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Process options for the retreatment of gold-bearing material from sand dumps*

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SYNOPSIS

Alternative procedures for the recovery of gold from old sand dumps are discussed, with emphasis on the use of heap leaching. The modification of material to improve its permeability prior to heap leaching is not currently receiving much attention in South Africa. The channelling of solutions through heaps and the high consumption of reagents sometimes ascribed to heap leaching can, as shown by the results described in this paper, be lessened by desliming of the sand prior to heap leaching and the treatment of the resulting slimes fraction by agitation leaching and carbon-in-pulp. This combined procedure results in a higher overall recovery of gold. Alternatively, the sand can be heap-leached as it is after agglomeration with lime and cement, which improves the mixing and neutralization of the material, as well as lessening the probability of channelling.

SAMEVATTING

Alternatiewe prosedures vir die herwinning van goud uit sandhope word bespreek met die klem op die gebruik van hooploging. Die modifisering van materiaal om sy deurtrekbaarheid voor die hooploging te verbeter geniet nie op die oomblik veel aandag in Suid-Afrika nie. Die resultate wat in hierdie referaat beskryf word, toon dat die kanaalvorming van oplossings deur hope en die hoë verbruik van reagense wat soms aan hooploging toegeskryf word, verminder kan word deur die ontslikking van die sand voor die hooploging en die behandeling van die resulterende slikfraksie deur roerloging en koolstof-in-pulp. Hierdie gekombineerde prosedure lei tot 'n hoër totale herwinning van goud. Anders kan die sand soos dit is deur hooploging behandel word na agglomerasie met kalk en sement wat die menging en neutralisering van die materiaal verbeter en die waarskynlikheid van kanaalvorming verminder.

Introduction

Gold-bearing residues, in the form of sands, that resulted from the old vat-leaching process depicted in Fig. 1 were deposited over the years at many gold mines in South Africa. The sulphides in these sands have oxidized, and the dumps have become acidic. The partial oxidation of the sulphides has resulted in the exposure of some of the entrapped gold, and has made the gold available for direct recovery by leaching.

A number of these old sand-tailings dumps are at present being retreated for the recovery of their contained gold. One of the major procedures used is milling of the coarse gold-bearing sand to expose the gold, treatment of the resulting fine slime by cyanidation, and adsorption of the dissolved gold onto activated carbon[1]. This procedure yields what can be termed the 'maximum' gold recovery, but requires a high capital investment, as well as a high input of energy for milling.

However, many dumps are too small or of such a low grade that their gold content does not justify the capital outlay necessary for a conventional milling and carbon-in-pulp (CIP) plant. An alternative procedure for the treatment of these sands is heap leaching, or percolation leaching, in which mainly the gold exposed by oxidation is recovered. Since the gold entrapped in sulphides is exposed by oxidation, the proportion of gold in these sands that is directly recoverable depends on the extent to which the sand has been oxidized or weathered.

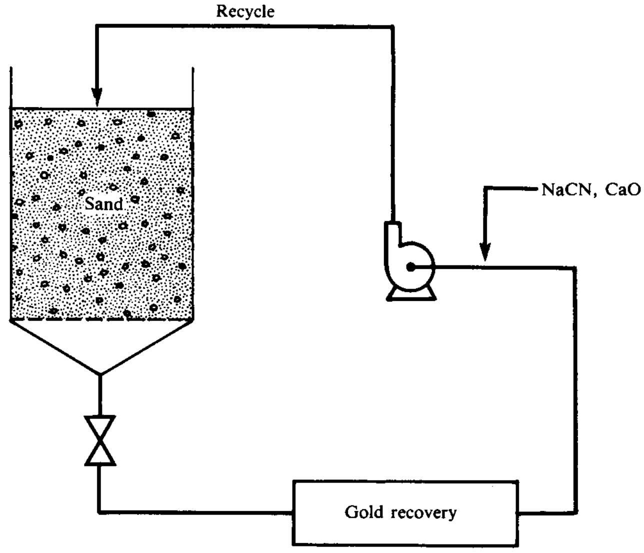

Fig. 1—Schematic representation of vat leaching

The major advantages of this heap-leaching procedure are the low capital requirements and the low operating costs. Heap leaching can therefore also be employed for the generation of cash flow during the early stage of a large project. However, as indicated above, heap leaching yields a lower gold recovery than the fine-grinding route and, in practice, is also less predictable than the milling

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and cyanidation route. In addition, a number of serious problems have been encountered on some heap-leaching plants. These problems can be attributed broadly either to severe oxidation, causing a high consumption of lime and cyanide by the acid and ferrous salts in the sand, or to difficulties with percolation, usually resulting from the high proportions of fine material in the sand.

To overcome these problems, to improve the recoveries of gold, and to increase the predictability of the heap-leaching process, a number of pretreatment steps to precede heap leaching of the sand can be considered.

In this paper, three alternative heap-leaching procedures are described briefly, and the results obtained from pilot-plant tests of each of these procedures on a single bulk sample of sand are compared. This testwork started at the Council for Mineral Technology (Mintek) in 1986. The results obtained on a full-scale sand-leaching plant are also given.

Heap Leaching of the Sand As It Is

During this procedure, there is no pretreatment of the sand other than mixing with lime for neutralization.

The flow diagram shown in Fig. 2 depicts the process route for the recovery of gold in the heap-leaching plant of The Rand Leases Gold Mining Company, where sand is heap-leached in the 'as-is' state. The operation entails the addition of lime to each truckload of sand (about 10 kg of lime per ton of sand). The sand is then loaded by front-end loader to a height of 4 m on one of three slightly-inclined, impervious asphalt pads. Each pad is 60 m long by 20 m wide, having an area of about 1200 m^2, and each heap contains about 10 kt of material. While the heaps are being constructed, perforated pipes are laid on the floor of the pad across the width to assist in the drainage of the leach liquor from the bottom of the heap. Leaching solution containing lime and sodium cyanide, both at a concentration of 0,02 per cent, is then sprayed onto the heaps at a rate of approximately 14 m^3/h, which is equivalent to 0,2 l/min per square metre, or 0,005 U.S.gal/min per square foot.

The solution percolates through the heap and gravitates to a pond. This pregnant solution is then pumped through adsorption stages containing granular activated carbon, which adsorbs the gold content. After the addition of leaching chemicals, the solution is recirculated through the heap for between 20 and 40 days. After leaching, the 'barren' sand is deslimed in a cyclone, and the resulting slime is pumped to a separate dam. The results obtained from a heap-leaching operation are summarized in Table I.

Typical gold analyses of the pregnant solution from the plant at Rand Leases are shown in Fig. 3.

The advantage of this method lies in its simplicity, but it suffers from the following disadvantages.

(a) The high content of fine material (smaller than 75 μm) can lead to certain areas in the heap being impervious to the leaching solution, and can cause preferential percolation (channelling) of the leaching solution through areas where coarser material predominates,

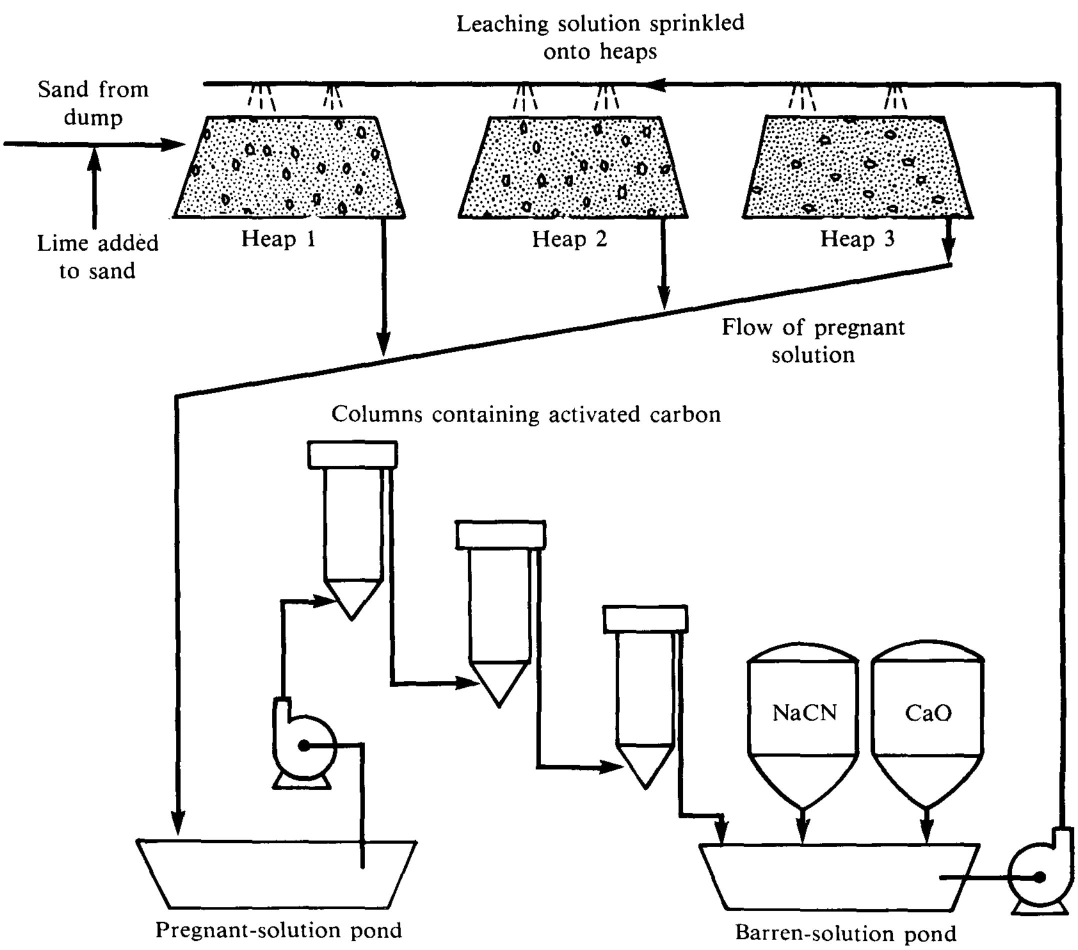


Fig. 2—Flowsheet for the heap-leaching plant at Rand Leases

TABLE I
RESULTS OF THE HEAP-LEACHING OPERATION AT RAND LEASES

Gold head value g/t	Gold in residue g/t	Gold extraction %	Consumption, kg/t	
			CaO	NaCN
1,3 to 1,7	0,5 to 1,0	40 to 60	7 to 10	0,8 to 1,0

resulting in lower overall extractions of gold.

(b) The dry mixing of sand with lime as the heap is constructed often leads to the non-uniform neutralization of the sand, resulting in alkaline and acidic localities in the heap.

(c) Leaching reagents, e.g. sodium cyanide, are consumed by acid and by deleterious salts in the sand.

Desliming

The principle of desliming is illustrated in Fig. 4. Sand is mixed with water and lime into a pulp with a pH value of about 10, thus achieving uniform neutralization of the acids and salts. The pulp is then aerated to oxidize ferrous iron to ferric iron, thus further reducing the consumption of cyanide and oxygen during leaching. The classification of the pulp into a sand fraction and a slime fraction facilitates the quick and efficient extraction of gold from the slime fraction by agitation leaching and

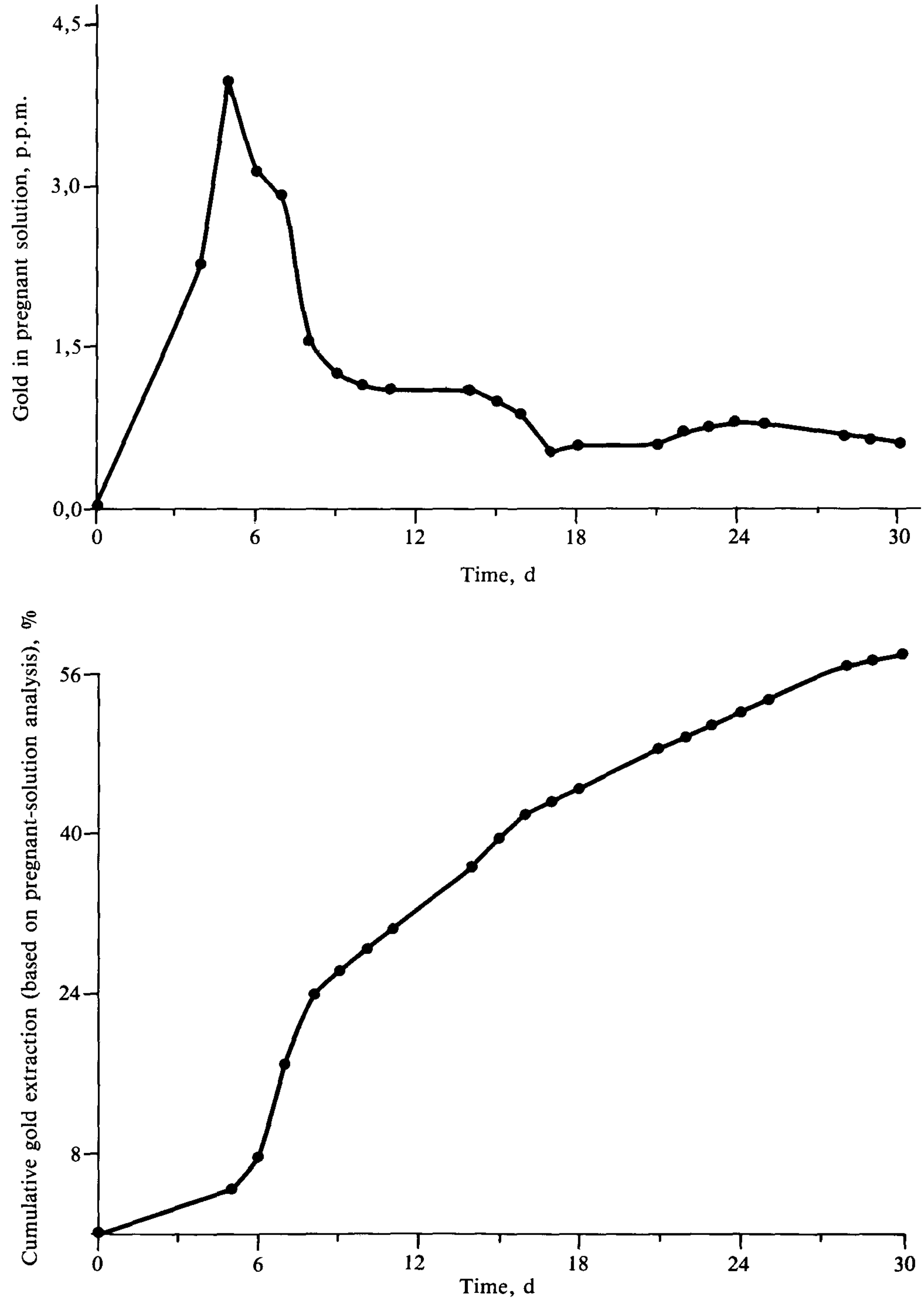


Fig. 3—Examples of operating results from full-scale heap leaching

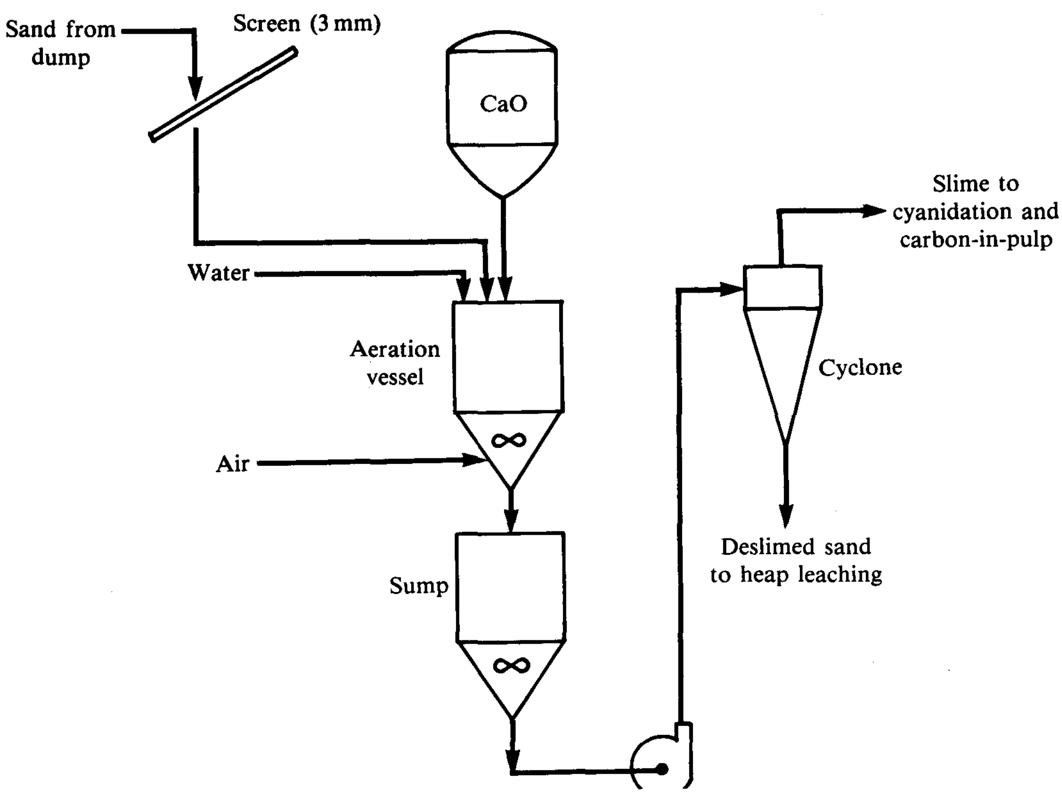


Fig. 4—Postulated flowsheet for the removal of slimes (desliming) from sand

the CIP process. The sand, now uniformly neutralized and rid of its fine material and deleterious salts, is more amenable to heap leaching. The amount of gold remaining in the heap after leaching should be lower than in the 'as is' method because of the high permeability of the material. However, the deslimed wet sand now has a much lower angle of repose, and low precast walls may be necessary to contain the sides of the heap. Large-scale tests will be needed to indicate the stability of this material.

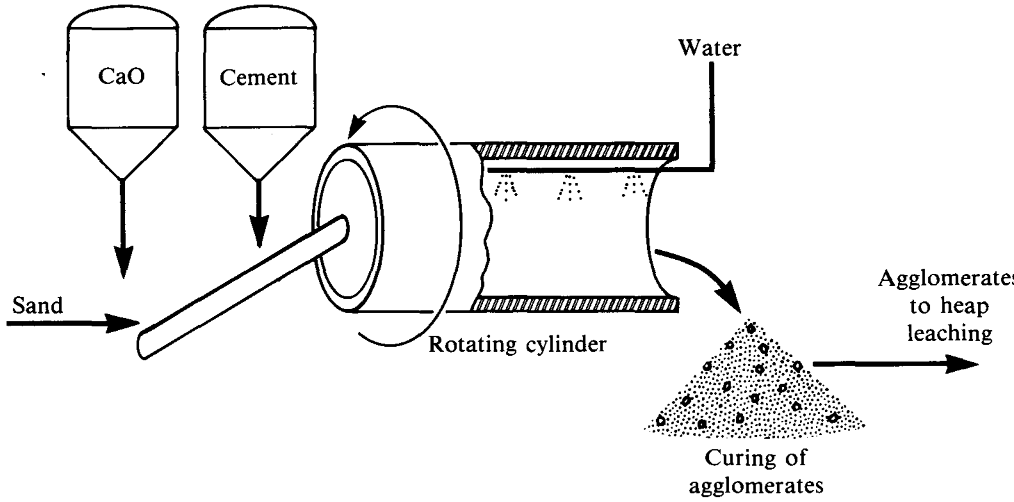
This route appears to offer advantages over heap leaching in the 'as-is' state but, if a CIP plant does not already exist in the vicinity of the heap-leaching plant, the need for such a facility, as well as a slimes dam, will add to the capital requirement. It is likely that this procedure will be tested on a large scale at the Rand Leases plant in the near future.

Agglomeration

The agglomeration of material containing large proportions of clay or fines prior to heap leaching is a well-established process[2-4], which is illustrated in Fig. 5.

The material is mixed with lime and cement, and the mixture is then rolled while it is being sprayed with a coarse water spray. In the case of fine tailings materials, the water droplets act as nuclei for the formation of large agglomerated particles with uniform permeability, thus avoiding the channelling caused by the presence of fine material in the heap. After a curing period of up to 3 days, these agglomerates can be stacked and heap-leached in the normal way. However, fairly careful control of the properties of the feed material and the agglomeration process is essential. Agglomeration will increase the capital and operating costs of a heap-leaching operation above the costs of an 'as-is' plant.

Fig. 5—Flowsheet for the agglomeration of sand prior to heap leaching



Experimental Procedure

The tests described below were conducted at The Rand Leases Gold Mining Company Limited.

Preparation of a Bulk Sample

During the construction of a 10 kt heap at the Rand Leases plant, a representative sample of 100 t was obtained by the periodic removal of portions of the sand material as the heap was constructed. This sample was blended and stored under a tarpaulin. Sub-samples were taken from different areas of the bulk sample and, after being mixed for use in the pilot-plant tests, were sampled so that the gold head values could be determined by fire assay.

The Pilot Plant

The Mintek pilot plant that was constructed at Rand Leases consisted of six circuits, one of which is illustrated in Fig. 6. All the columns were of the same height as the heaps at the Rand Leases plant. Three of the columns were made of unplasticized polyvinyl chloride (UPVC) 225 mm in diameter, and each had a capacity of 180 kg of sand. The other three columns were made of rolled mild steel 600 mm in diameter, and held 1240 kg of sand each. The outlets at the bottom of the columns were covered with horizontal stainless-steel screens with beds of crushed stone 300 mm high on top of the screens to assist the drainage of the leaching solution.

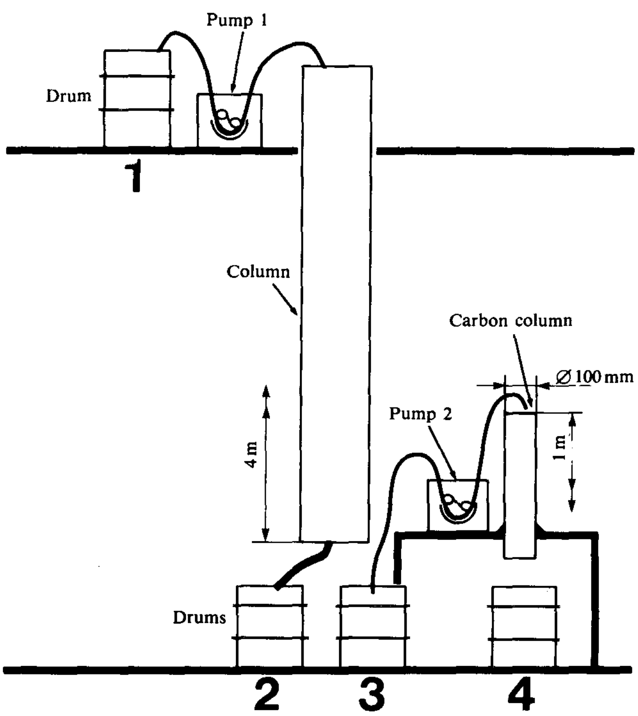


Fig. 6—Layout of the pilot plant for the heap-leaching tests

The leaching solution, which contained 0,02 per cent calcium oxide and 0,02 per cent sodium cyanide, was prepared in drum no. 1 and then pumped into the top of the loaded column. Coarse filter paper, which was placed on top of the sand bed, ensured that the leaching solution was spread evenly over the whole cross-sectional area of the column. The pregnant solution was collected in drum no. 2. The volume of pregnant solution was recorded once a day, a sample was taken, and the solution was then transferred to drum no. 3, from where it was pumped through a column of activated carbon for the adsorption of its gold. The barren solution was collected in drum no. 4 and recycled as a batch to drum no. 1, where lime and sodium cyanide were added as make-up.

Simulation of Heap Leaching

For heap leaching of the sample in the 'as-is' state in the pilot plant, the mixing of dry sand and lime (as practised on the Rand Leases plant) was simulated by the addition, at intervals as the sand was loaded into the column, of the amount of lime needed for neutralization.

Desliming was simulated by the classification, after neutralization and aeration, of the sand in a 15 cm-diameter spiral classifier. The sand and slime fractions from the spiral classifier were sampled periodically during the desliming procedure, and these samples were mixed to yield composite head samples of each fraction for the determination of gold values. The sand fraction was loaded into a column for heap leaching; the slime fraction was accumulated in a storage tank, where it was allowed to settle, and the supernatant liquid was decanted. The final mass of slime was determined from its volume and density. The mass of the sand fraction was calculated from the difference between the original amount of material and the mass of the slime. The thickened slime was agitated, and a sample was taken and filtered. The filter cake was cyanided in rolling bottles for 24 hours so that the possible gold extraction from the slime fraction could be determined.

Pilot-plant agglomeration was carried out by the mixing of sand, lime, cement, and water in a 240-litre cement mixer, in the manner described earlier for the agglomeration process. Two tests were carried out in a 225 mm UPVC column, and one test was conducted in a 600 mm mild-steel column for each of the three procedures.

Calculation of Gold Recoveries

After leaching had been completed, the leached sands were thoroughly sampled as they were discharged from each vessel. The residual gold values in the leached sands were determined by fire assay so that the percentage gold extraction could be calculated.

A similar procedure of accounting, i.e. based on head and residue values, was followed for the leaching of the full-scale heap at Rand Leases from which the 100 t sample for the pilot-plant tests was obtained.

The overall extraction for the desliming route was calculated as the sum of the gold extracted from the sand in the pilot plant plus the gold extracted from the slime in the laboratory test, expressed as a percentage of the calculated gold content of the material prior to desliming and leaching.

Results and Discussion

Effect of Fine Milling

A portion of the bulk sample was sized, and the size fractions were assayed. A further portion was leached with cyanide for 24 hours, and the leached size fractions were again assayed for gold. The percentage extraction of gold from each size fraction is shown in Table II.

TABLE II
EXTRACTION OF GOLD FROM DIFFERENT SIZE FRACTIONS BY CYANIDATION

Size range µm		Mass %	Gold head value g/t	Gold in residue g/t	Gold extraction %
>425		8	2,1	0,86	59
>212	<425	44	1,1	0,76	31
>150	<212	19	1,0	0,26	74
>75	<150	18	1,0	0,20	80
	<75	11	5,0	0,34	93
Combined values (calculated)		100	1,6	0,53	67

The extent to which milling exposes entrapped gold, making it available for direct recovery, was illustrated as follows: 2 kg samples of sand from the 100 t bulk sample were ground to different degrees of fineness, and were then leached in rolling bottles for 24 hours. Table III shows that the milling resulted in higher recoveries of gold. However, the additional recovery of gold by this procedure would have to be sufficiently high to pay for the cost of a milling plant.

TABLE III
THE EFFECT OF MILLING ON THE EXTRACTION OF GOLD FROM SAND

Size % passing 200 mesh	Head value g/t	Gold in residue g/t	Gold extraction %
11 (unmilled)	1,6	0,61	62
50	1,6	0,18	89
60	1,6	0,11	93
70	1,6	0,11	93

Effect of Procedure and Scale of Treatment

Table IV summarizes the average extractions of gold obtainable from sand-dump material by leaching according to various procedures.

TABLE IV
GOLD EXTRACTIONS OBTAINABLE FROM 'AS-IS' SAND-DUMP MATERIAL WHEN LEACHED BY VARIOUS PROCEDURES

Method	Duration days	Head value g/t	Gold in residue g/t	Gold extraction %
Rolling bottle	1	1,65	0,82	50
Rolling bottle	2	1,65	0,66	60
Rolling bottle	7	1,65	0,51	70
Pilot plant (average of 3 'as-is' tests)	30	1,63	0,56	66
Industrial plant (similar 'as-is' material)	36	[1,32] plant value	0,62	52

The dissolutions from the rolling-bottle tests increased from 50 per cent after 24 hours of leaching to 70 per cent after 7 days of leaching. The pilot-plant dissolution (66 per cent after 30 days) was slightly less than the maximum obtained in the rolling-bottle tests. The gold in the residue from the industrial plant (0,62 g/t after 36 days) was slightly higher than that in the residue from the pilot plant. However, the problems involved in the sampling of the large mass of sand on the full-scale plant (10 kt) could have been responsible for inaccuracies in the results of this large-scale test.

Recoveries by Different Heap-leaching Procedures

Table V shows that the gold content of the slime fraction is higher than that of the sand fraction. This means that the proportion of the gold that is diverted with the slime fraction to the quick and efficient procedure of agitation and cyanidation followed by CIP exceeds the mass fraction of slime in the sand.

TABLE V
DISTRIBUTION* OF GOLD IN THE SAND AND SLIME FRACTIONS

Total sulphide %	Head value g/t	Mass of sand fraction %	Mass of slime fraction %	Au in sand fraction g/t	Au in slime fraction g/t	Gold reporting to slime fraction %
0,3	1,60	80	20	1,2	2,8	37

* Average results of three desliming tests

Fig. 7 illustrates how the concentration of gold in the pregnant solution varied with time during a single set of pilot-plant tests. It was found that the concentration of gold in the pregnant solutions from the deslimed sand decreased faster than that in the pregnant solutions from the tests on 'as-is' and agglomerated sands. These low gold values can be attributed both to the reduced quantity of gold in the deslimed sand, and to the more rapid leaching of gold from this preoxidized and deslimed material. These lower gold values would justify the replacement of a heap with fresh material sooner than would be the case with 'as-is' or agglomerated material, thus allowing a higher rate of treatment of deslimed material. Heaps are usually replaced as soon as the gold assay of the pregnant solution leaving the heap drops below a certain value.

Fig. 7 also depicts the cumulative gold extraction from each of these tests, derived from the gold concentrations in the pregnant solution. The gold-extraction curve, which represents the desliming procedure, illustrates the extraction of gold by the heap leaching of the deslimed sand plus the gold dissolved by the leaching of the slime fraction, expressed as a percentage of the gold contained in the material prior to desliming. It is assumed that the extractable gold in the slime can be recovered within one day; hence, an extraction of 37 per cent is obtainable in one day.

Table VI summarizes the average gold extractions obtained on the pilot plant from each of the three procedures. Slightly higher extractions of gold were obtained by the desliming and agglomeration routes (73 and 71 per cent respectively) than was obtained by the leaching of the 'as-is' sand (66 per cent).

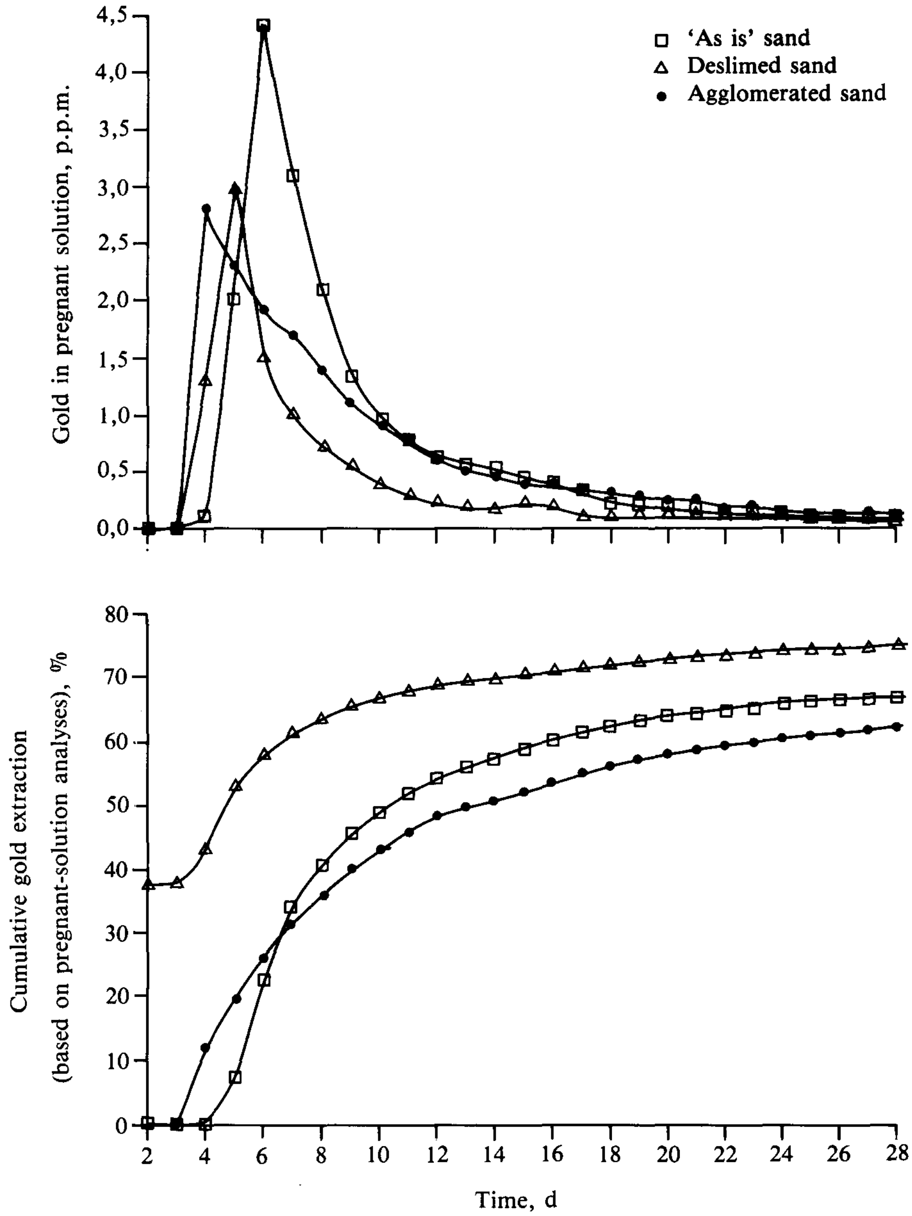


Fig. 7—Operating results from heap leaching in the pilot plant with columns of 225 mm diameter

TABLE VI
GOLD EXTRACTIONS* OBTAINED ON THE PILOT-PLANT SCALE

Pre-treatment	Gold in sand fraction %	Gold in slime fraction %	Gold extraction, %: From deslimed sand by heap leaching in the pilot plant	From slime by rolling-bottle leaching	Total	Time† days
'As-is'	N/A	N/A	N/A	N/A	66	24
Desliming	63	37	66	86	73	16
Agglomeration	N/A	N/A	N/A	N/A	71	27

* Averages of the results of three tests for each of the three procedures
† Time for the concentration of old in the pregnant solution to fall to below 0,2 mg/l
N/A Not applicable

Consumption of Reagents

Table VII summarizes the consumption of chemicals during the pilot-plant leaching. These results show that there was little difference in the consumption of reagents between the three procedures, the major exception being in the cement consumed in the agglomeration process. The lower total consumption of cyanide by the desliming route can perhaps be attributed to the removal of ferrous salts from solution by the aeration.

Conclusions

Old sand dumps are important sources of gold in South Africa. The following alternative procedures have been identified for the recovery of gold from this material, each with its own advantages and disadvantages:

(a) fine grinding of the sand, and leaching of the resulting slime in an agitated vessel, followed by the adsorption of the dissolved gold onto activated carbon;
(b) neutralization of the sand by dry mixing with lime, followed by heap leaching in the 'as-is' state;

TABLE VII
CONSUMPTION* OF LEACHING CHEMICALS AND CEMENT IN THE PILOT PLANT

Method of leaching		Consumption, kg/t		
		CaO	NaCN	Cement
'As-is'		10,5	0,20	0
Desliming	Sand fraction	10,5	0,10	0
	Slime fraction	9,5	0,35	0
	Combined	10,3	0,15	0
Agglomeration		10,5	0,20	5

* Averages of the results of three tests for each of the three procedures

(c) neutralization and aeration of the sand in the form of a pulp, classification of the pulp into a deslimed sand fraction and a slime fraction, cyanidation of the slime fraction in an agitated vessel, adsorption of the dissolved gold onto activated carbon, heap leaching of the deslimed sand (which can readily be done), and the selling or return of the sand to a dump; and

(d) mixing of the sand with lime and cement, and the agglomeration of the mixture by tumbling under a coarse spray of water, followed by heap leaching of the hardened agglomerated material.

The properties of any prospective source of gold in the form of sand should be thoroughly tested on a reasonable scale to ensure that the most advantageous process route is chosen.

Acknowledgements

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Reclamation of coal-mining wastes

The 3rd International Symposium on the Reclamation, Treatment and Utilization of Coal Mining Wastes will be held in Glasgow from 3rd to 7th September, 1990.

The original concept underlying the promotion of the Symposium was to provide, for those engaged in the British coal-mining scene, an opportunity for an exchange of experience and views in the field of reclamation, treatment, and utilization of wastes culminating from the mining and preparation of coal for market.

The participants, for whom the Symposium was organized, changed that concept because not only were papers received from Canada, France, Germany (FRG), Netherlands, Poland, South Africa, United Kingdom, USSR, India, and the USA, but delegates also attended from Brazil, Belgium, South Africa, Australia and the People's Republic of China—thus the Symposium developed a truly international flavour.

Therefore, following the overwhelming success of the 1st and 2nd International Symposiums on the Reclamation, Treatment and Utilization of Coal Mining Wastes held in Durham (1984) and Nottingham (1987), British Coal Corporation, Minestone Services are now organizing the Third, which it is hoped will become a regular three-yearly event.

Papers are invited on the reclamation, treatment, and utilization of coal-mining wastes. Abstracts of not more than 250 words should be submitted (in English only) to

Dr A.K.M. Rainbow
Head of Minestone Services
British Coal Corporation
Philadelphia, Houghton-le-Spring
Tyne & Wear
DH4 4TG
United Kingdom
Tel. (091) 5843631.

These should be forwarded as soon as possible, but not later than June 1989. The abstracts should clearly state the purpose, results, and conclusions of the final paper. Authors will be notified of preliminary acceptance within one month and final acceptance will depend upon review of the full-length paper.

A volume of reviewed papers will be published by an international publisher.