Gold Market Research

INTRODUCTION

The Australian gold industry is a significant contributor to the Australian economy, with export earnings of A$10.9 billion in 2007-2008 (ABARE estimate).

Australia was the world's third largest gold producer in 2007 (Geoscience Australia), accounting for around 10% of the total world gold production. Australia has the second largest economic demonstrated resources of gold in the world with approximately 12% of the world's holdings.

Most of Australia's gold is produced by leaching of gold from its ores using an alkaline cyanide solution. The gold is recovered from solution by adsorption onto activated carbon, which is then separated from the leached pulp by screening (this is generally referred to as the carbon-in-pulp (CIP) process). The gold cyanide is then desorbed from the loaded carbon and metallic gold recovered from the resulting high-grade solution by electrowinning. If the ore being treated is mineralogically complex, then a pre-treatment step may be required prior to leaching.

The Parker Centre is supported by gold producers and allied companies. Two of the world's leading gold mining companies – Barrick Gold and AngloGold Ashanti – are Industry Participants in the Centre.

A number of engineering companies and industry suppliers who are involved in the gold industry are also Industry Participants, namely Hatch Associates, WorleyParsons, Ciba Speciality Chemicals, Nalco Australia and Outotec. SME Straits Resources, another Industry Participant, includes a gold mine amongst its operations.

Parker Centre gold researcher Mrs Danielle Hewitt (far left) and two high school science students (who were participating in CSIRO's Student Research Scheme) getting ready to analyse a cyanide leach solution using the high performance liquid chromatography (HPLC) method for quantifying cyanide- and sulfur-containing species in solutions.

GOLD MARKET LEADER:
DR MATTHEW JEFFREY
(FROM SEPTEMBER 2007)
(CSIRO MINERALS)

The Parker Centre's gold research is addressing the following challenges for the gold industry:

- the technological advances required to access resources whose extraction is uneconomic with present technology, such as:
  - sub-economic complex and refractory gold ores
  - deeply buried paleochannel gold deposits
- improving current plant processes to increase gold recovery through:
  - process optimisation
  - on-line monitoring and control
- minimising the environmental impact of gold extraction via:
  - developing an alternative to cyanide
  - investigating options for copper and cyanide recovery in the processing of high copper-containing gold ores.

The Centre's 15 full-time equivalent gold researchers are metallurgists, chemists, mineralogists, chemical engineers and process engineers, and are based within three of the four Research Participants in the Centre. A unique range of research equipment and analysis techniques are available to these researchers for fundamental and applied studies. Their research in the past year included CRC-funded projects; an AMIRA project sponsored by 13 companies and one-to-one projects with Centre Industry Participants and other companies associated with the gold industry.

Collaborative research is undertaken with researchers at the Advanced Mineral Technology Laboratory (Canada), the Cape Peninsula University of Technology (South Africa) and Griffith University in Queensland.

GOLD RESEARCH CAPABILITIES

- mineralogical ore characterisation
- gravity gold recovery
- carbon fouling
- cyanide measurement and management
- process optimisation
- processing of complex ores, especially copper-gold ores
- treatment of refractory ores/concentrates
- assessment of, and treatment options for, preg-robbing ores
- alternatives to cyanide, particularly thiosulfate
- deportment/minimisation of environmental contaminants
- computer modelling and flowsheeting.

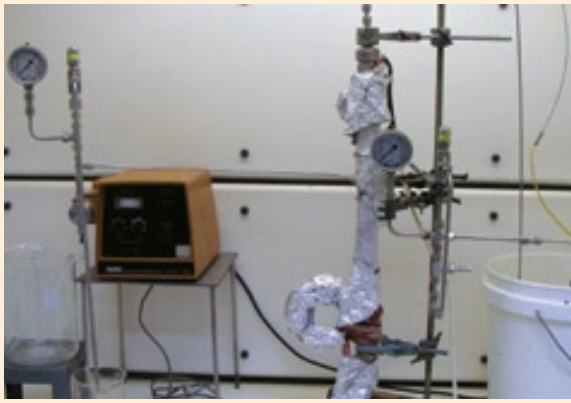
GOLD RESEARCH AREAS

The work undertaken by Centre researchers for the gold industry includes CRC-funded projects covering optimisation of the cyanidation process currently used by the industry, alternatives to cyanide for gold leaching, processing of complex and refractory ores and environmental issues related to gold processing.

Further details of the specific research in each of the CRC-funded projects are provided in the following list. The Centre also undertakes a wide range of other projects with companies involved in the gold industry, many of which are confidential projects.

CYANIDATION PROCESS OPTIMISATION

- Research on carbon management is contributing to the Parker Centre's Process Fundamentals activity theme, and includes:
  - the adsorption of frothers, copper and other foulants onto activated carbon
  - the impact of organic and inorganic foulants on gold adsorption by carbon
  - the adsorption of trace elements such as mercury, and their deportment during elution and carbon regeneration
  - developing a universal method for measuring carbon activity.



The laboratory-scale carbon elution column capable of high temperature/high pressure elution of metals from activated carbon. Developed within the "Carbon Management" project, the column has application in the investigation of removal of trace metal contaminants such as mercury from activated carbon in the gold industry.

- Work on flowsheeting and modelling/simulation of gold recovery processes is contributing to the Parker Centre's Education and Technology Transfer activity themes, and is focusing on:
  - incorporating copper leaching and copper cyanide solution chemistry and adsorption by carbon into a gold processing flowsheet
  - economic and environmental optimisation of gold processing circuits
  - predictive water chemistry and water balance modelling to assess water management options
  - expanding the capability of the SIMCIL computer simulation for modelling cyanide leaching/carbon adsorption to include:
    - preg-robbing factors
    - multi-element systems (gold, copper and silver)
    - heap leaching
    - an improved diagnostic option
  - extending the model that simulates gravity gold recovery to include:
    - gravity devices other than Knelson concentrators (such as Falcon concentrators, the Kelsey jig and the Gekko Inline Pressure Jig)
    - the flash flotation behaviour of gravity recoverable gold.

ALTERNATIVES TO CYANIDE

- Non-cyanide leaching and recovery of gold research is contributing to the Parker Centre's Breakthrough Technologies activity theme, and focuses on:
  - investigating thiosulfate leaching for *in situ* and heap leaching of gold
  - examining different oxidant systems for thiosulfate leaching
  - investigating pre-treatments of "difficult to leach with cyanide" gold ores that may enhance thiosulfate leaching of these ores
  - developing a new elution system for stripping gold thiosulfate from resins.

Gold Market Research

COMPLEX & REFRACTORY ORES

- Research aimed at improving the treatment of preg-robbing ores is contributing to the Parker Centre's Process Fundamentals activity theme, and includes:
  - investigating links between ore mineralogy and gold cyanide adsorption chemistry
  - using Raman spectroscopy to characterise carbonaceous preg-robbing ores
  - evaluating existing and new potential treatment options for preg-robbing ores.
- Research on processing copper-gold ores is contributing to the Parker Centre's Process Fundamentals activity theme, and is focusing on:
  - developing methods for treating gold ores with a range of copper concentrations, achieved through:
    - different flowsheets depending on copper concentration
    - understanding the mineralogy of copper-gold ores
    - generating novel flowsheets
  - developing innovative ways of treating sulfide concentrates with cyanide
  - reagent measurement and control in the processing of complex ores.

ENVIRONMENTAL

- Research on environmental aspects of processing complex gold ores is contributing to the Parker Centre's Process Fundamentals activity theme, and includes:
  - recovery of metallic copper and cyanide for recycling following cyanide leaching of high copper ores/ concentrates
  - copper recovery by adsorption on ion exchange resins, elution and electrowinning.
- Research on trace elements in gold process solutions is contributing to the Parker Centre's Process Fundamentals activity theme, and involves:
  - investigating the chemical behaviour of trace elements arsenic and mercury in the liquors of gold processing circuits.

INDUSTRY BENEFITS

The potential benefits to the minerals industry of the Centre's gold research include:

BENEFITS ARISING FROM BREAKTHROUGH TECHNOLOGIES RESEARCH

- access to a resource that is uneconomic with present technology: achieved by *in situ* thiosulfate leaching of paleochannel gold
- a non-cyanide based process for recovering gold that could be used in environmentally sensitive areas or to treat ores that are not amenable to recovery by cyanide

BENEFITS ARISING FROM PROCESS FUNDAMENTALS RESEARCH

- reduced losses of gold from carbon-in-pulp or carbon-in-leach circuits into the solution tails through improved operation of adsorption circuits
- lower capital expenditure for expansions and greenfield carbon-in-pulp or carbon-in-leach installations
- improved processing and utilisation of resources (eg water), achieved by flowsheet modelling
- treatment options to enable the processing of complex gold ores (eg high copper ores and sulfide concentrates) that are currently considered sub-economic
- advanced software tools to assist in optimising existing gold plant processes (gravity recovery, cyanide leaching and carbon adsorption) and practices, and for use in plant design
- a technique for differentiating between different types of carbonaceous mineralogy in preg-robbing gold ores, allowing separation of low preg-robbing mineralogy from high preg-robbing mineralogy
- identification of the best treatment method for specific preg-robbing ore types to maximise gold recovery and minimise cost for each ore type
- chemical speciation computer models of trace elements arsenic and mercury in gold process solutions, that can be incorporated into plant processing software to assist with management of these elements
- an enhanced industry skill base achieved through technology transfer and continuing education activities.

Gold Market Highlights 2007-2008

TECHNOLOGY TRANSFER & IMPACT

- The novel elution process for recovering gold thiosulfate from ion exchange resins was shown to work very well when combined with a continuous adsorption circuit (with recycling of both resin and eluent) and electrowinning. A full patent was granted for the elution process.
- The updated version of the total cyanide balance model that simulates the behaviour of cyanide in a gold processing circuit was released to the sponsors of the AMIRA P420C "Gold Processing Technology" project.
- Research results related to the X-ray microtomography-based identification of mechanisms for gold adsorption onto activated carbon, the measurement of activated carbon activity and the effect of frothers on gold adsorption were published in the international journal *Minerals Engineering*.
- An option for modelling leaching/adsorption for high silver-containing gold ores was added to the SIMCIL computer model that simulates leaching/adsorption in gold processing circuits.

ADVANCING THE SCIENCE

- The new leaching process for complex gold ores (such as refractory and copper-gold ores) which couples pressure oxidation with thiosulfate leaching was tested on a copper-gold ore, and the provisional patent for this process was re-lodged.
- The mineralogy of selected copper-gold ores was established using a range of chemical and physical methods to determine the mineralogical associations of the gold in these ores.
- Work on computer modelling of the gold thiosulfate process developed equilibrium models for the adsorption of gold and competing species (including copper and polythionates) onto resins from thiosulfate leach solutions. These models will be useful in future investigations of the potential of the thiosulfate process as they will allow gold loading in resin-in-pulp (RIP) circuits to be estimated for the process.
- Anaerobic column leaching studies were undertaken on a paleochannel gold ore in order to simulate *in situ* thiosulfate leaching. The preliminary column leaches were run for one month to assess the gold extraction from this ore, and more extensive trials are planned. A paper related to the *in situ* gold leaching was published in the journal *Minerals Engineering*.

DEVELOPING RESEARCH CAPABILITY

- A procedure that improves the prediction of preg-robbing was developed, in which the structure of the carbonaceous material in the ore is examined using Raman spectroscopy and then compared with the preg-robbing ability of the ore as measured by gold uptake from solution or in competition with activated carbon.
- New high performance liquid chromatography (HPLC) methods were developed to provide information about cyanide and sulfur species in a range of Parker Centre research projects, and to analyse samples for the gold industry related to the treatment of complex gold ores.
- A potential technique for improved recovery of minor toxic elements such as mercury from activated carbon was identified.
- Methods were developed to counteract the adverse effect of sulfide minerals during *in situ* thiosulfate gold leaching.
- Investigations into the dissolution of reactive sulfide minerals in cyanide solutions using new HPLC methods generated new understanding of the reaction mechanisms involved in dissolution, and the effect of pre-oxidation and/or lead(II) ion addition.

Resilient floating hexagonal barriers in place on a leach tank at Kalgoorlie Consolidated Gold Mines' operation in Kalgoorlie, WA during a trial by a Parker Centre team that showed that the barriers were effective in reducing diffusion of hydrogen cyanide gas ($HCN_{(g)}$) from the slurry surface. The trial was reported as part of the research on monitoring and minimising $HCN_{(g)}$ emissions that was published in a paper in the May 2008 issue of the *Minerals Engineering* journal.

Carbon Management

OBJECTIVES

Gold losses from carbon-in-pulp or carbon-in-leach circuits can result from fouling of the activated carbon used to adsorb the leached gold from solution. Carbon fouling by either organics or inorganics reduces the carbon's ability to recover gold. Previous work had developed a method that accurately measures residual frothers (from the flotation stage for mineral concentration) in the gold cyanide slurry. Frothers are organics that can contaminate the carbon. The ability to analyse for organic foulants offers the opportunity to improve the operation of existing circuits to reduce gold losses in the solution tails.

A recent development in the Australian context is the use of pump cells in an adsorption circuit. This equipment utilises high energy to increase adsorption rates. Gaining an understanding of the mechanism of the processes occurring in pump cells should lead to improved design of adsorption circuits.

Therefore this project's objectives include:

- measuring the adsorption rate of frothers, and their degradation products, onto carbon, and assessing the impact this adsorption has on gold adsorption rates
- investigating copper (an inorganic foulant) adsorption on carbon and its impact on gold adsorption
- assessing the impact of high energy (high agitation intensity) adsorption cells on the adsorption of selected foulants and on gold adsorption
- incorporating the impact of foulants and agitation energy into a flowsheet model of carbon adsorption.

OUTPUTS

- Project data on gold adsorption mechanisms and the use of X-ray microtomography to identify gold distribution on activated carbons was presented at the Precious Metals 07 conference in Brisbane in August 2007.
- Project results related to microtomography-based identification of gold adsorption mechanisms, the measurement of activated carbon activity and the effect of frothers on gold adsorption were published in the journal *Minerals Engineering* in May 2008.
- A potential technique for improved recovery of minor toxic elements from activated carbon was identified.

Flowsheeting and Process Modelling

OBJECTIVES

The hydrometallurgical industry is increasingly using process models to capture the existing knowledge base, identify areas where knowledge is lacking and understand the impact of circuit changes to guide process improvements and/or pilot work in a new process. Flowsheeting computer tools can be used to understand the impact of a change to one unit operation in a complex processing circuit on that individual unit, and also the upstream and downstream implications of the change.

Industry would also benefit from a sophisticated multi-option process model that incorporates interrelated variables such as metal recovery, processing costs, capital costs and environmental impact into account to determine the optimum circuit configuration for processing a new ore.

In addition, flowsheeting is a valuable tool to examine water management. Modelling the water balance in operating circuits and identifying water bottlenecks could offer options for minimising water use and increasing process efficiency.

This project is initially focusing on gold processing circuits but may expand to base metals. It aims to:

- build thermodynamic and kinetic reaction models for solution chemistry, leaching and adsorption
- develop complex flowsheets incorporating multiple processing options, and an optimisation framework, to determine the optimum economic and environmental circuit design/operation
- identify options to improve water management with the overall goal of reducing water consumption.

OUTPUTS

- The framework for a generic interface between any flowsheeting software package and any thermodynamic software package was developed. Extensive trials of the commercially available interface between the IDEAS simulator and OLI thermodynamic package were also undertaken.
- Equilibrium models for the adsorption of gold and competing species (including copper and polythionates) on resins from thiosulfate leach solutions were developed. These models will allow gold loading in resin-in-pulp (RIP) circuits to be estimated for the gold thiosulfate process.

Modelling/Simulation of Gold Recovery Processes

OBJECTIVES

Optimising gold recovery unit processes (gravity recovery, gold leaching and carbon adsorption) is the best short-term prospect for improving profitability for gold operations. Modelling/simulation packages of these unit processes are useful tools for assessing options for plant optimisation or reconfiguration: to improve gold recoveries and/or reduce operating and capital costs. Another valuable application is the capture and transfer of existing industry knowledge, which is particularly important due to the current shortage of experienced plant metallurgists.

Tools for simulating gravity circuits and leaching/adsorption in carbon-in-leach (CIL)/carbon-in-pulp (CIP) were developed in previous projects (a CRC-funded project and the AMIRA P420B "Gold Processing Technology" project). The leaching/adsorption model (SIMCIL) has been successfully applied commercially, with SIMCIL used to assess the performance of leach/adsorption circuits in over 20 gold operations to date. However, this model is limited to standard CIL/CIP circuits and relatively simple, non-complex gold ores.

Further evolution of the modelling packages is required because the ore bodies being processed are becoming more mineralogically complex and circuit configurations are becoming more varied. Therefore this project aims to extend the capabilities of the SIMCIL package by:

- incorporating a carbon column (heap leach) option
- evaluating alternative leaching/adsorption models as possible additions to SIMCIL
- developing laboratory procedures for obtaining calibration data for greenfields site assessments
- improving the "diagnostic" option that assists site metallurgists by identifying problems in existing circuits and recommending possible improvements
- evaluating the potential of directly linking SIMCIL with an expanded gravity/flotation model.

In parallel to this project, the AMIRA P420C project is undertaking more sponsor-specific development of SIMCIL, which is related to the processing of high silver and copper ores, and preg-robbing ores.

OUTPUTS

- An option for modelling leaching/adsorption for high silver-containing gold ores was added to the SIMCIL model.
- Laboratory procedures for obtaining the calibration data required to run SIMCIL for a new gold ore were evaluated.

Non-cyanide Leaching and Recovery of Gold

OBJECTIVES

While thiosulfate is an alternative to cyanide for leaching gold from gold ores and concentrates, it is unlikely that a future viable thiosulfate leaching process would universally replace the robust cyanide process. However there are niche applications where thiosulfate offers significant advantages over cyanide.

A thiosulfate process could be useful in environmentally sensitive areas or close to major population centres, or for intensive leaching of small masses. Other potential applications include heap leaching and processing gold ores that are difficult to leach with cyanide such as preg-robbing ores and high copper ores. A further opportunity is to use thiosulfate for *in situ* leaching by pumping a thiosulfate solution underground to leach paleochannel gold present in porous sandstones that abut impermeable beds, and then bringing that solution back to the surface to recover the gold.

This project's objectives are to:

- identify an environmentally acceptable process using thiosulfate for gold processing by heap and/or *in situ* leaching
- develop a flowsheet for the thiosulfate leaching of gold from complex ores
- identify improved processes for recovering gold thiosulfate from thiosulfate solutions or from resins since the gold thiosulfate complex does not adsorb to activated carbon.

OUTPUTS

- Methods were developed to deal with the presence of sulfide minerals in the *in situ* thiosulfate leaching of gold.
- Column leaching studies were undertaken on a paleochannel gold ore in order to simulate the thiosulfate *in situ* leaching process. The preliminary column leaches were run for one month, and more extensive trials have been planned. A journal paper related to *in situ* leaching was published.
- A new thiosulfate leaching process for complex gold ores that incorporates pressure oxidation was tested on a copper-gold ore, and a provisional patent for this process was re-lodged.
- Further development of the novel elution process for recovering gold thiosulfate from resins has shown that it works very well when combined with a continuous adsorption circuit (with recycling of both resin and eluent) and electrowinning. A full patent was granted for the new elution process.

Improving the Treatment of Preg-robbing Ores

OBJECTIVES

Preg-robbing is the term used to describe the loss of gold by the re-adsorption of dissolved gold cyanide onto carbonaceous ore components. This robbing of gold from the pregnant liquor (ie the gold cyanide solution) can be a significant cause of low gold recovery in conventional carbon-in-pulp processes.

Development of a rapid and reliable surface analysis technique for characterising the carbonaceous mineralogy, coupled with the ability to predict the preg-robbing potential of different types of carbonaceous material and determination of the effectiveness of various treatment options, would assist the gold industry to address this problem.

Gold producers would then be able to characterise their preg-robbing deposits into different types and apply the most appropriate, cost-effective treatment option. Gold losses could be minimised by modifying the processing on a daily basis.

This project is building on previous research conducted through CRC-funded projects and the AMIRA P420 "Gold Processing Technology" project series. It will undertake fundamental studies to support more applied work in the current AMIRA P420C project. The aims of this project include:

- gaining a greater understanding of the process chemistry and surface science of the adsorption of gold cyanide on carbonaceous ore components
- understanding and predicting gold losses during cyanide leaching of preg-robbing ores in terms of the mineralogy of the carbonaceous components (characterised using a range of surface analysis techniques)
- undertaking laboratory-based investigations of treatment options based on a review of current and proposed industry practices for dealing with preg-robbing gold ores.

OUTPUTS

- A procedure that improves the prediction of preg-robbing was developed: the procedure involves examining the structure of the carbonaceous material in the ore using Raman spectroscopy and comparing this with the preg-robbing ability of the ore measured by gold uptake from solution or in competition with activated carbon.
- Semi-quantitative assessment of the effectiveness of carbon-in-leach (CIL) as a process option for preg-robbing ores was undertaken.

Processing Copper-Gold Ores

OBJECTIVES

Copper-gold deposits represent a significant fraction of existing and future gold operations. However, exploiting these deposits using current processing options can be problematic, and can result in lower gold recoveries, increased operating costs and environmental liabilities, which impact on the economic viability. Better processing options for these ores could lead to increased revenue/decreased cost for current operations, and convert some uneconomic resources into usable reserves.

Copper-gold ores can be mineralogically very complex, particularly with respect to the deportment (location) of gold. An increased understanding of the mineralogy and chemistry of gold occurrence in copper-gold ores, and its effect on processing behaviour, should improve planning of the mining, blending and treament of these ores.

Therefore the objectives of this project are to:

- determine the mineralogy of typical copper-gold ores (particularly the deportment of gold) and investigate links between ore mineralogy and gold recovery by a range of processing technologies
- assess alternative and novel strategies for copper-gold ore treatment
- develop a predictive tool to enable effective and appropriate flowsheet selection for such ores.

OUTPUTS

- The mineralogy of selected copper-gold ores was established using a range of chemical and physical methods to determine the mineralogical associations of gold.
- Preliminary cyanide leaching experiments on two copper-gold ores and flotation concentrates, before and after pre-oxidation, were completed, with analysis of residues and leach liquors from these experiments to follow.

Processing Complex Ores

OBJECTIVES

As the free milling gold ore reserves are depleted, an increasing number of gold ore bodies are complex ores, containing copper and/or a high proportion of sulfide minerals. Complex gold ores require tailored treatment strategies to enable economic gold recovery from these ores.

Sulfide concentrates are traditionally smelted or roasted, but may also be pre-treated by different hydrometallurgical processes, before the gold in most cases is recovered in a cyanide leach. High reagent consumption and poor gold recovery is often a feature of the treatment of such material. However, careful management and/or reagent recycle can increase gold recovery and reduce reagent consumption.

While gold ores with high copper levels leach well with cyanide, the copper also complexes with the cyanide, causing high cyanide consumption and the discharge of large amounts of copper and cyanide to the tails. Options for recovering both the cyanide and the copper would thus be beneficial.

This project aims to develop options for treating high copper ores/concentrates and for treating sulfide concentrates with cyanide. Specific objectives include:

- investigating options for recovering copper and recycling cyanide, including methods involving adsorption of the copper cyanide complex onto activated carbon (following gold recovery) or ion exchange resins
- improving reagent measurement in the processing of sulfide concentrates, and investigating opportunities to increase the efficiency of gold leaching from sulfide concentrates through the application of techniques such as intensive leaching and the use of lead(II).

OUTPUTS

- The process for copper and cyanide recovery using carbon, after carbon-in-leach (CIL)/carbon-in-pulp (CIP) recovery of the gold, was further developed. The dissolution of copper is simultaneously used to enhance the recovery of copper and cyanide using activated carbon, which is then eluted and electrowon at low pH using electrodialysis to adjust and control the pH. This process is now ready for testing at a pilot scale.
- Investigations into the dissolution of reactive sulfide minerals in cyanide solutions using new high performance liquid chromatography (HPLC) methods have generated new understanding as to their reaction mechanisms, and the effect of pre-oxidation and/or lead(II) ion addition.

AMIRA P420C Project: Gold Processing Technology

OBJECTIVES

The AMIRA P420 series of collaborative industry-sponsored projects have undertaken research in the general area of gold ore processing since 1994. The current three-year project (P420C) commenced in March 2005 and is the fourth project in the series.

The P420C project has short- and long-term areas of research in gold processing, addressing process and environmental issues of current operations and evaluating future possible process options in thiosulfate leaching and the treatment of complex and refractory ores.

The project is organised into four concurrent modules to allow selective participation by sponsors. The modules and their aims are:

- Process Optimisation – which aims to optimise current plant processes through computer modelling
- Thiosulfate Process Development – which aims to develop a viable alternative to cyanide by further developing the novel thiosulfate leaching system patented during the P420B project
- Sustainable Cyanide Management – which continues development of a cyanide balance model describing the fate of cyanide on a mine site
- Complex & Refractory Ores – which aims to extend previous work on preg-robbing gold ores and alkaline oxidation treatment of refractory arsenopyritic concentrates, and research treatment options for copper-gold ores.

OUTPUTS

- The updated version of the total cyanide balance model that simulates the behaviour of cyanide in a gold processing circuit was released to the project's sponsors.
- Jig models for gravity gold recovery of sulfides and gold were developed.
- Investigation of the novel gold thiosulfate leaching system continued.

Trace Elements in Gold Process Solutions

OBJECTIVES

The circulation of liquors in gold plants commonly leads to an accumulation in solution of trace elements from the gold ore(s) being processed. As a result, the concentrations of these trace elements at steady state can be much higher than their concentrations in the various input streams. In the case of toxic trace elements (including mercury and arsenic), elevated concentrations can cause problems related to occupational health & safety (OHS) and environmental emissions.

Developing appropriate remediation strategies requires a detailed knowledge of the chemical behaviour of each trace element in the complicated, multicomponent system that constitutes a gold process solution. The key is to identify the predominant interactions, and resulting chemical forms (chemical speciation), of the trace element in the mixture. And then design effective processes for capture or removal of problematic chemical species.

The gold industry requires a detailed understanding of trace element behaviour in process liquors, in order to minimise the OHS hazards and the environmental impact of emissions.

This project aims to assist the industry with this issue by:

- investigating the chemical speciation of mercury and arsenic in gold process liquors through experimental measurements and computer modelling
- using the acquired knowledge to generate computer models that simulate the chemical behaviour of mercury and arsenic in gold processing circuits.

OUTPUTS

- A preliminary model of mercury speciation in gold process solutions was established.
- A chemical probe to determine redox potentials in gold process solutions was developed.

Gold Market Research Portfolio

Project	Research Team	Research Collaboration	Project Duration	Activity Theme Contribution
CRC-funded Projects				
Carbon Management	Ron Pleysier (Project Leader), Peter Austin, Karl Bunney, Xianwen Dai, Patrick Merrigan, John Rumball (CSIRO Minerals)		2005-2008	Process Fundamentals
Flowsheeting and Process Modelling	Matthew Jeffrey (Project Leader), Parisa Arabzadeh-Bahri, Vishnu Pareek, Ricardo Pascual, John Rumball, Heather Evans (PhD student), Abrar Muslim (PhD student), Abbas Razavimanesh (PhD student)	CSIRO Minerals, Curtin University, Murdoch University	2005-2008	Technology Transfer
Modelling/Simulation of Gold Recovery Processes	Greg Wardell-Johnson (Project Leader), Alan Bax, David Millin, Bill Staunton, Andrew Taylor	Murdoch University, BizAnyWare	2006-2009	Education
Non-cyanide Leaching and Recovery of Gold	Matthew Jeffrey (Project Leader), Paul Breuer, Karl Bunney, Danielle Hewitt, John Rumball, Hongguang Zhang, El-Sayed Oraby (PhD student)	CSIRO Minerals, Curtin University, Griffith University	2005-2008	Breakthrough Technologies
Improving the Treatment of Preg-robbing Ores	Bill Staunton (Project Leader), Jim Avraamides, David Millin, Jeff Vaughan, Michelle Helm (PhD student)	Curtin University, Department of Industry and Resources (WA), Murdoch University, Advanced Mineral Technology Laboratory (Canada)	2006-2009	Process Fundamentals
Processing Copper-Gold Ores	Jim Avraamides (Project Leader), David Millin, Bill Staunton, Andrew Taylor, Jeff Vaughan, Humza Pradhan (Honours student), Duane Semini (Honours student)	Curtin University, Department of Industry and Resources (WA), Murdoch University, Advanced Mineral Technology Laboratory (Canada)	2006-2009	Process Fundamentals
Processing Complex Ores	Paul Breuer (Project Leader), Byron Benvie, Karl Bunney, Xianwen Dai, Danielle Hewitt, Matthew Jeffrey, John Rumball, Rebecca Meakin (Student-Industry Research Program student) (CSIRO Minerals)		2005-2008	Process Fundamentals
Trace Elements in Gold Process Solutions	Peter May (Project Leader), Erich Koenigsberger, Zoltan Paksi (Murdoch University)		2007-2009	Process Fundamentals
Collaborative AMIRA Projects				
AMIRA P420C Project: Gold Processing Technology	Bill Staunton (Project Leader), Jim Avraamides, Alan Bax, Matthew Jeffrey, David Millin, Allan Nesbitt, Mike Nicol, Venny Tjandrawan, Paul van der Plas, Jeff Vaughan, Greg Wardell-Johnson, Hongguang Zhang, Michelle Helm (PhD student)	Curtin University, Murdoch University, BizAnyware (software support), Cape Peninsula University of Technology (South Africa)	2005-2008	

Industry Collaboration

In 2007-2008, the Parker Centre's Gold Market engaged with the following companies through collaboration and one-to-one projects:

Amdel, Advanced Mineral Technology Laboratory (AMTEL), AMIRA International, AngloGold Ashanti, Anglo Research, Apex Gold, Ausenco, Barra Resources, Barrick Gold Corporation, Bateman Engineering, BatteryLimits, BHP Billiton, BizAnyware, Boddington Gold Mine (BGM) Management Company, Chemistry Centre (WA), Como Engineers, Earth-Water-Life (EWL) Sciences, Gekko Systems, Gold Fields Australasia, Hatch Associates, Intec, Internet Engineering, Kalgoorlie Consolidated Gold Mines (KCGM), Kemix, Knelson Concentrators, Lycopodium, Newcrest Mining, Newmont Mining Corporation, OceanaGold, Orica Australia, Rio Tinto, Sabodala Mining Company, SNF, Starfield Resources, St Barbara Mine and Wesfarmers CSBP

Postgraduate Projects

Project	Postgraduate Researcher	Supervisor(s) (Organisation)
Design and CFD Simulation of Pipe Reactors for the Pre-treatment of Refractory Gold Ores	Congli Cheng (PhD student)	Moses Tadé (Curtin University), Vishnu Pareek (Curtin University)
Modelling and Flowsheet Design for Solvent Extraction Circuits	Heather Evans (PhD student)	Parisa Arabzadeh-Bahri (Murdoch University), John Rumball (CSIRO Minerals)
Characterising Preg-robbing Ores	Michelle Helm (PhD student)	Bill Staunton (Murdoch University), Jeff Vaughan (Curtin University), Mike Nicol (Murdoch University)
Modelling the Gold Thiosulfate Leaching System	Abrar Muslim (PhD student)	Vishnu Pareek (Curtin University), Matthew Jeffrey (CSIRO Minerals)
Thiosulfate Leaching of Gold	El-Sayed Oraby (PhD student)	Richard Browner (Curtin University), Matthew Jeffrey (CSIRO Minerals)
Dealing with Copper Rich Ores in a CIP/CIL Plant	Humza Pradhan (Honours student)	Bill Staunton (Murdoch University)
The Pre-Treatment of Gravity Gold Concentrates to Remove Native Copper Prior to Cyanide Leaching	Duane Semini (Honours student)	Bill Staunton (Murdoch University)