GOLD TECHNOLOGY DEVELOPMENTS AND TRENDS

By

Alan Taylor

ALTA Metallurgical Services, Australia

Presented by

Alan Taylor
alantaylor@altamet.com.au

CONTENTS

1. INTRODUCTION

Recent gold industry news has understandably focused on the meteoric price rise. However, although processing technology has been out of the limelight, it has not been standing still, and developments have been occurring in a number of key areas. Drawing from published information and data, this paper identifies and outlines some of the main developments.

2. APPLICATION OF HIGH PRESSURE GRINDING ROLLS (HPGR)

Following successful application in the copper industry, high pressure grinding rolls are making inroads into gold ore treatment, typically to supplement or replace SAG milling for coarse grinding of relatively low moisture fresh ores. A key factor in the increased use of HPGR for hard rock applications has been the development of metal carbide studs and tiles designed to produce an autogenous wear layer(1). The main attraction of HPGR is higher energy efficiency, especially if operated in closed circuit with fine screening(2). Other advantages include reduced grinding media consumption and greater flexibility. A recent example is the massive Boddington Expansion Project in Western Australia, designed to treat 35 mtpa of copper/gold ore. The flowsheet, shown in Fig. 1(3), involves primary and secondary crushing, HPGR (supplied by Polysius), flotation of a saleable copper concentrate, and cyanidation of the flotation tailings to produce gold bullion.

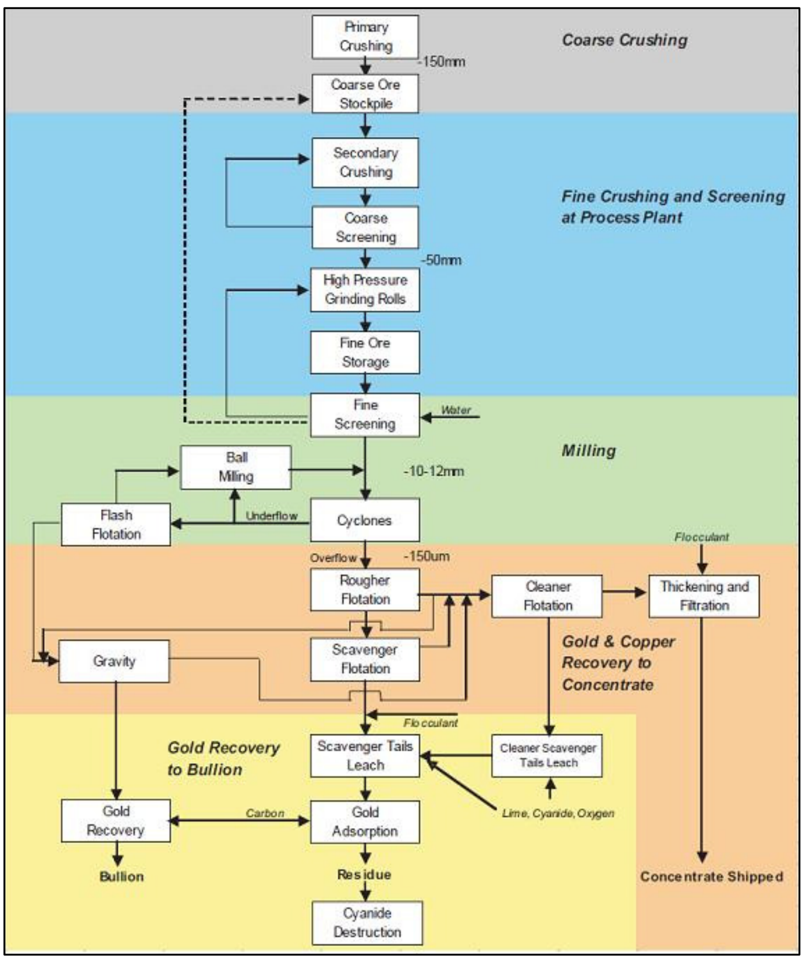

Figure 1: Boddington Expansion Flowsheet
(Ref. 3: Newmont/Boddington Gold Paper at World Gold 2007)

High pressure grinding rolls are also being considered for fine crushing in gold heap leach projects in place of cone crushers and vertical shaft impactors. PotentIal advantages of HPGR for heap leaching applications include the ability to achieve a fine procuct size at high energy efficiency together with micro-fracturing of the ore and increased fines production, which have the potential to significantly increase the leaching rate and gold recovery [(1) (4)]. On the debit side, the increased fines may increase the need for cement addition for agglomeration. A conceptual flowsheet is shown in Fig. 2 which includes gold recovery by standard carbon adsorption technology.

The main HPGR suppliers are Polysius (Thyssen Krupp), Köppern, and KHD Humboldt Wedag, all of Germany.

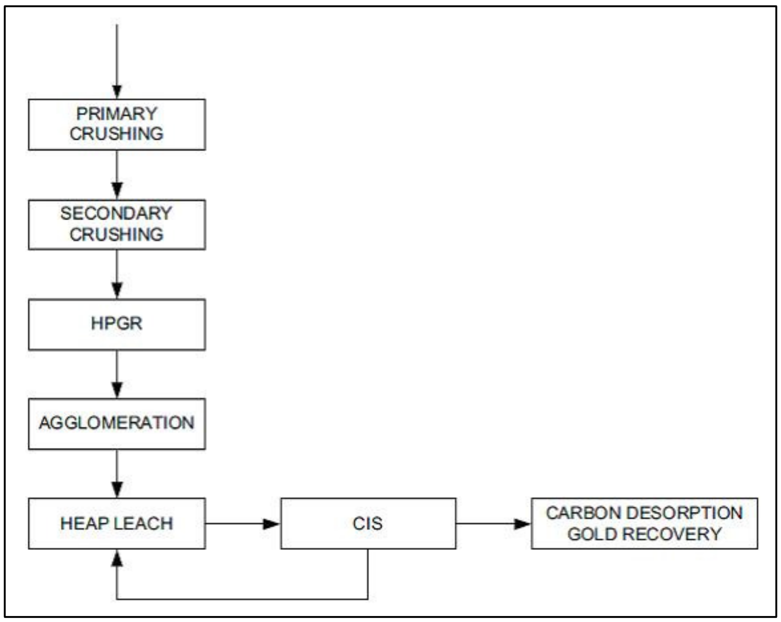

Figure 2: HPGR Heap Leach Flowsheet
(Ref. 4: Orway Paper at HR Crushing & Grinding 2006)

3. ORE UPGRADING

3.1 UNDERGROUND PROCESSING

Gekko Systems have introduced the "Python" Underground Processing Plant which is designed to upgrade run-of-mine ore underground resulting in savings in haulage, ventilation, back fill, grinding, staffing, tailings disposal and environmental costs [(5)]. The modular system typically consists of jaw crusher, vertical shaft impactor or HPGR, in-line pressure jig circuit and flash flotation. The concentrate representing 5-35% of the feed weight is either pumped or dewatered and placed in skips or trucks for cartage to the surface for further processing. A prototype 20 tph system has been operated at the Central Rand Goldfield in South Africa, and two 50 tph units are being added. An outline flowsheet is depicted in Fig. 3. The process is most applicable to ores which respond effectively to gravity and flotation.

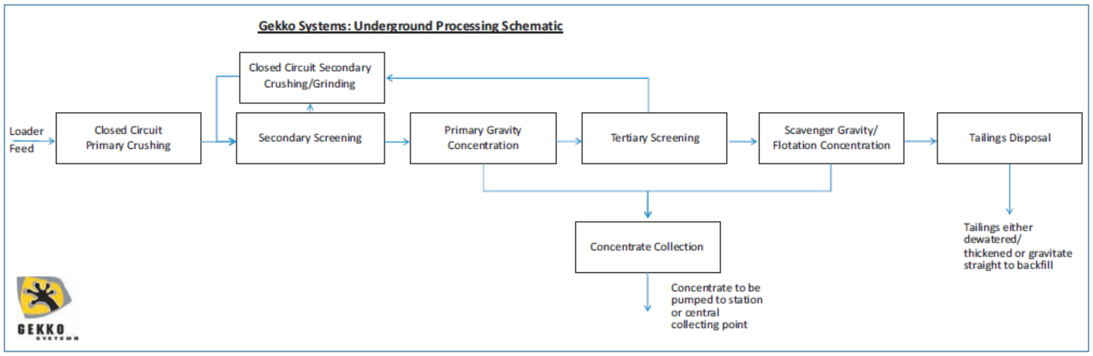

Figure 3: Gekko Underground Processing (Python) Flowsheet
(Ref. 5: Gekko/Central Rand Gold Paper at First International Future Mines Conference 2008)

3.2 ORE SORTING

Optical ore sorting was tested in an 82 tph pilot plant by Commodas Ultrasort in 2004 for upgrading a low grade waste rock dump at the Kloof Gold Mine in South Africa [6]. More recent optical sorting tests were carried out for Central Rand Gold.

The Kloof pilot plant, shown in Fig. 4, included a feed hopper, variable speed feeder, conveyors, washing screen, water circulation pump as well as the sorter.

Figure 4: Optical Ore Sorter Pilot Plant at Kloof Gold Mine
(Ref. 6 Commodas Ultrasort Paper World Gold 2009)

The program focused on the plus 16 mm size material. Pilot plant operating data is presented in Table 1. About 70% of the gold in the plus 16 mm material was recovered into a relatively low mass pull concentrate of 5–10% of the feed weight.

Table 1: Pilot Plant Operating Data Grades and Recovery
(Ref. 6: Commodas Ultrasort Paper World Gold 2009)

Period	Head grade (g/t)	Conc Grade (g/t)	Slimes Grade (g/t)	Total product grade (g/t)	Tailings Grade (g/t)	Recovery (%)	Yield (%)
Sep/Oct 2003	0,32	3,06	1,41	2,65	0,12	69,55%	7,93%
Nov/Dec 2003	0,30	3,42	1,40	2,86	0,11	71,28%	7,16%
Jan 2004	0,29	3,40	1,40	2,82	0,10	71,72%	6,94%
Feb 2004	0,25	5,00	1,40	3,41	0,10	70,33%	4,53%
Jun 2004	0,27	5,76	1,50	3,89	0,08	68,45%	2,78%
Total	0,29	4,13	1,42	3,12	0,10	70,27%	5,87%

CommodosUltrasort have also tested XRT sorting on rejects from the DMS treatment of sulphide ore at Simmer and Jack's TGME operation in South Africa[21].

4. CYANIDE CONTROL, DESTRUCTION AND REPLACEMENT

4.1 ON-LINE CYANIDE ANAYSIS

On-line cyanide analysis and automatic control are being increasingly used to optimize cyanide addition, and CNWAD on-line analyzers for weak acid dissociable cyanide have recently been introduced[7]. As more operations are adopting the International Cyanide Management Code, it has become increasingly important to monitor and log residual cyanide.

4.2 CYANIDE DESTRUCTION

CyPlus have supplied two Cold Caro's Acid systems for Jaguar Mining Inc. at their Turmalina and Paciencia gold operations in Brazil in 2009[17]. The process is said to very economical with regard to hydrogen peroxide and sulfuric acid consumption.

Another recent development is the SART Process (Sulphidization–Acidification–Recycle–Thickening) in which a reagent such as sodium hydrosulphide (NaHS) is used to precipitate copper and zinc as sulphides and convert cyanide to HCN. The precipitate is removed for possible sale or further processing, and the solution is neutralized with sodium hydroxide or lime and recycled back to the leaching process to re-use the cyanide. A simplified flowsheet is shown in Fig. 5. Bio-generated H_2S gas can be used in place of sodium hydrosulphide, as discussed in Section 5.1 below. A SART facility has been operated at the Newcrest Telfer plant in Western Australia[8].

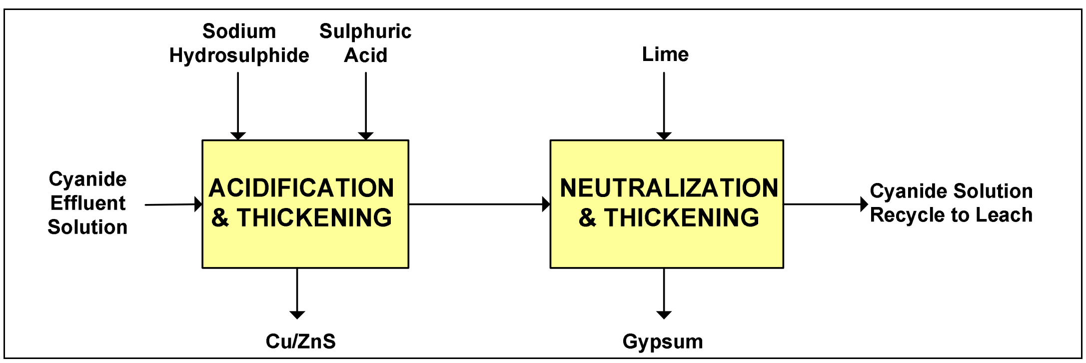

Figure 5: Simplified SART Flowsheet

4.3 NON-CYANIDE LIXIVIANTS

In the field of non-cyanide lixiviants, the Parker Centre (CSIRO) in Perth is developing ion exchange technology for recovering gold from thiosulphate leach solution[9]. The process involves the use of a synergistic mixture of chloride and sulphite to elute the gold from the loaded resin. Thiosulphate leaching has potential applications for locations where cyanide is prohibited, and for processing preg-robbing ores for which it can yield a higher gold recovery than cyanide. The European parliament is seeking a European Union (EU) ban on using cyanide technologies in mining before December 2011. If this goes ahead, efforts to develop viable options to cyanide will likely increase.

5. TREATMENT OF ORES CONTAINING SOLUBLE SULPHIDES AND COPPER

5.1 COPPER SULPHIDE PRECIPITATION USING BIO-GENERATED H_2S

BioteQ in Canada and Paques in the Netherlands have developed BIoSulphide and THIOTEQ bio-reactor technology respectively for the generation of H_2S gas for the precipitation of copper sulphide from copper rich cyanide solutions from a sulphur source such as elemental sulphur. The H_2S is used instead of sodium hydrosulphide in a SART type flowsheet to regenerate and recycle cyanide and yield a copper sulphide by-product. The additional capital cost is said to be outweighed by the lower operating costs due to the cheaper sulphur source and reduced acid consumption. The benefits tend to increase with plant throughput and feed solution copper content.

Paques' THIOTEQ technology together Outotec's OKTOP reactors is being installed at the Pueblo Viejo operation in the Dominican Republic, owned by Barrick and Goldcorp[10], while BioteQ's BIOSULPHIDE technology has been applied at the Lluvia de Oro operation in Mexico. A flowsheet for the BioteQ Biosulphide Process is given in Fig. 6

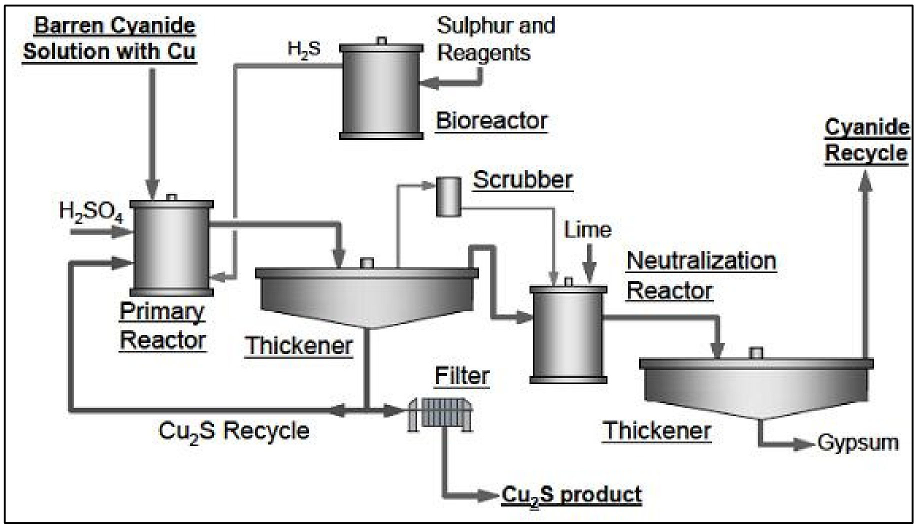

Figure 6: Bioteq BioSulphide Process Flowsheet
(Ref. 8: BioteQ Paper at Precious Metals 07)

5.2 SELECTIVE ION EXCHANGE

Anglo Asian Mining has adopted Mintek developed IX technology using DOWEX MINIX strong-base resin for the Gedabek gold-copper heap leaching operation in Azerbaijan[11]. This is the first application of the resin which is very selective for gold in the presence of high copper levels. It has been previously applied for the recovery of gold from carbonaceous preg-robbing ores at Avocet Mining's Penjom mine in Malaysia.

5.3 ADDITION OF LEAD NITRATE

The AngloAshanti Morila Mine in Mali has reported that the addition of lead nitrate for treating ore containing the reactive sulphide pyrrhotite improves gold recovery, enhances leach kinetics and reduces cyanide consumption [12]. Also, Mineral Engineering Technical Services (METS) of Perth have reported improved leach performance with the addition of lead nitrate when testing a gold-silver ore [13].

6. TREATMENT OF HIGH SILVER ORES

CANMET, Canada, have introduced CELP (CANMET Enhanced Leaching Process) aimed at reducing cyanide consumption and leaching time for ores with a silver content above 50 g/t [14]. The first commercial installation came on stream in 2008 at Kupol in Far East Russia, now owned by Kinross Gold [15], treating 3,000 tpd high grade ore with initial grades of 28.2 g/t Au and 324 g/t Ag. The inclusion of CELP allows the residual cyanide concentration to be reduced to 410 ppm which eliminated the need for an AVR plant to recover and recycle cyanide. Gold and silver recoveries in 2008 were 95.4% and 85.6% respectively with a cyanide consumption of 1.3 kg/t. Performance data is given in Table 2. Refractory sulphide and antimony silver minerals are said to be efectively leached because CELP produces more oxidized mineral surface relative to conventional cyanidation. It is reported that CELP uses standard agitated leach tanks. The Kupol operation includes a calcium hypochlorite cyanide destruction facility as the efluent is regulated on total cyanide and thiocyanate concentrations.

Table 2: Summary of 2008 Kupol Performance with CELP (Ref. 15: Kinross/CANMET Paper World Gold 2009)

	Mill tonnage	Mill feed grade		Overall recovery (Grav + leach/CCD)		Precious metals production	
Month	(tonnes/hour)	Au (g/t)	Ag (g/t)	Au (%)	Ag (%)	Au (oz)	Ag (oz)
May	30 430	21.0	252.0	96.2	91.5	1 452	819
June	73 890	36.6	427.4	95.8	87.8	57 823	564 778
July	84 524	26.1	308.7	95.3	85.7	85 953	948 285
August	92 732	28.2	312.5	95.4	86.0	82 981	865 585
September	81 012	25.3	295.6	94.9	85.0	63 940	638 598
October	94 533	33.4	334.4	95.6	83.8	90 123	917 694
November	96 225	27.9	371.0	95.3	86.1	90 864	951 162
December	94 986	23.1	263.0	95.2	82.8	68 825	680 733
2008 YTD	648 332	28.2	324.8	95.4	85.6	541 962	5 567 654

7. TREATMENT OF REFRACTORY ORES

7.1 LEACHOX PROCESS

The Leachox Process has been has been adopted for Vasgold's Vasilkovskoye project which is under construction in Kazakhstan, and for Banro's planned Tangiza project in the DRC. Previous applications of Leachox technology include two refractory gold operations in South Africa. The Leachox Process is a development of Maelgwyn Mineral Services (MMS) in the UK, aimed particularly at lower grade refractory deposits[16][17]. Gold recoveries are said to be lower than with roasting and pressure oxidation, but similar to to bio-oxidation, while capital and operating costs and plant footprint area are said to be reduced. In the process, a concentrate is produced by MMM centrifugal pneumatic flotation ("G-Cell") cells or gravity concentration, followed by ultra-fine grinding in Deswick vertical stirred bead mill mills. Low pressure partial oxidation with oxygen is carried out in MMM ("Aachen) in-line type gas-liquid mass transfer reactors, and the gold is recovered in MMS cyanide leach columns and resin ion exchange columns.

Figure 7: Schematic of MMS Archen Reactors and Leach Columns (Ref. 17: Mining Magazine Jan./Feb. 2010)

7.2 ALBION PROCESS

The Albion Process has been selected for two refractory gold projects - Enviro Gold at Las Lagunas in the Dominican Republic and European Goldfield at Certej in Romania. Albion is a relatively low capital cost process using ultrafine grinding with Isamills to produce an activated finely ground concentrate. This is followed by hot oxidative leaching at atmospheric pressure with oxygen sparging in conventional agitated tanks in alkaline conditions and CIL[(18)]. An outline flow diagram is shown in Fig. 8. The technology is owned by Xstrata (formerly MIM) and Highlands Pacific/OMRD (a Japanese consortium), with CORE Resources, Queensland, as the exclusive global marketing agent.

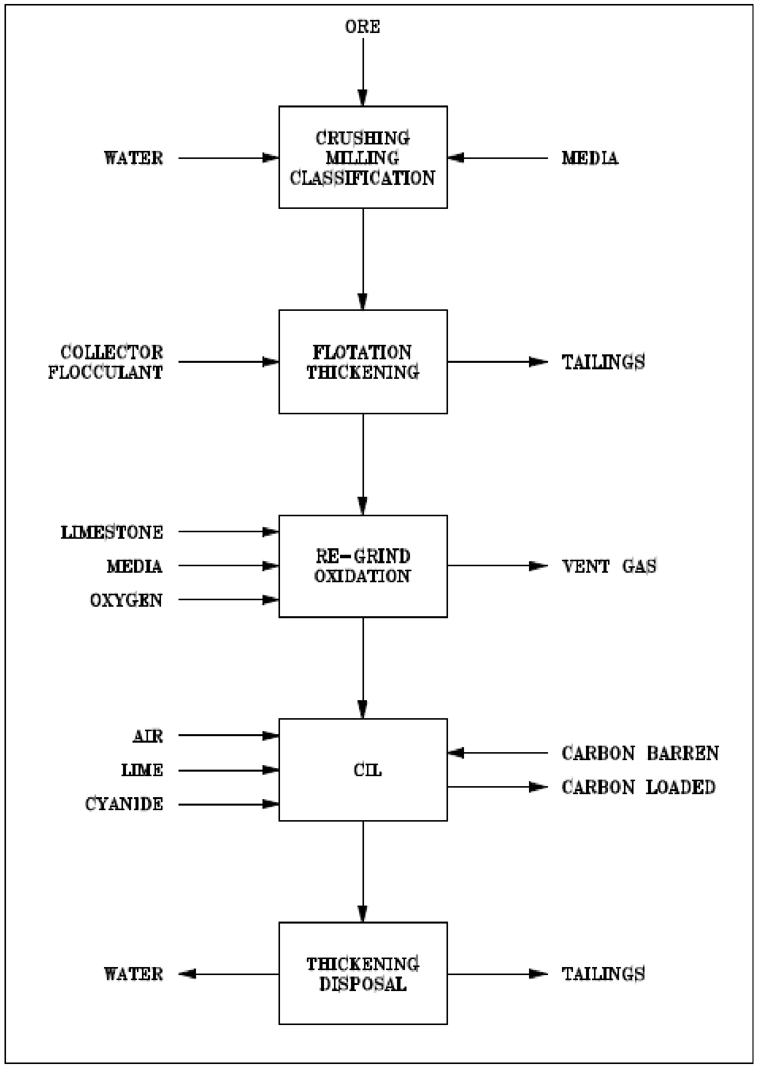

Figure 8: Albion Outline Process Flow Diagram
(Ref. 18: Xstrata/Core/Aker Paper at Randol Forum Perth 2005)

7.3 ROASTING, PRESSURE OXIDATION & BIO-OXIDATION

The more established roasting, pressure oxidation and bio-oxidation processes continue to find favour. Resolute Mining, Perth, commissioned the Syama Project in Mali in 2009 iwhich included roasting, and Agnico-Eagle of Canada brought the Kitilla pressure oxidation operation in northern Finland on stream in 2009. In the field of bio-oxidation the Kokpatas plant in Uzbekistan came into operation in 2008 using Gold Field's BIOX technology, while the rival BacTech technology was used for the expansion of the BioGold operation in China in 2007.

8. IN-PLACE LEACHING

The Parker Centre (CSIRO) in Perth is undertaking initial investigations for the in-place treatment of oxidized gold deposits[(19.] Because of environmental concerns, only non-cyanide lixiviants are being considered. Bench scale testwork has identified two promising systems - sodium thiosulphate-thiourea-ferric EDTA (ferric ethylenediamine) in which thiourea is a catalyst for gold oxidation and ferric EDTA an oxidant, and iodide–iodine, in which iodine is an oxidant. Testwork has shown that these lixiviant tend to break down in contact with pyrite, so the current focus is on pyrite free oxidized deposits. The permeability of these deposits is consifered to be generally too low for true in-situ leaching, and permeability enhancement methods are condidered to be necessary (which is why the process is designated as in-place rather than in-situ). Possible options include blasting and hydraulic fracturing. The results to date are sufficiently encouraging to warrant field studies, which could start in 2011 with the support from government and mining companies.

"In-situ" processing has also been suggested for possible application in back-filled Witwatersrand gold mines in South Africa[20]. (As with the Parker Centre program, in-place would be beter terminology.)

9. CONCLUSIONS

Gold ore processing technology is progressing in a number of key areas. Driving forces include the trend towards the treatment of lower grade, carbonaceous, copper bearing and refractory ores, and increasing environmental pressure against the use of cyanide including calls for a total ban in Europe and elsewhere. Developments include the application of HPGR, ore upgrading, gravity and flotation, cyanide monitoring and control, application of ion exchange, alternative lixiviants, ultrafine grinding, various oxidation processes and in-place leaching. These are being encouraged by the significant rise in the gold price.

10. REFERENCES

1. C. Morley, Fluor Signet Engineering, "HPGR in Hard Rock Applications", Mining Magazine, Sept. 2003.
2. H. Von Michaelis, Randol International, "How Energy Efficient is HPGR?" Proceedings of World Gold 2009, Oct. 2009, Gauteng, South Africa.
3. R. Dunne et al, Newmont Mining and Boddington Gold, "Boddington Gold Mine – An Example of Sustaining Gold Production for 30 Years", Proceedings of World Gold 2007, Oct. 2007, Cairns, Australia.
4. B. M^{c}Nab, Orway Mineral Consultants, "Exploring HPGR Technology For Heap Leaching Of Fresh Rock Gold Ores". Proceedings of HR Crushing & Grinding Conference 2006, Mar. 2006, Townsville, Australia.
5. T. Hughes, Gekko Systems and G. Cormack, Central Rand Gold, "Potential Benefits of Underground Processing for the Gold Sector – Conceptual Process Design and Cost Benefits", Proceedings of First International Future Mines Conference, Nov. 2008, Sydney, Australia.
6. L. Von Ketelhodt, Commodos Ultrasort, "Viability of Optical Sorting of Gold Waste Rock Dumps", Proceedings of World Gold 2009, Oct. 2009, Gauteng, South Africa.
7. T. Mulpeter, Sadiola Hill Gold Mine and D. Kotzen, Process Analytical Systems, "Online Cyanide Analysers Optimise Cyanidation and Ensure Cynide Code Compliance fro Plant Tailings", Proceedings of World Gold 2007, Oct. 2007, Cairns, Australia.
8. M. Adams, and R. Lawrence, BioteQ, "Biogenic Sulphide For Cyanide Recycle and Copper Recovery In Gold-Copper Ore Processing, " Proceedings of Precious Metals 2007, Brisbane, Australia, Aug. 2007.
9. R. Thyer, CSIRO, "Together Two Compounds Answer Gold Recovery Woes", CSIRO Process Magazine, Feb. 2010.
10. L. Williams, ""Barrick's $3 Billion Pueblo Viejo Gold Mine Buys Finish Copper Recovery Plant", International Mining, Oct. 2009.
11. "Mintek ion exchange resin aids gold recovery in Azerbaijan", International Mining, Dec. 2009.
12. T. Mahlangu et al., Univ. of Pretoria and Anglo Gold Ashanti, "Effect of Preoxidation and Lead Nitrate Addition on Sodium Cyanide Consumption and Gold Recovery at the Morila Mine Gold Plant", Proceedings of World Gold 2007, Oct. 2007, Cairns, Australia.

13. A. Voung, METS, “”Enhanced Gold Leaching”, Mining Mirror, Oct. 2009.

14. “Help from CELP”, CIM Magazine, Feb. 2009.

15. J. Rajala, Kinross Gold and G. Deschenes, CANMET, “Extraction of Gold and Silver at the Hupol Mill using CELP”, Proceedings of World Gold 2009, Oct. 2009, Gauteng, South Africa.

16. J. Chadwick, “Bigger and Better”, International Mining, Apr. 2007.

17. “Management in Action – Gold Processing”, Mining Magazine, Jan./Feb. 2010.

18. M. Hourn et al Xstrata Technology, Core Resources and Aker Kvaerner (now Aker Solutions), “Benefits of Using The Albion Process for a North Queensland Project, and a Case Study of Capital and Operating Cost Benefits Versus Bacterial Oxidation and Pressure Oxidation”, Randol Innovative Metallurgy Forum, 2005, Perth. Australia.

19. P. Roberts et al, Parker Centre CSIRO, “In place leaching of oxidised gold deposits. A new method for recovering stranded gold resources?”, Proceedings of World Gold 2009, Oct. 2009, Gauteng, South Africa.

20. N. Sreven, Rockwater Consulting, “Potential in situ leach exploitation of back-filled Witwatersrand gold mines: parameters and flow-rate calculations from a Zambian Copperbelt analogue”, Proceedings of World Gold 2009, Oct. 2009, Gauteng, South Africa.

21. Simmer & Jack; 2008; Developing new Gold Opportunities in South Africa’s oldest Goldfield, Presentation at the Mining Indaba, 5th February 2008.