at depth.

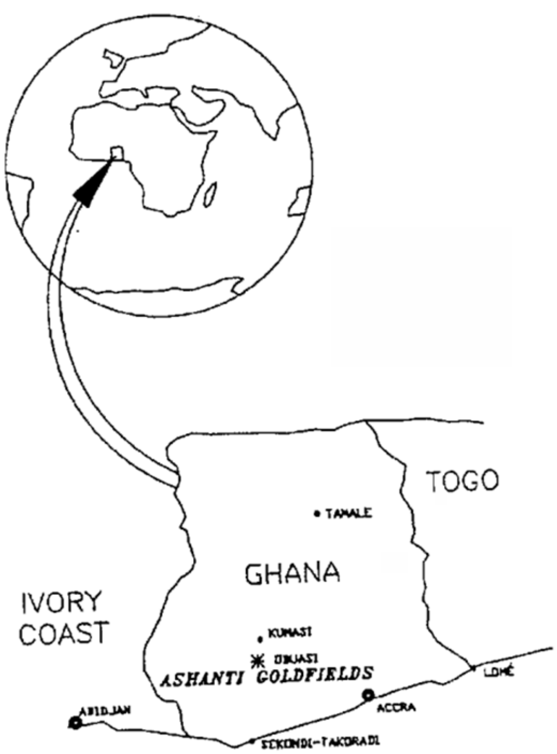


Figure 1. Ashanti's (Ghana) heap leach region map.

Extensive small-column tests were run to determine methods for producing competent agglomerates from the damp schists, and these were followed by a series of column tests up to 2 meters high and 0.3 meters in diameter. No large-column or field leach tests were deemed necessary.

In lab columns, material crushed to minus 25 millimeters and agglomerated with 1.2% cement had recoveries of 87% of fire assayable gold content in 60 days. Based on the laboratory data and previous experience with similar ores, it was projected that field heap leach recoveries would be approximately 83% during a total of 90 days leaching, broken into two 45-day countercurrent cycles.

Initial metallurgical review was kept simple for a few reasons, namely:

- Geological evaluation indicated that the deposit was relatively uniform; and
- The overall ore grade was high enough so that economic viability did not require an extremely accurate determination of percent gold recovery.

As is often the case, significant proportions of the actual ore delivered from the Sansu pits had characteristics different from the ore samples tested. Significant amounts of quartzite and phylite were encountered. Fortunately, the only effect these materials seem to have had has been to slightly lower the recovery rate. Overall recovery has not been affected; heaps placed under leach in March and April 1990 were sampled by auger drilling in October. Results indicate that recovery has slightly exceeded 80% of fire-assayed gold content.

PAD DESIGN & INSTALLATION

Clearing of the leach site began in January of 1989. A teak tree plantation belonging to AGC had to be removed prior to clearing and grubbing. In order to minimize start-up capital costs, a pad large enough to accommodate only the first year's production was constructed.

Pad preparation consisted of removal of topsoil, grading as required, and compaction of the exposed lateritic surface. Internal berms were built from truck-dumped soil excavated adjacent to the heap. The overall slope of the leach pad was five percent.

After initial pad preparation, a 1.0 millimeter HDPE liner supplied by Gundle Liners U.S., was installed and anchored into place. A layer of non-woven geotextile was installed over the entire pad and a 76 millimeter perforated agricultural drain pipe was placed on six meter centers and anchored to the pad surface.

During subsequent heap construction, a 350 mm thick layer of crushed and/or screened aggregate was placed over the geotextile/pipe system. The aggregate was sized at -25 + 6 millimeters to form a percolation base as well as to protect the liner from damage by the conveyor stacking equipment.

The leach pad is designed with intermediate berms up, down, and across slope to segregate the ore into modules of 45 days production. PVC pipes are installed through the downslope berm of each module to allow the process solutions to exit. Pipes from upslope modules run the length of the downslope modules and are subsequently buried when the downslope module is stacked.

At the downslope edge of the heap, each module collection pipe is connected to a distribution box which directs the solution to the appropriate process pond via large diameter plastic collection pipes located in a collection ditch. This ditch is lined with a 1.5 millimeter HDPE liner and geotextile, which are sufficiently strong and allow heavy for foot traffic.

DESIGN FOR HIGH RAINFALL

The Sansu heap leach site is situated in an area of very high rainfall. Precipitation averages 2.1 meters per year; however, a ten year annual rainfall event exceeds three meters. Rainfall occurs predominantly in a five month rainy season, with occasional one month rainfall of 0.5 meters.

Rainfall, even in the worst months, is not sufficient to affect heap operations or performance, but it must be accounted for in solution storage and removal systems. With sufficient pond capacity and a large area of installed sprinklers, it is possible to design a system to stay in complete water balance even in the worst years. However, it was decided to allow for neutralization and discharge in one year of every five.

Six ponds were constructed: three process ponds, a primary overflow pond (which will partially fill every rainy season), a secondary overflow pond (which will fill one year out of every five), and a neutralization/makeup water pond (to be used on a batch fill/neutralize/discharge cycle as soon as the secondary pond becomes full.) The three process and two overflow ponds are identical, each having a capacity of 11,600 cubic meters. The neutralization/makeup water pond has a capacity of 1,600 cubic meters.

Additionally, evaporation pumps and sprinklers capable of evaporating 20,000 cubic meters of solution per month were installed. These will be run continuously each rainy season whenever the process ponds are at 75% capacity or more.

POND DESIGN & CONSTRUCTION

The process ponds were constructed with crest dimensions of 80 x 60 meters and a depth of five meters with a 2.5:1 side slope. The ponds were lined with a double layer of one millimeter HDPE. Geotextile was placed between the liners to act as a wick to draw solution toward the leak detection sump.

Due to a high local water table, a drainage system was required underneath the ponds. The drainage system consisted of 0.5 meter deep trenches excavated on six meter centers along the bottom of the ponds. Perforated drainage pipe was then placed in the trenches, backfilled with drainage gravel, and covered in geotextile. The drainage trenches from each pond were connected to solid drain pipes. These drain pipes extended under/through the pond wall and sufficiently far enough downslope to allow natural drainage.

Solution passes through Parshall flumes immediately before entering the three process ponds.

PROCESS PLANT

Gold is recovered by carbon adsorption, then stripped from the carbon using an alcohol strip and electroplated. The plant is an unusual system, pioneered and perfected by Kappes, Cassiday & Associates through the installation of more than 16 plants. Six closed-top fluidized bed carbon columns, each containing approximately two tonnes of carbon, are used. Adsorption, stripping, and acid washing take place in sequence in the same columns.

The design allowed the plant to be constructed in a fully modular fashion in the U.S., requiring only piping connections once the modules arrived on site. The more traditional cascade systems cannot be shipped in modular fashion because of the need for 9 meters of elevation at the top of the first tank. Other advantages of the system installed at Ashanti include:

- The carbon is fully enclosed, which prevents pilferage of loaded carbon;
- The closed-top system permits a very large turn-up / turn-down ration. Satisfactory operation at 150 to 200% of design capacity is possible, whereas with the traditional systems a maximum 120% is achievable;

- The design inherently prevents major process upsets due to operator error, such as flow rate excursions when starting or testing pumps.

The plant was constructed at the KCA facilities in Nevada as a complete assembled plant in four standard-width containerized shipping modules. These were then disconnected and shipped by a series of methods including truck, rail, and ocean transport. At Ashanti, they were placed on a concrete slab (with partial building cover) and reconnected. Initial construction time was 14 weeks, and shipping/customs clearance required 10 weeks. Total field installation time was three weeks.

Design flowrate of the plant is 136 cubic meters per hour, sufficient for a heap leach processing 3,200 tonnes ore per day. AGC has run it satisfactorily for long periods at a rate equivalent to 4,000 tonnes ore per day.

During normal operations, a series arrangement consisting of two set of two columns (four columns total) are on line in adsorption mode at any one time. The other column set is being stripped or is on standby.

Two columns (4 tonnes) of carbon are stripped at a time, using a strip solution flowrate of 11 cubic meters per hour. The strip solution contains one percent each of sodium hydroxide and sodium carbonate and 20% ethanol. Strip solution is heated by an electrical immersion heater in the strip solution storage tank. Strip pressure is atmospheric and strip temperature is 83 degrees Celsius. Solutions are electroplated at normal strip temperatures.

The stripping section of the plant is capable of recovering gold at over twice the design rate of production, which allows considerable operating flexibility. Normal strip times are on the order of 12 hours.

Carbon is not normally removed from the columns other than for periodic regeneration. Regeneration of carbon has been performed twice during the eight months since startup.

CRUSHING

Based on the relatively soft, clayey nature of the majority of the ore, AGC chose a crushing system consisting of an apron feeder and three Mining Machinery Developments, Ltd (MMD) mineral sizers in open circuit. Nominal product size is minus one inch.

Two Caterpillar 966 loaders feed the plant from a nearby stockpile to the apron feeder. The feeder supplies ore to a primary MMD crusher at a rate of 250 tonnes per hour. The primary discharge is conveyed to two secondary MMDs operating in parallel which discharge onto a single agglomerating drum feed conveyor. A belt weightometer is installed on this conveyor.

AGGLOMERATING, CONVEYING & STACKING

Agglomeration of the ore is accomplished in a three meter diameter by 10 meter long rubber-lined drum. Drum speed is 10 rpm and inclination can be varied from 8 to 15 degrees depending on the characteristics of the ore. The lining is installed loose so the “flip-flop” action prevents material from building up on the drum wall. The crushers, agglomerating drum, and related equipment was supplied by Sepro U.K., Ltd.

Cement is used as a binding agent and is metered onto the agglomerating drum feed belt. It is delivered by bulk truck and is stored in two silos. It is transferred via a fixed speed screw feeder to a weight operated variable-speed feeder. Feedback from the belt weightometer controls the addition rate from the secondary variable speed feeders.

Barren solution is sprayed into the agglomerating drum through a system of spray nozzles mounted on a support bar in the drum. Solution is controlled manually. A flowmeter on the solution addition line is used to aid in operational control as well as for metallurgical balance purposes.

At the start of operations, the ore was agglomerated with 1.5% cement (slightly higher than laboratory tests indicated was necessary.) Cement dosages were later increased to 2.0% due to suspected instability of agglomerates in the lower part of the heaps.

Drum product is transferred to the heaps using a series of ten 60-meter long portable conveyors. At the end of the conveyor string, a 10 meter traverse conveyor delivers the ore to a 60 meter long self-propelled wheel-mounted steerable “grasshopper” conveyor, which feeds a 30 meter long radial stacker.

The radial stacker has a five meter “stinger” conveyor at its discharge end. The stinger is continuously extended and retracted under the control of the heap operator using a remote control. Normally the operator stands on top of the heap; he can operate the equipment so it constructs a totally smooth surface without the need for any mobile equipment on top of the heap.

The stacker can stack to a maximum height of 10 meters and can stack a 4.7 meter thick arc of pellets, containing approximately 2,600 tonnes, between each stacker move. The stacker is self-powered to travel radially and up and down slope. A steerable truck-type bogie is located on the feed end. Relocation time is about 30 minutes.

The conveyor transfer and stacking system were fabricated in the US, and supplied and installed by KCA.

HEAP & SPRINKLER SYSTEM OPERATION

Since the pellets are quite fragile, shade-cloth is placed on top of the heaps before the leach piping is installed. This material protects the pellets from the full force of the sprinkler and rainfall droplets falling onto the surface.

No. 8 Senniger wobbler sprinklers are installed on a six by six meter square grid pattern. Sprinkling is continuous 24 hours per day for a 90 day primary leach cycle, then for an additional 90 day secondary leach cycle. The use of sprinklers instead of the more common drip irrigation system is necessary because of the large amount of rain which must be evaporated. Experience indicates that evaporation can be substantial even in the worst periods of the rainy season.

Heap off-flow solution from the primary cycle flows to the pregnant pond and then through the recovery plant. Solution from the secondary cycle flows to an intermediate pond and then to the primary cycle.

The piping and sprinkler system is left on the heaps for several months following the completion of leaching. During very heavy rainy seasons, old heaps which have not yet been completely abandoned will be sprinkled to maximize evaporation. Heaps will be abandoned and pipes removed approximately 2 years after they are stacked.

INITIAL HEAP OPERATING EXPERIENCE

The first pad module (module 1A) was stacked to a height of seven meters. Sprinkler piping was placed on the heap as it was constructed, and leaching was initiated as soon as sufficient leach surface was available. The first ore was placed on the heap in late January, leaching commenced the first of March, and the first gold bar was poured on 20 March.

The first ore module contained 100,000 tonnes of ore. Average fire-assay grade of this material based on daily crusher sample assays was 2.96 grams per tonne Au (total gold contained = 296 kilograms.)

Total recovery from this module and subsequent modules took much longer than anticipated. After 45 days of leaching, gold recovery was only 45 percent of fire-assay gold content, substantially lower than predicted. At this time, however, solution flowrates and grades indicated that over one percent per day was still being recovered from the heap. While a 90 day leach cycle was planned for, the low initial flowrates resulted in a decision to leach for 180 days. The segmented pad modules and provision for countercurrent leaching allowed this extended leach period without any changes to the system, or any decrease in production rate.

At the end of the leaching cycle (180 days total), an auger was used to obtain tailing samples of the first pad module. From a total of 20 samples, the average fire-assayable gold content was 0.44 grams per tonne, whereas the head grade had been 2.93 grams per tonne. Final recovery was therefore 85%, which exceeded the projections.

The slow recovery is primarily attributed to the fact that this early ore contained significant amounts of high grade quartzites. The quartzites contributed to increased wear in the MMD sizers. The MMD sizers have performed well, but, due to a delivery problem, replacement segments for the sizers were unavailable for an extended period of time. This led to significant portions of the initial heaps being crushed to two to three inches instead of the design one inch.

Behavior of the first pad module and appearance of the pellets were initially quite acceptable, and initial solution grades form the heap indicated rapid gold recovery. As a result, the next three modules were built 10 meters high. When the recovery rate problems were noted, heap height was returned to seven meters, and it appears that a 10 meter lift height is yielding target recovery now that operational procedures have been optimized.

CAPITAL & OPERATING COSTS

Approximate capital costs for complete installation of the project are shown below (converted to US dollars):

Table 1 - Complete Installation Capital Costs (Approximate in Millions)

Crush/Agglomerate/Stack Equipment	$ 2.5
Site Preparation & Pond Liners	$ 1.8
Heap Piping & Recovery Plant	$ 1.1
Power Supply	$ 0.4
Site Laboratory	$ 0.1
Cement Trailers	$ 0.5
Mobile Equipment	$ 0.8
Aggregate Crushing Plant	$ 1.0
Miscellaneous Startup Equipment	$ 0.6
TOTAL CAPITAL INVESTMENT	**$ 8.8**

These capital costs are similar to costs which would be realized at a similar U.S. heap leach operation, and have benefited from the fact that Ashanti has an extensive existing infrastructure. The cost of a 3,000 tonne per day heap leach, if built at an undeveloped site in Ghana by a newly formed company, could be expected to be nearly twice that at Ashanti.

Heap leach site operating costs including mining per dry tonne of ore processed are approximately $9.50 per tonne.

The major reagent cost is cement, which (at a use level of two percent of ore weight) costs $2.00 per tonne of ore.

Mining is performed by a contractor, at a cost of approximately $2.50 per tonne of ore delivered to the crusher stockpile.

Labor costs are $0.15 per tonne. Operators earn approximately $1.00 per day. A totally Ghanaian staff of 30 operators, three shift supervisors and one general manager have been dedicated to the project.

Electricity is supplied cheaply, $0.04 per kilowatt-hour, from a nearby Volta River Authority (hydroelectric) substation. Total power consumption for all process installations including crushing are estimated to be about 7 kilowatt-hours per tonne, costing $0.28 per tonne.

PRESENT STATUS & PROJECT ECONOMICS

Production of mine waste and a minor amount of ore began in late January, 1990. Stacking of ore on the heaps began in early March. The value of gold production during April exceeding the April operating costs, and the positive cash flow position has continued to steadily increase since then.

As of 1 October 1990, the Sansu heap leach had processed 525,000 tonnes of ore. A total of 706 kg of gold (22,700 ounces) have been recovered.

Total site-related production costs have been approximately $174 per recovered ounce, which (at current rates of production) will yield a 100% return on invested capital in slightly less than one year.

Since the production rate is still slightly below target due to operational problems which are being slowly corrected, costs should continue to decrease.

Also, the operation is still relatively immature in a leaching sense; much of the gold production is scheduled to be produced from heaps in the secondary leach cycle and there are not yet sufficient heaps available to fully utilize this cycle. For this reason alone, costs should eventually drop to $126 per ounce.

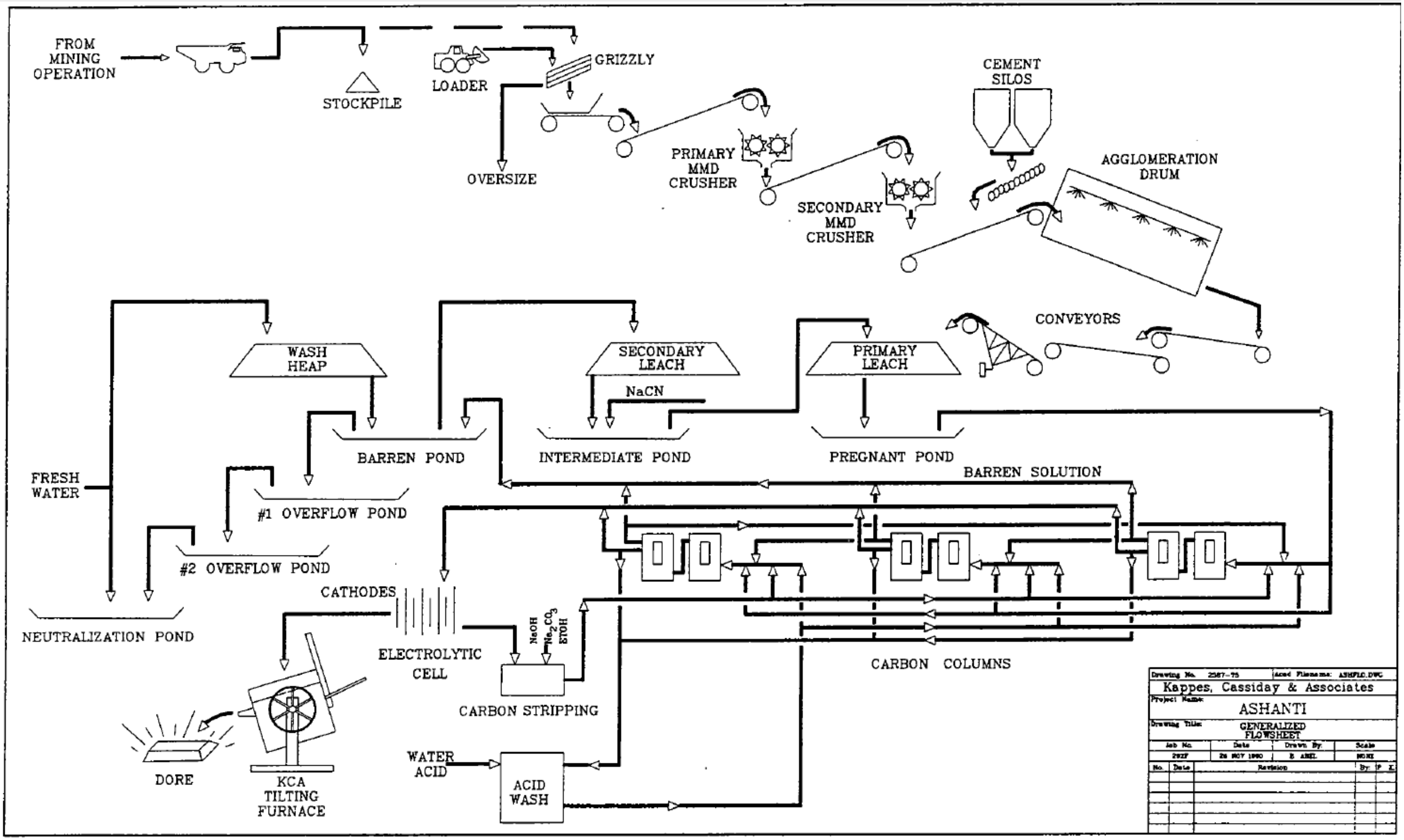
SUMMARY

The successful startup record at Sansu attests to the fact that heap leaching, even at remote sites, can provide a much lower risk and higher return on investment than other gold ore process methods. The Sansu heap leach presented several formidable challenges; how to process a high clay ore in a high rainfall environment, in a country where there was very little previous heap leach experience.

Fortunately, specialized equipment and procedures have now been developed for heap leaching, whereas earlier heap leaches simply adapted equipment and methods designed for other purposes. The Sansu operation is a prime example of the very substantial advances which have been made in development of this technology.

ACKNOWLEDGEMENTS

The authors wish to thank the management of Ashanti Goldfields (GH) Ltd, for permission to write and present this paper. The authors would also like to thank the management and staff of Ashanti Goldfields Corporation, Kappes, Cassiday & Associates, Gundle Liners U.S., and Sepro U.K. for their participation in the project.


FROM MINING OPERATION
STOCKPILE
LOADER
GRIZZLY
OVERSIZE
PRIMARY MMD CRUSHER
SECONDARY MMD CRUSHER
CEMENT SILOS
AGGLOMERATION DRUM
CONVEYORS
WASH HEAP
SECONDARY LEACH
PRIMARY LEACH
NaCN
BARREN POND
INTERMEDIATE POND
PREGNANT POND
BARREN SOLUTION
FRESH WATER
#1 OVERFLOW POND
#2 OVERFLOW POND
NEUTRALIZATION POND
CATHODES
ELECTROLYTIC CELL
NaOH
Na2CO3
ETOH
CARBON STRIPPING
CARBON COLUMNS
DORE
KCA TILTING FURNACE
WATER
ACID
ACID WASH
Kappes, Cassiday & Associates
Project Name:
ASHANTI
Drawing Title:
GENERALIZED FLOWSHEET
Job No.
Date
Drawn By.
Scale
No.
Date
Revision
By: