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RECOVERING THE LOST GOLD OF THE DEVELOPING WORLD: BIBLIOGRAPHIC DATABASE

E J Evans & C J Mitchell

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INTRODUCTION

This report contains a library of 181 references, including abstracts, prepared for Project R7120 "Recovering the lost gold of the developing world" funded by the UK's Department for International Development (DFID) under the Knowledge and Research (KAR) programme. As part of an initial desk study, a literature review of gold processing methods used by small-scale miners was carried out using the following sources; the ISI Science Citation Index accessed via Bath Information and Data Services (BIDS), a licensed GEOREF CD-ROM database held at the BGS's Library in Keyworth and IMMage a CD-ROM database produced by the Institution of Mining and Metallurgy held by the Minerals group of BGS. Information on the search terms used is available from the author.

Results of this literature review were compiled in digital form as an Endnote® bibliographic library containing 181 individual references. Endnote® is primarily a type of data management software capable of storing and interrogating information held in bibliographic form. In addition, Endnote® is also a bibliographic construction tool used to compile reference lists in word processor files. The library of bibliographic references listed in this report is intended to: (1) Act as an information resource for the project team and their collaborators in less developed countries; and (2) Enable compilation of reference lists for project documents.

A digital copy of this Endnote® library and a full paper copy of each reference are held by the author. It is anticipated that the Endnote® library will constantly be updated over the lifetime of the project as new information comes to light.

ENDNOTE® BIBLIOGRAPHIC LIBRARY

A list of references currently held in the Endnote® bibliographic library is provided below. For each individual reference, the following format is adhered to:

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- Conference proceedings: -conference name, date, venue, editors, pages, publishers
- Report: - title, institution, number
- Keywords: - included where available
- Abstracts: - included where one was available

(1) Agar, G (1993).
Assessment of gravity recoverable gold.
Proceedings - 25th Annual Meeting of the Canadian Mineral Processors, Ottawa, **Paper 13,** 13-15.
Abstract: The distribution of gold in the grinding-classification circuit of an operating gold plant was determined by assaying the size fractions of samples from each of the streams. This analysis identified the streams with the maximum potential for gravity recovery of gold and revealed that there was up to seventy-five times as much gold in the primary cyclone underflow as in the concentrator feed.
Laboratory jigging and tabling tests were done on samples from two of the streams to determine what the recovery might be with a gravity circuit and to show that a high grade concentrate could be produced. A numerical simulation procedure was used to calculate a material balance for a circuit that included gravity separation on the primary cyclone underflow. The numerical simulation optimistically indicated that as much as 84% of the gold might be recovered in a reasonable grade of concentrate even though the recovery in batch bench scale tests was only 14%.
Incorporation of a gravity separation device would reduce the inventory of gold in the grinding-classification circuit.

(2) Anon (1978).
Semi-industrial scale test results, wide angle hydrocyclones for gold.
World Mining, 128-130.
Abstract: In the June issue of World Mining, Soviet Summaries surveyed laboratory work being conducted to improve gold recoveries by employing wide angle or short cone hydrocyclones to recover fine gold particles from gold bearing minerals. The wide angle hydrocyclone equipped with an internal rotor was described and tested.
This summary describes positive test results obtained using wide angle hydrocyclones in semi-industrial scale tests on various gold ores. Several hydrocylone operating parameters and their influence on gold recovery are discussed.

(3) Anon (1981).
Hydrocyclones improve gold recovery on dredge plants.
World Mining, (July), 49-50a.
Abstract: At today's gold prices, whether you calculate them in Rands or Roubles, increasing gold recoveries, particularly fine gold recoveries, by scavenging tailings makes sense. W.M. Majkov et al published a report in Tsvetnye Metally No.1 January 1981, pages 81-85 describing how hydrocyclones can be successfully used to recover fine gold in dredge-mounted plants. The use of wide-angle hydrocyclones to improve gold recovery has been described in previous Soviet Summaries (see World Mining, June and September 1978)

(4) Anon (1986).
A mineralogical and process evaluation of the Shamva gold gravity concentrator and leaching plant.
Rep Inst, Min. Res. Univ. Zimbabwe, **62** (February), 139-143.

(5) Anon (1995).
Transfer of New Gravitational Gold Concentration Technologies to the Small Mining Sector of the Atacama Region, Chile.
Small Mining International Bulletin, (February 8), .

(6) Anon (1997).
A closer look at mining practices.
In Hocker, PM (Eds.), *Golden Dreams, poisoned streams- how wreckless mining pollutes America's waters, and how we can stop it,* .

(7) Anon (1997).
The SuperBowl - a new generation in gravity gold recovery.
The Chambers of Mines Journal, **39** (3 March), 57-62.
(8) Bacon, W G; Hawthorn, G W & Poling, G W (1989).
Gold analyses - myths, frauds and truths.
CIM Bulletin, **82** (931 November), .
Keywords: Mineral processing, Gold analyses, Assays.
Abstract: "Unassayable gold and platinum group metals " have come into vogue in the 70s and 80s in certain jurisdictions as a means of perpetrating fraud. Usual arguments are that a particular ore is not amenable to "conventional re assaying". Explanations for unassayable gold usually revolve around: evaporation of micron-size gold; vaporisation of organic gold complexes; volatization of gold halides; alloying of gold with PGM's which prevents fusion or alloying which prevents collection.
This paper reviews several of the myths and truths of gold and PGM assaying with the knowledge that not a single mine operates in free world producing gold from unassayable ore.

(9) Bartram, J A; Heape, J M T & Caithness, S J (1991).
The Mount Kare Gold Project.
In Rogerson, R (Ed.), *PNG Geology, Exploration and Mining Conference Proceedings*, Rabaul, The Australasian Institute of Mining and Metallurgy. .

(10) Berube, M A (1982).
La mineralogie aplliquee au traitment des minerais.
CIM Bulletin, **75** (847 November), 121-?
Notes: French

(11) Berube, M A & Marchand, J C (1983).
Etudes de liberation des minerais a l'Universite Laval (Quebec).
CIM Bulletin, **76** (850 February), 55-.
Notes: French

(12) Bezerra, O; Verissimon, A & Uhl, C (1996).
The regional impacts of small-scale gold mining in Amazonia.
Natural Resources Forum, **20** (4), 305-317.
Abstract: Gold mining is the major economic activity in the Upper Tapajos River Basin of the Brazilian Amazon. This article studies the structure, economy and impacts of gold mining operations in this region. Mining has significant environmental impacts in this region resulting in the removal of approximately 67 million m3 of sub-soil per year and accompanied by an annual release of some 12 tons of mercury to air, ground and rivers. In the early 1990s there were 245 mines in operation, employing some 30,000 people and producing around 35t gold per year, valued at approximately $400 million yr-1, the profits being about $110 million yr-1. Miners spent most of their earnings on local goods and services, while mine owners and merchants in the gold towns invested in land (mainly for ranching), business ventures and money markets. Wealth gained from mining has served as an engine for development in other regions of the world and could, theoretically, achieve the same for Amazonia. However, before this could happen, the Government of Brazil would need to mark a strong presence in the area by providing technical assistance and developing and enforcing mining/ environmental regulations. The likelihood of such a development materialising in the foreseeable future is small. In the meantime, gold mining acts, not as an 'engine for development', but as a destabilising force -provoking environmental damage, social discord and public health hazards in the region. Copyright 1996 United Nations.

(13) Bheemalingeswara, K (1995).
Possible effects of iron oxide coating in the recovery of particulate gold from stream sediments.
Journal of Geochemical Exploration, **52** (3), 373-380.
Abstract: The influence of iron hydroxide/oxide coatings on the recovery of gold was studied using 13 stream sediment samples collected from an area of known gold mineralisation. Magnetic products collected from a Frantz isodynamic separator showed higher gold values than did non-magnetic fractions. An acid-treated magnetic product when run through the isodynamic separator yielded a significant amount of non-magnetic component which, when viewed by binocular microscope, showed the presence of gold grains in both bulk sample and in bromoform-separated heavy mineral concentrate. It is suggested that concentrates are treated with 10% HCl prior to magnetic separation where iron oxide coatings are conspicuous.

(14) Blenkinsop, T G & Erikson, K A (1995).
Gold concentration in the Witwatersrand reefs by footwall cannibalisation.
Economic geology, **90** (1995), 200-202.

(15) Bliss, J D; Orris, G J & Menzie, W D (1987).
Changes in grade, volume and contained gold during the mining life-cycle of gold placer deposits.
CIM Bulletin, **80** (903 July), 75-80.

(16) Boas, R (1992).
Geopolitics of the new materials: the case of the small scale mining and new materials developments.
Technologia Mineral, **59** .
Abstract: This paper presents the mining businessmen concerns about the declining curves in metals demand, and discusses some issues regarding dematerialization and transmaterialization as affecting the minerals world.
The economic cycles and their effects on the consumption of ores and metals are presented through the transmaterialization concept of materials demand.
Small scale mining definitions are presented and the small scale mining concept is focused on the production of chemical compounds directly from ore bodies. As an illustration a case study, showing the production of a copper salt, is presented.

(17) Boyes, B A & Hall, J (1991?).
Industrial use of saline water for gold processing in Western Australia.
BMR Journal of Australian Geology & Geophysics, **12** (3), 267-269.

(18) Bradford, B (1987).
Gravity concentration for gold recovery.
Engineering and Mining Journal, **188** (6), 64-65.

(19) Braithwaite, J C & Jury, A P (1993).
Alluvial gold mining and treatment in New Zealand.
In Woodcock, J T; Hamilton, J K (Ed.), *The Sir Maurice Mawby Memorial Volume*, The Australasian Institute of Mining and Metallurgy. **2 Monograph 19,** .

(20) Brewis, T (1995).
Gravity Separation.
Mining Magazine, (May), 279-?

(21) Burt, R O (1984).
Gravity Concentration Technology.
Developments in Mineral Processing, **5** 1-605.

(22) Cashion, J & Brown, L (1998).
Gold mineralogy and extraction.
Hyperfine Interactions, **111** (1-4), 271-280.
Abstract: Several examples are examined in which Mossbauer spectroscopic analysis of gold mineral samples, treated concentrates and extracted species has provided information not obtainable by competing techniques. Descriptions are given of current work on bacterial oxidation of pyritic ores and on the adsorbed species from gold extracted from cyanide and chloride solutions onto activated carbon and polyurethane foams. The potential benefits for the gold mining industry from Mossbauer studies and some limitations on the use of the technique are also discussed.

(23) Cashion, J D; McGrath, A C; Volz, P & Hall, J S (1988).
Direct Analysis of gold species on activated carbon by Mossbauer spectroscopy.
Transactions of the Institution of Mining and Metallurgy Section C Mineral Processing and Extractive Metallurgy, **97** (September), C129-C133.
Abstract: The composition of gold species adsorbed on to activated carbon was investigated by 197Au Mossbauer spectroscopy. The Au(CN) -2 ion was identified in samples that were contacted in the laboratory with potassium dicyanoaurate solution (pH 11.5) and in a sample loaded under industrial conditions, the gold having been dissolved from a calcined concentrate by sodium cyanide solution (pH 10.5). No evidence of the presence of AuCN or Au could be found. Spectra of gold metal and a Au3 + species were observed in a sample loaded from H[AuCl4] in solution.

(24) Chakrabarti, P (1996).
Search for Placer Gold in Eastern India - A Geomorphological Approach.
Journal Geological Society of India, **47** (1 January), 99-105.

(25) Chapman, R & Housely, K (1996).
The effect of particle geometry on the recovery of gold grains by gravity concentration methods.
Proceedings, 28th Annual meeting of the Canadian Mineral Processors, Ottawa, **Paper 23,** 335-357.
Keywords: gravity concentration, gold, shape factors, north Wales, alluvial

(26) Chatterjee, A (1998).
Role of particle size in mineral processing at Tata Steel.
Int. J. Miner. Process, **53** (1-2), 1-14.
Abstract: In process industries, for a variety of operations the particle size is a critical parameter and the choice of the process to be chosen during mineral processing is determined largely by the initial size of the mineral. This paper reviews some of the beneficiation techniques used and the influence of the particle size based on the work done at Tata Steel.

(27) Chiyankie, T (1991).
Alluvial gold mining in Zimbabwe.
Alluvial Mining, Institution of Mining and Metallurgy, Barking, England, Elsevier Applied Science. 36-52.
Abstract: The alluvial mining sector which had virtually died by 1979 reappeared on the Zimbabwe mining scene soon after Zimbabwe's political Independence (1980). This sector has grown tremendously to the stage of having an estimate of up to 50,000 both part time and permanent individuals involved in alluvial mining. Presently all the major rivers and tributaries draining the gold bearing formations are being worked in numerous places for alluvial gold. Alluvial gold mining has been and still is confined to small-scale miners. This paper examines the present status of the Zimbabwe alluvial gold mining sector and considers those factors which affect the expansion of the sector as well as its potential.

(28) Chryssoulis, S L & Cabri, L J (1990).
Significance of gold mineralogical balances in mineral processing.
Transactions of the Institution of Mining and Metallurgy Section C Mineral Processing and Extractive Metallurgy, **99** (C1-C10), .
Abstract: The significance of gold mineralogical balances in planning detailed metallurgical testing and in the process optimization of difficult gold ores has been examined. A procedure for obtaining a complete and quantitative mineralogical balance for gold has been developed and tested on 32 gold and gold-bearing ores. The procedure is based on the determination of the 'visible' gold fraction by diagnostic cyanidation and the characterisation of the 'visible' gold minerals by optical microscopy and electron-probe microanalysis. The concentrations of 'invisible' gold, i.e. colloidal-size gold and gold in solid solution, both of which contribute to a refractory response to direct cyanidation, are determined directly by quantitative ion-probe micro-analysis (SIMS). Thus, all gold carrier minerals are identified directly, resulting in accurate and precise determinations. Five selected examples are presented. The aim is to provide the systematics for the study of the process mineralogy of gold by identifying the forms of the gold to assist in process design and optimisation.

(29) Clarkson, R (1994).
The use of nuclear tracers to evaluate the gold recovery efficiency of sluiceboxes.
CIM Bulletin, **87** (979), 29-37.
Abstract: Sluiceboxes can provide a much higher concentration ratio than most other gravity concentrators (up to 50,000:1) at very high overall placer gold recoveries (greater than 99%). They are also very reliable, inexpensive and simple to operate. This combination is very difficult to beat and explains why the sluicebox is still the most important placer gold concentrator in Canada's Yukon Territory.
A sluicebox is a rectangular flume containing riffles on matting, through which a dilute slurry of water and alluvial gravel flows. Sluiceboxes operating under ideal conditions are actually centrifugal concentrators whose riffles overturn ribbons of slurry to form vortices. At the bottom of these vortices, centrifugal and gravitational forces combine to drive placer gold particles into matting.
Testing sluiceboxes with conventional sampling and evaluation techniques is very costly, time consuming and problematic. The effect of a single gold particle can cause large unpredictable errors (nugget effect) even when large sample volumes are processed with care. Nuclear tracer tests are more accurate, faster, cheaper, and safer than conventional sampling.
In 1989 through to 1991, the recovery efficiency of several sluicing systems was determined by mixing radioactive gold particles (tracers) into the feed steams of 27 placer mines in the Yukon Territory. Four distinct sizes of nuclear traces were used and their recovery was related to the design and operational characteristics of the individual sluiceboxes and their pay gravels.
Over-all gold losses ranged between 71% and 0, or from $2.5 million to less than $1000 per 1200 hour season. One of the triple-run sluiceboxes and one of the single-run boxes lost more than they recovered. The sluiceboxes which were fed with pre-screened gravels (minus 25 mm) had the lowest losses of all, averaging only $47,000 per season. Three of these sluiceboxes recovered 90% of their gold.
Many of the mine recovery plants tested in 1990 had already implemented recommendations from the 1989 test program including the use of unbacked Nomad matting, coarse expanded metal and 25 mm angle iron riffles. None were using double expanded metal riffles and few were using cocoa matting or Monsanto matting. Four operators installed screening equipment which increased their gold recovery by 10% to 20%. Another four operators modified their sluicing systems and increased their gold recovery by 3% to 44%.
This paper presents a summary of the existing and potential gold recoveries, and recommends sluicebox designs and operating parameters based on the results of nuclear tracer testwork from 1989 through 1991, conventional sampling in 1988 and laboratory investigation in 1989-1990.

(30) Clarkson, R (1997).
The use of radiotracers to locate and eliminate gold traps from the grinding circuit at La Mine Doyon.
CIM Bulletin, **90** (1015), 83-85.
Abstract: Free gold particles occur in many base metal and precious metal mines throughout the world. Due to the high density and malleability of gold, large circulating loads of free gold particles can build up over time in grinding circuits. This gold is often deposited in unintended traps throughout the mineral processing system.
These unidentified free gold deposits represent a serious security risk as well as an inaccessible inventory of gold. Deposits of free gold particles often remain undetected by mine management until they are accidentally discovered while repairing mill equipment
Nuclear tracers have been used to determine the free gold recovery efficiency of gravity recovery equipment, drills, and sampling equipment (Clarkson, 1994, 1995; Walsh and Rao, 1986; Walsh and Kelly, 1992). in November, 1993, the author inspected the grinding circuit at La Mine Doyon in Rouyn-Noranda, Quebec and made recommendations to recover coarse gold and to eliminate gold traps from the circuit. In 1995, the author salted mineral processing circuits with radioactive gold particles.

(31) Cohen, D; Booth, G; Govett, G & Beck, R (1990).
Sizing of particulate gold in placers - a statistical method.
Placer deposits: a symposium, Sydney, Australia, AusIMM. 213-218.
Abstract: In sampling geological materials during geochemical exploration programs, analytical sub-sample representivity must be maximised to increase the probability of correctly identifying background and mineralised sites. In the case of auriferous mineralisation, the level of representivity is linked to the expected number of gold particles per sub-sample, which is a function of the gold particle size and bulk gold concentration.
Using a binomial statistical technique on data from replicate analyses of homogenised sub-samples, a direct link is made between analytical variation and the expected number of gold particles present in a sub-sample. From these estimates, particle dimensions are inferred. A program - "GOLDCALC" - has been developed to predict the particle sizes, based on the sample replicate gold data.
This rapid and relatively inexpensive statistical sizing method has been tested on a wide range of geological materials and gold morphologies (sub-micron gold inclusions in sulphides to coarse placer gold) and has provided comparable size estimates to those determined directly by microscopy and other physical sizing techniques. The form of the gold does not appear to affect the application of the method.

(32) Cohen, D R; Booth, G W; Govett, G & Beck, R W (1992).
A statistical and analytical approach to sizing of particulate gold.
Journal of Geochemical Exploration, **43** 1-23.
Abstract: In geochemical exploration programs, analytical sub-sample representivity must be maximised to ensure the greatest probability of correctly identifying background and mineralised sites. In the case of particulate gold, the level of representativity is linked to the expected number of gold particles per sample, which is a function of the gold particle size and bulk concentration. A binomial statistical technique is applied to data from replicate analyses of homogenized sub-samples to determine the expected number of contained particles and from these estimates particle dimensions are inferred. This rapid and relatively inexpensive statistical sizing method for gold particles has provided comparable size estimates to those determined directly by microscopy and other physical sizing techniques for samples with a wide range of host compositions and bulk gold concentrations. The method may be used in orientation geochemical exploration programs to assist in the selection of suitable components or fractions of soil or stream sediments for collection, and in determining the minimum analytical sub-sample size.

(33) Collins, D N (1997).
Advances in gold processing technology.
Minerals Industry International, (January), 9-11.

(34) Collins, R S (1975).
Mineral Dossier No 14 Gold. .

(35) Connor, C & Dunne, R (1994).
The flotation of gold bearing ores - a review.
Minerals Engineering, **7** (7), 839-849.
Keywords: flotation, gold-bearing ores
Abstract: The practice of flotation of pure gold and gold-bearing ores such as tellurides, aurostibite, kerogen, pyrite, pyrrhoite, copper-gold ores and mixed sulphides is reviewed. The factors which influence the choice of collectors, pH and Eh, are discussed as well as the application of differential flotation. The importance of proper conditioning is highlighted and applications of various flotation cells and circuits briefly discussed.

(36) Conwell, C (1981).
Recovery of fine gold in placer operation.
Western Miner, **54** (September (9)), 36-40.

(37) Cook, N J (1990).
Mineralogical examination of gold-bearing samples.
CIM Bulletin, **82** (931 November), 51-39.
Keywords: Mineralisation, gold-bearing ores, mineralogical examination
Abstract: Detailed mineralogical examination of gold-bearing rocks, ores, concentrates and other samples should be considered an integral part of any study of a deposit for which exploitation is being planned. Adequate mineralogical study, although time-consuming and often costly, can significantly improve understanding of the mineralisation, can help to optimise the results of any metallurgical testing and can be of great value in case of potential trouble-shooting. The advantages and disadvantages of various examination techniques are discussed with reference to a number of mineralogical studies of Canadian gold-bearing samples.

(38) Cooper, H R (1989).
New technology provides better crushed-ore sampling results.
Engineering and Mining journal, **190** (6), 54-57.

(39) Cristovici, M A (1986).
Recovery of gold from old tailing ponds.
CIM Bulletin, **79** (895 November), 27-33.
Abstract: In the last few years CANMET has taken the initiative by investigating the possibility of reactivating abandoned old tailings dumps (for gold production) which would be of potential economic interest across Canada.
Nova Scotia was one location where numerous gold processing plants were in operation in the early days. A survey of the old tailing dumps was conducted and some areas of interest were selected. Among them were the sites identified as Lake Charlotte and Forest Hill.
Ore samples collected from those tailing ponds were examined for their chemico-mineralogical composition and investigated for gold extraction. Three technological concepts were tested: flotation, direct cyanidation and flotation followed by cyanidation of the flotation concentrate. The combined flotation-cyanidation variant, yielding a gold recovery in the range of 90%, was recommended for processing the tailing ore.
Pilot-plant runs carried out by a commercial testing firm (data not included in this paper confirmed the conditions and results of CANMET's technology.
As a result a consulting-engineering firm designed the processing plant which is expected to begin operation in the near future.

(40) Dahlberg, E (1984).
Small-scale gold mining a manual based on experience in Suriname. Intermediate Technology. .
Abstract: As a result of the increased price of gold, interest in gold mining in Suriname is growing once again. This development is encouraged by the GMD, because their primary function is to support mining activities. This manual was written for people who want to take up gold mining, and as such is part of the facilities provided by the GMD. The saying 'look before you leap' is more relevant here than in any other undertaking. Gold's lucrative character, interwoven with legendary stories of rich gold occurrences, has in the past resulted in many hasty mining ventures, doomed to failure.
The technical and commercial aspects must be very carefully thought through. In the following pages we shall try to acquaint the interested outsider with the nature of gold deposits and with factors which have to be borne in mind before starting out on a mining venture.
Suriname had a prosperous gold mining industry at the turn of the century on a large, medium and small scale. The collapse of that industry was caused by
-the exhaustion of easily exploitable areas and a lack of prospecting and exploration activities to establish further reserves.
-lack of management expertise resulting in unsound mining plans and purchases of unsuitable equipment.
-the waste during mining of gold occurring in the form of fine particles resulting in substantial losses.
-poor control of selling of gold resulting in the formation of a black market and low prices for the producer.
-sub-leasing by the concession holder to small producers resulting in an unsatisfactory relationship.
-the freezing of the gold price on the world market.
This handbook will show, in logical order, the steps necessary to bring an economically exploitable gold deposit into production.
Notes: (Held in BGS library Keyworth)

(41) Davidson, J (1993).
The Successful development of small-scale mining enterprises in developing countries - an overview.
United Nations Department of Social and Economic Development Steenrd, Minerals Branch, **International Agency for Small-Scale Mining, Montreal, Quebec, Canada**.

(42) Davies, R H (1992).
Peak gold mine-a different approach to underground mining.
The AusIMM Conference 'The State of the Art - A Product of 100 Years of Learning', Broken Hill, The Australasian Institute of Mining and Metallurgy. .

(43) Day, S J & Fletcher, W K (1989).
Effects of valley and local channel morphology on the distribution pf gold in stream sediments from Harris Creek, British Columbia, Canada.
Journal of Geochemical Exploration, **32** (1-3), 1-16.

(44) Day, S J & Fletcher, W K (1991).
Concentration of magnetite and gold at bar and reach scales in a gravel-bed stream, British Columbia, Canada.
Journal of Sedimentary Petrology, **61** (6), 871-882.

(45) Delaney, T A & Fletcher, W K (1993).
Size distribution in some gold soils associated with selected gold mineralization in Canada and in the United States of America.
Journal of Geochemical Exploration, **48** (3), 309-327.

(46) Deschenes, G (1986).
Literature survey on the recovery of gold from thiourea solutions and the comparison with cyanidation.
CIM Bulletin, **79** (895 November), 76-83.
Abstract: This literature survey discusses the recovery of gold from thiourea solutions. An overview of techniques used and general comments on the basic cyanidation methods are presented. The chemistry and mechanisms of cementation, activated carbon, resins, electrowinning, solvent extraction and pressure reduction are examined. Conclusions and recommendations give orientation for future research and development activities in this field.

(47) Dowd, P A (1995).
Björkdal gold-mining project, northern Sweden.
Transactions of the Institution of Mining and Metallurgy Section A Mining Industry, **104** (January - April 1995), A149 - A163.
Abstract: An overview is given of the Björkdal gold-mining project, northern Sweden, from exploration and discussion to current operations. Emphasis is placed on those aspects of the project which most critically affect viable operation-specifically, geological interpretation, ore-reserve estimation, selective mining, grade control and reconciliation. The Björkdal deposit was discovered during the implementation of an innovative exploration technique that has now been applied to much of Scandinavia. Since production began in 1988 Björkdal has steadily increased production to become the largest gold producer in Europe. The mine has adapted and improved its mining methods to achieve significant productivity increases and cost reductions. Most of the improvements have been achieved through better understanding of the controls on mineralisation and the implications of these controls for the ability to mine selectively. Geostatistics has played an important role in the quantification of grade variability and gold occurrence; improved blasting and loading techniques have improved selectivity; grade control has been enhanced by a grade-control drilling programme; and significant improvements have been made in the processing of the ore.

(48) Ek, C (1991).
Beneficiation of auferious gravity tailings.
SME (Society for mining, metallurgy, and exploration, Inc.) Annual Meeting, Denver, USA.
Abstract: Tailings originating from the gravity concentration of a gold ore containing about 14g/t Au have been treated by various beneficiation methods. These tailings have been screened on the 147 and 74 micron sieves and the two coarsest fractions have been separated on shaking tables with unsatisfactory results, but the concentrates have been examined in polished thin sections for mineralogical analysis. Very simple flotation flowsheets have been applied to collect most of hte gold, recovery and grade varying with the regrinding time in a ball mill. Cyanidation tests have shown that this type of treatment is also applicable to such tailings.

(49) Eltham, J A (1984).
Mining and processing of a low grade gold orebody in the Wau Valley, Papua New Guinea.
The AusIMM Conference, Darwin, The Australasian Institute of Mining and Metallurgy.

(50) Elvish, R D & Huber, A L (1988).
The use of the Cyanosave^{TM} detoxification and cyanide recovery process for cyanide tailings.
Minerals and exploration at the crossroads the international outreach, Sydney, Australia, The Australasian Institute of Mining and Metallurgy. .
Abstract: The use of the CYANOSAVETM detoxification and cyanide recovery process for recovering both free and complexed cyanides from cyanide plant tailings and effluents enables stringent environmental standards to be met. Cyanide is recovered for direct recycling to leaching circuits. Traces of dissolved gold, silver and other metals complexed with cyanide which are normally lost to tailings are also recovered, thereby improving overall plant efficiency.
Test work performed on pulps and clarified solutions is presented. Titratable cyanide is demonstrated to be both captured by VITROKELETM adsorbent with rapid kinetics and loaded to high levels. This concentrated cyanide may be recovered for re-use.

(51) England, J K; Kilgour, I & Kanau, J L (1991).
Processing Copper-Gold Ore at Ok Tedi.
In Rogerson, R (Ed.), *Proceedings of the PNG Geology, Exploration and Mining Conference*, Rabaul, The Australasian Institute of Mining and Metallurgy. .

(52) Erceg, M M; Craighead, G A; Halfpenny, R & Lewis, P J (1991).
The exploration history, geology and metallurgy of A high sulphidation epithermal gold deposit at Wafi River, Paua New Guinea.
PNG Geology, Exploration and Mining Conference Proceedings, Rabaul, The Australasian Institute of Mining and Metallurgy. .

(53) Eyles, N (1995).
Characteristics and origin of coarse gold in Late Pleistocene sediments of the Cariboo placer mining district, British Columbia, Canada.
Sedimentary Geology, **95** (1995), 69-95.
Abstract: The Cariboo placer mining district (10()0 km2) sited in the Interior Plateau of central British Columbia, Canada, is the primary placer gold mining district of the Province. Gold is recovered from three Late Pleistocene sedimentary facies: postglacial fluvial gravels (< 10 Ka), Late Wisconsin till (ca. 25-10 Ka), and "older" fluvial gravels (> 25 Ka). This study reports the morphology (size, roundness, sphericity) of 1636 gold grains, ranging in size from 0.25 to 17 mm, recovered from 19 placer mines. Older gravels contain the smallest gold grains (mean grain size 1.53 mm), grains of intermediate size occur in till (2.23 mm) and the coarsest gold occurs in postglacial gravels (2.34 mm) with a mean of 1.93 mm for the mining district as a whole. The most common grain shapes are sub-rounded, discoidal (14.73% of the grain population), sub-angular, discoidal (1().88%), and sub-rounded, sub-discoidal (9.59%); the most angular grains occur in postglacial gravels. In-situ growth of coarse, angular grains is indicated by a composite grain structure, consisting of aggregates of gold particles welded together by high-grade (Ag = < 2%) filamentous gold; in-situ coarsening may be reliant on organic complexing agents produced below a dense forest cower. An evolutionary sequence of grain form, from angular aggregates to rounded "pumpkin seed" grains, is suggested. Rounded grains commonly show a crystalline structure which may result from the cold hammering of gold during transport; fracturing along crystal boundaries is common. Gold grains may undergo cycles of coarsening, rounding, diagenesis and breakup in response to repeated recycling through Pleistocene sedimentary environments.

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A low-cost, heap -leach operation at the Ayrshire gold mine, Banket, Zimbabwe.
Sub-Saharan Economic Geology Special Publication, **3** 237-244.

(55) Fajardo, T & de Korver, M (1997).
Babaket isnan Minas - The Role of Women in Indigenous Gold Mining.
The Minewatch Bulletin - Women and Mining Special Issue, (12), 3-5.

(56) Feather, A; Sole, K C & Bryson, L J (1997).
Gold refining by solvent extraction - the Minataur ^{TM} Process.
Journal of the South African Institute of Mining and Metallurgy, **97** (4 July/August), 169-173.
Abstract: The Minataur™ Process (Mintek Alternative Technology for Au Refining) is a novel route for the production of high-purity gold using solvent extraction. Following the successful demonstration of the process on a pilot-plant scale, a full-scale 24 t/a production plant has been commissioned at Harmony Gold Mine in Virginia, Free State. The commercial implementation of this process represents not only a significant advance in gold-refining technology, but may be instrumental in initiating important changes in the legislation regulating the marketing of gold in South Africa.
Gold of either 99.99% or 99.999% purity can be produced from intermediate process products having a wide range of gold contents. The process comprises oxidative leaching of the solid feed, followed by selective solvent extraction of the gold from the leach liquor to reject impurities, and precipitation of high-purity gold powder. This paper outlines the process, presents selected results of two pilot-plant trials in which 5 kg/d of high-purity gold was produced from silver-refining anode slime and gold-electrowinning cathode sludge, and provides some details of the cost benefits.

(57) Ferree, T J (1993).
Application of MDL Reichert cone and spiral concentrators for the separation of heavy minerals.
CIM Bulletin, **86** (975 November/December), 35-39.
Abstract: There has been a major evolution of mineral processing technology in the past decade. The evolution has been driven by recognition of broad environmental changes which have impacted various areas of the world. Numerous government regulations have required many mining and mineral processing organisations to introduce chances to reduce the undesirable effects on the environment, many mining companies have voluntarily introduced new technologies and practices which surpass the limits imposed by the regulations. Surprisingly, some of the 'new' technologies are modifications of concepts developed decades earlier. Gravity separation technology is in this category.
Mineral Deposits Limited, an Australian company, has been a world leader in the development of mining concepts, reclamation practices and equipment technology that is environmentally suited to today's requirements. This paper relates to equipment used for gravity concentration and electrostatic separation systems, including Reichert cones, spirals, and electrostatic separators. The basic devices and technologies were developed more than forty-five years ago, but use of the systems was quite limited until environmental and conservation practices were recognised and introduced. Spiral concentrators, for example, were patented in the mid-1940s by I.B. Humphreys in Denver, Colorado. The two types of spirals marketed (the Model 24A for minerals and the Model 24C for coal) remained essentially unchanged until expiration of the patents. During this early period most spirals were used in iron-ore wash plants on the Mesabi Range to recover fine iron which previously had been discarded. About the same time sand mining plants in Florida incorporated spirals to recover titanium minerals and zircon from low-grade beach sands. The Labrador Trough opened new opportunities for spirals when hard-rock iron-ore deposits were developed; approximately 10,000 Model 24A Humphreys spirals were installed between 1958 and 1966. About 5000 spirals of this model are still operating in the same capacity, in spite of the fact that extensive improvements have since been made in gravity separation technology.
Mineral Deposits Limited was conducting mineral sand mining operations in Eastern Australia in the 1960s, and they required new methods and equipment to improve metallurgical efficiency because of the decreasing grades of their deposits. Humphreys spirals were neither cost-effective nor efficient in the Australian environment, so MDL undertook to develop new concepts and equipment for high capacity gravity separation. Their program resulted in the development of the Reichert cone, a device that is now recognised and accepted world-wide as an efficient high-capacity gravity concentrator. In a parallel development program MDL constructed their own spiral concentrators, developing improved trough profiles and using new materials of construction. In the intervening years, MDL has continued development programs on spiral concentrators and now has more than thirty-five different models, types, and configurations which are used for various mineral and coal applications.

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The fineness of gold, with special reference to the Morobe Goldfield, New Guinea.
Economic Geology, **XL** (6), 449-495.

(59) Folinsbee, J A & Hewitt, B (1997).
Gravity concentration at Campbell Mine.
Prep soc min engrs AMIE?, **36?** 1-4.
Abstract: Placer Dome Canada owns and operates the Campbell Mine at Balmertown, in the North-western corner of the Province of Ontario, Canada.
The mine operates at 1500 stpd and produces in excess of 300,000 oz of gold annually
Recent changes to the gravity concentration circuit have resulted in a 10-15 % increase in gravity recovery. The circuit changes responsible for these improvements will be the focus of this paper.

(60) Foster, R P (1990).
Gold Mineralisation :recent advances in predictive metallogeny.
Terra Nova, **2** (3), 215-225.
Abstract: The 1980s has seen the world's greatest and probably last gold rush, inspired by the soaring gold price of the late 1970s. The enormous input of time, manpower and money has resulted in gold production in the western world more than doubling from 946 t in 1980 to 2207 t in 1989 (Murray et al., 1990). This intense industrial activity stimulated an equally high level of related research ranging from fundamental ('pure') science to highly applied investigations designed to contribute directly to mineral exploration strategies and techniques. The observations, results and interpretations of these investigations have been presented in a large number of special volumes and at a number of international symposia, one of which was Gold 89 in Europe held in Toulouse. Six papers from the Toulouse meeting are published in this volume of Terra Nova. This introductory review of developments in understanding gold metallogeny is intended to update the reader who is unfamiliar with some of the more important aspects of gold mineralisation and also to provide a framework for the subsequent papers.

(61) Foster, R P (1996).
Gold in the year 2000: a global overview.
Australian Journal of Earth Sciences, **43** 1-14.
Abstract: Following the dramatic increase in the gold price during the late 1970s, the western world's gold production increased rapidly from about 750 t to more than 1200 t in 1985 and to the current level of 1900 t in 1993 and 1994. A slight drop in gold production during 1994 and a shortfall of demand over supply of 199 t are in agreement with a detailed evaluation that suggests a growing undersupply of gold to the marketplace over the next five years. Volatility of the gold price during 1994 was low and currently investors do not regard the metal as the important hedge against risk that it was in previous years. Nevertheless the fundamentals are sound and a progressive increase in the gold price is predicted. Cash costs per ounce of gold mined are commonly $210-280 and total costs are generally $50-80 higher. Increased costs, legislative constraints and threats of royalties are encouraging many companies to consider alternative exploration plays, particularly in South America, Eastern Europe and the former Soviet Union, and West and East Africa. In addition to South America, considerable successes in terms of new discoveries and joint ventures have been reported from West Africa and the former Soviet Union respectively. The Indian subcontinent also has considerable potential for new discoveries. Successful exploration requires integration of geophysical surveys, especially aeromagnetic-supported mapping and high-resolution magnetic surveys, and regolith geochemistry surveys based on a thorough understanding of the development history of the regolith and of the consequent, sometimes multistage, dispersion of the gold. Identification of target areas and specific targets can be achieved by modelling of fluid flow and fracture connectivity through one or more of seismic profiling, fractual analysis of veins and shear zones, and stress mapping. On a more detailed scale it is important to recognise the many controls of gold precipitation including sulphidation, phase separation, the contrasting roles of thio- and chloro-complexing in different fo2-pH environments, and adsorption on semiconducting sulphide surfaces. Important recent technological advances within the industry include the development of a diamond wire rope to aid stoping of the conglomeratic 'reef' horizons and the growing use of bacteria-catalysed sulphide oxidation ('bio-leach') to process refractory gold ores.

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Gold mining and exploration in Africa towards 2000.
Transactions of the Institution of Mining and Metallurgy Section B Applied Earth Science, **105** (January-April), B1-B2.
Notes: Preface

(63) Fricker, A & Acker, J (1981).
Distribution of gold on a table.
New Zealand Journal of Science, **24** (3-4), 275-279.
Abstract: The distribution of alluvial gold by weight and particle size has been measured along the length of a riffled table receiving a screened feed. About 80% of the gold reports in the first 15% of the table, which is in accordance with earlier published work. The position for the peak occurrence of gold by particle size moves down the length of the table as the particle size decreases. As it does so, it is reasonable to suppose that the percentage recovery of that size also decreases. This hypothesis, however, has yet to be tested.

(64) Fricker, A G (1984).
Metallurgical Efficiency in the Recovery of Alluvial Gold.
The AusIMM Bulletin and Proceedings, **289** (February), 59-67.
Abstract: The character of alluvial gold deposits presents severe difficulties and sometimes limitations, on the extent to which metallurgical efficiency can be measured. Very little monitoring of metallurgical performance is practised. An indication of performance is often extracted from the comparison of production to the estimate. This is a dubious practice. The recovery efficiency of conventional practices, viz. sluices, tables and jigs, falls off sharply below 0.2 mm. Field evaluation procedures tend to simulate these conventional practice Thus the presence of fine gold may not be detected, particularly if obscured by clay. There is increasing evidence that fine gold could, in places, be present in sufficient concentrations to be economic. Most gold in palaeoplacers is finer than 0.1 mm. There are established practices elsewhere in the mineral industry that may physically recover gold down to 5 microns in size and which could find application for fine alluvial gold.

(65) Fricker, A G (?).
The Processing of Placer Gold.
In Kear, David (Eds.), *Mineral Deposits of New Zealand The Gordon J Williams Memorial Volume Monograph 13,* The Australasian Institute of Mining and Metallurgy. Parkville Victoria. .
Abstract: The development of the new characteristic 'mini-dredge', the environment in which it has emerged and production of gold are briefly traced. The actual production of recent years appears to be much greater than the official production (1265 klg in 1986), thereby masking the significance of the industry to the national economy and in local employment. Most production comes from fluvioglacial gravels which are readily processed despite the presence of large boulders. The recovered gold is between 0.2 and 5mm in size, whereas the beach gold is mostly finer than 0.2mm. The gravels are usually mined with a digger and processed in a mobile land based or floating wash plant incorporating a trommel and riffled tables. There is still little quantitative data on the metallurgical efficiency of such methods, despite their age. The circumstantial and overseas evidence however suggests an efficiency of around 80%, which could be much improved by more sophisticated methods but at a greater cost. This is not to suggest that the present methods are not the most cost effective. The economic significance of the associated detrital minerals is briefly discussed.

(66) Frimmel, H E (1997).
Detrital origin of hydrothermal Witwatersrand gold-a review.
Terra Nova, **9** (4 August 1997), 192-197.

(67) Frimmel, H E & Gartz, V H (1997).
Witwatersrand gold particle chemistry matches model of metamorphosed, hydrothermally altered placer deposits.
Mineralium Deposita, **32** 523-530.

(68) Garcia, M A; Marti, V; Meinhardt, E; Cortina, J L & Granados, M (1997).
Metal cyanide control in hydrometallurgical processing of gold ores by multivariate calibration procedures.
Analytica Chemica Acta, **353** 123-131.
Abstract: This paper is focused on the development of a spectrophotometric method and the calibration procedure the metal cyanide control through the different steps of the hydrometallurgical processing of gold ores. The spectrophotometric procedure is based on multivariate calibration for the simultaneous determination of different components of the leached solutions (Au(CN)-2, Fe(CN)4-6, Cu(CN)3-4 and Ni(CN)2-4) and uses the spectral features of these species in the UV region. The method was applied to the analysis of leached solutions from gold ores and samples from ion exchange adsorption column experiments. The results obtained with the spectrophotometric procedure were in good agreement with those obtained by inductively coupled plasma-atomic emission spectroscopy.

(69) Garnett, R H T (1991).
Components of a recovery factor in gold and tin dredging.
Transactions of the Institution of Mining and Metallurgy Section A Mining Industry, **100** (September - December), A121 - A145.
Abstract: The usual measure of performance in gold and tin dredging is the R/E factor it compares actual production or recovered grade for a given period with that estimated from the original sampling. The factor is a multiple of four component factors, each ideally approaching 1 00
The estimation factor reflects the errors involved in determining the grade and depth of single drill-holes or pit. It is influenced by the characteristics of the gold or cassiterite and of the host sediments, the sampling method and the manner in which the sample is evaluated. The results are combined into an ore reserve, from which a planned dredge course is selected. An optimum *selection factor* is achieved by a higher drilling density. The drill-hole spacing is dictated by cost, the grade variability, the reserve estimation method, the size of the dredge and the cut-off grade relative to the average grade.
Any failure of the dredge to excavate the total volume contained within its course affects the *escalation factor*. An irregular bedrock profile, permafrost and some operating procedures are important contributing factors. The required dredge throughput rate influences not only the success in digging recovery but also the *treatment factor*, which reflects the equipment, the conditions under which the plant is operated and the physical features of the gold or cassiterite
No two alluvial deposits are the same, but, in general, the greatest divergence from 1 00 is invariably demonstrated by the estimation factor. A major variation in one of the other three factors may also sometimes be the chief cause of the overall R/E factor being significantly different from the ideal figure of 1 00.

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Tailings disposal at a placer mining operation by West Gold, Alaska.
Marine georesources and geotechnology, **13** 41-57.

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Characteristics of ore minerals associated with gold at Prestea mine, Ghana.
Mineralogical Magazine, **61** (December), 879-894.

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An economic appraisal of small to medium scale alluvial gold mining systems in Papua New Guinea.
In Rogerson, R (Ed.), *Proceedings of the PNG Geology, Exploration and Mining Conference, 1991 Rabaul*, Melbourne, The Australasian Institute of mining and Metallurgy,. 117-124.

(73) Hangi, A (1996).
Environmental Impacts of Small-Scale Mining: A case study of Merelani, Kahama, Nzega, geita and Musoma.
CEEST Research Report Series, (1), .

(74) Haque, K E & MacKinnon, D J (1996).
The halide mediated electro-oxidation of ammonia, cyanide, cyanate and thiocyanate in mine/milled waste waters.
CIM Bulletin, **89 June 1996** (1001), 104-106.
Keywords: Ammonia, chloride electro-oxidation, cyanide, cyanate, electro-oxidation, mediated oxidation, mineral processing, thiocyanate, waste water
Abstract: Ammonia present in a variety of mine/mill waste waters was almost completely oxidized to nitrogen by chloride mediated electro-oxidation. A closed circuit operation of preconcentration of ammonia on a suitable adsorbent (e.g. zeolite or a resin) followed by brine stripping of ammonia and electrolysis of the strip liquor seems to have sound technical, economic and environmental merits. The removal of ammonia, cyanide, cyanate or thiocyanate from a mine/mill waste water (e.g. gold mill either individually or collectively, is also feasible by chloride mediated electro-oxidation technique. Further R&D investigations are necessary for the development of a closed circuit operation for the removal of ammonia, cyanide and thiocyanate; and also to obtain technical data for process cost estimates.

(75) Harris, D (1984).
The Knelson concentrator - applications in Australia.
In *Gold mining, metallurgy and geology*, Kalgoorlie, Australia, The Australasian Institute of Mining and Metallurgy. 101-106.
Abstract: The Knelson Concentrator is a centrifugal gold concentrator developed in Canada, which utilises the combination of high gravitational ("G.") forces and a unique fluidising action to efficiently recover free gold particles from minus 6 mm to fine micron gold in both alluvial and hardrock applications.
Operating parameters including water requirements, fluidising pressures and feed rates are given, as well as an indication of their various effects on gold recovery.
Results include a Colorado School of Mines Research Institute (CSMRI) report comparing the Knelson concentrator with various other gravity concentrators. Recoveries for various testwork and production operations involving alluvial deposits in Australia are included. Location of the concentrator at various points in a hardrock gold treatment plant allows fine gold recovery from streams such as circuit tailings, cyclone overflow, mill recirculating loads and sulphide flotation concentrates.
These results indicate the efficiency and versatility of the Knelson Concentrator for the collection of fine free gold. Coupled with its advantages of low maintenance, compactness, simplicity of operation, manpower requirements and tolerance to abuse, the Knelson provides a new dimension in gold recovery.

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Liberation analysis.
Transactions of the Institution of Mining and Metallurgy Section C Mineral Processing and Extractive Metallurgy, **92** (September), C129-C137.
Abstract: A technique for calculation of the degree of liberation in the feed to separations is presented. The separations must be conducted on an incremental basis and should be continued until at least one concentrate increment at a grade less than that of the feed has been recovered. The liberation can be determined by plotting the cumulative concentrate grade and the liberation function or by using selection and collection efficiencies in a similar manner. Comparisons with other proposed criteria and methods are provided and several examples of applications are presented. The method can be applied to any type of separation and does not require the use of specialized mathematical techniques.

(77) Hollaway, J (1989).
Gold assaying for small mines. Simple low-cost facilities speed assay returns and give adequate accuracy in remote mine areas.
Engineering and Mining Journal, **190** (6), 46-47.

(78) Hollaway, J (1997).
Small-scale mining: how to combine development with low environmental impact.
UNEP Industry and Environment, (October-December), 44-48.
Abstract: The only sure way to contain the environmental effects of small-scale mining is for the governments concerned to accept small-scale mining as a valid part of an integrated, tenured local mining sector, with the same environmental rights and obligations as larger operations. During the last decade there have been proposals from development agencies and others to address small-scale (including artisinal) mining as part of the overall development agenda.

(79) Holloway, J (1993).
A review of technology for the successful development of small-scale mining.
In*Guidelines for the development of small/medium-scale mining, UN Interregional Seminar*, Harare, Zimbabwe, 47-59.
Abstract: The technology available for small formal mines is well-established. However, the needs of small-scale miners in the informal sector have seldom been addressed. Such miners are mainly working for gold and precious stones, usually on alluvial, eluvial or palaeoplacer deposits.
Apart from the general problems of breaking ground without explosives and of miffing without a power source, for these miners there are three principal technical challenges associated with their work. These are:
I) Pumping water, either to pump it out of the workings or to use it for beneficiation.
2) Screening out coarse particles from the gravel prior to washing
3) Beneficiating the screened gravel
The equipment to do this must be of very low cost, yet also be simple, sturdy and fairly efficient. This paper examines these obstacles, based on experience in Africa, and makes suggestions on how they can be overcome.
(80) Holloway, J (1993).
Small-scale mining inTanzania- a technical assessment.
Report- United Nations Development Programme Project URT/90/020, 11-22.

(81) Holloway, J (1996).
Lessons from Zimbabwe for best practice for small and medium scale mines.
In .
Abstract: Mining activities have played a vital role in the economy of Zimbabwe from precolonial times. Although about 80% of Zimbabwe's production comes from major mining groups, the complex geology of the country - coupled with an exceptionally liberal mining law, has led to a large number of small formal underground mining operations. In additional artisanal gold winning in river beds and along the river banks has become widespread since independence. The mining regulations require that on closure there is a degree of claen-up and the protection of openings before a quittance certificate is issued that allows the site to be abandoned. These have recently strengthened with the promulgation of guidelines requiring EIAs and EMSs to be implemented on larger mines. Although the resources for regulation are inadequate, public pressure has caused the formal sector to develop a self-regulatory pattern. However this approach is inadequate for the burgeoning informal sector and lessons from this area include:
: The need for disproportionately greater regulated resources when small scale and artisanal mining become common rural activity, even though it is operating with existing mining title legislation
: Its conversion into formal, regulated sector must be acknowledged as an objective by Government as the route that will enable the control the environmental effects to be achieved

(82) Hughes, N; Coats, J S & Petts, G E (1995).
Local variability of gold in active stream sediments.
Journal of Geochemical Exploration, **54** (?), 137-148.
Abstract: The distribution of gold in a short 120 m reach of an upland stream in Scotland has been investigated using an established freeze-core sampling method that avoids problems of elutriation. Thirty cores were taken from six sites chosen to represent the variety of geomorphological settings. Bed sediments varied between sites (24.3 > D50 > 9.2 mm). Gold distribution is described in terms of concentration mass and number of grains. Data are erratic in coarse fractions (> 500 mm) because of the low number of individual gold grains and the high frequency ol barren samples. The < 63 mm fraction gave the most consistent results especially for gold loads (g kg ') reflecting the high number of individual grains. The distribution of gold is discussed in relation to the geomorphological controls and sediment transport processes that lead to enrichment and dilution of gold deposits. The sampling method is shown to provide a practical approach for obtaining representative and quantitative data on fine-grained gold distributions.

(83) Inculet, I; Castle, G; Quigley, R & Hodgson, K (1988).
Electrostatic beneficiation of gold ores.
IEEE Transactions of Industry Applications, **24** (3), 380-386.
Abstract: Since gold is an important industrial material, and thus an important element in the world economy, the development of better technology in the concentration of gold ores is of some economic significance. The authors present very encouraging results obtained in separation of the Doyon gold ores when using the electrostatic inverted roof apparatus, which was developed at the Applied Electrostatics Laboratory of the University of Western Ontario and described elsewhere. The electrification phenomena through combined tribo- and inductive charging was studied at various relative humidities. Contrary to expectations, the experimental work showed that the best separations are achieved at relatively high humidities of ~ 70 percent or higher. One of the main cost factors in electrostatic beneficiation of minerals is that of drying the material. The lesser drying required of this gold ore may be of considerable economic importance.

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How to make a simple retort for separating gold-mercury amalgam.
Leaflet produced by intermediate Technology, .

(85) Johns, J W (?).
Further tests in flotation of free gold.
Engineering and Mining Journal, **136** (10), 498-499.

(86) Jones, W G; Klauber, C & Linge, H G (1989).
Loading of $Au(CN)_c^-$ Solution Onto Activated Carbon.
In *Education, Training and Professional Development industrial Minerals Project Development and Processing*, Perth-Kalgoorie WA, The Australasian Institute of Mining and Metallurgy. .
Abstract: The key element in the carbon-in-pulp process for gold processing is the loading of dissolved AU(CN)2- from solution onto activated carbon. The mechanism and kinetics of this step have been examined by solution adsorption-desorption and X-ray photoelectron spectroscopy for both coconut derived activated carbon and peat based activated carbon. The results show that these carbon types have the same mechanism and kinetics of adsorption. There is no contribution to the bonding from carbon-oxygen funtionalities on the carbon surface, as has been invariably supposed in all previous theories for the mechanism of the reaction. It is shown that Au(CN)2- is reversibly adsorbed intact on and parallel to the graphitic planes of the carbon with the formation of a weak carbon-gold p-donor bond. The kinetic measurement of carbon gold loading reactivity is discussed and use of the Murdoch equation for this test is critically assessed.

(87) Kabongo, K K (1995).
Low-density ammonium nitrate fuel oil to improve gold recovery.
Journal of the South African Institute of Mining and Metallurgy, **95** (1 January / February), 1-6.
Abstract: Blasting in a gold mine has to satisfy the following set of techno-economic conditions: good fragmentation, minimum stope width, minimum number of rock falls, cost effectiveness.
Results of a comparative study of the performance of a Low Density Anfo (LDA) and a conventional Anfo (ANFEX) are discussed. LDA appears to be more cost effective. The same borehole volume can be charged with material of reduced specific gravity. The velocity of detonation (VOD) is increased in the case of LDA resulting in more breakage as a result of shock energy than from the energy in the gas phase. This leads to less damage to the excavation and more favourable breakage of the excavated rock. As a result the overall economics of the mining operation is improved.

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More facts on the flotation of free gold.
Engineering and Mining Journal, **136** (3), 116-118.

(89) Laplante, A; Liu, L & Cauchon, A (1990).
Gold gravity recovery at the mill of Les Mines Camchib inc., Chibougamau, Quebec.
In *Gold '90 Mining Metallurgy Exploration*, Salt Lake City, **Chapter 25,** 251-259.
Abstract: This gravity circuit at Les Mines Camchib Inc. consists of two pinched sluices to bleed a feed to one of two 76 cm (30") Knelson concentrator. The Knelson concentrate is upgraded to smelt-table grade with a smaller Knelson (18/30 cm) and a riffleless table. Their tails are column cyanided and washed prior to recycle to the grinding circuit. This paper details size-by-size circuit performance. The Knelsons recover around 90% of free gold (as determined by Mozley Laboratory Separator), even below 37 mm. The sluices are ineffective, with upgrading ratios around 2, but approaching unity in the fine sizes. Much of the effectiveness of the circuit lies in the high gold circulating loads in the grinding circuit, which partly atone for the poor sluice performance, and the ability of the Knelsons to recover free gold. Secondary upgrading recovers slightly above 99% of the primary concentrate gold, 90% of it in a 65% Au concentrate and the balance in a heavily loaded (10 to 20 oz/st) pregnant solution, generated by intensive column cyanidation.

(90) Laplante, A; Vincent, F & Luinstra, W (1996).
A laboratory procedure to determine the amount of gravity recoverable gold - a case study at Hemlo Gold Mines.
In *Proceedings, 28th Annual Meeting Canadian Mineral Processors*, Ottawa, **Paper 6,** 69-82.
Keywords: gold, Hemlo, gravity, knelson concentrator, test method
Abstract: A test to determine the amount of gravity recoverable gold (GRG) in an ore is described. Typical GRG results are given; possible uses are discussed. A case study of how the technology was used at Hemlo Gold Mines is presented.

(91) Laplante, A; Woodcock, F & Noaparast, M (1995).
Predicting gravity separation gold recoveries.
Minerals and metallurgical processing, **12** 74-79.
Abstract: Novel methodology for estimating gold recoveries in gravity-separation circuits is presented. The methodology makes use of a population-balance model. The model represents gold liberation, breakage and classification behaviour and applies preconcentration and recovery-performance curves to gravity-recoverable gold. The derivation of the necessary parameters is explained and demonstrated using data from an actual gravity circuit and from a projected application.
The methodology makes it possible to estimate the performance of a gravity circuit having a large gold circulating load and a relatively-low unit recovery (e.g., a jig) or having a high recovery on a bleed of the circulating load (e.g., a Knelson Concentrator).

(92) Laplante, A R; Huang, L & Harris, G B (1996).
Defining overload conditions for the 7.6cn Knelson concentrator by use of synthetic feeds.
Transactions of the Institution of Mining and Metallurgy Section C Mineral Processing and Extractive Metallurgy, **105** (January - April 1996), C126 - C132.
Abstract: Synthetic feeds of fine and coarse (80% passing 100 and 600 mm) silica and magnetite (to mimic gangue) with fine (8-75 mm) tungsten (to mimic gold) were used to study the Knelson concentrator. The optimum flow rate of fluidization water was first determined for each gangue type; this varied from 1.7 l/min for fine silica to 5.6 l/min for coarse magnetite. Overloading of the Knelson concentrator was then investigated at the optimum flow rate. With the fine silica gangue no overload occurred under any of the operating conditions studied. There was very little overload with the fine magnetite gangue, but the coarse silica gangue produced appreciable overload-though only after a significant bed of tungsten concentrate had been formed. With the fine magnetite gangue the onset of overloading occurred earlier than with coarse silica. Finally, with coarse magnetite severe overloading occurred almost immediately. Overloading was modelled using a first-order kinetic rate constant for erosion of the concentrate bed and a critical mass of concentrate above which it takes place. The results clearly demonstrate the importance of removing oversize to maximize recovery by the Knelson concentrator, particularly with a high-density gangue.

(93) Laplante, A R; Woodcock, F & Noaparast, M (1994).
Predicting gold recovery by gravity.
Prepr Soc Min Engirs AIME?, (94-158?), 1-10.
Abstract: A novel methodology to estimate gold recovery by gravity is presented. The methodology makes use of a population balance model which represents gold liberation, breakage and classification behaviour and applies preconcentration and recovery performance curves to gravity-recoverable gold to predict overall recovery. Derivation of the necessary parameters is explained and demonstrated using data from an actual gravity circuit and one projected application.
The methodology makes it possible to estimate the performance of circuits with large gold circulating loads and relatively low unit recoveries (e.g. jigs), or with high recoveries on a bleed of the circulating load (e.g. Knelson concentrators) .

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Developments in the application of carbon-in-pulp to the recovery of gold from South African ores.
Journal of the South African Institute of Mining and Metallurgy, **94** (3 March Centenary Issue), 189-203.

(95) Lecomte, P & Colin, F (1989).
Gold dispersion in a tropical rainforest weathering profile at Dondo Mobi, Gabon.
Journal of Geochemical Exploration, **34** (3), 285-301.

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Performance of a new centrifuge (Falcon) in concentrating a gold ore from Texada Island, B.C., Canada.
Minerals Engineering, **5** (10-12), 1113-1121.
Keywords: gravity concentration, centrifugal concentrator, Falcon; gold ore characterisation; gold recovery
Abstract: The gravity treatment of fine minerals has experienced a promising advance with the introduction of centrifugal concentrators in the market, particularly to recover fine gold, as is the case of, for example, the very well known Knelson concentrator. The new Falcon centrifuge works without counter flow water, does not have internal ribs to trap the gold particles and rotates at very high speed, so as to exert on a particle a centrifugal force 300 times the force of gravity. This paper describes the mineralogical study of the gold ore used in the pilot plant tests and the evaluation of two models of Falcon concentrator.

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Some chemical aspects of gold particles flotation.
In *XVIII International Mineral Processing Congress*, Sydney, The Australasian Institute of Mining and Metallurgy. **5 Gold Processing and Hydrometallurgy and Dewatering and Miscellaneous,** .
Abstract: A great part of the research on froth flotation of gold ores deals with ores containing gold associated mainly with sulphides, resulting in a largely accepted view that what takes place with sulphides (e.g. pyrite) in a flotation cell also happens to gold particles. This Paper is concerned with the influence of some inorganics (CuS04, CaO and NaCN) on gold particles flotation, using ethyl or amyl xanthates as collectors. The bench-scale tests were carried out with ground quartz and gold particles mixtures. Some findings stemmed from this study: flotation of the gold particles of size 0.16 mm was efficient adding only forther, larger gold grains were better recovered by the use of stronger collector; CuS04 did not seem to be an activator for gold; the addition of NaCN up to 200 g/t or CaO up to 2000 g/t did not depress the gold grains when amyl xanthate was used as collector although with ethyl xanthate the gold depression was verified.

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The development of a jet reactor for the leaching of valuable metals.
Journal of the South African Institute of Mining and Metallurgy, **97** (7 November/December), 285-288.
Abstract: An investigation into the use of impinging stream (jet) reactors for the leaching of a free milling ore produced an increase in gold recovery by 10% while decreasing leaching time by up to 90%. Tests on refractory ores demonstrate no apparent improvement in recovery. However, leaching kinetics are dramatically increased when these ore are subjected to jet reaction prior to agitation.

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Review of evaluation models for the representative sampling of ore.
Journal of the South African Institute of Mining and Metallurgy, **95** (4 July/August), 149-155.
Abstract: Evaluation errors and value-frequency distribution models of the gold ore bodies in the Witwatersrand and Free State systems are reviewed. It is found that the low-grade sections of the data are prone to the largest evaluation errors, and that an understanding of the shape of the value-frequency distribution is essential to the calculation of mean grade. The evaluation of a mineral process for a particular ore requires attention to mill-feed sampling, sample processing, and monitoring. In particular, the calculation of a representative mass of millfeed sample (Ms) should take account of size-by-size value variance. Alternative Ms models are discussed.

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Preprocessing of a cyanided Gold Calcine.
In *XVIII International Mineral Processing Congress*, Sydney, The Australasian Institute of Mining and Metallurgy. **5 Gold Processing, Hydrometallurgy and Dewatering and Miscellaneous,** .
Abstract: Laboratory testwork has been performed on ancient residues from the cyanidation of a previously roasted gold-containing pyrite and arsenopyrite ore.
By grinding to 95 per cent minus 60 microns, and after a strong aeration conditioning of the pulp, a gold recovery of approximately 67 per cent was obtained by cyanidation. This recovery was brought up to 80 per cent by leaching with thiourea, after a preleaching step with sulphuric acid under severe conditions of acidity and temperature.
To avoid excessive capital costs bound to such processes, it was decided to investigate the possibility of applying flotation after grinding at a size similar or finer than the one used for the leaching tests. The method turned out to give interesting results because of the natural flotability observed at pH values lower than two for particles rich in gold present in the residue. After two cleaning steps, a final concentrate, representing around one weight per cent of the feed, was obtained with an approximate gold content of 350 g/t, representing a batch recovery of gold of about 50 per cent. Apart from sulphuric acid, whose addition was very high (flotation slurries at 25 g/l H2SO4), other reagents were not found necessary. Additional flotation tests were carried out to examine whether the recycling of the cleaner tails was justified but the gain observed appeared insufficient.

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Fine Gold Recovery - a Modern Approach.
The AusIMM Bulletin, (2 April), 38-41.
Abstract: Theoretical analysis of fine particle transport in shear flow is extremely complex and most practical parameters for designing a placer gold separation plant are determined from investigations at bench and pilot scale. Laboratory studies focus upon the physical characteristics of the gold and their possible effects on settling. The pilot plant functions under simulated prototype conditions aimed at developing optimum conditions for process development and control. Fine gold recovery by conventional gravity means is restricted to particles larger than the limiting size for unsuspended transport. Centrifugal procedures for very small particles are still largely experimental.

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The capture of tin and fine gold.
School of Mineral Industry and Alaska miners Association, University of Alaska, .

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Precious metal recovery using sluice boxes in Alaska, Canada.
In *Gold Mining '88 2nd international conference*, Vancouver, Society of Mining Engineers. 385-396.
Abstract: Information gathered while studying geological parameters that govern fine gold deposition in the alluvial environment can be applied to the technological development and selection of fine gold recovery systems.
It is recognised that substantial gold losses occur in the minus 1.5 mm (minus 12 mesh) fraction using conventional sluicing systems. Within the past two decades much attention has been given the design and efficiency of these thick bed concentrators. Studies and comparisons drew information from several foreign and domestic placer operations. These studies concentrated on:
1) the physical and chemical properties of alluvial gold
2) the parameters that control fine gold deposition
3) the geometrical form, components and general working structure of conventional sluicing systems
4) the physical properties which contribute to the overall efficiency of a sluice system
5) the comparison of three major styles of conventional sluicing systems.
A dramatic improvement regarding fine gold recovery and water quality was observed when using modern multiple-channel sluicing systems.

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Small-scale mining technology for SADC member states -Handbook on the gemstone/gold mining, lapidary and jewellery industry.
SADC Mining Sector Coordinating Unit. Lusaka.
Abstract: The Deutsche Gesellschaft fur Technische Zusammenarbeit (GTZ) GmbH in Eschborn is actively promoting the small-scale mining (SSM) sector of the Southern African Development Community (SADC) by supporting the SADC Mining Sector Coordinating Unit (MCU), Sub-Sector Small-Scale Mining. Various assistance has already been given in the form of the following: Seconding a long-term advisor for the period 1989 -1994; providing short-term consultancies, laboratory and office equipment, field vehicle, books and other materials; sponsoring training courses for the counterpart in the areas of mining economics, gemmology and gemstone economics; as well as publishing a Manual Small-Scale Mining Technology for the SADC region.
The publishing of the Manual is in line with the German Government's aim at enhancing the development of small-scale industries in the SADC region, a sector which already provides employment to hundreds of thousands of small-scale miners, thus eventually improving their standard of living.
About 200,000 people are employed in small-scale mining in the SADC region, and more job opportunities are envisaged. Similar figures have been observed in other African countries, like Ghana (about 50,000) and the Central African Re-public (about 20,000).
Small Scale mining also supports other "down-stream" small-scale industries, such as small metal smelters, building or agricultural materials manufacture (lime, gypsum, cement, tiles, pipes, bricks), dressing and cutting of ornamental / masonry stone, lapidaries (gemstone cutting and polishing, ornaments making) and jewellery shops, etc., as well as local equipment manufacture.
The problems, however, of small-scale mining are the same worldwide. These are cheap but often inefficient unskilled labour, poor safety, little concern for environmental issues, lack of start-up funds, and poor technologies.
The objective of this Manual, therefore, is to propose and to demonstrate technologies for mining and for some down-stream industries which are economical, appropriate for small-scale conditions, "intermediate", but neither primitive, nor "high tech", safe for employees and workers, and environmentally acceptable.
Target users of this Manual are the mine operators, mining engineers and geologists of government ministries, as well as private consultants providing advisory and support to small-scale mining. This Manual is also intended to be used as reference material for the training of workers and staff.

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The centrifugal gravity concentration of fine alluvial gold.
In Forssberg, E (Ed.), *XVI International Mineral Processing Congress*, Stockholm, Elsevier Science Publishers. 925-935.
Abstract: The mass fraction of fine gold (<0.25 mm) in gravels of many placer deposits runs into 80 per cent and even more. Currently used technologies of gravel processing based on sluicing and jigging do not provide any effective recovery of fine gold. To intensify the process of gravel separation, a new refined technology of separation of placer materials containing fine gold has been developed. The advantages of this technology consist in the separation and separate processing of gravel and silt fractions with the help of both the most efficient processing devices available and optimal regimes. Now, in the process of gravel separation, both traditional devices (trommel sluices, hydrocyclones, jiggers, concentrators) and new centrifugal devices (separating hydrocyclones) may be used.
The developed technology has already been tested during 3 seasons. This has given the possibility to obtain a 20-30 per cent increase of gold recovery as compared to the sluicing technology, and hence, to obtain a sufficient profit.

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Procedures for dampling tailings from placer gold sluice operations.
CANMET Contract Report, .

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Comparison of merril-Crowe Precipitation and Carbon Adsorption for Precious Metals Recovery.
In *XVIII International Mineral Processing Congress*, Sydney, The Australasian institute of Mining and metallurgy. **5 Gold processing, Hydrometallurgy and Dewatering and Miscellaneous,** .
Abstract: Zinc cementation and carbon adsorption are both presently used for precious metals recovery from cyanide leach solutions. Each of these techniques exhibits unique processing features which renders them suitable to treat solutions with different properties and in different applications. In this study, the two processes are reviewed and compared. Operating data from a number of Merrill-Crowe precipitation and carbon adsorption plants in North America have been obtained and used in this analysis. The relative capital and operating costs for the two processes have also been considered.

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New Celebration Tailings Treatment Plant - 18 Months Later.
In *XVIII International Mineral Processing Congress*, Sydney, The Australasian Institute of Mining and Metallurgy. **5 Gold Processing, Hydrometallurgy and Dewatering and Miscellaneous,** .

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An engineering view of developments and innovation in Australian gold ore treatment.
Australasian mining and Metallurgy monograph Series, **2** (19), .
Abstract: Introduction
During the 1980s, the soaring actual and projected gold prices, the fairly ready accessibility of open cuttable free milling orebodies, and the entrepreneurial spirit of the times generated the largest gold rush that Australia had seen. Other contributing factors were new methods of financing gold projects, and technical and commercial developments in mining and extraction which allowed the smaller players, who were largely the genesis and backbone of the boom, to enter the field. It was the needs of and pressures from the initial and smaller developers that forced and nurtured the technical innovations in ore treatment that are the subject of this paper.
In the main these needs were conventional, being
1. high levels of gold extraction,
2. low operating costs with the usual emphasis on minimisation of consumables consumption and, particularly, minimisation of operating labour and required skills by plant compactness and simplicity, and
3. low maintenance costs by emphasis on accessibility and simplicity.
However, the relatively small size of the projects (with throughputs averaging about 250 000 t/yr for early plants), the short project lives (averaging about 4 yr), and the nature of the financing arrangements created a stronger-than-usual focus on the following factors in the role of maximising net present value (NPV) and decreasing sensitivity to adverse circumstances.
1. Low capital cost
2. Rapid design, construction, and commissioning to full production
3. Generous upside on throughput capability (few ore-bodies performed up to expectation).

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Engineering and mining journal, **190** (6), 36-39.

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Small-Scale Mining - A guide to appropriate equipment.
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Development of small mines/exploration industry in Papua New guinea.
In Rogerson, R (Eds.), *Proceedings of the PNG Geology, Exploration and Mining Conference 1994, Lae, Papua New Guinea,* The Australasian Institute of Mining and Metallurgy, Melbourne. .
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Operation of a gold extraction circuit for recovery of gold from uranium mill tailings at Cluff Lake, Saskatchewan.
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Gold Extraction Technology in Australia and New Zealand - models for illuminating short and long term trends in gold extraction metallurgy.
In *Minerals and Exploration at the Crossroads The International Outreach*, Sydney, Australia, The Australasian Institute of Mining and Metallurgy. .

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The language of gold: Glossary of terms in the world of gold.
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In Rogerson, R (Ed.), *PNG Geology, Exploration and Mining Conference*, Rabual, The Australasian Institute of Mining and Metallurgy. .

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New technology and equipment for gold and solver leaching from gravity concentrates.
In *XVIII International Mineral Processing Congress*, Sydney, Australia, The Australasian Institute of Mining and Metallurgy. **5 Gold processing, Hydrometallurgy and Dewatering and miscellaneous,** .

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Environmentally sustainable artisanal gold mining in the Lake Victoria regions, Tanzania.
In *3rd African Mining Conference*, Windhoek, Namibia, Institution of Mining and Metallurgy. 423-431.
Abstract: Artisanal mining has become a way of life in most developing countries including Tanzania. Providing employment for nearly 500,000 people and earning the nation the desperately needed foreign currency, artisanal mining can no longer be dismissed as ad hoc activities. However the lack of mining knowledge, appropriate equipment and infrastructural facilities has resulted into dangerous mining practices. The damage to the environment from these activities have already reached alarming levels. A programme aimed at sensitising artisanal miners in gold mining areas in the Lake Victoria region on safe and sustainable mining practices, is discussed in this paper.

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Small Capacity Processing Plants.
Mining Magazine, (November), 316-323.
Abstract: Small-scale mining and ore processing operations, of which there are many in Latin America, are frequently inefficient and wasteful of their natural resources. The reasons for this are discussed and suggestions offered as to how the situation may be improved, yielding better metallurgical performance, steadier and more efficient operations, lower costs and the production of more and higher value concentrates, cumulating in higher profitability and improvements to the regional and national economies.

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Success of the development of small-scale gold mining operation in Burkino Faso.
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Abstract: After its discovery in 1985, the gold deposits of Essakane in the north-eastern comer of Burkina Faso, in the province of Oudalan, was invaded by artisanal gold miners who engaged in mining by vanning and panning.
At the government's request, UNDP attempted to organize the artisanal gold miners on a rational basis, but finding it impossible to do so because they were so numerous (more than 20,000), it was forced to revise the project a few weeks after its implementation.
The work done by UNDP within the context of the project called "Assistance a l'Evaluation et a la Mise en Valeur des Petits Gites Auriferes" ["assistance in the Evaluation and Development of Small Gold Deposits"], after abandoning the attempt to organise the artisanal gold miners, made it possible to determine the existence at Essakane of substantial reserves in the tailings left by the artisanal miners. The project also financed metallurgical-treatment trials conducted by McClelland Laboratories in Nevada, United States of America, under the supervision of the firm FLORENT J. GAUTHIER & ASSOCIES INC (FJG), and concluded that the tailings could be profitably exploited by the heap-leaching method.
While the treatment trials were in progress in the United States, "Filiere or" ["vein of Gold"], a Burkina Faso state company responsible for the incorporation of the artisanal gold miners (who by then were considerably fewer in number), installed a small gravimetric plant at Essakane to treat the tailings, but the recovery of gold by this process was very poor and the attempt was abandoned as unprofitable. "Filiere or" then merged with a French import-export company established in Burkina Faso, forming the Compagnie d 'Exploitation des Mines d 'Or au Burkina (CEMOB) [Burkina Faso Gold Mine Operating Company] which, after some new trials conducted by the School of Mines in Nancy, France, confirmed the data of FJG.
Since August 1992 the small mine at Essakane has been successfully exploiting the tailings of artisanal gold miners.
The investments are in the order of 800 million CFA francs (US$3,200,000), and annualproduction is estimated at 500 kg. The mine employs 40 persons
In view of the success of this operation, about ten employees of Burkina Faso companies, both private and state-operated, have participated in a training course at the Essakane site, under the direction of a consultant financed by UNDP, the objective of the training course being to show private Burkina Faso companies how they should go about operating small gold mines

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Distribution and dispersion of gold in point bar and pavement sediments of the Huai Hin Laep, Loei, north-eastern Thailand.
Journal of Geochemical Exploration, **47** (1-3), 251-268.

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Hidden valley gold project development summary, 1987-1991.
In Rogerson, R (Ed.), *Proceedings PNG geology, Exploration and Mining Conference, 1991*, Rabaul, The Australasian Institute of Mining and Metallurgy. .

(123) Petruk, W (1989).
Recent progress in mineralogical investigations related to gold recovery.
CIM Bulletin, **82** (931 November), 37-39.
Abstract: Mineralogical investigations in connection with gold metallurgy are usually performed to find the reason for poor recoveries by cyanidation or by other leaching techniques. Poor recoveries most commonly are obtained when (1) native gold is encapsulated in an insoluble mineral as "invisible gold "; (2) native gold is coated with a precipitate; (3) gold-bearing products are insoluble in cyanide solutions; (4) carbonaceous material in the ore adsorbs gold; and (5) associated minerals decompose and consume cyanide. Samples of refractory material quite often have low gold tenors. It is difficult to find the gold-bearing minerals in such samples with an optical microscope because the probability of finding trace minerals in samples is small The probability decreases with decreasing grain size of the gold-bearing mineral and with decreasing gold tenor of the sample Techniques have been developed to increase the success rate of finding gold grains; some are (1) concentrating heavy minerals; (2) preparing special polished sections; (3) searching with an image analyzer; and (4) dissolving associate silicate and sulphide minerals

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Small Mining International Bulletin, (February (8)), .

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Effect of roasting and ammonia leaching on the mineralogy of multimetal sulphides.
metals Materials and Processes, **9** (1), 3-44.
Abstract: This paper describes the significance of mineralogy applied to metal extraction from complex sulphide ore of Ambaji (Ambamata) origin, Gujarat, India. The textural associations of various sulphide minerals in the ore as such, are described first and followed by a description of the original intergrowth of minerals still retained in the bulk concentrates. An effort has been made to characterise the mineralogical changes that occur during roasting or during ammonia leaching of Cu-Zn-Pb bulk concentrates. The data, thus generated, are found useful for identification of various mineral phases of partial roast/leach residues thereby making it possible to relate the extraction process to mineral/ore structures so as to achieve specific results. For example, some originally intergrown particles may still be present in the bulk concentrates even after heating to approximately 800°C. The liberated independent grains undergo sequential oxidation steps during roasting or during oxidative ammonia leaching. Reaction sequence thus deduced from the oxidation behaviour of multimetal sulphides is compared with thermodynamic data on sulphide minerals from the literature.

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Practical considerations in assessing alluvial gold mining operations in North Queensland.
In *North Queensland Gold '89*, Townsville, Queensland, Australia, Australasian IMM. **3/89,** 129-133.
Abstract: Since 1985 there has been a revival in the alluvial gold mining industry in North Queensland. However, not all mines which have become established have been successful, some times due to a misconception that alluvial mines are quick to establish and easy to operate. A check list of factors which need to be considered when assessing alluvial mining projects in North Queensland is presented and their relative importance is briefly discussed.

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Gravity concentration systems in gold ore processing.
In *Gold mining, metallurgy and geology*, Kalgoorlie, Australia, The Australasian Institute of Mining and Metallurgy. 89-100.
Abstract: The use of gravity concentration is, and has always been, the conventional primary method for gold recovery from alluvial deposits. The development of high capacity cone concentrators and metallurgically efficient wash-waterless spiral separators has had some impact in the technology for alluvial gold processing, but perhaps more significantly has led to the relatively recent use of this gravity concentration technology in grinding circuits of hard rock ore for "coarse" gold removal and for scavenging gold locked in sulphides from cyanidation tailings streams.
Gravity concentration systems are relatively low-cost, non-polluting and energy efficient; and their judicial use in gold treatment plants can significantly reduce overall capital and operating costs.
The application of modern gravity concentration technology to hard-rock and alluvial gold ore treatment is discussed. Flowsheets and test and operating data from a number of gold processing operations Incorporating gravity concentration treatment are presented.

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High capacity gravity separators - a review of current status.
Minerals Engineering, **10** (9), 973-982.
Keywords: Gravity concentration
Abstract: Flowing film gravity separation devices, including sluices, spiral separators and cone concentrators have undergone significant development over the past two decades, and are now well established technology in the processing of a wide variety of fine mineral feeds.
The recent resurgence of interest in cone concentrators has resulted from a recognition of the benefits that this high-capacity and low-cost separator offers. These attributes are re-examined with reference to a number of recent innovative applications.
The benefits of high unit capacity are also reflected in the evolution of high capacity spiral separators which similarly offer operational simplicity and plant sizing and cost savings. These benefits are accompanied by demonstrable gains in metallurgical performance.
Examples of recent applications of high capacity cone and spiral systems are examined and metallurgical performance data presented.

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Abstract: The new developments in gravity separation techniques has increased the separation efficiency for particles as fine as 40 microns in the primary concentration and as fine as 10 microns in the secondary concentration. This paper is intended to provide an increased understanding of the available gravity processing technology for the recovery of placer minerals, modern practices, types of primary concentrators, and the latest gravity separation developments for the recovery of fines. Alternative options for placer processing are also discussed.

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Journal of the South African Institute of Mining and Metallurgy, **96** (5 September / October), 215-220.

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A New Dry Processing Approach to Alluvial Deposits.
In Hallenstein, C P (Eds.), *Technical Program Proceedings "Australian Mining Looks North - The Challenges and Choices' AusIMM Annual Conference, 1994 Darwin,* The Australian Institute of Mining and Metallurgy. Parkville, Victoria. 269-271.
Abstract: Dissatisfied with conventional wet processing methods for alluvial deposits, Resource Trend Pty Ltd of Cairns set out to develop a better process. After comprehensive investigation of existing dry techniques the principals have now developed a rotary dry concentrator that can handle the fine-grained fraction of alluvial deposits as well as the coarse. Four of these units have been mounted on an integrated towable treatment plant which has been in successful commercial operation for four years in northern Queensland. A second plant is now under construction for use in the United States. Grades of less than 0 2 g/lcm have been profitably mined at throughputs of about 80 cubic metres per hour and 85 per cent availability the operation runs round the clock with an establishment of four.
Major benefits, apart from lower capital and operating costs, are environmental. Ore is picked up, treated, and replaced in its original mixed condition within 25 m of its initial location. Rehabilitation is completed almost immediately behind the plant as it advances, leaving no slimes dams, coarse stockpiles, or haul roads. In 1993 the company won a Premier's Award for Environmental Excellence in the Queensland Mining Industry
The principal disadvantage is moisture, and the company is now actively seeking deposits in the deserts of the world. In Queensland mining is normally possible only for six months of the year.

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Vitrokele - Commercial Application in the Gold Industry.
In *The AusIMM Annual Conference Diversity the Key to Prosperity*, Perth, The Australasian Institute for Mining and Metallurgy. .
Abstract: Vitrokele technology is a resin process that can be applied in gold plants to reduce both capital and operating costs. The Vitrokele resin can be used for both precious metal recovery and for recovering free and combined cyanide from effluent streams.
Vitrokele resin has been extensively tested at pilot plant level and is now applied successfully at a commercial heap leach facility in Zimbabwe where it is used in place of activated carbon for recovery of gold from pregnant leach solution. Significant capital cost savings were achieved by installation of a resin plant instead of a conventional carbon adsorption plant. Operation to-date has not seen any significant physical or chemical degradation of the resin either in terms of adsorption capacity/kinetics or physical appearance/size.
This gold recovery process is equally applicable to slurry streams where it would be implemented in stirred tanks with interstage screens in a similar manner to a conventional carbon adsorption plant.
Vitrokele technology can also be applied to the recovery and recycle of free and complexed cyanide from tailings slurries and solutions for detoxification purposes. Extensive on-site piloting has shown that this technology can economically recover cyanides from tailings down to levels below 1 ppm total cyanide.
Examples of Vitrokele application for gold recovery and for effluent treatment are given using data from commercial or pilot plant operations.

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Characteristics and controls of the largest porphyry copper-gold and epithermal gold deposits in the cicum-Pacific region.
Australian Journal of Earth Sciences, **44** 373-388.

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Placer gold methods.
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Principles of sluicing.
International Journal of Mineral Processing, **15** 157-171.
Abstract: The theoretical background of the mechanism of concentration in the sluice is analyzed in detail by broadly categorizing the involved mechanisms into two separate different actions; vertical stratification in the homogeneous flowing suspension and the same time moving dilated bed, beneath the former.
The significance of the many design and operational variables and their interrelationships are then examined together with the modelling of the cone variables The cone's application is also discussed.
The design aspects of certain forms of sluices are analyzed to show how theoretical and operational considerations should be knittted to achieve an improved performance. Failure to obey such considerations is certain to make any sluice unpopular as is the case of Lamflo sluice.

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The Technology of Gold Recovery from Black Sands by the Method of Liquid Phase Chlorination.
In *XVIII International Mineral Processing Congress*, Sydney, The Australasian Institute of Mining and Metallurgy. **5 Gold Processing, Hydrometallurgy and Dewatering and Miscellaneous,** .
Abstract: A method of selective gold recovery from black sands has been elaborated which is based on the liquid phase low temperature chlorination of materials. A liquid agent mixture of sulphur monochloride S2Cl2 and sulphur dichloride SCl2 is used. This method ensures the gold extraction either in the state of AuCl3.SCl4 complex salt solution or as metal. The kinetics and main physico-chemical parameters of the process (e.g. density, solid: liquid ratio, temperature) have been investigated. The materials investigated were quartz-insipid ride samples with low sulphur and high iron (up to 70 per cent Fe2O3) contents. Gold recovery is 96-99 per cent at temperatures not exceeding 100°C. Most of the associated minerals remain in the cake. To obtain metallic gold, the resulting solution of the AuCl3.SCl4 salt after leaching is reduced by hydrazine with subsequent annealing. The elaborated method is remarkable for small energy expenditures owing to low process temperature and a high gold dissolution rate. The solution of sulphur chlorides and other reagents are used in closed cycle.

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Sampling practices and problems.
In Erickson, A J (Eds.), *Applied Mining Geology,* Society of Mining Engineers of the American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc. New York. .
Abstract: The sampling of precious metal deposits entails inherent problems due to the low mineral abundances, high mineral specific gravities, skewed grade distributions and wide ranges of mineral particle sizes. Sampling practices and precautions are discussed with particular attention to each of the tripartite stages of sampling - sampling acquisition, sample preparation and sample assaying. Practical examples of approaches to the sampling problem are given and some examples of significant sources of error are provided from gold and silver deposits in North America.

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Non-toxic recovery. As increasing concern is expressed worldwide over cyanide and mercury hazards, many operations are re-evaluating alternative gold recovery routes.
international Mining, **?** (October), 29-33.

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The AusIMM Bulletin and Proceedings, **291** (8 December), 81-85.
Keywords: gold, gravity separation, heavy mineral, Papua New Guinea, sluice box
Abstract: Small scale gold mining operations in Papua New Guinea (PNG) have been observed to use very low flow rates of water in sluice boxes. In a series of laboratory experiments carried out to determine whether this approach was unsatisfactory or not for their situation, indications were obtained that it had some advantages in the recovery of fine gold but at the cost of considerable throughput. The separation mechanisms operating in such a system are analysed.

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Improving the sluice box.
International Journal of Mineral Processing, **39** 119-136.
Abstract: The simple sluice box which has been in use for thousands of years for the recovery of heavy minerals, notably gold, is a complex system in terms of the physical mechanisms operating in the box and not well understood. The challenge is to improve the recovery of fine heavy mineral in the sluice box. The study described in this paper has increased our understanding of the mechanisms operating and in particular has established the importance of the behaviour of the settled gangue layer in the box. It also describes how the design of a sluice box can be modified to improve its effectiveness so that both grade and recovery of fine material can be improved.

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The use of mercury in small-scale gold mining operations: effectiveness and pollution aspects.
In Rogerson, R (Eds.), *Proceedings of the PNG Geology, Exploration and Mining Conference 1994, Lae, Papua New Guinea,* The Australasian Institute of Mining and Metallurgy. Melbourne. 264-270.
Abstract: The use of mercury for amalgamation has been an integral part of the small-scale gold mining industry in developing countries owing to its low investment cost, simplicity of the technique and high gold recovery. However, its impact on health and environmental hazards have not been given the attention they deserve. In spite of the growing awareness and concerns over the mercury pollution problem by regulatory authorities, precautionary measures such as bans on the use of mercury in some countries have been largely ineffective.
This paper first reviews some of the mechanisms of mercury pollution, and mercury toxicity which varies according to its oxidation state. It then describes how mercury released to the atmosphere would go through the "Mercury Cycle". Comparisons have also been made with previously measured mercury levels in small scale Papua New Guinean miners with their counterparts in other developing countries.
Recent investigations into the use of mercury in sluice-boxes have shown that it requires sufficient contact between gold particles and mercury over a sufficiently long period of time before effective amalgamation takes place. These studies have produced experimental evidence to discredit the idea that placing mercury within sluice box riffle compartments compartments captures significant amounts of fine gold.
An upper boundary to the mercury pollution levels that can occur in sluicing operations has also been established. In the light of these investigations, it is possible to highlight some of the major causes of mercury pollution by such small scale mining operations.
Finally, possible alternatives to the amalgamation process in recovering fine gold have also been suggested, in order to alleviate the problem of mercury pollution in such operations .

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Drawbacks in sluice operation practices in Papua new Guinea.
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Optimally Designed Sluice-Boxes for Small-Scale Gold Mining Operations in papua New Guinea.
In No3/93, The Australasian Institute of Mining and Metallurgy Publication Series (Eds.), *XVIII International Mineral Processing Congress, Sydney,* **2 Physical Processing, Instrumentation and Simulation,** The Australasian Institute of Mining and Metallurgy. Parkville, Victoria. .

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Optimal design of sluice-boxes for fine gold recovery.
Minerals Engineering, **6** (11), 1155-1165.
Keywords: sluice box, gold recovery
Abstract: Sluice-box designs and their operating conditions adopted by small scale miners in PNG, who use them for the recovery of gold from alluvial deposits, vary widely. Some use small flowrates to increase the recovery of fine gold recovery at the expense of efficient separation while others use high flowrates resulting in high throughput rates with increased fine gold losses.
This paper describes how a non-linear optimisation procedure could be used to identify the optimal conditions of sluice configuration and operating flowrate, in order to maximise the metallurgical efficiency of sluice-boxes treating alluvial deposit with given gold and gangue size distributions.

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Ghana's golden glow. Interest revives in the gold coast.
Engineering and Mining Journal, **190** (6), 22-33.

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Gold mining in Africa -the final frontier.
Gold mining in Africa Transactions of the Institution of Mining and Metallurgy Section B Applied Earth Science, **105** (January-April), B3-B11.

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The effect of pH on the recovery of uranium and gold by high-gradient magnetic separation.
International Journal of Mineral Processing, **17** 83-98.
Abstract: Results of the experimental investigation of the effect of pH on the recovery of uranium and gold by high-gradient magnetic separation are presented. It has been demonstrated that, by alteration of the surface potential of the minerals present in the uranium-gold tailings, the quality of the magnetic concentrate can be enhanced and the recovery of uranium increased. Gold is observed to follow uranium closely in the magnetic concentrate as a function of pH. The experimental results imply that the highest metallurgical performance of a magnetic separator can be expected at a pH value at which the surface potentials of the valuable and gangue minerals have the same sign, and the pH value is not too far removed from the point of zero charge of the valuable mineral.

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Mining and minerals processing information: where and how to get it.
?, **?** (?), 555-570.
Abstract: The planning and evaluation of new ventures in mining and mineral processing requires strategic information of the highest quality. However, specialized technical information on mining and related activities is poorly represented in the electronic media. Africa has been particularly neglected by the international information industry, even in comparison with other developing areas of the world, and African countries typically lack the resources to fund and develop their own information services. Increased co-operation between the mining and information industries, and between the developing countries, is needed to remedy the situation.

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magnetic separation cleans placer black sands.
Engineering and Mining Journal, **190** (6), 71 (only).

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Alluvial gold dredging :a case study of effects on groundwater turbidity.
Transactions of the Institution of Mining and Metallurgy Section B Applied Earth Science, **106** (January-April 1997), B24-B30.
Abstract: A floating gold dredge operating in coarse alluvial gravels of the Grey River on the west coast of the South Island, New Zealand, generated high concentrations of clay and colloidal particles in the dredge pond, which entered the groundwater system. In the gravels colloidal sediment was visible in groundwater samples 235 m down Sow from the dredge. The variation of suspended sediment concentration with distance was of the form C(L) = COe - loL for clean bed filtration in a uniform porous medium, but filter coefficients computed from measured field parameters underestimated the movement of sediment through the gravels by about two orders of magnitude. Only colloidal particles penetrated these coarse sandy gravels beyond about 40 m from the dredge pond.

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The evolution of slime treatment of the Witwatersrand Gold Mines.
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Tracking information sources of gold mining.
Geoscience Information Society Proceedings, **24** (1993), 125-128.
Abstract: When the price of gold increases, there is a surge of interest for gold mining information in geologic libraries (public, university and survey). This paper will provide key information sources as dictionaries, handbooks, classic textbooks, indexes and databases which might be consulted. Attention will also be given to government publications from state and federal geologic and mining agencies.

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CIM Bulletin, **90** (1007 February), 7.

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Rate-determining mechanisms for the adsorption of gold di-cyanide onto activated carbon.
Journal of the South African Institute of Mining and Metallurgy, **96** (3 May/June), 109-118.
Abstract: The kinetics of adsorption of gold di-cyanide onto activated carbon has been investigated extensively over the past two decades. These studies have demonstrated that both film and intra-particle mass transfer affect the kinetics. The dominant mechanism of intra-particle mass transfer has not yet been identified. In the work described surface diffusion and pore diffusion are considered as possible rate-determining mechanisms of intra-particle mass transfer. Mathematical models are described that incorporate film mass transfer and the respective intra-particle mass transfer mechanism with equilibrium described by a Freundlich isotherm. Rate constants of film mass transfer and pore or surface diffusivities were estimated by the fitting of the respective models to experimental carbon adsorption data. The estimated pore diffusivities after they had been corrected for the porosity and tortuosity of the carbon were found in most instances to be higher than the molecular diffusivity of dilute gold di-cyanide in aqueous solution. This situation is not physically viable. The surface-diffusion mechanism acting in parallel with the pore-diffusion mechanism is thus responsible for the intra-particle transportation of most of the gold.

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Concentration profiles of gold inside activated carbon during absorption.
Journal of the South African Institute of Mining and Metallurgy, **97** (7 November/December), 299-312.
Abstract: The gold concentration profiles which develop inside the activated carbon particles during the adsorption process were measured so as to obtain additional direct proof of intra-particle mass transfer rate-control and to determine bow individual carbon particles in a population vary in their gold uptake behaviour. The observed gold concentration profiles inside the activated carbon particles were typical of situations where an intra-particle mass transfer mechanism is rate controlling. Gold di-cyanide penetrated the carbon particles with a wave-like front until it was uniformly distributed throughout the particle. This corresponds with the profiles predicted by the film and surface diffusion model. However, the rate with which gold di-cyanide was transported inside the individual carbon particles varied within the population of carbon particles. This variation was characterised by a lognormal distribution in surface diffusivity. Because the estimated variances of these surface diffusivity distributions were small, the dynamic adsorption behaviour of the carbons used in the present study did not deviate significantly from that predicted by a model based on film transfer and a single surface diffusivity. Van Deventer (1984, 1985 and 1986a) reported data that could not be adequately described by a model based on film mass transfer and a single surface diffusivity. In this study a model based on film mass transfer and a wide lognormal distribution of surface diffusivity values was applied to his data. It was shown that a population of carbon particles with a wide distribution in surface diffusivity values could offer an alternative explanation to the mechanism proposed by Van Deventer which was based on film mass transfer with partitioning of the carbon into micro and macropores with surface diffusion in the macropores and slow mass transfer into the micropores.

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UNECA Centres: a way to reduce mercury emissions from artisanal gold mining and provide badly needed training.
UNEP Industry and Environment, (October-December), 49-51.
Abstract: The concept of "UNECA" (UNit of gold Extraction and Controlled Amalgamation) Centres was developed y UNIDO and a private Venezuelan company. It is based on Amalgamation centres introduced by the Venezuelan government in the early 1990s. UNECA Centres could provide artisanal miners with safe gold extraction services and with various types of training. Information on mining's health and environmental effects (in particular, the need to avoid mercury vapour inhalation and consumption of mercury-contaminated fish could be disseminated through these Centres to miners and their families.

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Gold Mining Activities in the Amazon: Clean-up Techniques and Remedial procedures for Mercury Pollution.
AMBIO, **24** (6 September), 371-375.
Abstract: Economic and social problems have increased informal mining operations ("garimpos") in the developing countries of Central America, South America, Asia, Africa and Oceania. South America, in particular the Amazon region, accounts for more than 100 tonnes of gold annually, produced using gravity and amalgamation processes. Although mercury (Hg) is used illegally in these activities at a price five times above the international level, gold recovery by amalgamation is typically above 90% with a cost below 0.02 g of gold per tonne of ore treated. Mercury pollution, occurring at rates of about 1 kg per kg of gold produced, derives from inadequate amalgam distillation practices (80%) and from the dumping of amalgamation tailing into watercourses (20%). More than 1 million informal miners are working in the Legal Amazon Region. Some of the miners who burn amalgam show signs of mecurialism while fish-eating people living some distance from mining activities show high Hg concentrations in blood. Remedial procedures can be viewed from two perspectives: i) clean-up methods for highly polluted sites; ii) education and training of the miners and local population centers. This paper describes the clean-up methods most often used to control mecury pollution including selenium addition, covering polluted sites with adsorbent materials, cementation with iron scrap or dredging operations followed by mercury and residual gold extraction.

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CIM Bulletin, **88** (993 September), .

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Recent developments in mineral processing techniques.
Journal of mines, metals and fuels, (December), 414-423.

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An investigation of the performance of a spiral using radioactive gold tracers.
Minerals and Metallurgical Processing, **9** (August (3)), 105-109.
Abstract: The behaviour of gold particles on a spiral was studied using radioactive gold tracers. The method allowed the effects of particle size, particle shape, pulp density, feed rate and splitter settings to be studied. Although the method has been successfully applied to other gravity concentrators, it was found that reliable results were more difficult to obtain on the spiral. However these preliminary results show that, with suitable precautions, the technique is capable of providing valuable information, unobtainable from conventional studies, that could be used to better optimize spiral performance.

(164) Walsh, D & Kelly, E (1993).
Technical note - nominal diameters of gold particles.
Minerals Engineering, **6** (2), 193-198.
Keywords: nominal diameters, terminal velocity, gold
Abstract: Relationships between a number of nominal diameters have been derived from terminal velocity data on gold particles. For flaky gold particles, the different nominal diameters can vary by factors over 10.

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Gravity recoverable gold from -13mm crushed ore, Ester Dome, Alaska.
Minerals and metallurgical processing, **8** (November (4)), 179-183.
Abstract: A pilot-scale study was performed to evaluate the potential for gravity concentration of gold from -13mm (-1/2in.) crushed ore from Ester Dome, AK. 9.04t (9.94 st) of crushed ore were sampled and processed through a Pan-American jig-Wilfley table pilot plant. Plant products were sampled for assay and material balance calculations.
Gold recovery through one stage of jigging and two stages of tabling was 17.4% at a concentration ratio of 615:1. Concentrate grade was 766.3g/t (22.4 oz/st). The feed grade to the plant was calculated at 1.71 g/t (0.05 oz/st). Jig tailings, primary table tailings and secondary table tailings grades were 1.44 g/t (0.042 oz/st), 1.30g/t (0.038 oz/st0, and 5.47 g/t (0.16 oz/st), respectively. Significant coarse, free-milling gold values were shown to remain in the jig tailings. Concentrate mineralogy is discussed.

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Placer Gold Unit Process Investigations with Radiotracers (^{198}Au).
Marine Mining, **8** 405-424.
Keywords: Mineral processing, gold recovery, placer gold, concentrators, radiotracers, settling velocity
Abstract: A process evaluation technique developed by MIRL employs the use of neutron activated gold (198Au)) and radiation detection circuits that monitor the unit operation 's product pulp streams. Gold distribution is determined from the ratio of the number of gold particles detected in any one pulp stream to the total number of gold particles detected over all monitored pulp streams. Beginning in 1984, MIRL conducted radiotracer studies of unit processes, which included jigging, static wedge wire screening, elutriation, and concentration with compound water cyclones.
A closed circuit jig system, with associated radiotracer detection circuits, proved adequate to detect per particle activities of 83,000-2300 dps. Gold particle of four size-shape ranges were used during this project: 14 x 0.1, 50 x .07, 50 x 0.3, and 100 x 0.3 (ASTM mesh x Corey 's shape factor). Residence times within the jig, observed for these gold particles , were approximately 20, 15, 30, and 40 seconds, respectively.
Using an elutriation system, the settling velocities of 35 manufactured gold particles (97 mg to 0.03 mg) were determined in order to produce working gold settling velocity versus size-shape graphs for practical engineering application. A generalised randomised block design was generated to explore the effects of three variables on the settling velocity of gold grains. The three variables studied were water temperature, clay concentration in the fluid, and the clay mineralogy of the suspended clays. The data suggest that the clay mineralogy (rheological properties) of suspensions is perhaps the most influential parameter with respect to settling velocity determination.
Laboratory testing of a l-sq-ft section of wedge-wire screen with 2.0 mm slot dimensions showed that despite gold 's high specific gravity and often flattened nature, it was not preferentially screened as compared to gangue particle. Gold sizes from 12 mesh through 80 mesh were tested in this study.
A 4in. compound water cyclone, CWC, was tested to evaluate its gold recovery characteristics when processing minus 3/16 in., run-of-pit, placer material. The effect on gold recovery of gold size and shape, feed pulp density, feed pressure, vortex finder clearance (VFC), CWC cone type, top size of the feed solids, presence or absence of heavy minerals in the feed, and the quantity of - 400 mesh slimes in the feed was investigated in more than 300 tests.

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Development of a radiotracer technique to evaluate gold recovery by gravity concentrators.
CIM Bulletin, **79** (895), 34-38.
Abstract: Gravity concentrators are evaluated either in closed or open circuit. The process developed by MIRL employs the use of neutron activated gold (198Au) and radiation detection circuits which monitor the concentrator's product pulp streams. Concentrator recovery is determined from the ratio of the number of gold particles detected as passing into the concentrate to the total number of gold particles detected over all monitored pulp streams. This system eliminates the experimental errors introduced by sampling, sample reduction, and assaying and allows recovery to be evaluated for gold particles of specific sizes, shapes, and flatness. In addition to allowing for a more accurate and detailed recovery analysis, this process significantly reduces the time and cost required for unit evaluation when compared to other gold recovery analysis procedures. This system enjoys its greatest utility where a large number of tests are to be run in order to evaluate a concentrator over a variety of operational settings, i.e. factorial designs, and allows accurate testing of concentrators operated in closed circuit systems.

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Study of the compound water cyclone's concentrating efficiency of free gold from placer material*.
CIM Bulletin, **81** (919 November), 53-61.
Abstract: A four-inch compound water cyclone (CWC) was tested to evaluate its gold recovery characteristics when processing -4.8 mm run-or-pit, placer material. Neutron activated placer gold particles (840 to 37 microns) were used as radiotracers (198Au) in a closed circuit CWC test loop to determine concentrator recovery; a procedure believed unique to this study. The effect on gold recovery of gold size and shape, feed pulp density, feed pressure, vortex finder clearance (VFC), CWC cone type, top-size of the feed solids, presence or absence of heavy minerals in the feed, and the quantity of -37 micron slimes in the feed was investigated in over 300 tests.
CWC concentration ratio and the top-size of the underflow solids were both affected by cone type, VFC, and feed pressure. Gold recovery was significantly affected by gold size, gold shape, and concentration ratio. These effects are complex, because significant size-concentration ratio and size-shape interactions exist. Radiotracer techniques showed gold particles had a residence time within the CWC of approximately one second. This study suggests CWC gold recovery is a concentration. This work suggests CWC gold recovery is a function of particle size and shape, and the flow rate through the cyclone. CWC cone "bed density" is considered important only as a thin, protective layer, which shields coarser gold particles from the entraining currents and facilitates their movement through the CWC.
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The effect of sulphide and lead on the rate of cold cyanidation.
In *1989 Annual Conference Education, training and Professional Development Industrial Minerals Project Development and Processing*, Perth-Kalgoorlie, .
Abstract: Sulphide ion is a powerful poison in gold cyanidation, however, the detrimental effect is less severe in plant practice. This is thought to be due to the presence of depassivating elements in the ore, mainly lead.
Trace amounts of lead can counteract the poisonous effect of considerable amounts of sulphide. The reaction is instantaneous and is likely to be a direct involvement in the electrochemical surface reaction.
Lead addition cannot be regarded as an all-round cure when experiencing poor leach efficiencies. A possible beneficial effect depends on the mineralogy of the ore and has to be determined individually for every material.

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The effect of extended milling on minerals.
CIM Bulletin, **90** (1007), 64-68.
Keywords: Mineral processing, extended milling, ball milling, milling
Abstract: The effect of extended ball milling has been studied for two industrial processes: (1) the processing of metal sulphide concentrates; and (2) the carbothermic reduction of ilmenite to synthetic rutile. The plant concentrates were a gold ore with 128 g/t Au of which 8% was non-refractory and a zinc concentrate with copper impurities.
The gold concentrate showed complete dissolution of the gold bearing minerals after milling giving almost complete gold liberation. The zinc concentrate showed almost all of the sulphides had solubilized leaving the gangue and elemental sulphur. A study of pure pyrite and arsenopyrite shows that selective dissolution should be possible by a simple leaching process directly after milling.
The milling of ilmenite and coal together results in a temperature decrease of 150°C in the subsequent carbothermic reduction of ilmenite, in addition to improving both the rate of reaction and the selectivity of reduction.

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Contemporary practices in gravity recovery installations in the Canadian gold mining industry.
Minerals Engineering, **4** (3/4), 399-409.
Keywords: Gravity; gold; Corona; Jolu; jigs; tables
Abstract: There are now over sixty gold mining operations in Canada, many designed built and commissioned or modernised during the last ten years. The majority of these recover gold by cyanidation and carbon-in-pulp, or carbon-in-leach. Many of the new plants use semi-autogenous grinding.
This paper reviews current practice in those Canadian mills that use some form of gravity concentration.
The gold mill at Corona Corporation's Jolu mine is described in some detail. This is a good example of many recent gold plants and successfully uses gravity concentration and carbon-in-pulp to achieve a gold recovery in excess of 97%.

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Methods for recovering fine placer gold.
CIM Bulletin, **76** (860), 47-56.
Abstract: Devices and flowsheets for recovering fine placer gold are reviewed. Inefficiencies of gravity processing techniques are documented and discussed. Prospects of combining gravity and froth flotation techniques are presented. Possibilities of using other separation techniques, such as magnetic and electrostatic devices are also discussed.

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Boliden improves processing economics.
Engineering and Mining Journal, **186** (7 (July)), 32-36.

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Scale-up procedures for gold-adsorption systems. Part 1: Adsorption kinetics.
Journal of the South African Institute of Mining and Metallurgy, **95** (4 July/August), 167-177.
Abstract: Little is reported in the literature that is directly useful for the in-pulp adsorption of film coefficients for the in-pulp adsorption circuits used in gold metallurgy. This can create a problem if the design or operation of these circuits is to be optimized by the use of simulation techniques. To address this problem, a study was undertaken on the influence of mixing intensity, scale, and geometry on the film coefficient in adsorption systems typical of the carbon-in-pulp plants used for gold extraction. This, the first paper deals with the influence of these factors on the film coefficient shows that the specific power to just disperse the carbon in the slurry is an important variable. This variable is also strongly dependent on mixing intensity, scale, and geometry-a dependence that is dealt with in the second paper in the series. From the information obtained, practical scale up procedures were developed. These procedures are considered to be applicable to resin-in-pulp as well as to carbon-in-pulp plants.

(175) Woollacott, L C & Afewu, K I (1995).
Scale-up procedures for gold-adsorption systems. Part 2: Mixing requirements.
Journal of the South African Institute of Mining and Metallurgy, **95** (4 July/August), 179-194.
Abstract: The design of in-pulp adsorption vessels in the gold industry has, for the most part, been seen as a problem involving the suspension of fine particles of ore in a slurry. The need for the vessel to be designed as a mass-transfer contactor has received insufficient attention.
The current series of papers addresses this need. The previous paper considered the question of the scale dependence of the film transfer coefficient. This paper examines the mixing considerations that are relevant. A review of the literature and an examination of a limited set of data provide some insight into the mixing conditions needed for the dispersion of the particles of adsorbent. The mixing requirements for the suspension of the ore particles are also considered and conclusions are drawn in regard to the design of mechanically agitated vessels for gold in-pulp adsorption circuits.

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Saattopora. Outokumpu opens Lapalnd gold mine, first new Finnish mine in years.
Engineering and mining journal, **190** (6), 40-43.

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Concepts for geochemical gold exploration based on the abundance and distribution of ultrafine gold.
Journal of Chemical Exploration, **55** 93-101.
Abstract: Conventionally, geochemical exploration for gold is based on the assumptions that (1) gold is chemically inert in surficial environments; (2) gold occurs mainly in discrete grains; and (3) gold is transferred by mechanical means to form clastic dispersion halos and dispersion trains. Consequently, the commonly adopted methodology has been (1) to determine gold in tiny mineral concentrates; (2) to use large samples in order to improve the reproducibility of gold analyses; (3) to use high detection limits and thresholds; and (4) to determine total gold contents and pathfinder elements in the samples. However, these methods are not always successful in locating gold deposits, and they have limited application in the search for buried or blind deposits.
In China, studies of the distribution and migration or particulate and ultrafine gold indicated that (1) gold is active and mobile in surficial environments; (2) gold (occurs not only as discrete grains, but also as ultrafine particles and other complex forms; and (3) regional low-concentration gold anomalies as well as local anomalies over buried gold deposits originate from ultrafine gold and other complex forms of gold. The methodology developed in China for regional and local geochemical gold exploration is based on this experience. Results of investigations around two gold deposits in China are presented.

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Discussion of Some Technological Problems in Increasing the Recovery of Gold and Silver Associated with Sulphides.
In *XVIII International Mineral Processing Congress, 1993*, Sydney, The Australasian Institute for Mining and Metallurgy. **5 Gold Processing, Hydrometallurgy and Dewatering and Miscellaneous,** .
Abstract: Based on the author's research and plant practice experience of the last decade, several technological approaches have been developed to increase the recovery of gold and silver associated with sulphides. This paper gives a general discussion of some technological problems encountered in this area in five aspects and introduces the different approaches employed in three typical mineral processing plants to increase recoveries of associated gold and silver. On the basis of studying occurrence characteristics of gold and silver minerals in sulphide ores and of determining loss locations of gold and silver on notation process, a remarkable improvement on the recovery of gold and silver in all these three plants was made by choosing proper grinding fineness, using combined collectors of good selectivity, properly decreasing the grade of main metal concentrates, making reasonable arrangement of the products of main metals, or a combination thereof.

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A rapid analytical method for gold in geochemical exploration.
Journal of Geochemical Exploration, **55** 49-53.
Abstract: A rapid field method for gold analysis in geochemical exploration has been developed. Cold extraction of Au, at room temperature, using a mixture of sodium bromide, sulphuric acid, hydrogen peroxide is performed; the technique has the advantage of avoiding the irritating odour of commonly used aqua regia digestion. Polyurethane foam is used to concentrate gold from solution. After desorption of Au using mixed reagents (0.5% Na2SO3-NaCl solution at pH 8), two sequential procedures, depending on the concentration, are followed for the determination of gold. (I) A 1 mL portion of desorbed solution is used to form Au-TMK-DBS (Thio Micher's Ketone and dodecyl benzene sodium sulphonate) ternary complex. Concentrations below 20 ng/g Au are determined by visual colour comparison of the organic layer with a series of standards. (2) if the concentration is greater than 20 ng/g Au, a complexation reaction using the same reagents is followed by fibre-optic colorimetry. The method is rapid and simple, and the tiresome operation of ashing the foam is avoided. The limit of detection is 0.5 ng/g Au and eighty determinations can be made in one working day. The method could be used for rapid follow-up of rock sample or in situ drill core analyses. About 600 samples from 5 gold districts were tested by this method. The results are very satisfactory.

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New Zealand Journal of Geology and geophysics, **39** (4), 493-508.

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