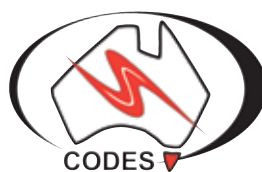


ARC Centre of Excellence in Ore Deposits

Annual Report 2007



Australian Government
Australian Research Council

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CODES

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VISION

To be the premier international research centre in ore deposit geology.

MISSION

To significantly advance collaborative and innovative ore deposit research for Australian and international researchers and the minerals industry.

CENTRE GOALS

- To undertake and publish high-quality research.
- To lead the global minerals industry in research on the exploration and recovery of new mineral resources.
- To equip the Australian minerals industry with world-class graduates.
- To communicate the Centre's research to the wider research, industry and general communities.

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Director's Report



2007 has been another exceptional year for CODES. Research support from the minerals industry has reached an all-time high, international collaborations have continued to grow, and research output in ISI journals topped the 60 mark for the year.

There have been many research achievements during the year that are outlined in this annual report, and I would like to highlight just four of these.

Our geometallurgy research continues to grow and now involves eighteen international mining companies, contributing in excess of \$6 million in support of the GeM^{III} P843 ARC-AMIRA project. This is now the largest multidisciplinary global geometallurgy research program, working on a diverse range of mining sites in Alaska, Ontario, Utah, New South Wales, Queensland and Western Australia. GeM^{III} is a frontier research project involving cutting-edge technology aimed at developing step change in the procedures used by industry to relate geology, mineralogy and ore textures to hardness, crushing and processing, to ultimately improve mine planning and mineral recoveries. The project involves three of the major partners in the Centre of Excellence: UTAS, University of Queensland and CSIRO Exploration and Mining. Very significant progress has been achieved to date, and a number of project outcomes are being reviewed by the industry for adoption. Several spin-off research projects, including Enviro-GeM and Hydro-GeM are currently being evaluated.

Through a joint project with CSIRO, CODES continues to be involved in development of a new generation detector for the X-ray microprobe at the Australian Synchrotron for the purposes of mapping element and valency-state distributions in minute samples. A prototype detector system for deconvolution of the

synchrotron XRF spectral data into separated elemental images, Maia-96, has been successfully tested at the National Synchrotron Light Source at Brookhaven National Laboratory in New York.

Our three-year ARC-AMIRA project on sediment-hosted gold deposits concluded at the end of 2007. This innovative, technology-driven project, focussing on world-class gold districts in Nevada, Siberia and Victoria, has developed a new and controversial genetic model for gold-arsenic deposits hosted in black shale and turbidite successions, that is directly relevant to exploration. Several follow-up projects are being negotiated to apply this new research approach to other gold-bearing sedimentary basins.

A new project has been developed and negotiated to follow on from the recently completed and highly successful porphyry copper–epithermal gold project ARC Linkage-AMIRA P765. The new project aims to develop the explorer's toolkit for porphyry and epithermal districts using innovative geological and geochemical techniques in green rocks and lithocaps. Sixteen international mining and exploration companies have joined the project with a commitment of \$1.8 million over three years.

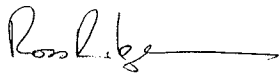
On the geophysics front, we have been gradually building our team to integrate with the geology and geochemistry research programs. A highlight, from Ralf Schaa's PhD research, has been an important mathematical breakthrough in regard to the modelling of electromagnetic data. His unique approach utilising 'independent spheres' will dramatically reduce the computational time required for 3D inversion of electromagnetic data. This will result in the rapid evaluation of much larger datasets in 3D space.

Major international collaborations continued with the Mineral Deposit Research Unit at the University of British Columbia particularly in porphyry-copper research and with the Colorado School of Mines in sediment-hosted copper research. New major collaborations in mafic magma modelling and nickel research have been developed with the Vernadsky Institute of the Russian Academy of Sciences and the Key Laboratory for Ore Deposit Research within the Chinese Academy of Sciences. Other very active collaborations have continued with the United States Geological Survey, Smithsonian Institution, DMR Thailand, Geological Survey of Canada and Lakehead University (Canada).

The shortage of geoscientists in Australia, due to the current minerals boom, has had an adverse impact on our ability to hire experienced researchers to keep pace with our project growth. To combat this problem we have developed a strategy to search internationally for young talented graduates fresh from their PhD studies. Four postdoctoral fellows (from the USA, Germany, France and Australia) were hired in 2007 and a further seven are being sought for various research projects in 2008. A similar approach has been taken to find candidates for PhD research, with all of our recent intake coming from international applicants.

The current healthy cohort of 53 PhD students is made up of 38% Australian and 62% international students.

One of the enduring strengths of CODES is our people, and their dedication to solving problems with innovation and teamwork. It is very pleasing to see our collaborative research, particularly with the JK Mineral Research Centre (University of Queensland) and Mineral Deposit Research Unit (University of British Columbia), but also with all our other partners, working successfully to develop productive outcomes.



Ross R Large

Director and Chief Operations Officer

CODES AT A GLANCE 2007

Academic research staff	45
Postgraduate students	79
Major research projects	38
Publications in ISI journals	62
Research reports to industry	180
Countries involved	16
Industry funding	\$2.8 million
ARC funding	\$3.6 million
UTAS funding	\$1.7 million
Collaborating institutions	CSIRO E&M, UTAS, University of Queensland, University of Melbourne, Australian National University, Johns Hopkins University, University of British Columbia, Colorado School of Mines, Mineral Resources Tasmania



View west across the giant Post-Betze-Screamer deposit (~40 Moz Au) on Barrick Gold's Goldstrike (Nevada, USA) property. The mine buildings adjacent to the entrance to Newmont's Deep Post underground mine (accessed from within the open pit) can be seen in the lower centre of the photograph. The black rocks exposed in the pit belong to the Devonian Popovich and overlying Rodeo Creek Formations (the latter is exposed on the upper western wall of the pit). A series of steeply-dipping, light-coloured Jurassic and Cretaceous felsic dykes are exposed on the north wall of the pit (right). Project P2.L2 CODES AMIRA P923

Staff and Management

Centre Director

Ross Large, Research Director and Chief Operations Officer, is responsible for the scientific leadership and operational management of the Centre. He is supported in this by Bruce Gemmell (Deputy Director), the Advisory Board and the Executive Committee.

Advisory Board

The Advisory Board meets annually to review progress of the Centre and to advise on future directions. The Advisory Board is composed of major industry sponsors, University of Tasmania senior management and key national geoscience organisations and is chaired by John Dow, a geologist with significant management experience in the minerals industry and a strong international reputation in economic geology.

Science Planning Panel

The Science Planning Panel meets annually for a one-day forum of presentations concerning the Centre's scientific research progress and to discuss potential new research the Centre may undertake. The membership is wider than that of the Advisory Board and includes a representative from all sponsor companies. The Panel is designed to provide industry with an opportunity to influence future research directions of the Centre.

Centre Research Committee

The Centre Research Committee includes all collaborating partner chief investigators and meets each year to discuss research progress, new research opportunities and particularly to focus on effective collaborative activities across all Centre partners.

Executive Committee

The Executive Committee membership consists of the Centre's Director, five program leaders and administrative managers. This committee meets,

on average, six times a year. The Executive Committee works closely with the Director to develop the Centre's goals, strategies and performance indicators.

Staff Appointments in 2007

Sandrin Feig recently completed his PhD at the University of Hannover (Germany) working on experimental constraints on crystallisation of mafic magmas. He has joined CODES to work with Leonid Danyushevsky and Andrew McNeill within the Location Program focussing on the nickel-PGE potential of mafic magmas.

Chris Hollitt joined CODES technical staff within the Technology Program. He is responsible for maintenance and operation of the laser microprobes and mass-spectrometers within the LA ICPMS analytical facility.

Anya Reading joined the School of Earth Sciences/CODES in February 2007 as a Senior Lecturer in Geophysics. She previously held teaching and research positions at the University of Edinburgh (UK) and the Australian National University. Anya has extensive research experience in both field and computational geophysics. She will carry out research into tectonic evolution, and diverse applications of seismic, electromagnetic and other geophysical modelling, in the Formation and Discovery programs.

Jeff Foster joined CODES to be Leader of the Discovery Program. He has 20 years of industry experience and was previously with WMC, BHP and Geodiscovery, having worked in a diversity of global locations. He has an international reputation for his research and exploration in magmatic nickel and PGE deposits. Jeff will be driving the integration of geology, geochemistry and geophysics at CODES, and establishing new projects in nickel and PGE research.

Jacqueline Halpin completed her PhD at the University of Sydney studying Precambrian metamorphic rocks from Antarctica. She has joined CODES to work with Tony Crawford, Khin Zaw and Sebastien Meffre in the Location Program, and with Dave Selley's sedimentary copper team in the Discovery Program.



Science Planning Panel and Advisory Board members.

CODES staff 2007

		% in CODES
Director, Professor Ross Large, BSc Hons (UTAS), PhD (UNE)	Volcanic-hosted and sediment-hosted base metal and gold ores	100
Deputy Director, Professor J Bruce Gemmell, BSc (UBC), MA, PhD (Dartmouth)	VHMS deposits and epithermal gold-silver	50
Academic/research staff at UTAS		
Dr Sharon Allen, BSc (Massey), MSc (Auckland), PhD (Monash)	Volcanic facies analysis	50
Associate Professor Ron Berry, BSc, PhD (Flinders)	Structure of mineralised provinces, CHIME dating, geometallurgy	50
Dr Stuart Bull, BSc Hons, PhD (Monash)	Clastic and carbonate sedimentology and volcanology	75
Dr Zhaoshan Chang, BSc (PKU), PhD (PKU, WUS)	Skarn, porphyry and epithermal deposits; LA-ICPMS zircon dating	100
Associate Professor David Cooke, BSc Hons (Latrobe), PhD (Monash)	Fluid-rock geochemistry, porphyry copper-gold	50
Professor Tony Crawford, BSc Hons, PhD (Melbourne)	Petrology, geochemistry and tectonics of volcanic arcs	50
Associate Professor Leonid Danyushevsky, PhD (Vernadsky Inst.)	Petrology, geochemistry, application of melt inclusions	100
Dr Garry Davidson, BSc Hons (ANU), PhD (UTAS)	Sulfur isotope geochemistry and copper-gold ores	50
Dr Paul Davidson, BSc Hons, PhD (UTAS)	Melt and fluid inclusions	100
Dr Mark Duffett, BSc Hons, PhD (UTAS)	Regional geophysics	75
Dr Trevor Falloon, BSc Hons (Canterbury), BTeaching, PhD (UTAS)	Marine geoscience, petrology	50
Dr Sandrin Feig, MSc, PhD (Hannover)	Petrology	100
Associate Professor Jeff Foster, BSc Hons (City), MSc (Leicester)	Magmatic ore deposits	100
Dr Jacqueline Halpin, BSc Hons (Melbourne), PhD (Sydney)	Metamorphic petrology, geochronology	100
Dr Anthony Harris, BSc Hons, PhD (UQ)	Ore deposit geology/geochemistry	100
Dr Julie Hunt, MSc (UBC), PhD (JCU)	Geometallurgy, IOCG deposits	100
Dr Maya Kamenetsky, PhD (UTAS)	MLA-SEM, geometallurgy, petrology	100
Professor Vadim Kamenetsky, BSc Hons (Moscow), PhD (Vernadsky Inst.)	Petrology and geochemistry of melt inclusions	50
Associate Professor Khin Zaw, BSc (Rangoon), MSc (Queen's), PhD (UTAS)	Fluid inclusions, SE Asian metallogenesis	100
Dr Peter McGoldrick, BSc Hons, PhD (Melbourne)	Geochemistry of ore deposits and their halos	75
Dr Andrew McNeill, BSc Hons, PhD (UTAS)	Petrology, VHMS deposit, mineral exploration	100
Professor Jocelyn McPhie, BA Hons (Macquarie), PhD (UNE)	Volcanic facies architecture and volcanic textures	50
Dr Sebastien Meffre, BSc Hons, PhD (Sydney)	Petrology and tectonics of the SW Pacific	100
Dr Karin Orth, BSc Hons (Monash), PhD (UTAS)	Volcanology	50
Dr Anya Reading, BSc Hons (Edinburgh), PhD (Leeds)	Geophysics, seismic	50
Dr Michael Roach, BSc Hons (Newcastle), PhD (UTAS)	Geophysical responses of ore deposits	50
Dr Robert Scott, BSc Hons, PhD (Monash)	Structural geology, gold deposits	100
Dr David Selley, BSc Hons (Adelaide), PhD (UTAS)	Structural geology/basin analysis, sedimentary copper	100
Dr Michael Solomon, MSc, PhD (UTAS), DSc (London)	Geochemistry and genesis of mineral deposits	20
Professor Steve Walters, BSc Hons, PhD (Sheffield)	Node Leader: geometallurgy, applied mineralogy, exploration technologies	50
Dr Tony Webster, BSc Hons (Latrobe), BA (UNE), MSc (JCU), PhD (UTAS)	MTEC Senior Lecturer and Masters Program Coordinator	100
Academic/research staff based at collaborative institutions		
Professor Ben Adair	University of Queensland	12
Dr David Belton	CSIRO Exploration & Mining	50
Professor Alan Bye	WH Bryan Mining Geology Research Centre, University of Queensland	20
Professor Steve Cox	Node Leader; Australian National University	5
Dr Nenad Djordjevic	University of Queensland	30
Dr Peter Fullagar	Fullagar Geophysics Pty Ltd	30
Professor Grant Garven	Johns Hopkins University	20
Associate Professor Jeff Hedenquist	Colorado School of Mines	10
Associate Professor Janet Hergt	Node Leader, University of Melbourne	10
Professor Murray Hitzman	Colorado School of Mines	20
Dr Toni Kojovic	JKTech, University of Queensland	20
Luis Martinez	WH Bryan Mining Geology Research Centre, University of Queensland	80
Dr Simon Michaux	University of Queensland	100
Dr Rob Morrison	University of Queensland	15
Dr Khoi Nguyen	University of Queensland	100

CODES staff 2007 cont.

Dr Chad Paton	University of Melbourne	100
Dr Chris Ryan	CSIRO Exploration and Mining	20
Dr Christian Schardt	Johns Hopkins University	50
Dr Richard Tosdal	University of British Columbia	30
Professor Steve Walters	Node leader, University of Queensland	50
Dr Yicai Wang	University of Queensland	100
Dr Jon Woodhead	University of Melbourne	30
Technical/administrative staff		
Mr Ruben Chan, BComp (UTAS)	Database and Website Manager	
Mr Peter Cornish	Laboratory Manager	
Mr Keith Dobson	IT Support Manager	
Ms Sarah Gilbert, BSc Hons (UTAS)	Senior Technician ICPMS	
Ms Christine Higgins, Grad.Cert.Management (UTAS)	Finance Manager	
Mr Christopher Hollitt	Senior Technical Officer	
Mrs Katrina Keep	Personal Assistant	
Mrs Katie McGoldrick	Laboratory Assistant	
Mr Zen Miles	IT Support Assistant	
Ms Caroline Mordaunt, BA Hons (King's College London)	Administrative Assistant	
Ms June Pongratz	Publications and MRC Manager	
Dr Donna Roberts, PhD (UTAS)	Communications Manager	
Mr Philip Robinson, BSc Hons (Nottingham)	Analytical Services Manager	
Miss Helen Scott, BSc Hons (UTAS), BEd (QUT)	Finance Officer	
Mrs Dianne Steffens	Finance Officer	
Mr Simon Stephens, BSc (UTAS)	Lapidary Services Manager	
Ms Isabella von Lichten, BSc Hons (UTAS)	Curator/MTEC Admin. Assistant	
Mrs Gina Zalmstra	Administrative Assistant	

Advisory Board

Chair: John Dow	Consultant
Allan Canty	Pro-Vice Chancellor Research, UTAS
Jim Reid	Dean, Faculty of Science, Engineering & Technology, UTAS
Ross Large	Director, CODES
Bruce Gemmell	Deputy Director, CODES
Jocelyn McPhie	Coordinator Graduate Research, CODES
Steve Walters	Recovery Program Leader, CODES
Ben Adair	Director, JKMRC
Tony Brown	Executive Director, Mineral Resources Tasmania
Alan Goode	Research Director, AMIRA International
John Holliday	Principal Geologist - SE Australia, Newcrest Mining Limited
Graham Carr	CSIRO
Noel White	Consultant
Ian Willis	VP Exploration, Anglo American
Steve Turner	Chief Geologist, Newmont Exploration
Ed Eshuys	Managing Director & CEO St Barbara Limited
John Larson	VP Exploration, Zinifex
Angela Lorrigan	Senior Exploration Geologist, Zinifex
Steve Cox	Australian National University
Steve Beresford	BHP Billiton
Janet Hergt	University of Melbourne
Jamie Wilkinson	Imperial College

Executive Committee

Chair: Ross Large	Director, CODES
Bruce Gemmell	Deputy Director, CODES
Tony Crawford	Location (1) Program Leader
David Cooke	Formation (2) Program Leader
Jeff Foster	Discovery (3) Program Leader
Steve Walters	Recovery (4) Program Leader
Leonid Danyushevsky	Technology (5) Program Leader
Jocelyn McPhie	Coordinator Graduate Research
Christine Higgins	Finance Manager
Katrina Keep	Personal Assistant to the Director
June Pongratz	Publications Manager
Donna Roberts	Communications Manager

Science Planning Panel

(includes the Executive Committee and all CODES research staff)

Chair: Ross Large	Director, CODES
Ian Willis	Anglo American
Donna Sewell	AngloGold Ashanti
Trevor Beardsmore	Barrick Gold
John Holliday	Newcrest Mining Limited
Steve Turner	Newmont Exploration
Paul Agnew	Rio Tinto
John Thompson	Teck Cominco
Ian Sandl	Teck Cominco
Angela Lorrigan	Zinifex
Alan Goode	AMIRA International
Steve Cox	Australian National University
Noel White	Consultant
John Dow	Consultant
David Belton	CSIRO
Chris Ryan	CSIRO
Graham Carr	CSIRO
Grant Garven	Johns Hopkins University
Kevin Tuckwell	Minerals Council of Australia
Tony Brown	Mineral Resources Tasmania
Geoff Green	Mineral Resources Tasmania
David Green	Mineral Resources Tasmania
Janet Hergt	University of Melbourne
Ben Adair	University of Queensland
Peter Thompson	St Barbara Mines
Jamie Wilkinson	Imperial College

Executive Committee



Research – The Foundation For Success

Objectives

Since its formation in 2005, the Centre of Excellence in Ore Deposits (CODES) has cemented its position as one of the world's leading research centres in ore deposit genesis, mineral exploration and geometallurgy.

As the worldwide demand for resources grows at an exponential rate, the need to find new ore bodies and improve recovery methods becomes increasingly important.

The burgeoning economies of countries such as China, India and Brazil have continued to add momentum to the phenomenal boom in resource markets. The value of Australian mineral exports (excluding oil and gas) increased by a further 16% in 2006/07, amounting to a total value of \$90.8 billion.

To meet this challenge, CODES has developed a strategic focus that harnesses its resources in the following key program areas: Location, Formation, Discovery, Recovery and Technology.

The **basic objectives** of these programs are as follows:

LOCATION

Improve understanding of the links between tectonic setting, magmatism, basin evolution and ore deposit formation in modern and ancient terrains.

FORMATION

Develop practical, process-based exploration models for hydrothermal and magmatic ore deposits that will help increase discovery rates.

DISCOVERY

Develop techniques for the acquisition, processing and interpretation of ore deposit geophysical and geochemical data that will assist in the discovery of deep earth resources.

RECOVERY

Create an integrated, cross-disciplinary, geometallurgical research platform that delivers fundamental knowledge, tools and methods to the global mining industry for optimising sustainable and profitable mineral extraction.

Develop more effective approaches to the definition of mineralogy, element deportment and texture that can be linked to mineral processing performance and efficiency at a range of scales.

TECHNOLOGY

Develop new analytical techniques, ensuring that research in the Centre is driven by innovative technology, and that the Centre is at the cutting edge of analytical developments of relevance to ore deposit research.

Provide CODES research staff and students with access to state-of-the-art micro-analytical equipment within Australia and overseas, and to maintain their awareness of new analytical developments.

The research framework – synergy, teamwork and collaboration

CODES has a nucleus of fundamental research programs that are linked to a suite of applied programs executed in collaboration with the minerals industry.

Fundamental research underpins all the work performed at CODES and provides the catalyst for success in the applied programs, which build on the breakthroughs and innovations developed via the fundamental research activities.

The ARC Centre of Excellence grant provides the financial support for the fundamental research projects and partly funds the applied projects, with the balance of funding coming from industry partners.

The five linked and complementary research programs are: Location, Formation, Discovery, Recovery, and Technology.

The **research framework** for each of these programs is as follows:

LOCATION

This program builds on our expertise in magmatic, volcanic and tectonic processes in diverse tectonic settings and includes groundbreaking research into magmas associated with nickel-PGE mineralisation.

FORMATION

CODES has built a fine reputation for its research into process-based exploration models for hydrothermal and magmatic ore deposits. These programs are enhanced by employing an integrated approach to solving metal source-transport-trap problems and utilising targeted collaborations with other leading research institutes.

DISCOVERY

The centre's innovative work in the field of geology and geochemistry is augmented by its pioneering work in ore deposit geophysics.

This research is strongly supported by the mining industry, which recognises that increasing efficiencies in the discovery of deep earth resources is essential to the long-term growth of the industry.

RECOVERY

CODES works in collaboration with the Julius Kruttschnitt Mineral Research Centre (JKMRC) at the University of Queensland, which is recognised as a world leader in metallurgical research. The alliance of these two benchmark organisations has created a synergy that has resulted in a number of innovative improvements to recovery methods that have provided wide ranging benefits throughout the industry.

TECHNOLOGY

To maintain its position as one of the world's leading research centres, CODES ensures that it has the latest, state-of-the-art micro-analytical equipment. Its investments in cutting-edge technology, such as the New

Wave UP-213 Laser Ablation System, have played a key role in the development of analytical techniques that have revolutionised the industry. It also has access to an array of additional world-class equipment through its collaborations with a variety of organisations, including the University of Melbourne, CSIRO and the Australian National University.

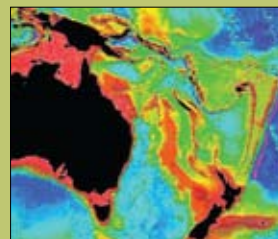
Teamwork – a competitive advantage

One of the keys to the Centre's continued success is its emphasis on teamwork and collaboration. This team approach has become the hallmark of all activities associated with CODES, and is particularly evident in the following important core aspects of the operation.

The five key programs – Location, Formation, Discovery, Recovery and Technology – form an overlapping and interlinked process that follows a logical progression from area selection through to exploration discovery and recovery. This integrated research structure encourages a cohesive team approach that fosters collaboration between program teams.

Within the centre, there are currently 124 researchers, including Honours, Masters and PhD students. These team members, who are treated as part of the CODES family, thrive in an environment that is conducive to cooperation and synergy.

The Centre has forged mutually beneficial alliances with a range of major research groups, industry partners, government organisations and industry bodies.



LOCATION



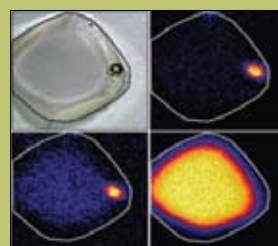
FORMATION



DISCOVERY



RECOVERY



TECHNOLOGY

Student Projects in Australia

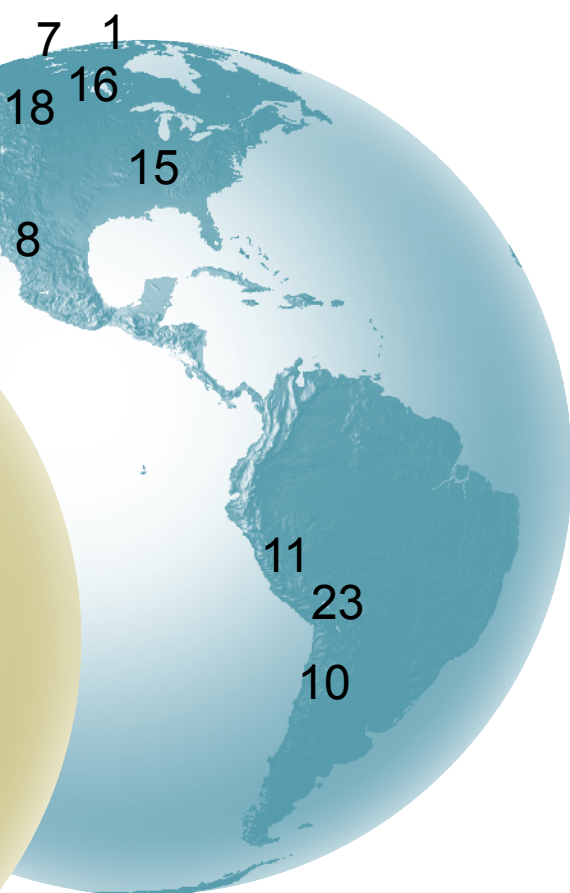
	<i>Name</i>	<i>Project Location</i>		<i>Project</i>
1	Agangi, Andrea	Australia	SA	Magmatic and volcanic evolution of giant intraplate felsic igneous provinces and associated ore deposits: Gawler Range Volcanics and Hiltaba Suite, South Australia
2	Andrews, Darren	Australia	Tas	Geophysical monitoring of acid mine drainage at Savage River Mine, northwestern Tasmania
3	Baker, Michael	Australia	Qld	Palaeoproterozoic magmatism in the Georgetown Block, North Queensland, and comparisons with Broken Hill Block
4	Belford, Susan	Australia	WA	Genetic and chemical characterisation of the Archaean Jaguar VHMS deposit
	Boakye, David (BRC)	Lab-based		Geostatistical modelling of geometallurgical attributes
	Bonnici, Natalee	Lab-based		Textural and mineralogical characterisation of Cu-Au systems in relation to process mineralogy
5	Bowden, Bryan	Australia	SA	Geology, geochemistry and genesis of the Prominent Hill IOCG deposit, South Australia
6	Brownlie, Alyce	Australia	Tas	Reliability study of the Durham soil moisture and density indicator utilizing time domain reflectometry; a Tasmania-specific study
7	Chmielowski, Reia	Australia	Tas	The metamorphic history of Tasmania
8	Cuison, Ana-Liza	Australia	NSW	Geology and genesis of the Ridgeway porphyry Au-Cu deposit, New South Wales
9	Denwer, Kim	Australia	Tas	Mineralogical, geochemical and isotopic investigation of the Mount Lyell Cu-Au ore body and alteration system
	Evans, Cathy (JKMRC)	Lab-based		The relationship between mineral characteristics of ores and the variation in their processing attributes
10	Evans, Lee	Australia	Tas	Ground waters in wet, temperate sulfide mining districts: delineation of modern fluid flow and predictive modelling to improve management after mine closure (Rosebery)
11	Farran, Michelle	Australia	WA	Volcanic, metamorphic and structural architecture of the Prospero-Tapinos nickel sulfide host succession
12	Ferguson, Paul	Australia	Macquarie Is	Origin of large negative magnetic anomalies in oceanic crust, Macquarie Island
13	Fox, Jodi	Australia	NT	Potential field modelling of magnetite lenses in the Attuttra Metagabbro, Northern Territory
14	Fox, Nathan	Australia	NSW	Controls on alteration and mineralisation in the Cadia East Au-Cu porphyry copper deposit, New South Wales
15	Frankcombe, Laura	Australia	WA	Geochemical and structural controls of gold mineralisation, Mars mine, Western Australia
16	Hamilton, Cam	Australia	WA	A potential field investigation of the Wagon Pass Pb/Zn prospect, Lennard Shelf, Western Kimberley, Western Australia
	Hoschke, Terence	Lab-based		Geophysical signatures of gold-copper porphyry systems
17	Humphrys, Meg	Australia	Tas	The origin of felsic segregations and massive granophyre in Jurassic dolerite intrusions
18	Keeney, Luke (JKMRC)	Australia	NSW	Integrated geometallurgical modelling of the Cadia East deposit
	Leigh, George (JKMRC)	Lab-based		Multiresolution image analysis for process mineralogy
19	Lorimer, Tom	Australia	Tas	An investigation of the upper crustal structure of eastern Tasmania using active source seismic tomography
20	Mackay, Wallace	Australia	SA	Sedimentology and structure of the Curdimurka Subgroup, Willouran Range, South Australia
21	Maier, Rodney	Australia	NT	Pyrite and base metal trace-element halos in the northern Australian Zn-Pb-Ag deposits
	McMahon, Claire	Lab-based		Controls on the major and trace element contents of pyrite in hydrothermal alteration envelopes
22	Methorst, Thomas	Australia	Tas	Gravity survey of Flinders Island
	Parbhakar, Anita	Lab-based		Predictive environmental mineralogy and geochemical techniques: a new approach to integrated ARD characterisation
23	Reynolds, William	Australia	NSW	Distal alteration at Ridgeway Deposit, New South Wales
24	Robson, Lee	Australia	Tas	Application of remote sensing for geological mapping in western Tasmania
	Schaa, Ralf	Lab-based		Rapid approximate imaging of electromagnetic data acquired using distributed multichannel data acquisition systems
	Singoyi, Blackwell	Lab-based		Controls on the geochemistry of magnetite in hydrothermal fluids
25	Stegman, Craig	Australia	NSW	Geochemistry and structure of gold-base metal mineralisation in the Cobar Gold Field, New South Wales
	Vasyukova, Olga	Lab-based		The origin of quartz and fluid inclusions in mineralised porphyries
	Vatandoost Kohnehsahri, Adel	Lab-based		Automated petrophysical characterisation of drill core as a link to mineral processing attributes
26	Wellard, Jeneta	Australia	Tas	Sequence stratigraphy of the Myrtle Formation, Gordon Group Limestone, Zeehan, western Tasmania
27	Zukowski, Wojciech	Australia	NSW	Geology and mineralisation at Lake Cowal district, New South Wales

unnumbered projects are laboratory-based



Student Projects Outside Australia





	<i>Name</i>	<i>Project Location</i>	<i>Project</i>
1	Bath, Adam	Canada	The geochemistry of melt inclusions and mineral phases from the Mount Polley and Lorraine alkalic Cu-Au porphyry deposits: implications for the formation of ore deposits
2	Blackwell, Jacqueline	Papua New Guinea	Characteristics and origins of breccias in an alkalic epithermal gold deposit: Ladolam, Lihir Island, Papua New Guinea
3	Braxton, David	Philippines	Boyongan and Bayugo porphyry Cu-Au deposits, NE Mindanao, Philippines: geology, geochemistry, and tectonic evolution
4	Croaker, Mawson	Zambia	Geology and genesis of the Nkana copper deposit, Zambia
5	Cromie, Paul	Laos	Geological setting, geochemistry and genesis of the Sepon Mineral District, Laos PDR
6	Dinh, Quang Sang	Vietnam	Geochronology and geological evolution of the northern margin of the Kontum massif, central Vietnam
7	Fulton, Russell	United States	Geology and geochemistry of the hanging wall argillite, Greens Creek VHMS deposit, Alaska: implications for ore genesis and exploration
8	Galvan, Victor	Mexico	Palmarejo carbonate base-metals silver-gold epithermal deposit, Trogon Project, Chihuahua, Mexico
9	Gordee, Sarah	Greece, Japan	Characteristics of subaqueous pyroclastic facies in arc settings
10	Ireland, Timothy	Chile	Geological framework of porphyry and epithermal mineralisation in the Collahuasi District, Region de Tarapaca, Chile
11	Jones, Benjamin	Peru	Tectonic setting and magmatic evolution of the Antapaccay porphyry copper-gold and skarn deposit, Peru
12	Jutzeler, Martin	New Zealand and Japan	Behaviour of submerged eruption plumes using data from facies analysis of a variety of submarine pyroclastic successions
13	Kamvong, Teera	Thailand	Geology and genesis of porphyry-skarn Cu-Au deposits at the northern Loei Fold Belt, northeast Thailand and Laos
14	Manaka, Takayuki	Laos	Geological setting and mineralisation characteristics of the Long Chieng Track and Ban Houayxai deposits, Laos PDR
15	Moye, Robert (Joe)	United States	Genesis and chemical and kinematic evolution of the late Proterozoic Ridgeway gold deposit in the Carolina Terrane of the central South Carolina piedmont, USA
16	Pass, Heidi	Canada	Chemical and mineralogical zonation patterns in alkalic mineral systems- Implications for ore genesis and mineral exploration
17	Pollington, Nicole	Zambia	Sedimentology, mineral paragenesis and geochemistry of the Konkola North copper deposit, Zambia
18	Sack, Patrick	United States	Characterisation of the footwall lithologies, Greens Creek VHMS deposit, Admiralty Island, southeast Alaska
19	Salam, Abhisit	Thailand	Geology and genesis of the Chatree Au deposits, Phetchabun Province, central Thailand
20	Srichan, Weerapan	Thailand	Petrochemistry, geochronology and tectonic implications of Chiang Khong-Lampang-Tak Volcanic Belt, Northern Thailand
21	Sutopo, Bronto	Indonesia	The Martabe Au-Ag high-sulphidation epithermal mineralization in the Tapanuli Selatan District, North Sumatra Province, Indonesia: Implications for ore genesis and exploration
22	Tetroeva, Sofia	South Pacific	Petrology and geochemistry of adakites and related rocks from the Hunter Ridge, Southwest Pacific
23	Urzua, Felipe	Chile	Regional geology of the Escondida district, northern Chile
24	Woolward, Ian	Russian Federation	The geochemistry and mineralogy of the Centralnyi Creek Sill, Dovyren Mafic-Ultramafic complex
25	Micko, Janina	Canada	The hydrothermal genesis of the alkalic Cu-Au porphyry deposit Galore Creek, Northwestern British Columbia

Location

PROGRAM 1



Objective ... to better understand the links between tectonic setting, magmatism, basin evolution and ore deposit formation in modern and ancient terrains



TEAM LEADER

Tony Crawford

TEAM MEMBERS

Sharon Allen, Ron Berry, Stuart Bull, Leonid Danyushevsky, Paul Davidson, Sandrin Feig, Cathryn Giffkins, Ben Jones, Maya Kamenetsky, Vadim Kamenetsky, Roland Maas*, Peter McGoldrick, Andrew McNeill, Jocelyn McPhie, Sebastien Meffre, Jon Woodhead*, Khin Zaw

(*partner research organisation team member)

PhD STUDENTS

Andrea Agangi, Michael Baker, Susan Belford, Sang Quang Dinh, Sarah Gordee, Teera Kamvong, Rodney Maier, Carlos Rosa, Abhisit Salam, Weerapan Srichan, Sofia Tetroeva, Olga Vasyukova

HIGHLIGHTS

A six-week field trip to the Dovyren mafic-ultramafic intrusion in Siberia successfully completed in the first year of AMIRA Project P962 'Nickel-PGE potential of mafic and ultramafic magmas – a combined melt inclusion and numerical modeling approach'.

Publication of Special Issue of *Australian Journal of Earth Sciences* on the Macquarie Arc of central western New South Wales, containing 11 papers by CODES researchers from Programs 1 and 2.

Leonid Danyushevsky awarded the third R/V *Southern Surveyor* cruise to the Hunter Ridge to build on the existing knowledge of this globally important site of hot subduction.

Tony Crawford awarded the Royal Society of Tasmania's Clive Lord Medal for 'contributions to the natural sciences in Tasmania; specifically, to improve understanding of the geological evolution of Tasmania'.

Six sponsors in place for new SE Asian metallogenesis-tectonics and geochronology project to commence January 2008.

COLLABORATORS

Anglo American Exploration – Alan Wilson, David Braxton, Paul Polito
Centre for Mineral Exploration Under Cover (Australia) – David Giles
Department of Mineral Resources (Thailand) – Somboon Khositantont
Frogtech (Australia) – Nick Direen
GeoForschungsZentrum (Germany) – Rainer Thomas
Geomarine Research (New Zealand) – Bruce Hayward
Geoscience Australia – Terry Mernagh
Geological Survey of New South Wales – Barney Stevens and Dick Glen
Geological Survey of Queensland – Ian Withnall
Institute of Earth Sciences-Academia Sinica (Taiwan) – Georg Zellmer
Institute of Experimental Mineralogy (Russia) – Eduard Konnikov
Institute for Frontier Research on Earth Evolution (Japan) – Yoshihiko Tamura
Institute of Geological and Nuclear Sciences (New Zealand) – Cornel de Ronde
Institute of Geology and Mineral Exploration (Greece) – Georgos Vougiakakis
Institute of Geology and Mineralogy (Russia) – Sergey Smirnov
Indian School of Mines (India) – Deepanker Asthana
Jabiru Metals – Neil Martin
Leibnitz Institute of Marine Sciences (Germany) – Armin Freundt
Monash University (Australia) – Reid Keays
Perilya Ltd – John Penhall and Mark Manly
Primary Industry and Resources South Australia – Martin Fairclough, Stacey Curtis
Smithsonian Institution (USA) – Richard Fiske
State Key Laboratory for Ore Deposits, Chinese Academy of Sciences (China) – Xieyan Song
United States Geological Survey (USA) – Poul Emsbo
University of California, Riverside (USA) – Timothy Lyons
University of Hong Kong (China) – Jonathan Aitchison, Meifu Zhou
University of Lisbon (Portugal) – Jorge Relvas, Fernando Barriga
University of Naples Federico II (Italy) – Benedetto De Vivo
University of Oregon (USA) – Cathy Cashman, Paul Wallace
University of Washington (USA) – George Bergantz
Vernadsky Institute of Geochemistry (Russia) – Alexei Ariskin and Vladimir Naumov

CORE RESEARCH

Geodynamic controls on fertility of fold belts and cratons P1.F1

Modern magmatism in the Southwest Pacific Ocean P1.F2

Felsic magmas: volatile and metal budgets during magma evolution – a combined melt inclusion and volcanological approach P1.F3

Nickel-PGE potential of mafic and ultramafic magmas – a combined melt inclusion and numerical modelling approach P1.F4

Global ocean chemistry, marine basins and mineralisation P1.F5

Geochronology, metallogenesis and deposit styles of Loei Foldbelt in Thailand and Laos PDR. P1.L1

(F prefix denotes fundamental research project; L prefix denotes industry-linked project)

P1.F1 Geodynamic controls on the fertility of fold belts and cratons

Project Leader: A Crawford

Project Members: S Allen, R Berry, S Bull, P Davidson, C Gifkins, V Kamenetsky, S Meffre, P McGoldrick, A McNeill, J McPhie, R Scott, K Zaw

Students: M Baker, S Belford, SQ Dinh, C Rosa, W Srichan

Collaborators: D Asthana (Indian School of Mines), R Maas, J Woodhead (UMelb), R Keays (MonashU), D Giles (UAdelaide), N Direen (FrogTech), J Penhall, M Manly (Perilya Ltd), N Martin (Jabiru Metals), M Mirmohammadi, F Daliran (KarlsruheU), J Relvas (ULisbon), B Stevens, D Glen (Geol Surv NSW), I Withnall (Geol Surv Qld), P Polito (AngloAmerican), T Lyons (UCalifornia Riverside), S Khositanont (Dept Mineral Resources, Thailand), P Emsbo (USGS)

The aims of this project are to investigate and better understand the conjunctions of geological factors that are responsible for the location, timing and scale of ore deposit formation linked directly or indirectly to magmatism. A number of discrete but thematically overlapping sub-projects constitute this project, and these are listed and summarised separately below.

P1.F1.1 Palaeoproterozoic mafic magmatism in the Broken Hill Block, and in the Georgetown Block and Mount Isa Eastern Succession in northern Queensland; a role in mineralisation?

We have developed a challenging new model for the origin of the stratiform zinc-lead deposits at Broken Hill in which the ore metals, S and ubiquitous Mn in the alteration halo all derive ultimately from advanced synkinematic fractionation of typical 1685 Ma rift tholeiites along a major crustal scale extensional shear zone now defined by the line of lode. We have demonstrated that exceptionally strong fractionation produced very Fe-rich tholeiitic magmas along this shear zone, and we hypothesise that enormous volumes of requisite complementary FeTi oxide-rich gabbroic cumulates occur in the subsurface, and are well imaged by the Thorndale Gravity High east of the line of lode. Exsolution of late magmatic fluid provided the hydrothermal fluids responsible for the lead-zinc mineralisation, metals being leached from the lead-zinc-enriched magmatic rocks along the shear zone. Ferrogabbroic ilmenites typically have 1–2% manganese oxide, and their alteration by such hydrothermal fluids provided the abundant manganese and iron that characterises alteration assemblages around the ore bodies. Zinc may also concentrate in ilmenite, a hypothesis we will be testing using LA-ICPMS in 2008. All S is magmatic, accounting for the puzzling mantle-like S-isotope values in the Broken Hill ores.

Work on this project during 2007 was divided between two different sub-projects on the Broken Hill metabasic sills.

1: With support from Perilya Ltd (John Penhall, Mark Manly), we systematically sampled across a number of thicker (30–200 m) sills along the line of lode, and tested, using major and trace element compositions, whether compositional profiles were useful in determining ‘way up’ in such concordant intrusions. The sill profiles appear to be useful indicators

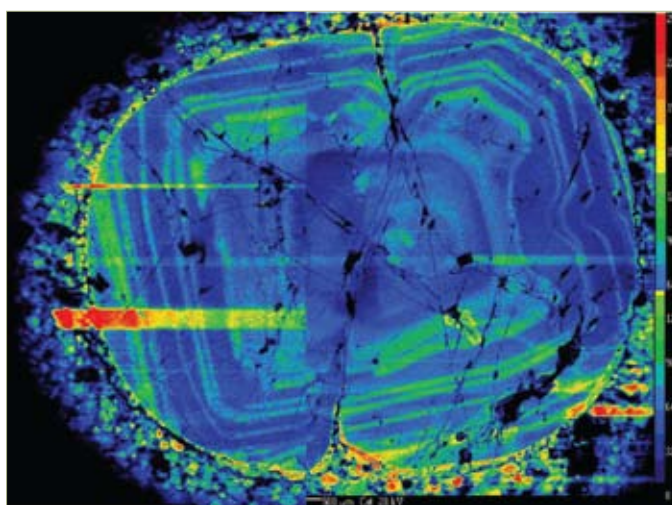
of structure around the line of lode, and further work is planned in 2008 to build on this outcome.

2: An important test of the veracity of the mafic magmatic-hydrothermal origin model for the Broken Hill orebodies lies in lead-isotope studies of the mafic rocks and comparison of this new data with the well-established fields for the Broken Hill ores. To this end, a comprehensive analytical program was devised using both wholerock and mineral separate lead-isotope measurements obtained using the MC-ICPMS facility at the University of Melbourne, in collaboration with Roland Maas and Jon Woodhead. More than 90% of the data have now been collected, including data for progressive leaching experiments, and LA-MC ICPMS data for plagioclase and amphibole separates. At this stage, our data support the model proposed.

A complementary study of Palaeoproterozoic mafic rocks in the Georgetown Block in north Queensland formed the core of a PhD study by Michael Baker, who graduated in 2007. A paper on the geochemistry of the Georgetown mafic rocks and comparison with those in the Broken Hill Block will be submitted to *Precambrian Research* in early 2008.

P1.F1.2 Geodynamic evolution and metallogenesis of the Ordovician Macquarie Arc, Lachlan Orogen, New South Wales

After a long gestation period, the outcomes of this SPIRT-funded project were published as a thematic issue of the *Australian Journal of Earth Sciences* edited by Tony Crawford, Dick Glen (Geol. Surv. NSW) and David Cooke. CODES staff and PhD students senior-authored eight papers and co-authored all but one of the 14 papers in this volume. The volume represents one of the largest single additions of new knowledge to the geodynamic evolution and metallogenesis of the Lachlan Orogen in the past 40 years, and concludes this major multi-disciplinary project.



Cathodoluminescence image of compositional zoning in a quartz phenocryst from Batu Hijau porphyry, Indonesia

P1.F1.3 Tectonic and volcanological studies of 'fertile' submarine volcanic successions that host massive sulfide ore deposits

This project includes a number of independent but thematically linked studies of the volcanology, geochemistry and tectonic setting of volcanic host packages to significant massive sulfide mineralisation. Study areas include the Cambrian Mount Read Volcanics in western Tasmania, the 2.6 Ga Archaean rocks that host the Teutonic Bore and Jaguar massive sulfide deposits in Western Australia, and the Iberian Pyrite Belt in Portugal and Spain.

Andrew McNeill, Tony Crawford and Cathryn Gifkins continued their study of the Sterling Valley Volcanics and associated mafic rocks, previously interpreted to be the basal unit of the mineral-rich Mount Read Volcanics. This project was expanded to include the Henty Dyke Swarm and Henty Fault Wedge sequences in 2007, and a major data compilation was carried out, including gathering new and published wholerock data for each magmatic suite. As a result, we plan to extend the neodymium- and hafnium-isotope study of these rocks (in collaboration with Jon Woodhead and Roland Maas at the University of Melbourne) to include these new units before preparing a paper for *Economic Geology* late in 2008.

Susan Belford's PhD research on the origin and setting of the Archaean Jaguar VHMS deposit has progressed significantly. Susan has defined the facies architecture of the succession and constrained the spatial and temporal relationships between the massive sulfide and the host facies. The basalts and andesites that dominate the succession have tholeiitic and calc-alkaline affinities, allowing reconstruction of the Archaean tectonic context and magma sources. Preliminary results were presented at the IGCP-502 Project 'Global comparison of VMS districts' conference held in Tokyo, and at the field workshop held in the Hokuroko VMS district, Honshu, Japan. The project is conducted in collaboration with Neil Martin of Jabiru Metals Ltd.

Carlos Rosa's PhD thesis on the volcanology of the Iberian Pyrite Belt in Portugal and Spain was accepted and Carlos graduated in 2007. The project involved collaboration with the University of Lisbon and was partly funded by a grant from the Portuguese Science and Technology Fund. One of the study areas was the giant Neves Corvo massive sulfide ore deposit, currently owned by SOMINCOR, where the submarine succession includes both pyroclastic and effusive rhyolitic facies. The character and origin of the Neves Corvo host succession is the subject of a manuscript accepted by *Mineralium Deposita*. These results were also presented at the 9th Biennial Meeting of the SEG in Dublin, Ireland (August 2007), and at a meeting devoted to the IGCP-502 Project 'Global comparison of VMS districts' held in Japan (October 2007).

P1.F1.4 Geological and tectonic evolution of the Greenvale region, Northern Queensland

The aim of this project was to examine the geological evolution of this important region that sits astride the northern termination of the Tasman Line, and to compare the tectonic development of the area with better known sections of the Tasman Line in western New South Wales, Victoria and Tasmania. The only further work on this project in 2007 has been initiation of collaborative work with AngloAmerican (Paul Polito) on a

series of intrusive units mapped as tonalites that occur south and west of Greenvale. Proposed field work on these rocks early in 2008 by Tony Crawford and AngloAmerican may involve an Honours student, and will include new LA-ICPMS dating and geochemical studies to compare these intrusive rocks with others mapped, dated and analysed from the Greenvale region during the earlier phase of this project.

P1.F1.5 Geological evolution of SE Asian terranes

This project encompasses the PhD projects of Weerapan Srichan 'Geochemistry and geochronology of the extensive early Mesozoic volcanics in northern Thailand', and Sang Q. Dinh, focussed on the northern margin of the poorly understood Kontum Massif in the Central Highlands of Vietnam. Both projects contribute to testing and improving the numerous existing models for the geological evolution of mainland SE Asia. The study of the Thai Mesozoic rocks is effectively complete, and a manuscript has been accepted by *The Island Arc* as part of a Special Issue on the geological evolution of SE Asia. This work was presented at the International Conference on SE Asian Geology in Manila.

The Vietnam project has advanced well during 2007, and has focussed increasingly towards geochronological data gathering in response to the dearth of good dates in the region, and the difficulty of mapping the rare continuous exposures in the Central Highlands. Data from both PhD projects will be incorporated into the planned new SE Asian project (see P1.L1) in 2008 and beyond.

P1.F1.6 The ultimate source of gold in the Palaeozoic turbidite-hosted central Victorian gold deposits

This collaborative work with Reid Keays (MonashU) attempts to demonstrate that the gold in the Victorian goldfields turbidite-hosted quartz reefs is ultimately derived from unusually gold-rich mafic igneous rocks in the basement of central and western Victoria. Included in the latter are Neoproterozoic picrites of the 600 Ma volcanic passive margin succession, and boninitic lavas of the Cambrian ophiolite that were thrust over this volcanic passive margin around 510 Ma. We have assembled more than 30 high-quality platinum group element and gold analyses of representative modern boninites and picrites, and Tasmanian and Victorian Neoproterozoic-Cambrian low-grade metamorphosed counterparts. We are currently using this data to prepare a paper for submission to *Geology*.

P1.F2 Modern magmatism in the Southwest Pacific

Project Leaders: L Danyushevsky, A Crawford

Project Members: S Allen, T Falloon, S Meffre, J Woodhead, P Plechov (Moscow State University), B Hayward (Geomarine Research, NZ)

Student: S Tetroeva

The major aim of this project is to improve understanding of magma generation and evolution processes, including submarine volcanic processes and products, in the complex convergent plate margin settings in the Southwest Pacific. This area is considered to be the likely modern

analogue of the geodynamic environments that existed during formation of ancient magmatic sequences in the fold belts in eastern Australia, which host numerous types of ore deposits. Understanding the processes, products and elements involved in the construction of continental crust is fundamental to developing a better interpretation of where and why major ore deposits form, and devising smarter regional exploration philosophies. Much of our focus has been on the Hunter Ridge, an aborted Miocene intra-oceanic arc that now forms the boundary between the inactive South Fiji Basin and active North Fiji Basin backarc basins. The Hunter Ridge is intersected by the southern termination of the main N-S spreading centre in the North Fiji Basin.

The project has five long-term inter-related aims:

1. To assess variations in the initial magma volatile and chalcophile element contents among closely spatially and temporally associated arc magmas on the Hunter Ridge, whose geochemical signatures cover a spectrum from boninite to tholeiite to calc-alkaline and adakite. This spectrum most likely results from the addition of variable subduction-related components (i.e., various H₂O-rich fluids, sediment melt, basaltic crust melt) to the mantle source of these magmas. Close spatial and temporal association of different magma types on the Hunter Ridge allows for all differences in their volatile and chalcophile budgets to be assigned to these subduction components. Other factors, such as regional and temporal differences in the composition of the mantle, can be eliminated.
2. To understand the behaviour of volatile and chalcophile elements during differentiation (basalt-andesite-dacite-rhyolite) of a single geochemical magma type. Samples collected from a single volcano on the Hunter Ridge record the entire differentiation history of a mantle-derived magma from high-Mg picrite to rhyolite. Detailed study of mineralogy and melt/fluid inclusions from this series, currently underway, will allow a better understanding of the degassing history of the magma and its effects on magma's metal budget.
3. To compare volatile and chalcophile element contents in the initial magmas erupted at backarc basin spreading centres spatially and temporally associated with diverse arc magmatism. The Hunter Ridge is unique in

that both arc and backarc magmas form contemporaneously within a few kilometres of each other. Our preliminary data indicate that the area is also characterised by a large range of backarc magma compositions, from a mid-ocean ridge-like magma, to magma with a strong subduction signature. The samples available to this project allow for comparison of metal budgets between different types of backarc magmas, and between closely associated arc and backarc magmas.

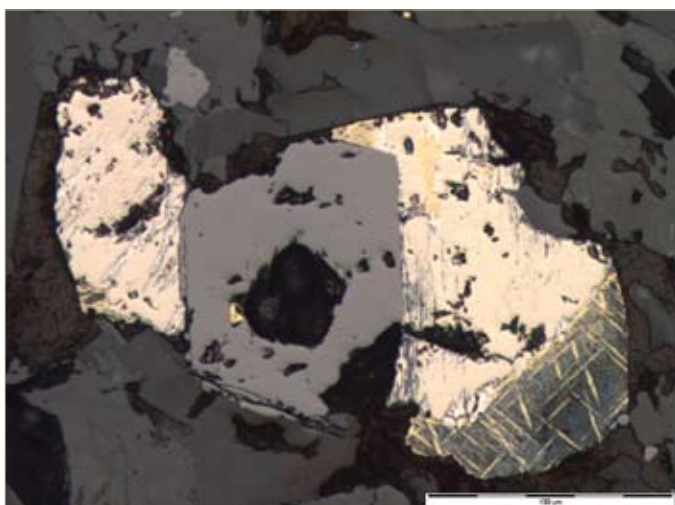
4. To evaluate the importance of magma generation conditions above subduction zones for the metal and volatile budget of magmas. The relatively abundant primitive, high-magnesian samples recovered from the Hunter Ridge allow an assessment of magma generation conditions of all the geochemical types sampled. This information can be used to improve understanding of magma generation conditions for the metal and volatile budget of subduction-related magmas.

5. To use detailed facies analysis to define the key facies associations characteristic of submarine clastic aprons around arc volcanoes. A field-based study of the architecture of arc crust has been underway, focussing on a Miocene, well-exposed arc succession in New Zealand. The study involves collaboration between Sharon Allen, Honours student Emma Mathews and Bruce Hayward (Geomarine Research), and has successfully produced a facies model for submarine volcanoclastic aprons in arc settings. Such aprons are typically the only long-term record of arc activity preserved in arc-related foldbelts. Sharon and co-authors have published the results in the *Bulletin of the Geological Society of America*.

A highlight for this project was the successful application for ship time (research voyage SS08/2008 of the National Facility research vessel *Southern Surveyor* in June–July 2008) to continue research along the Hunter Ridge. The 2008 voyage will complete sampling of the North Fiji Basin backarc basin propagating spreading centre; undertake sampling of an incipient rift within arc lithosphere at the western end of Hunter Ridge, east of the Hunter Island, discovered during the SS08/2006 voyage; and map and sample the central part of the Hunter Ridge that has not been sampled previously. The data obtained during the voyage will complement the existing datasets collected during voyages SS10/2004 and SS08/2006, and enable development of a comprehensive picture of the magmatic and tectonic processes within this complex area.

Our results from Kadavu demonstrate that there exists an adakite magma series which is the result of complex open system magmatic processes including magma mixing between high SiO₂ slab-derived melts and relatively lower SiO₂ mantle wedge derived melts of high-Mg adakite composition. The results from Kadavu Island suggest that adakite magma suites worldwide are likely to have more primitive high-Mg compositions, despite the lack of field evidence in many cases.

Also during 2007, following our existing research plan, work has focused on further analysis of samples from cruises SS10/2004 and SS08/2006. Results are expected to be available early in 2008.



Complex sulfide melt inclusion attached to a spinel grain in a mid-ocean ridge basalt from the Bouvet Triple Junction

P1.F3 Felsic magmas: volatile and metal budgets during magma evolution – a combined melt inclusion and volcanological approach

Project Leaders: J McPhie, V Kamenetsky

Project Members: S Allen, R Arculus, P Davidson, M Kamenetsky

Students: A Agangi, S Gordeev

Collaborators: K Goemann (UTAS Central Science Laboratory), T Mernagh (Geoscience Australia), C Ryan (CSIRO), B Hayward (Geomarine Research New Zealand), Y Tamura (Institute for Frontier Research on Earth Evolution, Japan), M Fairclough, S Curtis (Primary Industries & Resources South Australia), A Gurenko (Max-Planck-Institut für Chemie, Mainz, Germany), K Kano (Shizuoka University, Japan), R Fiske (Smithsonian Institution, USA), O Bachmann (University of Geneva, Switzerland), W Sun (Guangzhou Inst. Geochemistry, PRC), K Cashman (University of Oregon, USA)

This project examines the processes accompanying production, fractionation and eruption of felsic magmas using two complementary approaches: one makes use of our expertise in melt inclusion research and involves innovative experiments, whereas the other involves physical volcanology, especially textural studies, experiments and volcanic facies analysis. CODES is particularly interested in the role played by volatiles and their potential to contribute to hydrothermal systems that produce ore deposits in felsic igneous provinces.

Metal- and chlorine-bearing aqueous fluids are believed to be representative of the magmatic phase which is transitional to hydrothermal solutions. Studies of felsic rocks from the Okataina Volcanic Centre (New Zealand) and Rio Blanco copper-molybdenum deposit (Chile) demonstrate that quartz-hosted silicate melt inclusions contain bubbles of aqueous fluid. We have shown that these aqueous fluids coexisted with high-Si silicate melts and represent either post-trapping exsolution (in the case of Okataina), or co-trapping of phases already coexisting in the magma (in the case of Rio Blanco). Microthermometry proves that some of the bubbles are a single-phase aqueous liquid, and all are shown by PIXE analysis to be metal-rich saline solutions. We believe that these aqueous fluids provide the closest approximation to direct testing of the proposition that cooling magmas exsolve metal-rich aqueous fluid. In the case of pre-trapping exsolution at Rio Blanco, we have shown that some inclusions record and preserve magmatic emulsions (melt + aqueous fluid) that are the first stage in the evolution of hydrothermal fluids. We have demonstrated that heating experiments on volatile-rich melt inclusions can produce in situ exsolution of hypersaline metal-rich aqueous fluid bubbles, potentially permitting magma-chamber processes to be experimentally modelled.

Orthomagmatic theories rightly assume that many types of economic mineralisation relate to magmas and magma-derived fluids. But in reality, among many unanswered questions, we face a mass balance problem in linking magmas and ore deposits. In fact, a 'typical' magma-derived ore deposit requires either unusually metal-rich parental magma or very efficient mechanisms of metal extraction from large magma volumes. In many cases, orthomagmatic mineralisation is associated with felsic compositions (granites, pegmatites, rhyodacite-rhyolite volcanic rocks, 'quartz-porphyrries', etc.), and thus we focussed on understanding the origin of silica enrichment in felsic magmas. We targeted the internal

structure of quartz and the chemical composition of associated, and presumably coeval, inclusions, their distribution within quartz, behaviour during thermometric experiments, as well as concentrations of chlorides, metals and silica. Silica (analysed as SiO_2) is present throughout the groundmass as an interconnected network of shapeless blebs and individual quartz grains (0.2–2 mm). Most quartz grains are rounded or even spherical in shape (so-called 'quartz eyes'), and have distinct zoning or layering in cathodoluminescence (CL). The number of layers/bands varies from a few to several tens, and they have shapes from nebulous to ellipsoidal to perfect crystallographic. Egg-like and crystallographic shapes of layers are found interspersed within a single grain. The bands are randomly intersected by healed fractures (usually dark in CL), which are always decorated by aqueous saline inclusions and often contain sulfide blebs. The fractures often cause rupture, displacement and inflection of some bands towards the core of grains. Where large fractures intersect the grain surface the outermost bands are split and curved towards the fracture. In many cases solidification from an internal fracture or from the outermost boundary of the quartz grain can be implied from the observed banding. These textures of quartz grains are inconsistent with their origin as phenocrysts. We envisage in situ segregation of residual SiO_2 - and H_2O -rich liquid (e.g. silica-gel) into blebs and globules during magma cooling and crystallisation. The solidification of globules was unlike crystallisation, as they were developing coeval banding and conchoidal fractures, possibly as a result of compaction, and more likely as a result of coagulation. They perhaps remained in a plastic state even at low temperatures, when healing of fractures and trapping of chloride- and metal-rich substances, residual after coagulation of the silica gel, as fluid inclusions, occurred. This study is inter-related with methodological developments in Program 5.

The origin of siliceous magmas in modern spreading centres and ophiolites was considered in the study of the olivine-phyric basalt from 43°N, Mid-Atlantic Ridge. The exceptional feature of this sample is the presence of very primitive olivine crystals (90–91 mol% Fo) that



SEG student group on Mt Kujo, Japan.

are significantly variable in terms of CaO contents (0.15–0.35 wt%). A population of low-calcium olivine (0.15–0.25 wt% CaO) is also notably distinct from high-Ca olivine population in primitive mid-ocean ridge basalts (MORB), in having an unusual assemblage of trapped mineral and glass inclusions. Mineral inclusions are represented by high-Mg# (90.7–91.1 mol%) orthopyroxene, and chromium-spinel distinctly enriched in TiO₂ (up to 5 wt%). Melt inclusions associated with orthopyroxene and high-titanium chromite have unusually high-silica compositions (53–58 wt% SiO₂). Compared to the pillow-rim glass and ‘normal’ MORB inclusions, the Si-rich glass inclusions in low-calcium olivine have strongly reduced calcium and elevated concentrations of titanium, sodium, potassium, phosphorus, chlorine, and high incompatible trace elements. We argue that the observed compositional anomalies are mineralogically controlled, and thus may arise from the interaction between hot MORB magmas and crystal cumulates in the oceanic crust or magma chamber.

The behaviour of chlorine in evolved magmas is important for understanding origins of related ore deposits. Submarine volcanic glasses from the eastern Manus Basin of Papua New Guinea, ranging from basalt to rhyodacite, are used to clarify the geochemical behaviour of chlorine in arc-type magmas. For the Manus samples, chlorine is well correlated with non-volatile, highly incompatible trace elements, suggesting it was not highly volatile and discounting significant seawater contamination. The chlorine (Cl) partition coefficient is close to, but slightly lower than, that of niobium (Nb) and K₂O, a behaviour similar to that in MORB and ocean island basalts (OIB). The similar incompatibilities of chlorine and niobium imply that the Cl/Nb values of the eastern Manus Basin glasses reflect their source. For glasses from other west Pacific back-arc basins, Cl/Nb, Ba/Nb, and U/Nb increase towards the trench, indicating increased contribution of a component enriched in chlorine, barium, uranium and possibly economic metals. It is estimated that ~80% of the chlorine in the Manus arc-type glasses was added directly from subducted slab-derived fluids. Our study suggests that, at early stages of magmatic evolution, for magmas with initial H₂O content of < 4.0 wt%, chlorine is highly incompatible at all pressures. By contrast, for more evolved magmas at moderately high pressures and high H₂O contents, considerable amounts of chlorine can be extracted from the magma once H₂O saturation occurs. Accordingly, chlorine is usually highly incompatible in MORB and OIB because of their low H₂O contents and relatively low degrees of fractional crystallisation. The behaviour of chlorine in arc magmas, and related separation of metal-enriched brines, is more complicated, ranging from highly incompatible to compatible depending on H₂O content and magma chamber depth.

Several projects address the physical effects of volatile composition and abundance on eruption dynamics of felsic magmas. These projects focus on felsic volcanic successions that are well constrained in terms of setting, age and facies characteristics. The physical properties of samples from young sea-floor rhyolitic lava domes of the Izu-Bonin Arc south of Japan have been determined by Sharon Allen, and collaborators Yoshi Tamura (Institute for Frontier Research on Earth Evolution), Richard Fiske (Smithsonian Institution) and Kathy Cashman (University of Oregon). They have shown that dome pumice vesicularity is identical to that of subaerial pyroclastic pumice, and concluded that the eruption environment is the key control on eruption style. A paper on the subject has been submitted to *Earth and Planetary Science Letters*.

Sarah Gordee continued her PhD research on submarine rhyolitic

pumice-rich successions on Milos (Greece) determining the lithofacies characteristics and internal architecture. She visited Katherine Cashman's laboratory at the University of Oregon (USA) to measure the porosity and permeability of selected pumice samples collected from two texturally contrasting pumice-rich successions. These data are being combined with field observations in a manuscript focusing on the eruption and transport mechanisms, and their influence on the resultant volcanic facies.

Sarah embarked on a wider investigation of submarine volcanic facies architecture involving mapping and textural analysis of numerous diverse facies that are well-exposed on the southern Izu Peninsula (Japan). This research is being conducted in collaboration with Kenichi Kano (Shizuoka University, Honshu, Japan) and Richard Fiske (Smithsonian Institution, USA) and aims to develop a comprehensive and realistic model of the volcanic facies architecture of submarine arc successions.

PhD student Martin Jutzeler joined CODES midway through 2007 to undertake a project focussing on magmatic-volatile-driven, submerged, explosive eruption plumes and their products. His project involves field and laboratory data from a variety of submarine rhyolitic pumice breccia successions including examples in the Manukau Subgroup (New Zealand), the Shirahama Group (Izu, Japan) and the Ohanapecosh Formation (Washington, USA). Although only a few metres thick, the New Zealand pumice breccia is remarkably complex, including products of both pumiceous eruption-fed gravity currents and water-settled fall. Martin's field research in the Shirahama Group has led to the discovery that the very famous Dogashima ‘fall-signature’ unit has the characteristics of a syn-eruptive submarine pyroclastic gravity current and also contains juvenile andesite derived from an active seafloor dome or lava. Fieldwork in the Ohanapecosh Formation is planned for 2008.

We are also investigating felsic magmas that were generated in markedly different settings and that produced unusually voluminous rhyolitic lavas, as well as diverse pyroclastic facies. This research is centred on the Mesoproterozoic Gawler Range Volcanics and co-magmatic granitoid plutons of the Hiltaba Suite in South Australia, and is conducted in collaboration with Primary Industries and Energy South Australia. The province hosts the giant Olympic Dam gold-copper-uranium deposit. Two papers generated by this project were published in the *Journal of Volcanology and Geothermal Research*. Sharon Allen and co-authors provided a comprehensive account of the architecture and evolution of the Gawler Range Volcanics. Jocelyn McPhie and co-authors presented new anisotropy of magnetic susceptibility data that can be used to find the source location of the Eucarro Rhyolite, a widespread lava in the upper Gawler Range Volcanics.

PhD student, Andrea Agangi, has been mapping and sampling the Glyde Hill Volcanic Complex, one of the main successions in the lower Gawler Range Volcanics. Andrea has conducted a detailed study of quartz populations in both intrusive and volcanic rocks (lavas and ignimbrites) as a means of tracking the physical and chemical processes that accompany magma crystallisation. Andrea has discovered complex crystallisation histories using an electron microscope equipped with a cathodoluminescence detector (CL-SEM) that reveals internal growth zones. Low-detection-limit analyses of quartz phenocrysts show that titanium concentration, in particular, correlates with CL intensity. titanium substitution for silica within silica tetrahedra is favoured by increasing temperature and its uptake has implications for the crystallisation conditions.



Andrew McNeill checking the map during fieldwork on the Dovyren ultramafic-mafic massif in Siberia. Project P1.F4.

Andrea has also measured magma temperatures based on the homogenization temperatures of melt inclusions in quartz. The results span a wide range, in the region 850°–1050 °C. The higher temperatures are similar to estimates for units in the upper Gawler Range Volcanics based on pyroxene and feldspar equilibria, but the lower temperatures were unexpected and are being investigated further.

P1.F4 Nickel-PGE potential of mafic and ultramafic magmas – a combined melt inclusion and numerical modelling approach

Project Leader: L Danyushevsky

Project Members: A Crawford, S Feig, J Foster, V Kamenetsky, A McNeill

Collaborators: A Ariskin (Vernadsky Institute, Moscow), E Konnikov (Institute of Experimental Mineralogy, Moscow)

The project is an AMIRA/CODES (ARC)-funded project. Funding within P1.F4 is CODES contribution to the project as outlined in the approved project budget.

The main objectives of the project include:

1. A better understanding of the potential of various mafic/ultramafic magmas to form magmatic sulfide deposits. Can any mantle-derived magma produce a deposit providing other requirements are met, or are there some magmas that cannot? How can these be differentiated?
2. An improved understanding of the S-saturation histories of mafic magmas and their effect on the ability of magmas to form deposits of economic grade and size.
3. A better understanding of those processes during magma evolution responsible for the formation of a sufficient mass of sulfide to form a deposit, if all other conditions are met. In other words, what processes are required for a nickel-rich magma to form a major sulfide nickel deposit?
4. A better understanding of when and why sulfides are concentrated during magma evolution.
5. Improved criteria for the nickel-PGE fertility of mafic/ultramafic complexes in different tectonic settings.

The project has three modules:

1. The study of sulfide micro-inclusions in olivine phenocrysts in about 30 basalt samples from a range of tectonic settings.
2. Field and laboratory (bulk-rock geochemistry, mineralogy, isotope, and silicate and sulfide micro-inclusion) studies of a well-preserved volcanic-intrusive complex with known nickel-copper-PGE mineralisation (the Dovyren complex in eastern Siberia).
3. The numerical modelling of magma evolution. An existing software package (COMAGMAT) will be expanded to allow the modelling of fertile mafic complexes that have complex crystallization histories.

The project started on 1 March 2007. The first sponsors' meeting was held in Hobart in March 2007, when the research program was discussed and approved.

The first field season at the Dovyren magmatic complex (Siberia) was run in July–August 2007. The field work achieved all approved aims of the project. The shipment of samples from Russia to Hobart has been organised, but is taking longer than planned.

All three modules of the project have begun and the project is on track to fulfil its aims.

Collaborator Prof. Konnikov visited CODES for two months in November/December 2007.

P1.F5 Global ocean chemistry, marine basins and mineralisation

Project Leader: P McGoldrick

Project Member: S Bull

Student: R Maier

Collaborators: P Emsbo (US Geological Survey), T Lyons (University of California, Riverside)

This project aims to decipher the processes that controlled the sulfur chemistry and redox state of oceans that existed in northern Australia approximately 1.65 billion years ago, and to understand how coeval ocean water interacted with hydrothermal fluids responsible for forming the giant northern Australian Proterozoic sedex zinc-lead-silver deposits.

The main outcomes from new work in 2007 were:

1. A group of researchers from CODES, UC-Riverside and the USGS undertook field work in southern McArthur Basin, sampling key sections of the Barney Creek Depositional Cycle (BCDC) for carbonate-associated sulfur (CAS) work, and visiting McArthur River Mine open pit operation for the first time.
2. Peter McGoldrick spent two weeks at McArthur River Mine in mid-September to log and sample new core through the hangingwall of the HYC deposit; these cores will provide unique insights into a waning giant mineralising system.
3. A paper by Peter McGoldrick, Tim Lyons and Poul Emsbo entitled 'Microbes, sedex deposits and siderophile seawater at ~1.65 Ga in northern Australia' was presented at Goldschmidt2007 in Cologne.
4. Samples from a stratigraphic profile from the Century deposit have been obtained for conventional and laser S-isotope studies.

P1.F6 ARC Discovery Project and Australian Professorial Fellowship (DP0555984)

Unmixing in magmas: Melt- and fluid-inclusion constraints on identity, timing and evolution of immiscible fluids, salt and sulfide melts

Project Leader: V Kamenetsky

Students: A Agangi, A Bath, O Vasyukova

Collaborators: A. Crawford, K Goemann, M Kamenetsky, S Meffre, R Maas (University of Melbourne), A Golovin, V Sharygin, S Smirnov (Institute of Geology and Mineralogy, Novosibirsk, Russia), V Batanova, V Naumov, A Sobolev (Vernadsky Institute of Geochemistry, Moscow, Russia), M Elburg (Ghent University, Belgium), C Ballhaus (University of Bonn, Germany), WD Sun (Guangzhou Institute of Geochemistry, PRC), O Navon (Hebrew University, Jerusalem, Israel).

Several studies were devoted to deciphering compositions and evolutionary paths of kimberlitic magmas, the deepest terrestrial magmas and the principal source of diamonds (publications in *Chemical Geology*, *Geophysical Research Letters*, *Journal of Petrology*, *European Journal of Mineralogy*). Special emphasis was on the immiscible nature of chloride and carbonate liquid components in the kimberlite magma, which must have low viscosity and high buoyancy to account for exceptionally fast transport from mantle depths to the surface.

The source of saline metal-bearing aqueous fluids is assumed to be potentially characterised by the isotopic composition of chlorine. Our study, published in *Nature*, concluded that the chondritic (solar system), mantle and crustal chlorine isotope compositions are all nearly identical, and that there has been no variation in the crustal isotopic composition through time. Our new data eliminate some unreasonable restrictions on Earth formation mechanisms if different Earth reservoirs had distinct chlorine isotope values.

Separation of immiscible volatile-rich phases from crystallising magmas is believed to be a driving force behind catastrophic eruptions. Magmatic gases control vesicularity and fragmentation processes of the magma and consequently the style of the eruptions. Mount Etna is one of the world's most actively degassing volcanoes, yielding ~10% of the global CO₂ and SO₂ fluxes. However, because volatiles are almost completely degassed during subaerial eruption, it is difficult to measure pre-eruption volatile concentrations directly. One way around this problem is to analyse tiny samples of undegassed melt trapped inside of phenocrysts. The results on unique picritic magmas, eruption of which marked the beginning of the vigorous volcanic activity of Mount Etna, and olivine-hosted melt inclusions provide explanations for the 'behind the scenes' processes and controls in the volcano's conduit (publication in *Geology*).

The formation of immiscible sulfide melts during the evolution of picritic and basaltic melts is a longstanding problem that requires understanding of melt compositions with respect to sulfide saturation, oxygen fugacity and consequences of melt degassing and contamination. We concluded (paper in *Contributions to Mineralogy and Petrology*) that siliceous melt compositions (up to 58 wt% SiO₂) in the mid-ocean ridges can originate from the interaction between hot MORB magmas and crystal cumulates in the oceanic crust or magma chamber, and thus be responsible for sulfide saturation.



PhD Student Teera Kamvong standing on a gossan at the Put1 deposit, northern Thailand. Project P1.L1.

Several other petrological, mineralogical and melt inclusion studies were also directed at understanding of melt and fluid compositions in different tectonic settings ('The origin of medium-K ankaramitic arc magmas from Lombok, Sunda arc, Indonesia', published in *Chemical Geology*; 'Compositional diversity among primitive lavas of Mauritius, Indian Ocean: implications for mantle sources', *Journal of Volcanology and Geothermal Research*; 'Survival times of anomalous melt inclusions: Constraints from element diffusion in olivine and chromite', *Nature*) and the role of mantle sources and their respective magmas in contributing to Ni-sulfide deposits ('The amount of recycled crust in sources of mantle-derived melts', *Science*).

P1.L1 Geochronology, metallogenesis and deposit styles of Loei Foldbelt in Thailand and Laos PDR

Project Leader: Khin Zaw

Project Members: S Golding, S Meffre

Students: T Kamvong, T Manaka, A Salam

Collaborators: S Khositantont (Department of Mineral Resources, Thailand)

The Loei Fold Belt (LFB) project was undertaken from 2004 to 2006. The LFB is a N–S-trending arcuate magmatic-volcanic belt located between the Shan–Thai and Indochina terranes in mainland SE Asia. It hosts a variety of copper-gold deposits, such as epithermal gold, copper-molybdenum porphyry, mesothermal/skarn gold-copper and porphyry/skarn copper-gold systems. The project examined the age, style and origin of ore deposits in the LFB in relation to regional magmatic and tectonic processes, aiming to improve the geological and geochronological framework for exploration in the area.

We studied the entire belt using modern geological/geochemical and analytical techniques, focussing in particular on LA-ICPMS U-lead zircon geochronology, but also doing detailed studies on geochemistry, mineralogy and paragenesis of major copper-gold deposits. The final field sponsors meeting for the project was held in Phisanulok, central Thailand, on 8 February 2007, at which we submitted the final report.

For this project, the age, geochemical composition and lithological characteristics of around 140 samples were studied for most of the geological units in the region of interest. Results showed that many of the dated geological units have incorrect ages according to the current geological maps. The results were then synthesized into a revised geological history for the area, and the GIS package was updated. The raw data was summarised into a ‘Geological Atlas’ of the LFB detailing the textures, chemistry, affinity, location and age of each of the rocks analysed. The project also involved training two PhD, two MSc and four Honours students.

This project has had a significant impact on the scientific understanding of the geology and plate tectonic and mineralisation history of LFB and SE Asia. We have formulated a new geological history and time-space relationship for the LFB based on our new, robust data. The outcome and results of this successful project provide a modern geological data set to help our sponsors with target selection and regional exploration, and add to the broader scientific understanding of the geodynamic development of SE Asia.

In 2007, sponsors provided additional funding for further work on integrating the new tectonic framework with mineralisation and magmatism, and to highlight the exploration implications of our work. Additional LA-ICPMS lead-isotope and pyrite trace-element geochemical studies were undertaken, and ore deposit models for major copper-gold deposits in the LFB were also summarised into an ‘Ore Deposit Atlas’. In September 2007, we submitted a supplementary report to sponsors indicating that the lead-isotope data can be used to distinguish the nature and source of hydrothermal fluids associated with different styles of copper-gold deposits in the LFB. New data also suggested that the pyrite trace-element chemistry can be a potential tool for differentiating barren from mineralised hydrothermal systems.

In September 2007, we circulated an ‘Ore deposits of SE Asia’ project proposal to potential sponsors, proposing to extend the LFB work to the whole of SE Asia. Six sponsors have joined the project.



Leonid Danyushevsky, Professor Xieyan Song, mine geologist and Tony Crawford in Panzihua Fe-Ti-V mine in Panzihua Layered Intrusion, China. Project P1.F1.

Michael Baker: Palaeoproterozoic magmatism in the Georgetown Block, North Queensland, and comparisons with Broken Hill Block (graduated 2007)

Susan Belford: Genetic and chemical characterisation of the Archaean Jaguar VHMS deposit, WA

Sang Quang Dinh: Geochronology and geological evolution of the northern Khontum massif, Vietnam

Sarah Gordee: Characteristics of subaqueous pyroclastic facies in arc settings

Martin Jutzeler: Behaviour of submergred eruption plumes using data from facies analysis of submarine pyroclastic successions

Teera Kamvong: Geology and genesis of porphyry-skarn copper-gold deposits at the northern Loei Foldbelt, northeast Thailand and Laos

Rodney Maier: Pyrite and base-metal trace-element halos in the Northern Australia Zn-Pb-Ag deposits

Carlos Jose Paulino Rosa: Submarine volcanic successions in the Iberian Pyrite Belt, Portugal

Abhisit Salam: Origin and setting of the Chatree gold deposit, central Thailand

Weerapan Srichan: Petrology, geochemistry and tectonic significance of late Palaeozoic and Mesozoic volcanic and volcanoclastic rocks in the Chiang Khong-Lampang-Tak volcanic belt, northern Thailand

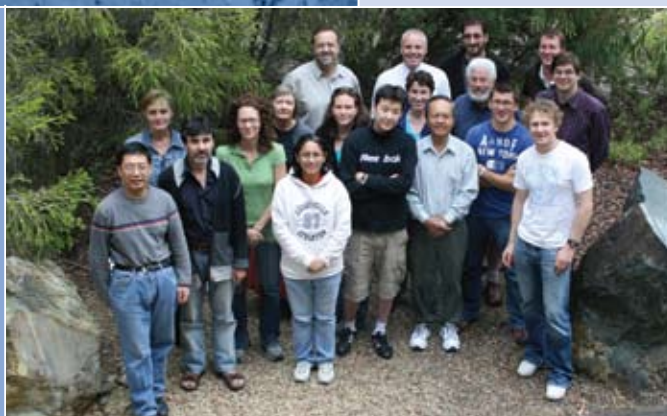
Sofia Tetroeva: Magmatism on the Hunter Ridge, SW Pacific

Olga Vasyukova: Types and origins of quartz and quartz-hosted inclusions in mineralised porphyries.

PhD projects in program 1

Andrea Agangi: Magmatic and volcanic evolution of giant intraplate felsic igneous provinces and associated ore deposits: Gawler Range Volcanics and Hiltaba Duite, South Australia

PROGRAM 2



Objective ... to develop practical, process-based exploration models for hydrothermal and magmatic ore deposits that will help increase discovery rates for Australia's mineral resources

TEAM LEADER

David Cooke



TEAM MEMBERS

Ron Berry, Thomas Bissig*, Stuart Bull, Claire Chamberlain*, Zhaoshan Chang, Stephen Cox*, Tony Crawford, Leonid Danyushevsky, Garry Davidson, Greg Dipple*, Grant Garven*, Bruce Gemmell, Sarah Gilbert, Jacqueline Halpin, Anthony Harris, Janet Hergt, Chris Hollitt, Dima Kamenetsky, Khin Zaw, Lyudmyla Koziy, Ross Large, Valery Maslennikov, Peter McGoldrick, Jocelyn McPhie, Sebastien Meffre, Christian Schardt*, Robert Scott, David Selley, Kirstie Simpson, Mike Solomon, Dick Tosdal*, Jon Woodhead

(* partner research organisation team member)

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MEconGeol STUDENTS

Jenny Catoc, Yansan Jamyanbaatar

HIGHLIGHTS

Completion of a highly successful three-year research project into the controls on the formation and sulfide trace-element signatures of sediment-hosted gold deposits.

New discoveries of submarine high-sulfidation massive sulfide mineralisation from an oceanographic survey of Palinuro Seamount, Tyrrhenian Sea, Italy.

Completion of the first-ever study into rates of both hypogene and supergene porphyry copper-gold mineralisation, uplift and burial in a tropical island-arc setting.

New models for the stratigraphic architecture and structural geometries of host rocks, cover rocks and mineralised intrusions in the Cadia porphyry Au-Cu district, NSW.

Initiation of a new CODES publication, *Breccia Textures*, which will help researchers and explorers describe and interpret breccias in hydrothermal environments.

COLLABORATORS

Anglo American Philippines – Paddy Waters
Australian National University – Charlotte Allen, Ian Campbell
Barrick Gold of Australia Pty Ltd (Porgera Operations)
Chinese Academy of Geological Sciences – Zengqian Hou
CSA Australia Pty Ltd – Rupert Crowe, Glenn Whalan, Nigel Wilson, Warren Woodhouse
CSIRO, Melbourne – Chris Ryan
Alfredo Ferreira
Orlando C. Gaspar
Geological Survey of Canada – Jan Peter
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IFM-GEOMAR – Sven Petersen
IGM, Portugal – Carlos Inverno
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Nanjing University – Lianxing Gu
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NorthParkes Mines
Primary Industries NSW – Ian Percival
Queens University – Dan Layton-Matthews
Russian Academy of Science – Valeriy Maslennikov, Svetlana Maslennikova
Somincor, Portugal – Gonçalo Barriga, Paulo C. Noiva, Nelson Pacheco
Teck Cominco – Andrew Davies
United States Geological Survey – Poul Emsbo
University Huelva – Reinaldo Saéz, Manuel Toscano
University of Alberta – Robert Creaser
University of British Columbia – Jim Mortensen
University of Malaya – Azman Ghandi, Teh Guan Hoe
University of Ottawa – Mark Hannington, Thomas Monecke

CORE PROJECTS

Porphyry copper-gold-(molybdenum) deposits P2.F1

Base-metal mineralisation in sedimentary basins P2.F2

Volcanic-hosted massive sulfide deposits P2.F3

District- to deposit-scale structural and geochemical evolution of the Cadia porphyry gold-copper deposits, NSW P2.L1

Controls on the formation and sulfide trace-element signatures of sediment-hosted gold deposits (AMIRA P923) P2.L2

Shallow and deep-level alkalic mineral deposits P2.L3

Genesis of the giant Sukhoi Log gold deposit, Siberia P2.L4

Phase and chemical composition of high-temperature hydrothermal systems undergoing interaction between silicate rocks/magmas and aqueous fluid P2.N1

Zinc and gold mineralisation in the Caijiaying deposit: geologic characteristics and genesis P2.N2

Polymetallic mineralisation and associated magmatic and volcanic activity in the Luzong basin, middle and lower Yangtze River, eastern China P2.N3

Breccia Textures. P2.N4

(F prefix denotes fundamental research project; L prefix denotes industry-linked project; N prefix denotes new initiative project)

P2.F1 Porphyry copper-gold-(molybdenum) deposits

Project Leaders: S Cox (ANU), D Cooke

Project Members: Z Chang, T Crawford, A Harris, V Kamenetsky, R Large, A Halfpenny (ANU)

PhD Students: D Braxton, B Jones, F Urzua

MEconGeol Students: J Catoc, Y Jamyanbaatar

Collaborators: Barrick Gold of Australia Pty Ltd (Porgera Operations), P Waters (AngloAmerican Philippines), NorthParkes Mines

This project now encompasses two sub-projects: (1) 'Effects of stress states and fluid pressure regimes on fluid dynamics and evolution of fluid compositions within intrusion-related hydrothermal systems,' and (2) 'Characterisation of porphyry deposits and their environments.'

In sub-project 1, we aim to:

- document geometries and styles of vein systems and their overprinting relationships around several different styles of mineralised intrusive complexes
- explore how stress states, stress field orientations and fluid pressures evolve during the development of intrusion-related hydrothermal systems, within the framework of our developing understanding of the dynamics of stress and fluid pressure regimes in contemporary, active magmatic systems
- explore the implications of these results for understanding the evolution of fracture-controlled hydrothermal fluid pathways and reactions, and determine impacts on the distribution of economic mineralisation in intrusion-related hydrothermal systems.

A shortage of suitably qualified PhD graduates delayed full implementation of the program, but in mid-2007 we appointed Angela Halfpenny (formerly University of Liverpool) and she arrived at ANU to take up her three-year appointment in January 2008 to commence the field-based research program.

The major focus of our initial field studies will be the evolution of fracture-controlled flow systems, and associated stress fields, deformation processes and fluid pressure states during the development of the Porgera gold deposit in PNG. Fieldwork will document the geometries and distribution of veins in these several case studies and use the geometry of vein systems to better understand the dynamics of changes in stress regimes in the evolving, intrusion-related hydrothermal system and thereby better understand factors controlling vein distribution, style, abundance, size and spacing.

Laboratory-based studies will document deformation processes associated with vein formation and employ SEM-based cathodoluminescence and electron backscatter diffraction techniques to complement optical microscopy studies to produce a rigorous understanding of mineral paragenesis. The structural studies will be combined with studies of vein mineralogy, associated hydrothermal alteration and evolving fluid chemistry in these systems to explore how the dynamics of the evolution of fluid pathways and reactions can influence the generation of well-endowed intrusion-related ore systems.

In sub-project 2, CODES has several graduates working on the characteristics and genesis of porphyry-related mineral systems. Ben

Jones is working on the Antapaccay porphyry copper-gold deposit in Peru (supported by BHP Billiton), and is well-advanced in his geochemical data collation and analysis. Ben gave an invited presentation on Antapaccay at the 'Ores and Orogenesis' symposium in Arizona in October. Felipe Urzua has completed the first draft of his PhD thesis on the regional geology of the Escondida porphyry copper-molybdenum district, Chile (supported by BHP Billiton) and is expected to submit his thesis in early 2008.

A major highlight of 2007 was the completion of David Braxton's PhD thesis on the Boyongan copper-gold deposit, Philippines. Dave achieved an excellent examination result. Several publications are anticipated from this broad-ranging thesis, which covered the hypogene genesis, exhumation, burial and supergene mineralisation history of one of the world's youngest porphyry deposits. This is the first-ever detailed study of the genesis and rate of both hypogene and supergene porphyry copper-gold mineralisation in a tropical island arc setting. Such was the significance of this work that Dave was invited to give a presentation at the SEG supergene symposium at the 'Ores and Orogenesis' conference in September 2007. Dave has shown that after the Boyongan deposit formed 2.3 million years ago, it was then uplifted and eroded, forming the world's thickest-known supergene copper mineralisation profile from a porphyry deposit. Boyongan was subsequently buried beneath a lake and covered by an active stratovolcano, and possibly inundated by the ocean during a period of global cooling. The results of this thesis have wide-ranging implications for our understanding of how quickly changes can occur to mineralising systems in subduction-related oceanic island arc settings, and how quickly supergene resources can form. A new PhD project on the Surigao district has been developed to follow on from Dave Braxton's PhD study, and a student is being sought to commence work on this project in 2008.

Two new Masters of Economic Geology students commenced research on porphyry deposits in 2007. Jenny Catoc began a study of the newly-discovered Aisaijur porphyry copper-gold prospect in Irian Jaya, Indonesia, supported by AngloAmerican (Philippines). Yansan Jamyanbaatar is being sponsored by Rio Tinto (Mongolia) to undertake a study of the E48 porphyry copper-gold deposit in NSW.



Gas venting textures from the Hall molybdenum-porphyry deposit, SW USA. Project P2.F1.

P2.F2 Base-metal mineralisation in sedimentary basins

Project Leaders: G Garven (Johns Hopkins U), S Bull

Project Members: C Schardt (Johns Hopkins U), D Cooke, L Koziy, R Large, P McGoldrick, D Selley

Collaborators: Johns Hopkins University, Colorado School of Mines

This project investigates the nature of fluid flow and the role of evaporitic salts in the formation of sedimentary ore deposits such as the Central African Copper Belt, European Kupferschiefer, the Proterozoic stratiform zinc orebodies of northern Australia and modern hydrothermal analogs such as the Red Sea hydrothermal systems. The project attempts to resolve the following questions:

- Do ore-forming brines in sediment-hosted base-metal systems have a common heritage?
- If so, why do we see remarkably diverse alteration styles and metal associations? Are they related to brine composition, process or the environment?
- Which intra-basinal brines are involved in ore formation: residual brines or evaporite dissolution brines?
- Are different metal tenors in different provinces a function of brine evolution, basin fill composition, varied depositional processes, or some combination of these?
- Are there important stages of brine evolution that control the development of fertile vs infertile basin systems?

This project uses three numerical models to investigate certain aspects of the Red Sea hydrothermal systems. These models were constructed based on published data of stratigraphy (basement, evaporites, marine sediments and basalt). Boundary and initial conditions as well as rock properties are based on literature data.

Due to the difficulty of combining fluid flow in porous media (Darcian Flow) and free convection in open water, work on the third model is still in progress. We are currently in the process of determining whether a combined simulation is feasible or if separate computer simulations will be employed to compare modelling results (fluid discharge) with field observations (brine pool characteristics).

Preliminary results indicate that the mixing of the discharging hot fluids with local sea water leads to a rising hydrothermal plume that eventually reverses buoyancy and ponds into the seawater-filled depression. We need to improve the modelling software so it can effectively mimic the development of layers within the brine pool.

P2.F3 Volcanic-hosted massive sulfide deposits

Project Leaders: B Gemmell, M Solomon

Project Members: R Large, Khin Zaw, L Danyushevsky, K Simpson, G Davidson

Students: K Denwer, R Fulton, P Sack, S Belford

Collaborators: C Ryan (CSIRO, Australia), T Mernagh (Geoscience Australia), R Saéz and M Toscano (U Huelva), C M C Inverno (IGM,

Lisbon), N Pacheco, P C Noiva and G Barriga (Somincor, Portugal), O C Gaspar and A Ferreira (Consultants, Portugal), M Hannington (U Ottawa), J Peter (Geol Surv Canada), D Layton-Matthews (Queens U), S Piercey (Laurentian U), T Monecke (U Ottawa), S Petersen (IFM-GEOMAR), V Maslennikov and S Maslennikova (Russian Academy of Science-Urals Branch), Z Hou (Chinese Academy of Geological Sciences, Lianxing Gu (Nanjing U), A Ghandi and T Guan Hoe (U Malaya), J Mortensen (U British Columbia)

This project encompasses four sub-projects:

1. The nature and origin of fluids that form high-salinity, volcanic-hosted massive sulfide deposits
2. The nature, diversity and genesis of volcanic-hosted copper-lead-zinc-silver-gold massive sulfide deposits
3. Hydrothermal event recognition and target vectoring in sedimentary strata for volcanic-hosted and sedex massive sulfide deposits
4. Active base- and precious-metal-rich massive sulfide-sulfate deposition associated with submarine volcanism.

For sub-project 1, a review of the ores and geology of the Bathurst mining camp, New Brunswick, has been completed and a paper proposing brine-pool deposition is in press in *Economic Geology*. An additional paper discards propositions that the ocean at the time of mineralisation was anoxic. Laser Raman spectroscopy and PIXE analyses have been carried out on a number of fluid inclusions from the Hellyer and Aznalcollar massive sulfide stockworks. The Raman studies revealed CO₂/CH₄ inclusions in the latter, only CO₂ in the former, while the PIXE data are currently being processed by the CSIRO. Textural studies of 60 samples from the Lombador orebody of the Neves Corvo deposit in Portugal have shown that the orebody formed on the sea floor, and that most of it is fragmental, with little reworking, probably due to small-scale, intermittent tectonic disruption during mineralisation. Seventy isotope analyses of sulfide sulfur (both conventional and laser ablation) from Lombador indicate a mantle derivation for most ore sulfur, with a component derived by biogenic reduction of ambient seawater sulfate during the final stages of mineralisation. The main isotope signature is similar to that seen in the granite-derived Sn and Sn-W ores of eastern Australia.

Sub-project 2 is investigating the spectrum of massive sulfide deposit types, from typical seafloor VHMS (zinc-lead-copper-silver-gold) deposits, through sub-seafloor shallow-water, replacement gold-rich epithermal styles, to deep sub-volcanic intrusion-related copper-gold-rich styles. In 2007 a new project aimed at dramatically improving the age and geochronological constraints on the development of the Mount Read Volcanic Belt (MRV), was initiated with Jim Mortensen (UBC). In June sampling was undertaken of all major lithological units (28 samples in total) throughout the stratigraphic sequence of the MRV and all samples were shipped to UBC for sample preparation and dating. Zircons have been recovered from every sample and U/lead dating of the zircons is proceeding. A few hornblendes recovered from several samples are being dated using argon/argon. This very exciting project is anticipated to yield significant results that will constrain the timing of the development of the MRV and associated VHMS mineralisation. Other sub-project 2 research was undertaken on the Jaguar (Western Australia), Greens Creek (Alaska), Yaman-Kasy (Russia), Hongtoushan and Baiyinchang (China) and Tasik Chini (Malaysia) deposits in 2007.

Sub-project 3 will investigate the sulfide-bearing, carbonaceous (graphitic), argillaceous sedimentary rock horizons that are a minor but ubiquitous feature of marine volcanic successions in ancient greenstone belts and in the modern seafloor environment. This new AMIRA-CAMIRO (Canadian Mining Industry Research Organization-Exploration Division) project is currently in development. It aims to provide an improved understanding of the concentrations and behaviour of trace metals associated with volcanic-hydrothermal processes in marine sedimentary and volcano-sedimentary successions and to develop new tools (mineralogical, geochemical, isotopic) to discriminate potentially mineralised versus unmineralised horizons in many mineralised districts. A key objective is to develop vectoring methodologies for exploration. Studies are planned or underway in the Abitibi greenstone belt, the central volcanic belt of Newfoundland, the Selwyn Basin and Finlayson Lake (Yukon), at Eskay Creek and Myra Falls (British Columbia), at Greens Creek (Alaska), and the MRV (Tasmania). Other districts will be considered based on industry interest and accessibility. The leader of sub-project 3 will be Steve Piercey (Laurentian University) with key researchers being Bruce Gemmell, Mark Hannington (University of Ottawa), Wayne Goodfellow and Jan Peter (Geological Survey of Canada) and Dan Layton-Matthews (Queens University).

For sub-project 4, Bruce Gemmell and Kirstie Simpson participated in a research cruise to investigate Palinuro Seamount in the Tyrrhenian Sea, Italy. This was organised by the Leibniz Institute of Marine Sciences at Kiel University (IFM-GEOMAR, Germany). Palinuro represents a complex submerged arc volcano that consists of several coalesced eruption centres located along an E–W-trending fault system. The Meteor cruise M73/2 used a robotic, lander-type drill to gather information from the sub-seafloor (<5 m). At Palinuro Seamount 13 holes (<5 m) were drilled in a closely spaced grid into the heavily sediment-covered deposit recovering 11 m of semi-massive to massive sulfides. Maximum recovery within a single core was 4.8 m of massive sulfides/sulfates with abundant late native sulfur overprint. The deposit is open to all sides and to depth since all drill holes ended in mineralisation. Metal enrichment at the top of the deposit is evident in some cores with polymetallic (zinc, lead, silver) sulfides overlying more massive and dense pyritic ore. The massive sulfide mineralisation contains enargite, tennantite, luzonite, and silver-sulfosalts, minerals that are not commonly encountered in mid-ocean ridge massive sulfides. In analogy to epithermal deposits forming on land, the occurrence of these minerals suggests a high-sulfidation state of the hydrothermal fluids during deposition, implying that the mineralising fluids were acidic and oxidising rather than near-neutral and reducing. Two abstracts detailing the preliminary results from the cruise were published in 2007.

Project P2.F4: Iron oxide copper-gold and related deposit types

Project Leader: GJ Davidson

Project members: Khin Zaw, S Meffre, R Berry, R Large

Students: B Bowden, C McMahon, B Singoyi.

Collaborators: R Skirrow, E Bastrakov (Geoscience Australia), P Hiethersay (PIRSA), Z Bonyadi, B Mehrabi (Tabiat Moalem University, Iran), S Smith (Oxiana Minerals), R Goad (Fortune Minerals)

This project evaluates the origins of iron oxide copper-gold (IOCG) and related ore systems. Current field sites are Prominent Hill (Mt Woods Inlier, South Australia), Oak Dam (Gawler Craton, Olympic metallogenic province), Sechahun deposit (Bafq district, Iran; Fe-only), Tennant Creek (NT), and NICO deposit (Great Bear Magmatic Province, Canada). An investigation of sulfur systematics is also occurring in the related project P5.F8. 2007 was the culmination of a collaboration with Geoscience Australia on the Gawler Craton, in which CODES contributed mainly stable-isotope source tracing and radiogenic-dating expertise, in addition to a case study at the Oak Dam East Cu-U-(Au) prospect. 'A Special Issue devoted to Proterozoic iron oxide Cu-Au-(U) and gold mineral systems of the Gawler Craton, South Australia' was published in *Economic Geology* in December 2007 with Roger Skirrow and Garry Davidson as guest co-editors. Project members were co-authors on four of the nine papers presented. The collaboration is continuing with a major deposit study at Prominent Hill; this work is the PhD topic of Bryan Bowden, but is being supported in-kind by Geoscience Australia, with financial support from Oxiana, Goldstream and PIRSA. Trace-element studies continued on pyrite and magnetite in some IOCG systems as part of the PhD studies of Claire McMahon and Blackwell Singoyi, respectively.

P2.L1 District- to deposit-scale structural and geochemical evolution of the Cadia porphyry gold-copper deposits, NSW

Project Leaders: D Cooke, R Berry, A Harris

Project Member: J McPhie

Students: A-L Cuisson, N Fox, W Reynolds, M Washburn

Collaborators: R Tosdal (MDRU); J Holliday, D Collett, I Tedder, C McMillan, G Smart (Newcrest Mining Limited); I Campbell, C Allen (ANU), I Percival (Primary Industries NSW), K Faure (IGNS), R Creaser (U Alberta)

CODES, with industry partner Newcrest Mining Ltd, is working towards a better understanding of the architecture of Australia's premier porphyry district, Newcrest's Cadia Valley operations in central New South Wales. The Cadia Valley is one of this country's largest gold producers. It contains several deposits (including the gold-rich Ridgeway alkaline-type porphyry deposit) and has a combined in situ resource in excess of 28 Moz. gold. CODES researchers and Newcrest geologists are working closely together to deconstruct the geometry of porphyry ore systems at the deposit- and district-scale of the Cadia Valley.

For her doctoral thesis, Ana-Liza Cuisson is researching the Ridgeway and Ridgeway Deeps deposits, in order to better constrain controls on porphyry emplacement. She has collected over 600 structural measurements of different vein stages throughout the Ridgeway and Ridgeway Deeps system. This information, together with a new understanding of the intrusive geometry, is proving critical in developing an improved 3D model of Ridgeway.

For his PhD, Nathan Fox is investigating lithological and structural controls on alteration assemblages in the giant Cadia East deposit. His project builds on a previously well-established paragenesis, and aims to enhance our understanding of the spatial distribution of alteration and

mineralisation assemblages to arrive at new models that constrain metal deposition along evolving hydrothermal fluid pathways. Preliminary field investigations have focused on extending the knowledge of alteration assemblages in the upper parts of the Cadia East system. This includes better documentation of lithologically controlled alteration minerals using petrographic and geochemical techniques. Both Nathan's and Ana-Liza's research projects combine structural/geometric, paragenetic, geochemical, mineralogic and isotopic techniques to categorise the different ore fluid stages, identify specific fluid sources, and trace their evolution through, and interaction with, the wall rock (including structures) they once infiltrated.

Benefiting from research outcomes of AMIRA P765 (P3.L2), our research team has documented in detail the distal 'green rock' alteration halo to the gold-rich Ridgeway porphyry system. As part of his honours research, William Reynolds documented subtle textural and geochemical variations that occur proximal to the mineralised zone at Ridgeway. William's research shows that the Ridgeway footprint has a distal expression considerably larger than previously thought.

Malissa Washburn (jointly supervised by MDRU-CODES) has completed detailed mapping of the Silurian rocks that cover the Ordovician porphyry ore deposits in the Cadia Valley. Despite covering

large parts of the district, this cover sequence was poorly documented prior to this study. Malissa's work is providing important new insights into the post-mineral deformation that has partially dismembered the district and juxtaposed different levels of the porphyry copper-gold systems. Detailed reconstruction of the Silurian succession, plus recognition of the hierarchy of faults, is proving vital to the ongoing reconstruction of the syn-mineralisation Ordovician architecture.

Anthony Harris has been unravelling the district-scale architecture and evolution of the Cadia Valley using aspects of structural and economic geology, volcanology, geochronology and geochemistry. Using a newly defined volcanic stratigraphy and intrusive architecture, Anthony has developed an improved understanding of the geometry of the deposits and the rocks that host them, which has led to a new working model for the reconstruction of the events critical to the formation of the porphyry ore deposits, and their subsequent dismemberment.

All research outcomes have been compiled and presented as practical field guides. Forming part of the Cadia Valley 'loggers toolbox', these guides include tools useful in describing volcanic rocks and those used in building the volcanic architecture. Using this newly defined stratigraphy, combined with re-evaluation of chronologic datasets (including collaborative research with geochronologists at ANU and palaeontologists at the Geological Survey of New South Wales), it has become possible to restore the volcanic complex to the time of Ordovician porphyry emplacement.

All research results to date were presented to the industry sponsors at a two-day workshop in Orange, NSW, in October 2007, where the forward program was also discussed. CODES researchers have made a demonstrable contribution to Newcrest's activities in the Cadia Valley. Newcrest geologists have used our findings to modify their in-house logging procedure, including improved documentation of igneous and volcanic rocks, and alteration facies. Implementation of these procedures is needed to take advantage of the newly defined volcanic stratigraphy so that future orebody models and reverse estimations can account for the complex structural dismemberment of the district. The modifications have been warmly accepted.

P2.L2 Controls on the formation and sulfide trace-element signatures of sediment-hosted gold deposits (AMIRA P923)

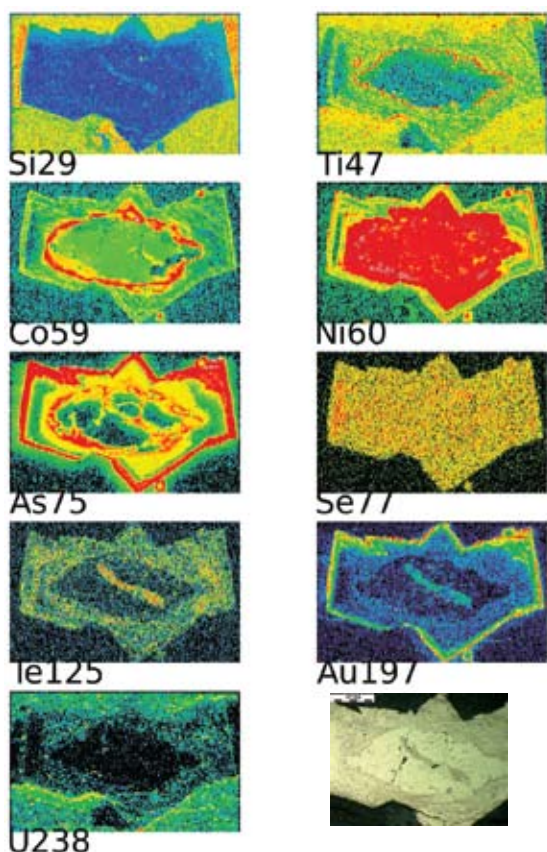
Project Leaders: R Large, R Scott

Project Members: S Bull, S Meffre, Z Chang, J Halpin, S Gilbert, C Hollitt, L Danyushevsky

Students: A Bath, J Blackwell, H Pass, W Zukowski

Collaborators: P Emsbo (United States Geological Survey), V Maslennikov (Russian Academy of Science)

The final meeting of this very successful three-year research project was held in December 2007. The research used advanced trace-element and isotope analytical techniques to investigate the extent, timing and origin of gold enrichment in pyrite in the host rocks to major sediment-hosted gold deposits in Nevada (Carlin District), Siberia (Lena Goldfield) and Central Victoria. In each of these areas, earlier generations of pyrite were,



Trace-element mapping of pyrite from Bendigo determined by LA-ICPMS scanning at CODES. Note the gold concentration in both the diagenetic core of the early pyrite, and the outermost metamorphic rim of the overgrowth pyrite. Projects P3.F2 and P5.F6.



Geothermal discharges in Lienitz open pit, Lihir gold mine. Project P2.L3.

at least locally, partially to substantially preserved through successive episodes of hydrothermal alteration and deformation. Constraints on the timing of pyrite growth based on overprinting relations (e.g., relative to soft-sediment deformation, diagenetic features, cleavages, etc.), dating of radiogenic mineral inclusions, and lead-isotope data enabled complex pyrite paragenesis to be determined. This information, combined with LA-ICPMS data on the trace-element compositions of the various generations of pyrite, has allowed the timing and element associations of gold introduced into these systems to be more fully elucidated.

Current models for gold deposits in the three study areas largely favour a single main episode of gold mineralisation, at a relatively late stage in the local deformation history of the respective areas. In contrast, the results of this study indicate that gold enrichment was protracted, if not episodic, with initial gold introduction early, during or prior to significant deformation of the host rocks. In some cases the initial gold enrichment is best interpreted as an early manifestation of the mineralising systems ultimately responsible for the epigenetic deposits; however in others, clearly distinct episodes of gold mineralisation can be recognised. The broad spatial coincidence of distinct gold mineralisation events in three world-class gold districts highlights the importance of the early enrichment events either for (i) establishing hydrothermal plumbing systems that are, at least in part, exploited in later mineralisation events, or (ii) providing a major source of gold for the later deposits.

P2.L3 Shallow and deep-level alkalic mineral deposits

Project Leaders: D Tosdal (MDRU), D Cooke, K Simpson (CODES/MDRU), C Chamberlain (MDRU), T Bissig (MDRU)

Project Members: Z Chang, G Davidson, B Gemmell, D Kamenetsky, J McPhie, G Dipple (MDRU)

Students: A Bath, J Blackwell, H Pass, W Zukowski, J Micko (MDRU), K Byrne (MDRU), A Henry (MDRU), P Jago (MDRU), M Jackson (MDRU)

Collaborators: G Dipple (MDRU)

Alkalic gold-(copper) deposits include some of the world's highest grade and largest porphyry-related gold resources (e.g., deposits of the Cadia Valley, NSW; Galore Creek, Canada), as well as some of the largest gold accumulations in epithermal settings (Ladolam, PNG; Porgera, PNG; Cripple Creek, USA; Emperor, Fiji). Although alkalic porphyry and epithermal deposits are known from several mineral provinces, particularly in British Columbia and eastern Australia, the quality of individual deposit descriptions in the public domain varies markedly. Thus, there are considerable gaps in knowledge regarding this important deposit type. Building a 3D integrated model for the alkalic porphyry-epithermal environment is the aim of an industry-funded confidential research project involving CODES, MDRU and nine industry sponsors: Amarc Resources Limited, AngloGold Ashanti Limited, Barrick Gold Corporation, Imperial Metals Corporation, Lysander Minerals Corporation, Newcrest Mining Limited, Newmont Mining Corporation, Novagold Resources Inc. and Teck Cominco Limited. Additional financial support has been derived from grants from the Natural Sciences and Engineering Research Council of Canada (NSERC) and Geoscience BC.

Some significant staff changes occurred on this project in 2007. The project coordinator, Claire Chamberlain, left MDRU and the alkalic project to work for Teck Cominco in February. Kirstie Simpson left the Geological Survey of Canada in May but remains part of the alkalic team as a joint research associate with CODES and MDRU. Kirstie spends 50% of her time on the alkalic project and is based at UBC. She guides all volcanic and breccia facies analysis undertaken in this project. She completed field seasons at Lihir, Galore Creek and Mount Polley in 2007. In October, Thomas Bissig, from the Universidad Catolica del Norte (Chile), joined MDRU and the alkalic project as the new project coordinator. He completed a field season at Cowal in November, collecting samples for a geochronological study of the Cowal volcanic complex.

This project involves a large component of higher degree research. Four PhD students (Adam Bath, Jacqui Blackwell, Heidi Pass, Wojciech Zukowski) are undertaking studies based at UTAS. Adam Bath completed a major field season at Lorraine (BC) in July–September. Jacqueline Blackwell completed her second field stint at Lihir (PNG) during the same period. Heidi Pass and Wojciech Zukowski completed their final field seasons at Mount Polley (BC) and Cowal (NSW) in November–December. A new MDRU-based MSc student (Kevin Byrne) joined the team in January, and started work on the SW zone at Galore Creek. Janina Micko (MDRU PhD candidate) completed her second field season on the central zone at Galore Creek. Amber Henry finished fieldwork at E42 (Cowal, NSW) in mid-2007, and is well-advanced in completing the first draft of her thesis. Meghan Jackson (Mount Polley) and Paul Jago (Lorraine) are preparing to defend their MSc theses in early 2008.

The alkalic team's graduate students won several awards in 2007. Adam Bath, Janina Micko and Heidi Pass won Geoscience BC scholarships. Adam Bath and Kevin Byrne both received Society of Economic Geologists scholarships. Amber Henry and Janina Micko received research grants from the Society of Economic Geologists. Paul Jago, Jacqueline Blackwell and Heidi Pass received 'Ores & Orogenesis' Grants. Most of the students gave oral or poster presentations at international conferences last year. Interim research results were presented to industry sponsors at a one-day meeting in Vancouver (September 2007).

This project is scheduled to conclude late in 2008, although some of the graduate student research will most likely continue beyond the final sponsors'



Adam Bath in his PhD field area, Lorraine, British Columbia. Project P2.L3.

meetings. Those field-based sponsors meetings are scheduled to be held in Kamloops (BC) and Orange (NSW) in October and November 2008.

P2.L4 Genesis of the giant Sukhoi Log gold deposit, Siberia

Project Leaders: R Large and V Maslennikov (Institute of Mineralogy, Russian Academy of Science)

Project Members: S Meffre, Z Chang, L Danyushevsky, S Gilbert, R Scott, J Woodhead, J Hergt

Collaborators: V Maslennikov

Sukhoi Log is a 50 Moz. gold deposit hosted in Proterozoic black shales in the Lena Goldfield adjacent to the eastern margin of the Siberian craton. It is the largest undeveloped gold resource in the world. Controversy has surrounded its origin since its discovery in the 1960s. Most previous workers considered it to be an orogenic gold deposit, with gold mineralisation of the black shales taking place during metamorphism and granite intrusion.

Following on from our pyrite paragenetic and LA-ICPMS trace-element geochemical study at Sukhoi Log, we have undertaken zircon/monazite geochronology and detailed lead- and S-isotope analytical research on the various pyrite stages to determine sources and timing of the mineralising fluids. The geochronology revealed a younger age (600 Ma) than previously reported, for the host black shale sediments. Two distinct types of monazite gave a diagenetic age of 570 Ma followed by a metamorphic age of 515 Ma. Laser ablation lead-isotope analyses were conducted on both the quadrupole ICPMS at UTAS and the MC-ICPMS at University of Melbourne. This study revealed three stages of lead introduction associated with pyrite and gold mineralisation. The smallest amount of radiogenic lead occurs in the early syngenetic gold-bearing pyrite. A separate lead-isotope signature is recorded in the gold-rich bedding-parallel pyrite-quartz veinlets, indicating a different fluid source for these. The third isotope signature is found in the metamorphic pyrites which show a mixing array to very radiogenic lead-isotope ratios. This study supports our earlier interpretations based on textures and geochemistry, for a series of multiple gold events spanning the 85-million-year period from sedimentation, through diagenesis to metamorphism. The S-isotope research reveals a clear seawater S signature for the deposit, demonstrating that modified sea water was the dominant hydrothermal fluid.

P2.N1 Phase and chemical composition of high-temperature hydrothermal systems undergoing interaction between silicate rocks/magmas and aqueous fluid

Project Leader: V Kamenetsky

Project Member: R Large

Collaborators: S Smirnov, V Thomas, V Sharygin (Institute of Geology and Mineralogy, Novosibirsk, Russia)

This project concluded in 2006. Outcomes of this project were presented in 2007 at the Goldschmidt conference and the Elliston symposium.

P2.N2 Zinc and gold mineralisation in the Caijiaying deposit: geological characteristics and genesis

Project Leader: Z Chang

Project Members: N White, D Cooke, B Gemmell

Collaborators: R Crowe, W Woodhouse, N Wilson, G Whalan (all CSA Australia Pty Ltd)

The Caijiaying zinc-gold deposit is hosted in Proterozoic high-grade metamorphic rocks. Features typical of both skarns and low sulfidation epithermal deposits are found at different locations of the deposit. This project investigates the deposit's geological characteristics and seeks to understand its origin to facilitate further exploration. With the injection of a large amount of funding from the company, the focus this year has shifted slightly towards the exploration-applicable end.

In 2006, a large alteration halo in the seemingly fresh volcanic cover rocks was recognised through its short wavelength infra-red (SWIR) spectral

features measured by a portable infra-red mineral analyser (PIMA), which has the potential to be very helpful in exploration around Caijiaying. This is one of the major findings that successfully attracted industry funding (\$100,000 for two years). In 2007 this project focussed on defining the horizontal and vertical extent of the halo, and investigating the variations of various SWIR features within the alteration halo, in order to make a direct impact on regional exploration around Caijiaying.

In 2007, researchers carried out 50 days of fieldwork, logged 19 diamond drill holes totalling ~3075 m, and collected 545 samples from drill holes, the surface and underground workings. In total ~1700 SWIR spectra were measured, and ~1750 spectra interpreted.

This work has allowed us to define the extent of the alteration halo in the bedrock on top of the known Caijiaying orebodies. The investigation of the vertical extent of the alteration halo is ongoing; the alteration proximal to orebodies has been characterised, whereas the distal alteration is under investigation. Some of the SWIR spectral features have been found to have regular variations in the bedrock above the orebodies, and also vertically in rocks around orebodies as shown by the cross-section the researchers have logged and measured. Based on the discoveries and understandings of the alteration, the researchers have suggested several potential locations that the company can investigate for follow-up exploration work.

CSA Australia, encouraged by the research results, purchased a portable near infra-red spectrometer (PNIRS) instrument, a Chinese version of PIMA, to assist the exploration. Researchers are calibrating the PNIRS against the CODES PIMA so the research results are comparable. We have also helped train the company operator to take measurements and interpret the SWIR spectra.

During geological logging, researchers have identified critical cross-cutting relationships regarding the timing of the skarn/breccia features and epithermal features; further laboratory work is pending. Some correlations between alteration types and high-grade gold ores have also been established.

P2.N3 Polymetallic mineralisation and associated magmatic and volcanic activity in the Luzong basin, middle and lower Yangtze River, eastern China

Project Leader: T Zhou

Project Members: Z Chang, S Meffre, F Yuan, Y Fan, D Belton

Collaborator: L Zhang (Hefei University)

This project aimed to improve our understanding of the volcanic and intrusive evolution of the Luzong volcanic basin in China. New data have been generated that provide insights into the relationships between alkalic magmatism (both intrusive and extrusive), porphyry deposits and massive polymetallic sulfide mineralisation in this basin, and into related tectonic and geodynamic processes.

Taofa Zhou returned to China in February 2007. Two field trips to the Luzong area were conducted in March, when major deposits in the Luzong and Ningwu volcanic basins were investigated. The final U-lead zircon age determinations for this project were completed between



Drilling at Cadia East, NSW. Project P2.L1.

January and May 2007, by LA-ICPMS. A set of high-quality age data has been generated, allowing the volcanic and intrusive history of the Luzong volcanic basin to be defined. Research is continuing into the relationships between alkalic magmatism (both intrusive and extrusive) and mineralisation, and the controlling factors for the polymetallic mineralisation styles. A new project on the mineralisation in Luzong and Ningwu volcanic basins at Hefei University has now been ratified through open competition. The new project has begun and it is expected that it will further enhance the results of this project.

P2.N4 Breccia Textures

Project Leader: K Simpson

Project Members: D Cooke, J McPhie, B Gemmell, S Stephens

Collaborator: A Davies (Teck Cominco)

A new CODES publication is in the early stages of development. The book, *Breccia Textures*, will provide exploration geologists and students with a practical, systematic approach to dealing with fragmental rocks in mineralised environments. In particular, it will focus on the description and interpretation of breccias in the subsurface and integrate key aspects of volcanology, ore deposit geology and structural geology. It will have

the same format as the highly successful CODES publication *Volcanic Textures*. Abundant photographs, illustrations and key supporting text will guide the reader through description to interpretation of these challenging rocks. In-depth case studies will be used to illustrate the applications of the approach in various geological environments. The book will be co-authored by leading experts in the fields of ore deposit geology, hydrothermal breccias and physical volcanology. Research, sample suite collection and writing has begun for several of the chapters and photographic and reference databases have been established and populated. The book follows the themes presented in the popular shortcourse 'Volcanology and breccias for the explorationist', which has been presented by the team members at the Cordilleran Roundup meeting in Vancouver for the past three years.

Work commenced in June 2007, when Kirstie Simpson was appointed as a joint CODES-MDRU research fellow, working 50% on this project. Initial activities have focussed on preparing a book chapter outline, preparation of high-quality polished slabs of key breccia samples for high-resolution photography, and writing first drafts of several chapters.

PhD projects in the Formation program

Adam Bath: The geochemistry of melt inclusions and mineral phases from the Mount Polley and Lorraine alkalic copper-gold porphyry deposits: implications for the formation of ore deposits

Jacqueline Blackwell: Characteristics and origins of breccias in an alkalic epithermal gold deposit: Ladolam, Lihir Island, PNG

Susan Belford: Genetic and chemical characterisation of the Archaean Jaguar VHMS deposit

Bryan Bowden: Geology, geochemistry and genesis of the Prominent Hill IOCG deposit, South Australia.

David Braxton: Boyongan and Bayugo porphyry copper-gold deposits, NE Mindanao, Philippines: geology, geochemistry, and tectonic evolution

Ana-Liza Cuison: Geology and genesis of the Ridgeway porphyry gold-copper deposit, New South Wales

Kim Denwer: Mineralogical, geochemical and isotopic investigation of the Mount Lyell Cu-Au ore body and alteration system

Nathan Fox: Controls on mineralisation and alteration assemblages in the Cadia East gold-copper deposit, New South Wales

Russell Fulton: Geology and geochemistry of the hangingwall argillite, Greens Creek VHMS deposit, Alaska: implications for ore genesis and exploration

Ben Jones: Tectonic setting and magmatic evolution of the Antapaccay porphyry copper-gold and skarn deposit, Peru

Claire McMahon: Controls on the major- and trace-element content of pyrite in hydrothermal alteration envelopes.

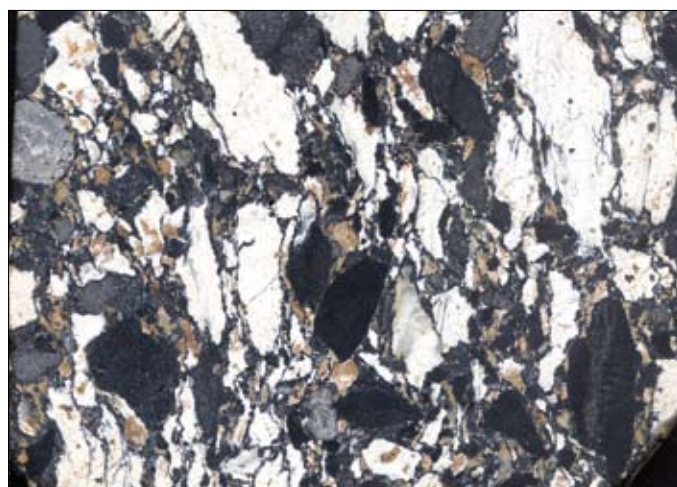
Janina Micko (MDRU): The hydrothermal genesis of the alkalic copper-gold porphyry deposit Galore Creek, northwestern British Columbia

Heidi Pass: Chemical and mineralogical zonation patterns in alkalic mineral systems: implications for ore genesis and mineral exploration

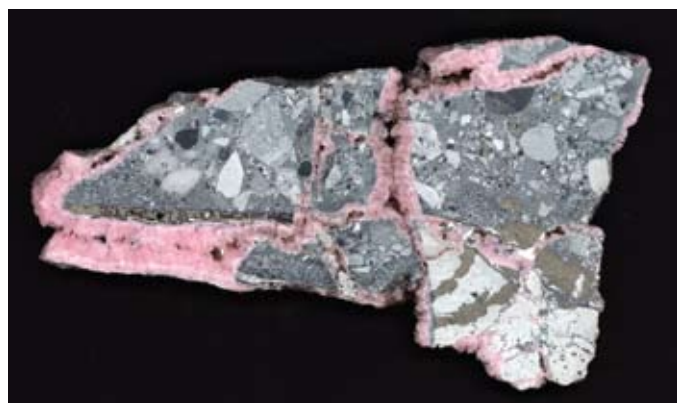
Patrick Sack: Characterisation of the footwall lithologies, Greens Creek VHMS deposit, Admiralty Island, southeast Alaska

Felipe Urzua: Regional geology of the Escondida district, northern Chile

Wojciech Zukowski: Geology and gold mineralisation of the Lake Cowal district, NSW.



Rhyolite-mudstone clast-rich breccia, Kelian gold mine, Indonesia. Project P2.N4.



Late-stage jigsaw-fit rhodochrosite-cemented breccia crosscutting early mudstone-matrix volcanoclastic breccia. Sphalerite - pyrite veins have crosscut the early breccia but are truncated by the late breccia. Kelian gold mine, Kalimantan, Indonesia. Project P2.N4.

PROGRAM 3



Objective ... to develop techniques for the acquisition, processing and interpretation of ore deposit geophysical and geochemical data that will assist in the discovery of Australia's deep earth resources

LEADER:

Jeff Foster



TEAM MEMBERS

David Broughton*, Stuart Bull, Zhaoshan Chang, David Cooke, Cari Deyell, Mark Duffett, Peter Fullagar*, Bruce Gemmell, Nick Harris*, Jeff Hedenquist*, Murray Hitzman*, Ross Large, James Macnae*, Peter McGoldrick, Andrew McNeill, Doug Oldenburg*, Anya Reading, Michael Roach, Robert Scott, David Selley, Noel White

(* partner research organisation team member)

PHD STUDENTS

Tim Ireland, Lyudmyla Koziy, Ralf Schaa and Bronto Sutopo

HIGHLIGHTS

Appointment of Associate Professor Jeff Foster to lead the Discovery Program.

The successful development of AMIRA International P765A 'Geochemical and geological halos in green rocks and lithocaps – The explorer's toolbox for porphyry and epithermal districts'.

Development of a method for determination of unambiguous apparent conductivity from fixed-loop transient electromagnetic data.

The initiation of new projects focussing on epithermal and sediment-hosted gold deposits.

Completion of a preliminary scoping study for the development of a fully integrated geophysical, geochemical and scale-independent target generation program.

The development of new projects focussing on the development of magmatic sulfide and hydrothermal fluid-related nickel mineralisation.

COLLABORATORS

University of Lubumbashi (Zaire) – Stanislas Sebagenzi

United States Geological Survey (USA) – Poul Emsbo

Lakehead University (Canada) – Peter Hollings

Hefei University (China) – Taofa Zhou

University of the Witwatersrand (South Africa) – Allan Wilson

Monash University – Reid Keays

Russian Academy of Sciences– Valery Maslennikov

Otago University (NZ) – David Craw and Doug Mackenzie

University of British Columbia (Canada) – David Mortenson

CORE PROJECTS

Geophysical characterisation and inversion of ore deposits P3.F1

Sediment-hosted gold-As deposits: Genesis and exploration models P3.F2

Approximate 3D inversion of transient electro-magnetic data P3.L1

3D geophysical inversion algorithm evaluation P3.L4

Shales and carbonates – improved vectors for Rosebery-Hercules-style VHMS in the central Mount Read Volcanics, Tasmania P3.L7

Low- and high-sulfidation epithermal mineral deposits, Australia and Southwest Pacific P3.L8

(F denotes fundamental research project; L denotes industry-linked project)

P3.F1 Geophysical characterisation and inversion of ore deposits

Project Leader: M Roach

Project Members: M Duffett, P Fullagar, D Oldenburg

Student: J Fox

This project aims to explore the relationships between measured petrophysical properties and those estimated from potential field inverse models as a means to investigate the effectiveness of alternative inversion methodologies.

Work has continued on development of the supervised classification approach to geological interpretation of potential field inverse models. This approach appears to have significant advantages over standard methods when applied in typical exploration areas which are characterised usually by only very limited surface or subsurface geological constraints.

In 2007, the utility of classification techniques in physical property volume discrimination was further demonstrated and confirmed by application to gravity and magnetic data acquired by Honours student Jodi Fox over the Unka magnetite-hosted vanadium prospect in the Northern Territory. Treatment of the potential field data as a multi-channel dataset, coupled with extensive physical property sampling, enabled the classification technique to robustly identify volumes likely (with quantifiable uncertainty) to consist of magnetite lenses.

P3.F2 Sediment-hosted gold-arsenic deposits: Genesis and exploration models

Project Leaders: R Large, S Bull

Project Members: S Meffre, L Danushevsky, R Scott

Collaborators: V Maslennikov, D Craw, D Mackenzie, D Mortenson

Following our successful research on the Sukhoi Log gold deposit in Siberia, and the Carlin deposits in Nevada, we propose to investigate the role of organic-rich sediments in the accumulation of gold and arsenic in some other world-class sediment-hosted gold districts. Our previous research has highlighted the critical role of euxinic sedimentary environments in concentrating early stratiform gold and arsenic during sedimentation and diagenesis of pyritic black shales. This type of gold may be the source of many orogenic gold deposits.

Discussions have been held with David Craw for a collaborative project on the source of gold, and concentrating mechanisms, in the Otago Schist Belt (New Zealand). Organic-rich sedimentary facies in the belt will be the main focus. Glass Earth Exploration Company is providing some support for the project.

A collaborative project with SkyGold Ventures has commenced to study the large low-grade sediment-hosted gold deposit at Spanish Mountain (British Columbia). The project will initially study the pyrite textures, geochemistry and siting of the gold.

Work on the sedimentary rocks hosting the Bendigo reefs (Victoria) will focus on the sedimentology, trace-element composition and background gold content.

P3.L1 Approximate 3D inversion of transient electromagnetic data

Project Leaders: P Fullagar, M Roach

Project Member: J Reid

Student: R Schaa

Collaborators: AngloAmerican

In this project the ground is represented as a packing of independent conductive spheres. A computer program, EMsphere, was written and verified to compute the TEM response of a conductive sphere. EMsphere was interfaced within an existing 3D modelling and inversion program, VPmg. The combined program, known as VPem, is compatible with the Gocad 3D geological modelling environment; this expedites application of geological constraints. Testing and refinement of VPem is in progress. In particular, the range of validity of the independent spheres assumption is being explored. Simple preliminary inversion tests have been completed successfully.

P3.L2 Transitions and zoning in porphyry-epithermal mineral districts (AMIRA P765)

Project Leaders: D Cooke, B Gemmell

Project Members: Z Chang, C Deyell, J Hedenquist, N White

Students: T Ireland, G Midgley, J Polanco

Collaborators: P Hollings (Lakehead University), T Zhou (Hefei University)

This ARC linkage project ran from January 2004 to December 2006. AMIRA International provided sponsorship of \$466,080 in cash and around \$500,000 in kind over three years. It aimed to improve understanding of ore genesis and exploration success in porphyry-epithermal mineral districts. Its major goals were to develop and test criteria that can be used by explorers to indicate prospective environments, discriminate between mineralisation styles, and vector towards ore zones – be they of porphyry, epithermal and/or other peripheral styles. The project was very successful in achieving its objectives.

AMIRA International was the research coordinator for this project and facilitated sponsorship by seven international mining companies (Anglogold Ashanti, AngloAmerican (Philippines) Inc, Barrick Australia, Gold Fields, Newcrest Mining Ltd, Newmont Australia and Teck Cominco). The four main case study sites were Mankayan and Baguio (Philippines), Batu Hijau (Indonesia), and Collahuasi (Chile). Two other sites, Pueblo Viejo (Dominican Republic) and Colquijirca (Peru) were used as comparators.

The project produced highly promising mineral chemistry vectors towards mineralisation centres as well as several other important outcomes of major practical and scientific relevance to exploration and porphyry intrusive systems. The companies that sponsored the original project through AMIRA International unanimously agreed to support further research on this topic. A supplementary final sponsors' meeting for P765 was held in Santiago in March 2007. At that meeting, the results that



Professor Stany Sebagenzi taking a gravity reading in the central African Copperbelt, Democratic Republic of Congo. Project P3.L3.

were originally presented at the December 2006 sponsors' meeting in Hobart were given to our South American sponsors.

In May 2007, the P765 team developed a new research proposal for a three-year project that builds on the success of P765, extending the results of the previous project and incorporating innovations to address additional research questions raised by the original project. The three-year project extension, to be coordinated by AMIRA International, has the designation P765A and is entitled 'Geochemical and geological halos in green rocks and lithocaps – the explorer's toolbox for porphyry and epithermal districts'. The proposal was distributed by AMIRA International to potential sponsors in August 2007, and successfully attracted sponsorship by 16 mining companies (Anglo American, AngloGold Australia, Barrick Gold Australia, Buenaventura, Codelco, CVRD, FMI, Kinross, Dundee, Gold Fields, Newcrest Mining, Newmont Mining, Rio Tinto, Xstrata, Oxiana and Teck Cominco). An ARC Linkage Grant application was submitted for matching funds in November 2007. A planning meeting for the new project was held in December 2007, where sponsors advised the research team of their preferred study sites and the likelihood of provision of logistical support.

P3.L3 Origin and setting of Congolese-type copper deposits (AMIRA-ARC P872)

Project Leaders: D Selley, S Bull, M Hitzman

Project Members: D Broughton, M Duffett, N Harris, P McGoldrick, R Scott

Student: L Koziy

Collaborators: S Sebagenzi (University of Lubumbashi/Gécamines), P Emsbo (US Geological Survey)

This project aims to improve the understanding of geology and base-metal mineralisation processes within the regional framework of the Central

African Copperbelt, and to develop practical exploration tools that can aid discovery of sediment-hosted stratiform copper deposits in basins around the globe. We are grateful for the financial and logistical support provided by industry sponsors via AMIRA (African Rainbow Minerals, Anglo American, Anvil Mining, BHP Billiton, CVRD, Equinox, Gécamines, Phelps Dodge and Rio Tinto), and the ARC.

A major Central African Copperbelt workshop and AMIRA-ARC P872 sponsors' meeting, held in Lubumbashi in May, was a highlight of 2007. This was the project's first significant gathering of students, researchers and industry representatives in central Africa, with nearly 50 delegates from local mining companies, the University of Lubumbashi and overseas. In addition to contributions from the P872 team, which included reviews of both the first two years' results of the current project, and a previous P544 Zambian-focused project, several presentations were provided by invited speakers: Professor Chabu Mumba (Chemaf), Mr Francois Ngoie (First Quantum Minerals), and Dr Poul Emsbo (USGS).

The Lubumbashi meeting coincided with a field program that focused on the ore characterisation and structural evolution of the supergiant Kolwezi system. Drill cores were selected to produce a comprehensive geochemical profile across variable facies associations and metal tenor. Sampling was designed principally to determine whether the relationship between extreme rare-earth-element anomalism and copper mineralisation, identified in previous P872 studies, persists throughout the deposit, and to characterise organic components within, and above, the level of ore. Difficulties in gaining permission to export samples from the Democratic Republic of Congo led to an eight-month delay in laboratory analyses. Samples arrived in Hobart in December, and results are expected in early 2008.

A complementary deposit case study was initiated by Murray Hitzman at the Lupoto prospect in the southern Congolese Copperbelt. The prospect occupies a transitional position, in terms of facies associations within the host stratigraphy, between the classical stratigraphic profiles of the Ruashi-Étirole system, and the more condensed profiles of the Kipushi region. Geochemical samples returned results in late December, and petrographic studies are ongoing.

A Cl-Br study of fluid inclusions from several Congolese and Zambian ores, undertaken by Poul Emsbo, has led to a fundamental shift in our understanding of the origin of saline mineralising fluids in the Central African Copperbelt. Of great consequence to previously presented alteration and hydrological models, is the complete lack of evidence for halite dissolution as a mechanism for generating basinal brines during any stage of mineral growth. Instead, solute ratios strongly indicate that the bulk of the basinal fluids were residual bittern brines that, via sustained evaporation and halite precipitation, evolved well past halite saturation to MgSO_4/KCl saturation. These Mg- and K- saturated fluid compositions are compatible with the principal alteration phases observed in Congo and Zambia, respectively. This highly evolved brine signature is compatible not only with other sediment-hosted copper provinces, including the Polish Kupferschiefer, but also many MVT and sedex ores, suggesting a hitherto unrecognised common fluid source in most sediment-hosted base metal systems.

The apparent lack of involvement of evaporite dissolution in brine generation or modification prompted Lyudmyla Koziy to expand her fluid modelling studies to investigate fluid driving mechanisms other

than previously examined buoyancy-driven convective flow (i.e., coupled effects of generating dense saline fluids and geothermal gradient). In these new models, Lyudmyla considered an evolving hydrology, from basin initiation to advanced stages of basin growth, where the principal fluid driving force is the compaction of a progressively accumulating sedimentary pile. Ongoing research aims ultimately to develop a unified mathematical code that will allow us to examine the relative effects of buoyancy and compactional forces in a single model.

An argon-argon dating study of potassic gangue phases associated with basement-hosted copper mineralisation at the Samba prospect, Zambian Copperbelt, was undertaken by Murray Hitzman. Previous P544 work showed intense potassic metasomatism in association with the classical stratabound Zambian ores, an event(s) that preceded the earliest phase of shortening during the Lufilian Orogeny. The results of the current study reveal temporally distinct, post-orogenic, phases of biotite and sericite growth, the latter intimately associated with copper-sulfides, and indicate that mineralising fluids continued to circulate, through basement at least, until the Ordovician. This age is more akin to those observed in the late Kipushi deposit and in the nearby emerald deposits of the southern Zambian Copperbelt.

Basin-architecture studies included vectorisation of the Gécamines geological map dataset, and acquisition of gravity data across central and northern parts of the Lufilian Fold Belt. The latter reveal first-order features in the residual Bouguer anomaly which are attributed to basement structure. However, there are qualitative indications of second-order gravity features associated with high-level Lufilian structures. These will now be targeted by modelling, in conjunction with the complete Hunting (1969) aeromagnetic dataset. Modelling will be constrained by petrophysical data acquired during 2007. Measurements of over 700 samples have now been obtained, encompassing all major components of the regional stratigraphy.

P3.L4 3D geophysical inversion algorithm evaluation

Project Leader: M Roach

Project Members: M Duffett, P Fullagar

This project uses a mineralised, structurally complex portion of western Tasmania as a test bed to evaluate several different approaches to 3D potential field inversion. The study area, between Zeehan and Rosebery (encompassing Renison) in western Tasmania, was chosen for its high physical property contrasts and relatively strong constraints from high-quality surface mapping and drilling.

In 2007 we concluded our extensive acquisition of petrophysical data from drillcore, complementing data previously obtained by Mineral Resources Tasmania. Compilation and translation of geological data was also completed. This enabled the construction of an initial 3D geological model, using 3D Geomodeller software, preparatory to testing of that software's associated inversion algorithm.

P3.L7 Shales and carbonates – improved vectors for Rosebery–Hercules-style VHMS in the central Mount Read Volcanics, Tasmania

Project Leaders: A McNeill, B Gemmell

Exploration for VHMS deposits in the Mount Read Volcanics is based on the concepts that all economic mineralisation occurs at a particular time horizon (the 'Holy Host') and that this horizon has been adequately tested to a depth of 150–200 m. The major problems for VHMS exploration in the Mount Read Volcanics are therefore:

- Defining the location and down-dip extent of the 'Holy Host'
- Locating alteration envelopes, hanging- and footwall, to the target VHMS mineralisation.

This project aims to address both these problems by using the chemistry of shales to aid in defining the position of the 'Holy Host', and by using the mineralogy and chemistry of shale and carbonates associated with the Rosebery and Hercules orebodies to define vectors to mineralisation.

This project commenced in November 2006, and work during 2007 comprised:

- Completing a database of existing shale compositional data and identifying where further analyses were required
- Logging and sampling relevant intervals of 18 drill holes for regional correlations of the Holy Host and eight holes on section 2400mN at the Rosebery mine to determine chemical and mineralogical variations of sulfides in the Rosebery shale above the orebody.

Major- and trace-element analyses of 37 samples have been completed and indicate that although there are subtle differences in the composition of shale units throughout the Mount Read Volcanics, only the Tyndall Group has a distinctive felsic signature.

Progress on this project is behind schedule as we have not been able to attract a student to work on it. The project has been extended until November 2008.

P3.L8 Low- and high-sulfidation epithermal mineral deposits, Australia and Southwest Pacific

Project Leaders: B Gemmell, D Cooke

Project Members: B Sutopo, S Groves, C Chamberlain

The geology and genesis of low- and high-sulfidation epithermal deposits in Australia and in the southwest Pacific region are being investigated. Research has concentrated on determining the geological and geochemical constraints on the formation of low- and high-sulfidation epithermal deposits, which will lead to improved genetic and exploration models.

Research on low-sulfidation deposits includes:

1. Epithermal gold-silver deposits: geological, geochemical and isotopic vectors to target major deposits.

Some of the results of the ARC Linkage/AMIRA P588 research project, which was completed in 2003, were published in 2007 in a special

issue of *Economic Geology* devoted to epithermal gold-silver deposits. Bruce Gemmell and Stuart Simmons were the guest editors.

Bruce Gemmell published a paper dealing with the mineralogy, geochemistry and exploration implications of hydrothermal alteration associated with the Gosowong epithermal gold-silver deposit, Halmahera, Indonesia. The Gosowong deposit has a resource of 0.99 million metric tons (Mt) at 27 g/t gold and 38 g/t silver. Gold mineralisation is hosted within multiphase, epithermal quartz-adularia and quartz-chlorite fissure veins, breccias, and stockwork veining within two gently south-plunging ore shoots along a 400 m section of the north-striking, east-dipping Gosowong fault. Alteration is zoned around the vein from proximal silicic to argillic to vein-related propylitic to distal regional propylitic alteration.

Bruce Gemmell gave a keynote talk in the Southwest Pacific ore deposits session of the 'Ores and Orogenesis' meeting of the Arizona Geological Society in Tucson (USA) on the exploration implications of hydrothermal alteration associated with epithermal gold-silver deposits. The important points of this research are that alteration zones surrounding low-sulfidation epithermal deposits are larger than the deposits, and that recognition of alteration mineralogical and geochemical zonation can be used for developing vectors to the deposit.

2. Gosowong-Kencana: Indonesia. In 2007, Newcrest Mining Ltd initiated and funded a combined post-doctoral and PhD project in the Gosowong goldfield, on Halmahera Island, Indonesia. The post-doctoral study involves a deposit- to district-scale study of the Gosowong goldfield and aims to characterise the Gosowong goldfield epithermal systems, through integration of structural, geochemical, geochronological and geological studies. The PhD project will investigate the geology and genesis of the Kencana epithermal gold-silver deposit, Gosowong Goldfield, Halmahera Island, Indonesia

3. Moonlight, Queensland. Steven Groves, a Master of Economic Geology student, successfully completed his thesis in 2007 on the geology and genesis of the Moonlight high-level, low-sulfidation epithermal prospect, Pajingo epithermal system, northeast Queensland. This project was sponsored by Newmont.

4. Cracow, Queensland. Corrie Chamberlain, a Master of Economic Geology student sponsored by Newcrest, is investigating the Kilkenny vein deposit within the Cracow epithermal system in Queensland.

Corrie's project involves describing the deposits (host rocks, structure, mineralisation and alteration) and detailed research into the vein paragenetic stages and textural and metal zonation throughout the horizontal and vertical extent of the vein. The aim of the project is to compare the Kilkenny deposit to other deposits in the Cracow goldfield

in order to gain a better understanding of the features and controls on mineralisation which can be applied to mineral exploration in the district.

Work on high-sulfidation deposits includes:

1. Martabe: Indonesia. Bronto Sutopo is a PhD student studying the high- and low-sulfidation mineralisation in the Martabe district (Indonesia) with the aim of understanding ore genesis and developing criteria for enhanced exploration in the district. This project is sponsored by Newmont. During 2007 Bronto was upgraded from a Master of Science (Exploration Geoscience) to a PhD student based on his research project and accomplishments.

Bronto presented papers outlining the results of his research at the Dublin SGA and the Arizona Geological Society's 'Ores and Orogenesis' meetings in 2007.

Significant new projects planned for 2008

1. The geology and geochemistry of the Platreef, Bushveld Igneous Complex. This diverse and challenging project will explore the complex relationship between magmas, mineralisation and metallurgy.

2. The geology, geochemistry and genesis of the Avebury nickel deposit: implications for exploration.

3. The Global Discovery Initiative (GLODISC) is a major program designed to bring together key aspects of geophysics, geochemistry and geology in one program. Key aspects of this program include:

- Geophysical and petrophysical characterisation of four major deposit types
- Petrophysical and geologically constrained 3D inversion models
- Ambient noise seismic tomography
- Geochemical templates for ore deposits
- Geochemical terrane fingerprinting
- High temperature to low temperature 'fluid' models
- Inverse theory applied to multivariate geochemical datasets
- Target generation through scale-independent data coring.

Research and knowledge transfer will occur through the development of industry-friendly software with key technology partners.

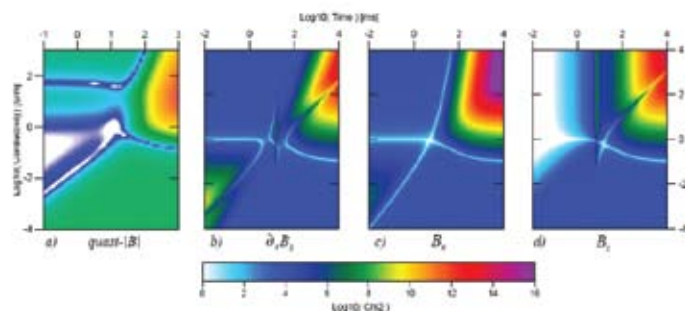
PhD projects in the Discovery program

Tim Ireland: Geological evolution of the Collahuasi District, Tarapaca, Chile

Lyudmyla Koziy: Numerical simulation of fluid flow and fluid chemistry in sedimentary basins (graduated 2007)

Ralf Schaa: Rapid approximation algorithms of TEM data

Bronto Sutopo: The Martabe gold-silver high-sulfidation epithermal mineralisation in the Tapanuli Selatan District, North Sumatra province, Indonesia: implications for ore genesis and exploration



Electromagnetics – Calculated B-Field. Project P3.L1.

PROGRAM 4



Objectives ... to create an integrated cross-disciplinary geometallurgical research platform that delivers fundamental knowledge, tools and methods to the global mining industry for optimising sustainable and profitable mineral extraction ... to develop more effective approaches to the definition of mineralogy, element deportment and texture that can be linked to mineral processing performance and efficiency at a range of scales ... to provide improved attributes or indices of processing performance that can be embedded in block models to define processing domains, which can be exploited in mine planning and optimisation ... and to deliver new cross-discipline geometallurgical education, training and awareness

HIGHLIGHTS

The AMIRA P843 GeM^{III} project (Geometallurgical Mapping and Mine Modelling) is the centrepiece of the CODES Recovery Program and is one of the world's largest research projects addressing the emerging multi-disciplinary area of geometallurgy.

Industry support continues to grow for the project with 18 companies involved and industry research funding in excess of \$6 million, in addition to \$2 million from CODES.

Development of new technology developments to support automated core logging, automated textural data acquisition and analysis, and small-scale comminution testing.

Application of automated petrophysical logging, imaging and SWIR-based logging instruments is continuing using core from Cadia East, Ernest Henry, Aqqaluk and Boddington.

Increasing inputs from W H Bryan Mining and Geology Research Centre (BRC) in the area of spatial and geostatistical modelling.

Development of new and improved geometallurgical simulation and modelling techniques that will form major project deliverables.



TEAM LEADER

Steve Walters

TEAM MEMBERS

Ron Berry, Nenad Djordjevic*, Peter Fullagar, Stephen Gay*, Julie Hunt, Jon Huntington*, Melissa Quigley*, Maya Kamenetsky, Toni Kojovic*, Simon Michaux*, Rob Morrison*, K Nguyen*, Yicai Wang*, Mike Roach, Claire MacMahon, A Cuison, Alan Bye*, Ryan McCasker*, Geoff Parkes*

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Natalee Bonnici, Cathy Evans (JKMRC), Luke Keeney (JKMRC), George Leigh (JKMRC), Adel Vatandoost, David Boakye (BRC), Anita Parbhakar

COLLABORATORS

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Bryan Mining Centre – Alan Bye

CSIRO – Jon Huntington, Melissa Quigley

CORE PROJECTS

AMIRA P843 GeM^{III} project (Geometallurgical Mapping and Mine Modelling – P4.L1). This is currently the only active project within Recovery and is based on six modules that address the needs of integrated geometallurgy, with individual modules equivalent in funding and scope to projects in other programs:

- Automated core logging linked to processing domain definition P4.L1.1
- Integrated micro-analytical mineral mapping P4.L1.2
Textural classification, simulation and modelling P4.L1.3
- Correlation and calibration of textural categories with processing performance P4.L1.4
- Geostatistical attribution of processing performance attributes P4.L1.5
- Provision of formalised geometallurgical awareness, education and training. P4.L1.6

Industry sponsorship and ARC funding for AMIRA P843

Eighteen companies support the AMIRA P843 GeM^{III} project with three levels of industry sponsorship — Level 1 involving a maximum of six significant site-based studies, Level 2 with no designated site-based studies and Level 3 ‘supplier’ sponsors who provide specialist services, software or hardware relevant to the project.

Level 1 Sponsors: Newcrest, Newmont, Rio Tinto, Teck Cominco, Vale Inco and Xstrata.

Level 2 Sponsors: AngloGold Ashanti, Anglo Platinum, Barrick, BHP Billiton, Codelco, Penoles, Vale and Zinifex.

Level 3 Sponsors: Datamine, Golder Associates, Metso Minerals and GEOTEK.

This represents over \$6 million of direct industry cash support over the life of the project with substantial in-kind support for site-based activities. A further \$2 million of ARC funds will be provided through the Centre of Excellence.

The six operations provided by Level 1 sponsors for site-based research activities represent a mix of world-class copper-gold, lead-zinc-silver and nickel-copper sulfide deposits with a predominance of hard-rock open pit mining methods and flotation-based mineral processing and recovery circuits. The six study sites provide opportunities for developmental research through comparison of new techniques and methodologies with existing data and current practices (typically involving mature operations); and validation research where the outcomes of development can be tested and trialled under operational conditions (typically involving deposits undergoing expansion or feasibility):

Aqqaluk zinc-lead-silver — a satellite deposit adjacent to the Red Dog mine in NW Alaska, USA; provided by Teck Cominco. Currently undergoing advanced feasibility.



The GeM^{III} mascot.

Boddington copper-gold — sulfide resource below the depleted Boddington oxide open pit mine south of Perth in Western Australia; provided by Newmont (JV with AngloGold Ashanti). The project is currently under development.

Bingham Canyon copper-gold-molybdenum — mature open pit porphyry copper/skarn system near Salt Lake City, USA; provided through Rio Tinto (Kennecott Utah Copper).

Cadia East copper-gold — porphyry copper system adjacent to the Cadia Hill and Ridgeway deposits near Orange, New South Wales, Australia; provided by Newcrest. Currently undergoing advanced feasibility study.

Ernest Henry copper-gold — mature open-pit iron-oxide-associated copper-gold system north of Cloncurry currently looking to extend production underground, NW Queensland, Australia; provided by Xstrata.

Sudbury nickel-copper-gold-PGE — underground nickel-sulfide operations in the Sudbury district, Canada; provided by Vale Inco.

Introduction to Geometallurgy

The emerging discipline of ‘geometallurgy’ is not new but is becoming increasingly recognised as a discrete and high-value activity that reflects an ongoing commercial and cultural trend towards more effective mine site integration and optimisation. Geometallurgy involves a quantified and spatially constrained approach to ore characterisation in terms of relationships to critical processing performance behaviours.

Geometallurgy requires integration across a wide range of existing activities and can also be referred to under a variety of different descriptors. It includes aspects of process mineralogy, mine geology, metallurgy, process control, resource modelling and geostatistics and can also be referred to under different terms such as ‘orebody knowledge’ or ‘ore characterisation’.

The emergence of geometallurgy as a more discrete activity requires a new level of cross-discipline integration involving effective communication, shared methodologies and a common technical language between the wide range of professional disciplines that support major mining operations — in particular economic geology, mining engineering and mineral processing. The CODES Recovery program was designed to provide innovative new research support to the emerging area of geometallurgy with AMIRA P843 GeM^{III} as the centrepiece of this new initiative.

Geometallurgy complements but does not replace existing approaches to design and optimisation of mining and mineral processing operations. The primary aim of geometallurgy is to provide constrained inputs that reflect inherent geological variability and its impact on metallurgical performance. This requires quantification of ore deposits in terms of machine-based process parameters such as hardness, comminution energy, size reduction, liberation potential and product recovery. These parameters are used to populate deposit-scale block models typically through the application of geostatistics. Incorporation of geometallurgical parameters into resource modelling supplements traditional geology and grade-based attributes, enabling a more holistic approach to economic optimisation of mineral production. Sophisticated geometallurgical block models can be used to predict and optimise economic attributes such as throughput, grade, grind size and recovery.

Detailed geometallurgical models that reflect inherent variability aim to reduce technical risk associated with the design and operation of mines. A systematic geometallurgical approach is particularly important in feasibility as a precursor to design, where physical access to and knowledge of an ore deposit is typically limited and evolving. Geometallurgical information can be used to optimise flow sheet design and equipment sizing with a view to predicting and optimising plant performance and production over the life of the project.

Industry support for AMIRA P843 GeM^{III} has doubled since inception in mid-2005, with a range of potential continuation and spin-off projects under discussion. This reflects the importance of the emerging area of geometallurgy and the high value placed by industry on supporting new cross-discipline research initiatives within CODES.

P4.L1 AMIRA P843 GeM^{III} project

P4.L1.1 Automated core logging linked to processing domain definition

Project Leader: S Walters

Project Members: J Huntington, M Quigley, M Roach, P Fullagar, A-L Cuisson, J Hunt, P Schultheiss

Students: N Bonnici, L Keeney, A Vatandoost

‘Traditional’ visual logging techniques produce outputs that are generally not designed to correlate with mineral processing attributes. In addition, visual logging has poor QA/QC compared to other data types and is often carried out by junior staff. This module employs a novel approach to overcome these problems based on automated bench-scale logging instrumentation for petrophysical and mineralogical measurement.

This involves use of a GEOTEK multi-sensor core logger (MSCL), the CSIRO HyLogger short-wavelength infra-red-based (SWIR) system and EQUOTip hardness logging. The GEOTEK MSCL system incorporates high-resolution digital imaging, gamma-ray attenuation bulk density, magnetic susceptibility, P-wave velocity and resistivity measurements. The CSIRO HyLogger is based on SWIR spectral reflectance which provides information on mainly hydroxyl-bearing minerals such as clays, chlorites and micas. Use of high resolution imaging allows meso-scale mineral identification linked to the application of advanced image-analysis software systems.

When combined with existing assay data and visual logging this provides a diverse ‘matrix’ of multivariate attributes involving direct measures and proxies of mineralogy and texture. This matrix can be used as inputs to predicting and modelling processing performance parameters such as throughput and recovery determined using other testing methods.

The underlying theme of the geometallurgical sampling and testing approach being developed in AMIRA P843 GeM^{III} is the use of small-scale, spatially constrained samples (generally 2 m of half core) that can be used to identify fundamental processing behaviours and associations as inputs into modelling. This contrasts with the bulk sampling and testing approach typically used in current practice, and has required the development of a new suite of small-scale physical testing methods (P4.

L1.4). Initial selection of samples for testing is based on the attribute information provided by continuous down-hole data provided by the automated core logging module.

P4.L1.2 Integrated micro-analytical mineral mapping

Project Leader: R Berry

Project Members: J Hunt, M Kamenetsky, C MacMahon, S Walters

Students: N Bonnici, C Evans, A Vatandoost

The past decade has seen major ongoing advances in the field of automated micro-analytical mineral mapping. These are mainly related to the development of automated SEM-based X-ray microscopy such as the JKTech MLA and Intellection QEMSCANTM systems.

SEM-based systems provide mineral identification and mapping capabilities which result in quantified digital imaging of classified mineral maps. These maps are highly amenable to software-based image analysis of mineralogy and texture. The techniques have proven highly effective for the quantified analysis and interpretation of liberation in comminuted products such as concentrates and tailings. The majority of major mineral companies now operate in-house facilities.

A key aspect of the AMIRA P843 GeM^{III} project has been to develop systems that can provide greater quantities of classified mineral mapping with a broader range of cost and resolution options. This has mainly involved the development of more automated optical microscopy systems linked to advanced image analysis software, and the use of continuous core scale imaging which can also be processed into classified mineral maps. The use of optical and core imaging systems provides information on meso-scale textural associations prior to size reduction and liberation. This provides a more predictive modelling approach compared to reactive analysis of processing product and waste. This particularly applies to mapping of gangue phases in low-grade systems which have a major influence on comminution performance.

The AMIRA P843 GeM^{III} project currently operates a GEOTEK high-resolution core imaging system, two Leica DM6000 automated



SAG and Ball mills at the Bingham Canyon Concentrator, Utah, USA. Project P4.L1.

microscopes, and a research MLA facility. This mineral mapping 'suite' provides a range of textural and mineralogical inputs that can be linked to simulation and modelling of processing performance (P4.L1.3).

P4.L1.3 Textural classification, simulation and modelling

Project Leader: S Walters

Project Members: R Berry, N Djordjevic , J Hunt, K Nguyen, Y Wang

Students: N Bonnici, C Evans , G Leigh

Geologists have traditionally used textural classification and categorisation schemes that are poorly correlated with and calibrated against processing performance. At the hand specimen/core scale, these classification schemes are largely based on visual observation, which tends to be subjective and experience-based.

Automated digital mineral mapping, as described in P4.L1.2, presents new opportunities for a more systematic and reproducible approach to textural classification and categorisation based on quantified, statistical methods. However, even computer-based classification methods find it challenging to deal with the large volumes of increasingly complex measurements produced by automated mineral mapping techniques.

The module aims to provide a range of more effective software-based methods for textural analysis, feature extraction and categorisation that are relevant to processing performance. This is being done through development of customised in-house software and use of advanced image processing software.

This work also aims to simulate and predict potential processing performance using classified mineral maps of intact texture. Important insights are being developed into the ways rock textures behave and interact under processing conditions. The resulting models can be compared and validated against actual physical processing behaviour in P4.L1.4.

P4.L1.4 Correlation and calibration of textural categories with processing performance

Project Leader: T Kojovic

Project Members: N Djordjevic, R McCasker, S Michaux, R Morrison, G Parkes, S Walters

Students: C Evans, L Keeney

A wide variety of physical tests are currently employed to assess processing performance. These include strength (UCS, Point Load), hardness (Bond Work Index) and comminution (JK Drop Weight and Sag Mill Comminution Tests) together with bench-scale flotation or leach testing. The majority of physical testing is conducted during feasibility with the results directly influencing processing plant design. Incomplete knowledge or non-representative results can have a major negative effect on achieving design capacity and economic performance, particularly during start-up.

A key objective of AMIRA P843 GeM^{III} is to create a new approach to geometallurgical characterisation that enables highly constrained (small volume) samples with defined textural and mineralogical attributes to be tested for processing performance. This has required development of a suite of new and modified physical testing methods capable of providing meaningful processing parameters based on large numbers of small sample volumes (typically 2 m of half NQ or HQ core).

This approach allows fundamental relationships to be determined based on geologically constrained inputs provided from the other research modules. The aim is to develop predictive models of processing performance through application of integrated and calibrated modelling based on textural and mineralogical attributes. Once identified many of these attributes could be supplied through other measurement technologies that do not necessarily require physical testing.



This has required extensive new method development largely carried out through the JKMRC, and which includes new testing equipment. Within the context of AMIRA P843 GeM^{III} these tests have to be capable of handling small sample volumes with a lower-cost structure compared to current practice.

P4.L1.5 Geometallurgical modelling and geostatistical attribution of processing performance attributes

Project Leader: A Bye

Project Member: P Fullagar, T Kojovic, A Richmond, S Walters

Students: D. Boakye, L Keeney, A Vatandoost

Significant progress has been made in this area over the past 12 months following the arrival of Alan Bye as director of the W H Bryan Mining Geology Research Centre. The key aspects of the previous modules are more quantified provision of multivariate attributes such as mineralogy, texture and rock strength likely to represent fundamental controls on mineral processing performance. This involves detailed investigation of the spatial attributes of non-grade attributes using a range of geostatistical techniques; and a new approach to rock type classification that reflects processing attributes rather than classical geological terminologies. The ultimate aim is to provide predictive processing attributes that can be embedded into resource models which more effectively represent true economic value.

P4.L1.6 Provision of formalised geometallurgical awareness, education and training

An important outcome of AMIRA P843 GeM^{III} is training and formal education delivered by JKMRC, BRC and CODES. The project involves a significant number of postgraduate students closely linked to site-based activity that will assist with technology transfer. The ultimate aim is to educate and enthuse the next generation of practitioners to enter the industry with a focus on geometallurgical integration. Discussions are under way regarding provision of formalised geometallurgical education and training, possibly along the lines of the current Master of Economic Geology program offered by CODES as part of the national Minerals Geoscience Masters program.

PhD projects in the Recovery program

David Boakye (BRC): Geostatistical modelling of geometallurgical attributes

Natalee Bonnici: Textural and mineralogical characterisation of copper-gold systems in relation to process mineralogy

Cathy Evans (JKMRC): Texture-related flotation characteristics of ores

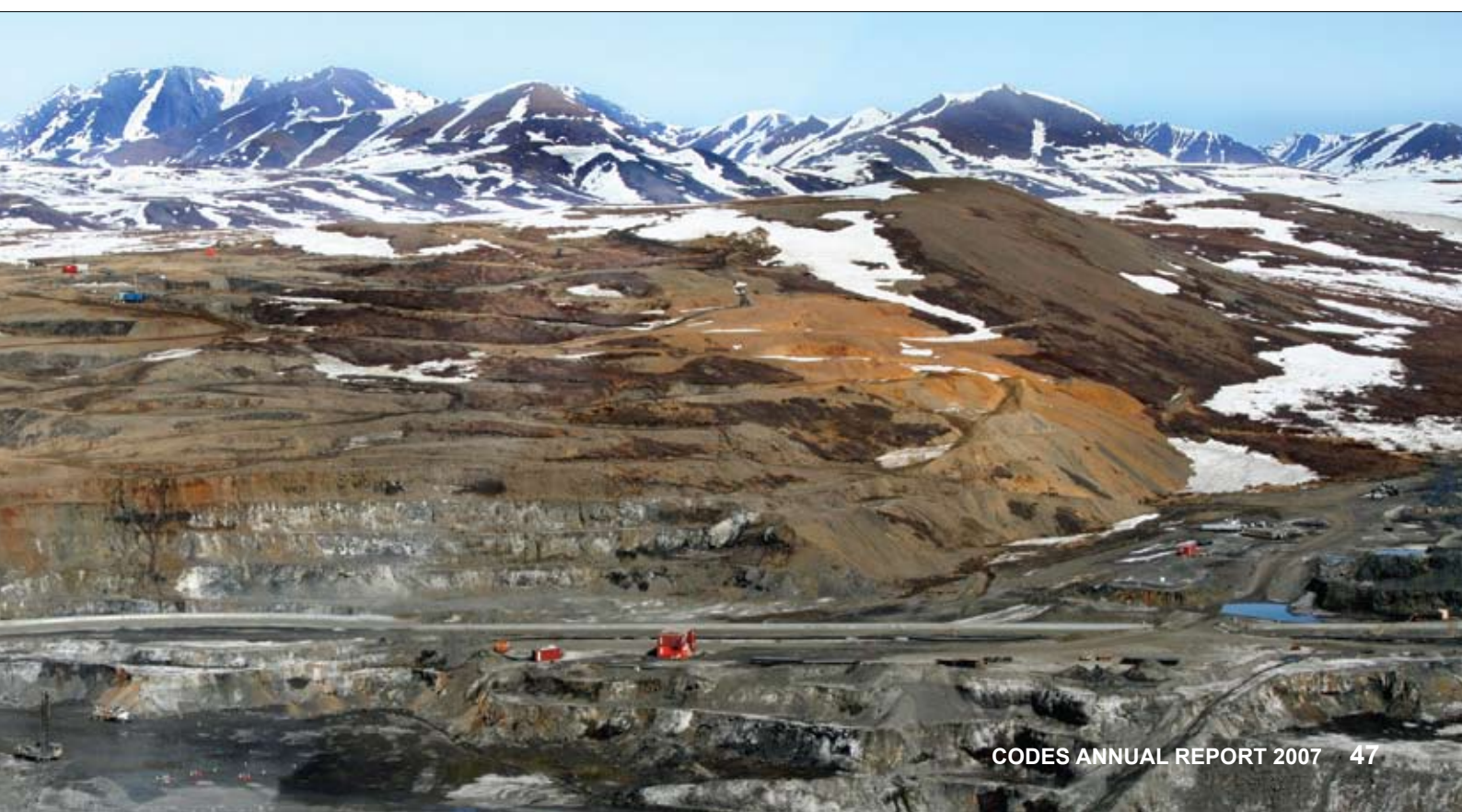
Luke Keeney (JKMRC): Integrated geometallurgical modelling of the Cadia East deposit

George Leigh (JKMRC): Wavelet analysis of texture parameters related to mineral processing

Anita Parbhakar: Texture-based approaches to predictive geo-environmental modelling

Adel Vatandoost: Automated petrophysical characterisation of drill core and potential relationships to mineral processing attributes.

Surface expression and drill access development, Aqqaluk deposit, Red Dog mine, Alaska. Project P4.L1.



PROGRAM 5



The role of the Technology Program within CODES is to explore and develop novel analytical and data-interpretation techniques based on the latest technological developments, such as a number of high spatial resolution microprobes, which will help in understanding, exploring and exploiting deep earth resources. Current research projects mainly focus on expanding the capabilities of in situ multi-element analysis by laser ablation (LA), inductively-coupled plasma mass-spectrometry (ICPMS), in situ isotope analysis by LA multi-collector (MC) ICPMS, and non-destructive multi-element analysis using nuclear (PIXE) and synchrotron-based X-ray microprobes. Many of the projects in this program include close collaborations with partners such as the University of Melbourne, CSIRO and the Australian National University.

HIGHLIGHTS

Development of a NiS standard for PGE and gold analysis of sulfide minerals.

Coordination of copper-chlorine species in a sulfur-poor reduced fluid system has been determined at the GSE-CARS beam-line at the Advanced Photon Source, Chicago (USA) to 750 °C, extending the data to some 350 °C beyond existing results.

Successful testing of a new prototype advanced fluorescence detector system for deconvolution of the synchrotron XRF spectral data into separated elemental images, Maia-96, at the National Synchrotron Light Source at Brookhaven National Laboratory in New York (USA).

Development of a new LA-ICPMS technique for generating images reflecting distribution of up 18 major and trace elements within rocks and minerals.



TEAM LEADER

Leonid Danyushevsky

TEAM MEMBERS

David Belton (CSIRO), Zhaoshan Chang, Garry Davidson, Sarah Gilbert, Anthony Harris, Janet Hergt (University of Melbourne), Chris Hollitt, Vadim Kamenetsky, Ross Large, Peter McGoldrick, Sebastien Meffre, Phil Robinson, Chris Ryan (CSIRO), Chad Paton (University of Melbourne)

COLLABORATORS

Imperial College, London – Andrew Berry

Australian National University – John Mavrogenes, Michael Shelley

CSIRO – Chris Ryan, David Belton

University of Melbourne – Janet Hergt, Jon Woodhead

Moscow State University – Pavel Plechov

CORE PROJECTS

Analytical developments in the CODES LA-ICPMS facility P5.F1

Pb and Cu isotopes in sulfides, silicate melt inclusions and fluid inclusions using multi-collector ICP-MS P5.F2

Developmental research into the use of synchrotron in ore deposit studies P5.F3a

CODES-CSIRO Synchrotron Technology development P5.F3b

Nuclear microprobe analytical developments P5.F4

Trace-element and isotope developments in the CODES LA-ICPMS facility P5.F6

Cracking the sulfate isotopic composition problem in ancient hydrothermal systems: application of the Carbonate-Associated Sulfate (CAS) method P5.F8

(F denotes fundamental research project; L denotes industry-linked project)



NiS standard (lower left) cut, mounted and polished (top right) ready for LA-ICPMS analysis. Project P5.F1.

P5. F1 Analytical developments in the CODES LA-ICPMS facility

Project Leader: L Danyushevsky

Project Members: S Gilbert, V Kamenetsky, P McGoldrick, P Robinson

In 2007, a NiS standard for PGE and gold analysis by LA-ICPMS was successfully synthesised. The standard was developed at CODES using a fire-assay technique and is now in the process of certification. It should be available for routine use by April 2008.

Work continued on fluid-inclusion analytical developments. Our approach to the analysis of dissolved silica in magmatic and hydrothermal fluids included a study of zoning in host quartz from mineralised magmatic rocks in terms of the distribution of fluid inclusions. Shapes and textures of quartz grains have been studied (by optical, cathode-luminescence and backscattered electron microscopy), together with the distribution of quartz-hosted fluid inclusions in a number of porphyries (Batu Hijao, Indonesia; Climax, USA; Panguna, PNG; Antapaccay, Peru; Rio Blanco, Chile). In most cases, trails of inclusions are aligned with healed fractures crosscutting growth planes or randomly oriented throughout quartz crystals. The fractures healed with later quartz are clearly visible in cathode-luminescence and have distinct abundances of trace elements (Ti, Al, Li, Ge, Ga). The trails, and inclusions in them, can be very abundant and so densely and randomly distributed that identification of truly primary inclusions is not possible. Three main types of inclusions are commonly present in single quartz grains: (1) aqueous vapour-rich with minor amounts of liquid, often containing a few euhedral crystals, (2) aqueous liquid-rich with a vapour bubble, and (3) crystal-rich with variable amounts of liquid and solids. Fluid inclusions are metastable and prone to spontaneous recrystallisation followed by changes in the number, shape and volume ratios of phases.

Substantial evidence was obtained for quartz crystallisation from a silica-gel, with quartz-hosted fluid inclusions representing residual brines and vapours. However, the final conclusion on the origin of fluid

inclusions and their host quartz awaits thermometric experiments and LA-ICPMS analysis of coeval fluid inclusions planned for 2008.

Work continued on the development of secondary standards for carbonate LA-ICPMS analysis. Preliminary assessment of LA and EMP data from an 'Iceland Spar' (calcite) sample is complete, revealing that most trace elements (with the exception of magnesium, manganese, iron, nickel, strontium and, possibly, barium and lanthanum) are at levels that are too low for this material to be a useful standard. Natural siderite samples from Lady Loretta and South Australia, and a synthetic calcite are currently being considered as alternatives to Iceland Spar.

P5. F2 Lead and copper isotopes in sulfides, silicate melt inclusions and fluid inclusions using MC-ICPMS

Project Leaders: J Hergt (UMelbourne), J Woodhead (UMelbourne), S Meffre

Project Members: Z Chang, L Danyushevsky, S Gilbert, R Large

Linked by the common theme of in situ lead-isotope analysis, this project has two strands focusing on the development of protocols for the study of silicate melt inclusions in phenocrysts from volcanic rocks and sulfide minerals, respectively.

Development work on protocols for in situ lead-isotope analysis was completed during 2007 and the methodologies were subsequently applied to a number of research projects. In terms of silicate melt inclusions, work continued on the two research projects which were initiated in 2006 investigating inclusion suites from the Hunter Ridge and Eimeshan flood basalt province, respectively, with a view to understanding both the processes of inclusion entrapment, and the nature of the processes recorded by inclusions. In addition our highly successful pyrite analysis methodology was applied to further samples from the sediment-hosted Sukhoi Log deposit in Russia and gold deposits from Laos. These have proved valuable in highlighting both some 'real world' limitations on the technique but also its great potential for provenance studies. A publication detailing the analytical method is now in preparation and a manuscript documenting the Sukhoi Log pyrite results has been accepted for publication in *Geochemica et Cosmochimica Acta*.

At the CODES planning meeting in July 2007, considerable interest was expressed in development of methodologies for copper-isotope analysis using MC-ICPMS and this has been a major theme towards the end of the year with much progress made in testing a variety of chemical separation techniques and mass spectrometric run routines.

2007 also saw the appointment of Chad Paton to the role of joint CODES-University of Melbourne post-doctoral researcher. Chad will be responsible for the day-to-day running of sample materials and will be instrumental in the development of the copper-isotope technique.

P5.F3a Developmental research into the use of synchrotron in ore deposit studies

Project Leader: A Harris

Collaborators: A Berry (Imperial College, London), D Cooke, V Kamenetsky

Constraints on transport and deposition of important ore-forming elements can be improved with new knowledge on the speciation (oxidation state and coordination environment) of aqueous metal complexes at magmatic temperatures. Most analytical studies have investigated metal complexes to temperatures typical of hydrothermal systems (up to 350 °C).

CODES, together with Imperial College, is working towards extending the current understanding of metal complexation to high-temperature magmatic conditions. We have undertaken in situ non-destructive spectroscopy experiments of natural fluid inclusions in miarolitic quartz in a granite intimately associated with reduced tin-rich ore deposits. Microanalysis of fluid inclusions confirms that the magmatic fluids contain significant concentrations of tin (thousands of ppm). In addition, PIXE geochemistry reveals extreme variations of metals (iron-zinc-manganese-copper) in fluid inclusions preserved in primary igneous textures. Some of the most primitive inclusions homogenise by 700 °C. Associated metal-rich (several wt% copper and iron) brines in composite silicate melt inclusions have also been reported.

Focusing on these high-temperature, metal-bearing fluid inclusions, spectroscopic experiments were undertaken at the GSE-CARS beam-line at the Advanced Photon Source, Chicago. Using high-energy synchrotron radiation, we have recorded copper (with limited zinc, iron and manganese) K-edge X-ray absorption near edge structure (XANES) and extended X-ray absorption fine structure (EXAFS) spectra for single fluid inclusions up to 700 °C. Our data shows copper exclusively as the linear species $[\text{CuCl}_2]$ – from 200 °C to at least 700 °C. Despite the high salinities of these natural inclusions there is no evidence for higher order coordination. Most importantly, our work has characterised the copper (and other important ore metal) chloride species to magmatic conditions, extending some 350 °C beyond other published studies, in a sulfur-poor reduced system.

P5. F3b CODES-CSIRO Synchrotron technology development

Project Leader: C Ryan (CSIRO)

Project Members: B Etschmann (joint appointment with CSIRO), A Harris, L Danyushevsky

Developments in the synchrotron project with CSIRO concentrated on implementing the advanced fluorescence detector system concept and solving analytical issues associated with huge arrays and the projection of X-ray absorption image data. A new prototype detector system, Maia-96, was developed this year and tested at the National Synchrotron Light Source (NSLS) at Brookhaven National Laboratory (BNL) in New York. The prototype has 96 detectors and 96 parallel channels of pulse-processing custom circuitry. It was interfaced to the CSIRO high-speed pipelined parallel processor for real-time processing of each detected event, which demonstrated a capacity of 108 events per second.

Count-rates in the detector of up to 6 Mc/s were achieved with full-spectral data-collection and real-time deconvolution of the synchrotron XRF (SXRF) spectral data into separated elemental images using the CSIRO Dynamic Analysis (DA) algorithm. Close integration of sample stage control enabled high-definition images to be acquired with up to 4 megapixels (2000 x 2000) and pixel dwells as short as 0.8 ms.



Advanced Photon Source, Chicago, USA. Project P5.F3.

The fast scanning approach enabled several X-ray Absorption Near Edge Structure (XANES) image stacks to be acquired with 533 x 533 spatial pixels at each of between 30–40 energy steps across the absorption edges of key multi-valence elements (e.g. vanadium, uranium and europium). Techniques have been developed to use the DA spectral deconvolution approach to construct XANES spectra at each pixel, and work is underway aimed at developing new techniques to deconvolute the XANES spectral data to project species (e.g. valence state) component images.

P5. F4 Nuclear microprobe analytical developments

Project Leader: D Belton (joint appointment with CSIRO)

Project Members: C Ryan (CSIRO), L Danyushevsky

Much of the activity on the CSIRO nuclear microprobe during 2007 was aimed at furthering the practical integration of PIXE data with the image-based data sets generated by the suite of in-house analytical methods routinely used by CODES researchers to study ore systems. Particular emphasis was put on three main aspects of this integration:

1. Broadening the range of available elements with developments in the detection of fluorine, phosphorus and sodium.
2. Improved detection of selected elements in challenging spatial contexts — primarily the non-destructive analysis of fluid inclusions.
3. Development of data treatments that permit the 2D PIXE data sets to be combined with spot analyses in more useful ways.

Over the year, planning and modifications to the University of Melbourne particle accelerator have been carried out to enable the use of a low-energy argon beam for the analysis of difficult elements such as phosphorus and sulfur. While this method is restricted to surface analysis, it has the benefit of increased sensitivity, since only a very small range of atomic numbers are excited by this beam. This development is an

extension of work from 2006, in which the practical advantages of low energy protons were demonstrated.

In order to improve the suite of quantitatively detected elements in fluid inclusions, a range of experiments was conducted, aimed at defining the characteristics of fluorine and sodium gamma rays at depth. The results of these experiments, combined with upgraded calibration of both the X-ray and gamma ray detectors, shows considerable promise for the detection of fluorine and sodium in fluid inclusions.

The potential of chemical age mapping with the nuclear microprobe was demonstrated last year, and this topic generated considerable interest at the 2007 AMAS Conference. This year the method was taken from a 'proof of concept' to a practical application. A dedicated research project was developed in conjunction with the University of Melbourne School of Physics to investigate the optimisation of proton beam energies. The research aimed to maximise proton interaction cross-sections simultaneously with X-ray emission. The project was carried out by Virginia Gill, who also developed algorithms for rapid 2D calculation of ages and error on a pixel by pixel basis. This approach allows us to automatically calculate the 40,000 chemical ages in a monazite grain image of 200 x 200 pixels.

Work continued on adapting traditional image-processing techniques and surface interpolation strategies to the special challenges of X-ray base trace-element data sets. This, along with the development of new graphical representations that allow blending of PIXE data with spot analyses, is the next step towards integrating LA-ICPMS and PIXE to maximise the extracted data from complex ore samples.

P5. F6 Trace-element and isotope developments in the CODES LA-ICPMS facility

Project Leader: S Meffre

Project Members: L Danyushevsky, G Davidson, S Gilbert, V Kamenetsky, D Selley

This project includes four strands.

1. Lead isotopes in galena using LA-ICPMS. Lead isotopes in galena are difficult to measure using LA-ICPMS due to high count rates under normal tunning conditions, even at very small laser beam sizes. An additional problem is the analysis of very small galena inclusions in pyrite due to rapid fluctuations in the intensity of lead signal.

During 2007, we addressed these problems by introducing a large mixing chamber between the ablation chamber and the ICPMS. This has the potential to generate a smooth lead signal at 1 Hz, which allows analysis of small inclusions in pyrite, provides an acceptable count rate and does not result in significant lead contamination. Excellent results were achieved for small galena inclusion in pyrite, however some problems remain with analysis of galena grains. The lack of good primary and secondary standards of galenas with contrasting lead-isotope values was addressed by analysing a set of five galenas with very different lead-isotope ratios by conventional solution ICPMS. The solutions were analysed in the second week of December and the galenas will be analysed with the laser during January 2008. The analyses will be performed using a number of different spot sizes and laser tuning conditions to evaluate the optimum analytical conditions.

2. Sulfur isotopes. A set of standard sulfides and sulfates with contrasting sulfur-isotope composition were analysed using the conventional (cuprous oxide) technique at the CSL, UTAS, and then analysed by LA-ICPMS using a 55 micron spot size and a special ICPMS tune to minimise interference from oxygen. Initial results were very promising, with groups of four analyses on standards correlating very well with the accepted values. However, when the technique was applied to unknown samples the results showed a systematic drift through time on the unknowns, which was not obvious for the standards, and the numbers of individual spot analyses scattered more widely than expected. It is probable that the problems stem from contamination of the results by sulfur deposits on the surface of the sample produced during previous analyses on adjacent spots. During the initial tests, four spots were analysed on each of the standards, whereas the unknowns were analysed using up to 12 individual spots, generally in pyrite containing a mixture of sulfides and silicates.

These problems are likely to be minimised by a different chamber design and/or different analytical conditions. Further experiments will be run in 2008 to assess the viability of the technique.

3. New ablation chamber. A number of different chambers were tested during 2007 to improve wash-out times and minimise surface contamination during analyses. The chambers were based on the small-volume, fast-response chamber developed at CODES, with an additional smaller chamber positioned around the ablation site to provide for constant gas flow. Although the modified chamber works well and overcomes the gas flow problems, it is difficult to use in routine analyses.

To resolve these issues, we have developed, with the help of Mike Shelley from ANU, a new chamber design. The development stage is finished, with technical drawing currently being finalised. We plan to build the new chamber in the first half of 2008.

4. Laser imaging. During 2007 we developed a new LA-ICPMS technique for generating images reflecting major- and trace-element distribution within rocks and minerals. The technique generates images showing the distribution of up to 18 elements within an area of up to 2 mm wide within a polished mount. The technique can be run automatically requiring about 30 minutes of user input at the beginning of the analysis. A computer program was written by Chris Hollitt to produce images within minutes of the completion of the analysis.

P5. F8 Cracking the sulfate isotopic composition problem in ancient hydrothermal systems: application of the carbonate-associated sulfate (CAS) method

Project Leaders: G Davidson, D Cooke

Project Members: K Harris, K McGoldrick, K Orth

Student: H Pass

In 2007 the project had two main strands:

1. Microprobe analysis and imaging of hydrothermal carbonates from the Kelian epithermal gold deposit, the Cadia East copper-gold porphyry, and the Mt Polley deposit.

2. Preliminary investigation of the effects of metamorphism upon sulfate mobilisation from sedimentary carbonates as a sulfur source for some

hydrothermal/metamorphic fluids. Analysis of samples from two sites did occur for the latter purpose in 2007, but the available samples are not ideal and we are currently seeking a better site with more continuous carbonate outcrop around a thermal source.

Excellent results have come from strand 1. Although our 2006 isotopic results provided carbonate-hosted sulfur-isotope-based temperatures that were consistent with other temperature estimates, our probe work found that sulfate in carbonate was below microprobe detection (~40–50 ppm). However, six late carbonate vein samples with minor chalcopyrite and pyrite from the Mount Polley porphyry contain high levels of sulfate-hosted carbonate, and this has been imaged and analysed to provide insight into how sulfate behaves during carbonate mineral formation. The Mount Polley samples contain early anhydrite-gypsum-calcite-prehnite assemblages [boron-rich datolite $\text{CaB}(\text{SiO}_4)(\text{OH})$ was also detected by Karin Orth, a first within the system]. This early inclusion-rich carbonate contains some of the highest sulfate values at the site (200–500 ppm). In places the anhydrite was replaced by high sulfate calcite (500–1000 ppm). The subsequent history was one of rebrecciation and new carbonate and silica veining. These younger carbonates vary from sample to sample. Zoned dolomite is earliest, and amongst these, 'saddle' geometries show the highest sulfate concentrations. This dolomite broadly gives way to clear calcite with low sulfate values. These results show that sulfate-bearing carbonates form and dissolve during hydrothermal activity, and consequently contribute to redox evolution of the system.

In 2008, the sulfide paragenesis will be carefully unravelled to provide a detailed understanding of the total sulfur behaviour of the Mount Polley veins. The microprobe analyses will be critically assessed to understand geochemical controls on sulfate incorporation into hydrothermal carbonate. Heidi Pass will be interpreting the sulfur-isotope data from these samples.



Anthony Harris with GSC-CARS, Advanced Photon Source, Chicago, USA. Project P5.F3.

Other activities within Program 5

Work continued on developing a database of chemical analyses produced at CODES LA-ICPMS facility. Ruben Chan, the CODES database manager, has designed the structure of the database and oversees data accumulation.

PhD projects within the Technology program

Heidi Pass: Chemical and mineralogical zonation patterns in alkalic mineral systems: implications for ore genesis and mineral exploration

Olga Vasyukova: The origin of quartz and fluid inclusions in mineralised porphyries

Graduate Research, Training & Outreach



Jocelyn McPhie, Coordinator Graduate Research

Objectives ... to provide high-quality training at Honours, postgraduate and post-doctoral levels, raising the skills base of the next generation of ore deposit researchers, exploration geoscientists and mining professionals ... to attract first-class Australian and international students and postdoctoral fellows into the Centre's programs ... and to transfer the Centre's research outcomes into innovative educational and outreach programs appropriate for professional and technical training

PhD Program

Enrolments in CODES' PhD program in 2007 were 53. This group includes four new students – Victor Galvan from Mexico, Martin Jutzeler from Switzerland, Anita Parbhakar from the UK, and Olga Vasyukova from Russia. Five of the group graduated in 2007 (Michael Baker, David Braxton, Lyudmyla Koziy, Stephen Lewis and Carlos Rosa) and one thesis was still under examination at the end of the year. Michael has taken a position with the NTGS, David has returned to industry, Lyudmyla has a post-doctoral position with CODES, Stephen has joined Geoscience Australia and Carlos has a post-doctoral position at the University of Lisbon.

Although total enrolments are above the target (40) for the Centre of Excellence, a significant number of students were studying part-time (9) or suspended their candidature (3), in almost all cases to take advantage of high-paying positions in the industry. Suspensions and part-time enrolments reduced the effective workforce to 35, which is adequate but below the target.

About two-thirds (62%) of the 2007 PhD cohort comprised international students representing 17 nationalities, seven of whom were at least partly funded by Centre of Excellence scholarships. The intake of new students was exclusively international and we expect this situation to continue into 2008. Our success in attracting students from overseas is a positive reflection of CODES standing as a research training centre internationally.

The majority of PhD projects (90%) are integrated into the Centre's five research programs and about two thirds (64%) involve collaborations with industry.

Master of Economic Geology Program

The CODES Master of Economic Geology degree is supported by the Minerals Council of Australia and forms a part of the national Minerals Geoscience Masters Program. Units are presented by UTAS, the University of Western Australia and James Cook University. In 2007, Curtin University of Technology (WA School of Mines) became a member and will be offering mining geology related units as part of an expanded 'G4' collaboration.

In 2007, MTEC made the decision to focus its educational funding at the Honours and undergraduate level and ceased to support the MTEC lecturer's position at UTAS. MTEC support for the MEconGeol program now consists of a single annualised payment for participating in the Minerals Geoscience Masters and support for a part-time administrative Executive Officer who is based at UWA. Work is ongoing for more centralised administration and marketing of the MGM.

In 2007 there were two short courses presented at CODES: 'Ore deposits of South America' and 'Ore deposit geochemistry, hydrology and geochronology'.

David Cooke and Bruce Gemmell led 20 course participants (five Master of Economic Geology students; eight industry geologists, four CODES Research Fellows; one Masters student from UBC and three CODES postgraduate students) through an intense two-week tour of Chilean and Peruvian ore deposits. Cesar Aguirre Mascarelli, Exploration

Manager for Newcrest in Peru (and a MEconGeol student), provided important local knowledge and logistical support, particularly with the Peruvian leg of the trip. Anthony Harris, Julie Hunt and Zhaoshan Chang supported David and Bruce throughout the hectic 14 days of the trip.

David Cooke was hard at work again as the leader of the 'Ore deposit geochemistry, hydrology and geochronology' course. The presenters were a high-level international group including Phil Blevin (consultant); Lesley Wyborn (Geoscience Australia); Jim Mortensen (UBC); Greg Dipple (UBC), Nick Oliver (JCU), Scott Halley (Mineral Mapping Pty Ltd) and Jamie Wilkinson (Imperial College, London). CODES expertise was also well represented. There were 11 MEconGeol students in attendance, with a large number of CODES postgraduates and Research Fellows attending many of the sessions. The CODES/SES SEG Student Chapter provided liquid refreshment throughout the two weeks of the course.

Two Master of Economic Geology theses were submitted and examined in 2007: 'Metal zonation and mineral distribution at Pueblo Viejo' by Gem Midgley (graduated December 2007) and 'The geology and genesis of the Moonlight Prospect, Pajingo epithermal system, northeast Queensland: an investigation of a high-level, low-sulfidation epithermal system' by Stephen Groves. Both theses were regarded as exceptional pieces of work by the examiners.

The Masters program has continued to attract new recruits from both within Australia and overseas (especially Canada and South America), with eight new students joining the program in 2007.

Honours Program

It was a very good year for the Honours Program. The student intake increased from eight students the previous year to nine in 2007. Although this was a relatively small increase, it was an encouraging turnaround in the downward trend of recent years. In addition, five of these students achieved a first-class grade, and the remaining four achieved a commendable second-class (upper) grade – an outstanding performance by the entire 'class of 07'.

This intake of students was sourced from within UTAS. Therefore, one of the opportunities in the coming year is to increase our communications efforts to appeal to a wider audience.

The breakdown of theses undertaken by the students is as follows:

Economic geology – two students.

Environmental geophysics - one student.

Igneous petrology – two students.

Regional geophysics – one student.

Resource geophysics – two students.

Sedimentology – one student.

The Honours year was administered by Garry Davidson, with Peter McGoldrick supervising the coursework aspects. Students were supervised by Michael Roach, Anya Reading, Leonid Danyushevsky, Mark Duffett, Stuart Bull, Andrew McNeill, Anthony Harris, Zhaoshan Chang, David Cooke, David Selley and Peter McGoldrick.

CODES research students.



Industry Links and Research Collaborations

Objectives ... to be a research focus for the national and international minerals industry ... and to strategically collaborate with other top-level national and international research groups in the field of ore deposits, mineral exploration technologies and mineral processing

CODES is recognised as a world leader in industry-linked collaborative ore deposit research. Strong relationships have been developed with a range of industry partners and researchers who invest in, support and contribute to our research. We will continue to collaborate with industry, and both national and international researchers and organisations, to further cement our place as a premier centre for ore deposit research.

Industry links

CODES has strong, enduring and mutually beneficial links with AMIRA International and a large group of the major Australian and international mining companies. These links have been critical for funding CODES research and for technology transfer to the mining and mineral exploration community.

Role of AMIRA International

AMIRA facilitates the funding of collaborative research involving university research groups and the minerals industry. AMIRA has agreed to fund a series of research projects within the Centre, which will run over a period of three to four years.

In 2007 AMIRA funded these major projects for CODES:

- P843 (GeM^{III} project – P4.L1) Geometallurgical mapping and mine modelling
- P923 (P2.L2) Controls on the formation and sulfide trace-element signatures of sediment-hosted gold deposits
- P872 (P3.L3) Origin and setting of Congolese-type copper deposits
- P962 (P1.F4) Ni-PGE potential of mafic and ultramafic – a combined melt inclusion and numerical modelling approach.

A new extension project, P765A 'Geochemical and geological halos in green rocks and lithocaps – The explorer's toolbox for porphyry and epithermal districts', has attracted sponsorship from 16 international companies and is due to start in January 2008

Role of industry partners

Eleven Australian and international mining companies make up the group of CODES industry partners: Anglo American, AngloGold Ashanti, Barrick Gold, BHP Billiton, Newcrest Mining Limited, Newmont

Mining Corporation, Rio Tinto, St Barbara Mines, Teck Cominco, Zinifex Limited and Great South Land Minerals. Each of our sponsor companies provides support of \$20,000 to \$120,000 in cash per year to the research budget of the Centre of Excellence. A total of \$1,850,000 has been guaranteed over five years. Senior representatives of these companies sit on the Science Planning Panel, along with other government and university researchers. This panel meets annually to discuss the results of CODES research and the potential directions for new research.

CODES industry partners benefit from sponsorship by having:

- association with, and first call on, a world-class research team in ore deposit science
- membership on CODES Science Planning Panel
- access to scholarships for staff undertaking Masters degree courses
- fee reductions on regular short courses and special in-house courses.

Research collaborations and International Visitors Program

CODES has a strong track record of research collaboration with other Australian and international universities and research organisations. In 2007 CODES undertook collaborative research with 17 international and 17 national organisations (see appendix).

Collaborative research between our international and Australian-based partners is also being facilitated by joint research appointments. The table below lists each of the collaborating institutions with the joint researchers and their funding source. These researchers are based at our collaborating partner institutions and incorporate research visits to CODES throughout the term of their research project.

Funding will continue to be used to support our International Visitors Program which attracts high-profile researchers to CODES. In 2007, the following major international research collaborators were supported to visit CODES for more than two months each:

- Eduard Konnikov (Institute of Experimental Mineralogy, Russia) – visited Leonid Danyushevsky from December 2007 to January 2008 to collaborate on Project P1.F4
- Xieyan Song (State Key Laboratory for Ore Deposits, Chinese Academy of Sciences, China) – visited Leonid Danyushevsky from December 2006 to March 2007 to collaborate on Project P1.F4
- Kirstie Simpson (Mineral Deposit Research Unit) – visited David Cooke from 1 June to 19 July 2007 to collaborate on Project P2.L3
- Taofa Zhou (Hefei University, China) – visited David Cooke in 2007 to collaborate on Projects P2.N3 and P3.L2
- Somboon Khositantont (Department of Mineral resources, Thailand) – visited Khin Zaw in 2007 to collaborate on Project P1.L1
- Alexei Ariskin (Vernadsky Institute of Geochemistry, Russia) – visited Leonid Danyushevsky from January 2007 to April 2007 to collaborate on Project P1.F4
- Dan Layton-Matthews (Queens University, Canada) – visited Bruce Gemmell in 2007 to collaborate on Project P2.F3

Researchers who work jointly in CODES and our collaborating organisations

<i>Institution</i>	<i>CoE ARC Grant</i>	<i>Node matching funds</i>	<i>Industry/AMIRA funds</i>	<i>University/CSIRO funds</i>
Julius Kruttschnitt Mineral Research Centre, University of Queensland	Steve Walters Robert Morrison Simon Michaux	Ben Adair	Nenad Djordjevic Khoi Ke Nguyen Yicai Wang	
University of Melbourne	Chad Paton	Jon Woodhead		Janet Hergt
Australian National University				Stephen Cox
CSIRO Exploration and Mining	Barbara Etschmann (50%) David Belton (50%)	Barbara Etschmann (50%) David Belton (50%)		Chris Ryan Weihua Liu
Johns Hopkins University, USA	Christian Schardt			Grant Garven
Mineral Deposit Research Unit, University of British Columbia (Canada)			Kirstie Simpson	Dick Tosdal



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Technology Transfer

Objectives ... to involve end-users (exploration and mining companies) in research planning, research evaluation and research adoption ... to promote technology transfer so that innovative research outcomes are accessible to end-users ... to comply with the national principles of intellectual property management for publicly funded research

Technology transfer activities

CODES undertakes strategic and applied research into the formation, location, discovery and recovery of ore deposits, and the development of innovative technologies to support these research endeavours, to create knowledge, processes, methods and solutions for the minerals industry and ore deposit researchers locally, nationally and internationally.

Research results and technical developments in the applied research programs are transferred to end-users via regular research meetings, research reports, monographs, books, digital presentations and software packages, where appropriate. In 2007, 180 research reports were presented to industry clients, and 12 meetings were held to present and discuss progress and adoption of research results.

Publications targeted at end-users

CODES also delivers knowledge and applications to end-users and the wider scientific community through a selection of special publications that represent the culmination of major research efforts by the Centre's staff.

- *Volcanic textures: a guide to the interpretation of textures in volcanic rocks* (1993). Authors: J. McPhie, M. Doyle and R. Allen (sold 231 copies in 2007)
- *New developments in Broken Hill-type deposits* (1996). CODES Special Publication 1. Editors: J. Pongratz and G.J. Davidson (sold 11 copies in 2007)
- *Basins, fluids and Zn-Pb ores* – CODES Special Publication 2 (1999). Editors: O. Holm, J. Pongratz and P. McGoldrick (sold 19 copies in 2007)
- *Volcanic environments and massive sulfide deposits* (2000). CODES Special Publication 3. Editors: J. Bruce Gemmell and June Pongratz (sold 13 copies in 2007)
- *The geology and origin of Australia's mineral deposits* (2000). Authors: M. Solomon and D.I. Groves (sold 24 copies in 2007)
- *Giant ore deposits: Characteristics, genesis and exploration* (2002). CODES Special Publication 4. Editors: D. Cooke and J. Pongratz (sold 42 copies in 2007)

- *24ct Au workshop* (2004). CODES Special Publication 5. Editors: D.R. Cooke, C. Deyell and J. Pongratz (sold 37 copies in 2007)
- *Altered volcanic rocks: a guide to description and interpretation* (2005). Authors: C. Gifkins, W. Herrmann and R. Large (sold 254 copies in 2007)
- *The geology of the Broken Hill Pb-Zn-Ag deposit, NSW, Australia* (2006). Author: A.E. Webster (sold 35 copies in 2007)

Commercial products and processes

Our geometallurgical research in Program 4, in collaboration with JKMRC at University of Queensland has the potential to deliver a number of commercial outcomes for industry. Due to the commercial-in-confidence nature of this research, details of the specific outcomes cannot be released at this time.

Short courses, workshops and conferences for end-users

CODES runs a series of workshops, short courses and conferences to facilitate the ongoing adoption of our research by industry. In 2007 we ran events in various locations including northern Chile, Peru, Vancouver, Dublin, Bejaia (Algeria), Bangkok and Perth. The courses are based on the results of our research programs and emphasise the application and adoption of our research to effect positive change in exploration practice and improve mineral exploration success rates.

A highlight for 2007 was a symposium to recognise the scientific contributions of John N Elliston to ore genesis and exploration. The symposium attracted over 60 Australian earth scientists on the theme of 'Syntaphral tectonics and diagenesis – 44 years on.'



Participants in the John Elliston Symposium held at CODES, November 2007.

2007 CODES short courses/workshops/conferences

<i>Title</i>	<i>Presenters (CODES presenters in bold)</i>	<i>Number of participants</i>	<i>Location</i>	<i>Date</i>
Volcanology and breccias for the explorationist – from description to interpretation	Jocelyn McPhie, David Cooke, Bruce Gemmell , Kirstie Simpson, Andrew Davies	50	Vancouver, Canada	26–28 January
Ore deposits of South America	David Cooke, Bruce Gemmell , Cesar Aguirre Mascarelli, Anthony Harris, Julie Hunt, Zhaoshan Chang	20	Chile and Peru	18–31 March
Spectral analysis workshop	Sasha Pontual (AusSpec International)	16	CODES	24–25 April
Ore deposit geochemistry, hydrology and geochronology	Ross Large, Bruce Gemmell, Garry Davidson, David Cooke, Khin Zaw, Tony Crawford, Dima Kamenetsky, Ron Berry, Anthony Harris , Greg Dipple, Jamie Wilkinson, Scott Halley, Jim Mortensen, Phil Blevin, Lesley Wyborn, Nick Oliver	11	CODES	4–15 June
VHMS deposits and volcanology	Jocelyn McPhie and Bruce Gemmell	12	Golden Grove, Western Australia (Oxiana)	30 July–2 August
How do we determine mineral chemistry and age of mineral formation ?	Sebastien Meffre	54	Department of Mineral Resources of Thailand, Bangkok	2 August
Sediment-hosted zinc deposits	Ross Large , Jamie Wilkinson	22	Dublin SGA International meeting	19 August
Lithogeochemical aspects of porphyry Cu-Au mineralisation	Tony Crawford	8	Anglo American, Perth (1 day in-house)	Sept
Tectonics and metallogenesis in SE Australia	Tony Crawford	10	St Barbara Mines, Melbourne	November
Introduction to field geology of porphyry ore deposits	Anthony Harris	6	China	15–28 November
Syntaphral tectonics and diagenesis – 44 years on (Elliston Symposium)	John Elliston, Rob Ryan, Tom Healy, Dima Kamenetsky , John Davidson, Ross Large , Dick Stanton, Brian Williams, Bob Richardson, Andrew Browne, Kim Wright, Jacob Rebec, Ian Gould	65	CODES, UTAS	22–23 November
Introduction to volcanology and volcanic facies analysis	Jocelyn McPhie	12	Bejaia, Algeria (Western Mediterranean Zinc)	5–9 December

Performance Indicators

<i>Key result area</i>	<i>Performance measure</i>	<i>Target</i>	<i>2007</i>
Research findings			
	Publications in international journals	40 pa	62
	Reports to industry collaborators	50 pa	180
	Special issues and/or research monographs	1 per 2 yrs	3 special issues
	Invitations to give keynote conference presentations	10 pa	14
	Papers at national/international meetings	60 pa	99
Investigators			
	Average % of CIs research in Centre (UTAS node)	70%	84%
	Average % of PIs research in Centre (Other nodes)	20%	20%
	Percentage of team-based projects	80%	74%
	Percentage of Australian cross-institutional projects	30%	49%
Research training and professional education			
	Percentage of RHD students attracted from other states of Australia (excluding Tasmania)	40%	35%
	Percentage of RHD students attracted from overseas	30%	53%
	Honours students in Centre programs	10	11
	RHD students in Centre programs	35	53 PhD, 3 MSc
	Percentage of student projects linked with industry	50%	77%
	Professional short courses/workshops for industry	5 pa	9
International, national and regional links and networks			
	Centre national or international major conferences/workshop	1 per 2 yrs	1 (Elliston Symposium)
	Registrants at Centre conferences/workshops	50 pa	167
	International and national visitors per year	30 pa	52
	Major collaborative projects with other global centres/groups	10	13
	External collaborators using Centre equipment	10 pa	11
End-user links			
	Frequency of meetings with industry representatives	10 pa	17
	End-user representatives to Science Planning Panel and Advisory Board	20%/50%	46%/39%
	Frequency of meetings with AMIRA Research Coordinator	10 pa	12
	Number of industry visitors to Centre	50 pa	52

<i>Key result area</i>	<i>Performance measure</i>	<i>Target</i>	<i>2007</i>
Organisational support			
	Annual cash contributions from UTAS (see Table 1)	\$1,300,000	\$1,714,152
	Annual cash support from CoE (see Table 1)	\$250,000	\$255,000
	Annual cash support from industry (see Table 1)	\$1,450,000	\$2,763,923
	Number of new organisations recruited to or involved in the Centre	1 pa	1 (Great South Land Minerals)
	New annual cash support from industry (see Table 2)	\$200,000	\$1,145,904
Governance			
	Joint post-doctoral appointments between collaborative institutions/organisations	5	8 (2 CSIRO, 1 JHU, 3 JKMRC, 1 UMelbourne, 1 UBC)
	Balance and experience of Advisory Board members		50% Academic, 40% Industry, 10% Government
	Annual review of strategic and business plans		Yes
	Effectiveness of Centre Research Committee		Needs improvement
	Effectiveness of Science Planning Panel		80%
	Public profile of Centre	High	Internationally – very high Nationally – high Locally – low
National benefit			
	Centre research has input into a major mineral discovery	1 per 5 yrs	Not in 2007
	Employment of Centre's postgraduates by minerals industry	>65%	70%

ARC contract and governance

The Australian Research Council (ARC) Centre of Excellence in Ore Deposits (CODES CoE) commenced on 1 July 2005. It was formerly the Centre for Ore Deposit Research, an ARC Special Research Centre. The CoE contract with the Commonwealth Government covers five years of funding from 2005–2010, with a mid-term review in November 2008. The Centre's financial affairs are conducted within the established procedures, controls and delegations of the University of Tasmania (UTAS) and the CoE's node universities and institutions. To ensure the ARC's CoE requirements are met, an inter-institutional agreement was established by the UTAS Research Office, formally binding all participating institutions to the ARC CoE requirements, including funding allocations from the CoE to its nodes and agreed matching contributions of those nodes. The CoE has a policy of assigning budget responsibility to node and Program Leaders, overseen by CODES Finance Manager and the Director.

2007 income

Total CODES income for 2007 was \$8.9 million (see Figure 1 and Table 1). This was derived principally from the ARC (36%), industry (31%) and the University of Tasmania (19%). The main income streams over time are compared in Figure 2, demonstrating that the ARC dollars are consistently being matched approximately 1.5:1 by other funding earned by the Centre (the original CoE agreement with the ARC was 1:1). All income streams have increased considerably since the start of the CoE, with industry funding showing strong growth.

Figure 1 Total income 2007

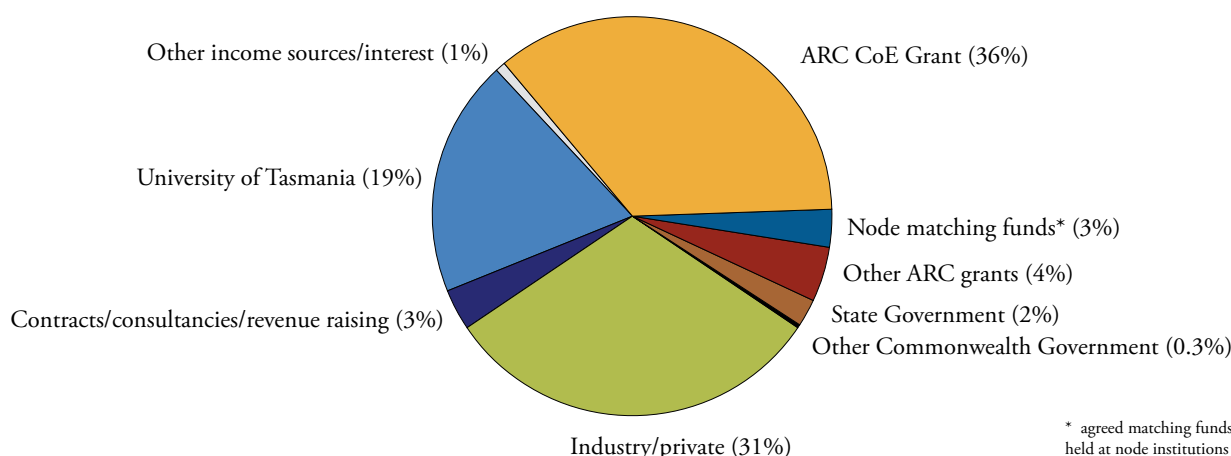


Figure 2 Comparison of CODES main income streams 2000–2007

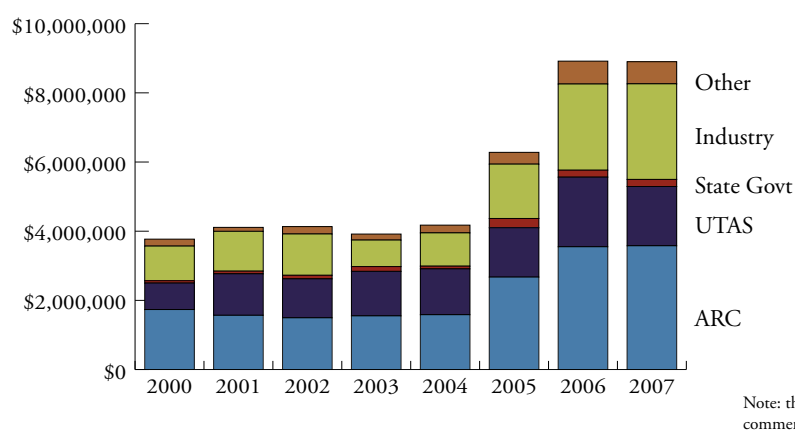


Table 1 Income financial statement 2005–2007

	2005 (half yr)	2006	2007
ARC - Centre of Excellence Grant			
2005 grant indexation (not received until 2006)	0	31,500	0
ARC Grant	1,500,000	3,121,198	3,184,402
	1,500,000	3,152,698	3,184,402
CoE nodes matching funds (agreed matching funds held at node Institutions)			
CSIRO Exploration and Mining - CoE core funding (see Tables 2 & 3)	0	100,000	100,000
University of Queensland - CoE core funding (see Tables 2 & 3)	0	75,000	50,000
University of Melbourne - CoE core funding (see Tables 2 & 3)	0	75,000	50,000
Australian National University - CoE core funding (see Tables 2 & 3)	0	45,000	55,000
	0	295,000	255,000
Other ARC grants			
Linkage Grants and Collaboratives	129,195	220,042	117,045
Discovery Grants	199,596	177,283	277,293
LIEF Grants		0	0
	328,791	397,325	394,338
Other Commonwealth Government funds			
Scholarships	0	0	7,000
Miscellaneous	7,184	19,649	17,666
	7,184	19,649	24,666
State Government funds			
Tasmanian State Govt. - CoE core funding (see Table 2)	200,000	200,000	200,000
Tasmanian State Govt. - scholarships	68,000	0	0
Directly funded research projects	0	0	4,000
Miscellaneous	0	852	0
	268,000	200,852	204,000
Local Government funds			
	0	0	0
Industry/private funds			
AMIRA International - CoE core funding (see Table 2)	514,590	956,825	1,325,713
AMIRA International - non-core projects	362,735	475,060	287,596
Industry - other projects	231,124	271,000	284,251
Industry - other projects - CoE core funding (see Table 2)	0	115,082	136,249
Industry - student funded projects	92,437	120,685	168,996
CODES Industry Partners - CoE core funding (see Table 2)	0	402,500	385,000
Minerals Council of Australia (MTEC) - CoE core funding (see Table 2)	78,584	148,100	162,988
Miscellaneous	13,979	2,807	13,130
	1,293,448	2,492,059	2,763,923
Contracts/consultancies/revenue raising			
Short courses	78,733	65,011	115,413
Symposiums	0	0	12,927
Book sales	37,521	96,111	74,453
Consulting	0	39,285	12,442
Miscellaneous	27,533	86,268	91,508
	143,787	286,675	306,743
University of Tasmania - Host institution support			
University - CoE core funding (see Table 2)	343,744	1,334,728	1,147,471
Additional support to salaries	236,396	572,953	505,738
General Operating Grant	29,550	22,635	0
Scholarships (non-core)	64,360	48,076	19,184
Institutional Research Grants (IRGs)	11,900	0	9,000
Student fee income (non-core)	17,000	32,400	32,760
Research Excellence Grants	3,750	0	0
Study leave	3,168	0	0
Miscellaneous	17,500	2,000	0
	727,367	2,012,792	1,714,152
Other income sources/interest			
Overseas government	8,000	0	25,028
Society of Economic Geologists - student scholarships	0	10,559	16,453
Student support	0	23,434	500
Specific projects	0	15,877	4,746
Miscellaneous	(3,652)	10,137	6,273
	4,348	60,006	53,000
Total annual income	\$4,272,926	\$8,917,056	\$8,900,226

The Centre of Excellence collaborator/contributor cash income agreement

The CoE funding agreement with the ARC requires that \$3 million per annum ARC funding will be matched with \$3 million per annum income from CoE collaborators/contributors. This income is used to fund core research projects in the CoE. Table 2 tracks the original income agreement (green section) against cash received to date (right hand section). The bottom section of the table lists additional industry funding commitments received after signing of the CoE agreement.

The right-hand section of Table 2 demonstrates all collaborator/contributor funding to the CoE was up-to-date at the end of 2007 (except UTAS which was slightly under, but will be caught-up in 2008). It also shows that to date CODES has received \$2.7 million more than the original agreement towards core CoE projects. This is mainly due to:

- Annual indexation of the ARC grant
- State Government paying in advance
- Increased Minerals Council of Australia funding
- Significantly increased AMIRA International and industry funding.

All collaborator/contributor funding is paid in cash to CODES annually, with the exception of the CoE nodes, which are treated differently as detailed below.

The following is a summary of the main income streams to the Centre of Excellence in 2007:

ARC income: In addition to the Centre of Excellence Grant (\$3.18 million), CODES received three ARC Linkage grants and two Discovery/Fellowship grants amounting to \$0.4 million. All other ARC grants previously held by CODES Chief Investigators were rolled into the Centre of Excellence grant in 2005.

Centre of Excellence node income: The Centre of Excellence nodes comprise the University of Queensland, University of Melbourne, Australian National University and CSIRO Exploration and Mining. The CoE agreement requires that CODES transfer an agreed annual portion of its ARC CoE grant income to each of the above nodes, to be expended at the node institution. In return the nodes agree to contribute a similar value of matching funds each year (see green section of Table 3). Although these matching funds are counted as income to the CoE (Table 1 and Table 2), they are actually held and expended at the node institution. Expenditure of both portions of node funding are reported annually to CODES (see Table 4 for expenditure of 2007 ARC funds).

To-date all nodes have received their agreed ARC income from CODES and all have contributed their agreed matching funds, in accordance with the CoE agreement (see right hand section of Table 3).

State Government income: As per the Centre of Excellence Agreement the State Government of Tasmania contributed \$200,000 towards research to support the Tasmanian minerals industry. The previous Tasmanian scholarship funding of \$68,000 per annum is now included in the \$200,000 annual allocation. The State Government contribution is currently paid \$100,000 in advance (see right hand section of Table 2).

Industry income: All sources of industry funding increased in 2007, mainly due to the start-up of new key industry research projects. This increase is contributing to the overall income surplus shown in Table 2.

Total industry funding was \$2.76 million, of which the largest contribution (58%) was from AMIRA International for CoE core and non-core research projects. AMIRA International is an independent association of mineral companies which develops, brokers and facilitates collaborative research projects between industry and research organisations.

Host institution support: The University of Tasmania provided \$1.7 million income to the CoE in 2007, of which \$1.1 million was their core funding commitment to the ARC Centre of Excellence. This funding relates to research salaries, PhD scholarships, equipment and research quantum earned by the Centre.

2008 income estimates

Industry income is expected to increase by approximately 10% in 2008. All other income streams will remain relatively stable.

2007 expenditure of ARC CoE Grant

Summaries in Table 4 and Figure 3 show how the CoE and its nodes have expended their ARC CoE Grant funds to-date. The major areas of expenditure were salaries, laboratory analyses, research equipment, student scholarships, research travel and general consumables.

The 2007 ARC CoE total income and carry forward of \$4,559,179 was matched by expenditure of \$3,847,200. The unspent carry forward of \$711,979 is due to two factors:

- The six-month delay to the start of the Centre of Excellence due to late signing of the agreement and the resulting late ARC payment of \$1.5 million in December 2005. This resulted in project start-up delays.
- Delays in filling key research appointments.

It is expected this carry forward will reduce significantly in 2008.

2008 expenditure estimates

Expenditure on salaries will be higher in 2008 due to several new research positions being filled during the year. Other expenditure will be similar to previous years.

Table 4 Expenditure of ARC Centre of Excellence Grant 2005–2007

	2007 detail - CODES plus nodes						Annual totals - CODES plus nodes		
	CODES	CSIRO	U Qld	U Melb	ANU	JHU	(half yr) 2005	2006	2007
Balance brought forward from previous year	1,127,599	(12,574)	1,228	67,620	148,522	12,793	0	954,886	1,345,188
Miscellaneous income (refund of expenses)	29,589						0	8,497	29,589
ARC income	3,184,402						1,500,000	3,152,698	3,184,402
ARC income transferred to CoE nodes*	(650,000)	100,000	350,000	100,000	100,000	0	0	0	0
Total income	3,691,590	87,426	351,228	167,620	248,522	12,793	1,500,000	4,116,081	4,559,179
Salaries	(1,469,018)	(83,125)	(208,815)	(57,645)	(10,000)	(4,706)	(348,511)	(1,237,351)	(1,833,309)
Equipment purchases	(232,393)	(35,241)	(6,217)	(32,140)			(890)	(83,645)	(305,991)
Equipment leased/hired	(6,894)						(362)	(22,635)	(6,894)
Shared equipment/facilities	(12,600)			(34,150)			(1,119)	(21,900)	(46,750)
Travel and accommodation (research)	(297,188)	(3,271)	(655)	(8,982)	(2,477)	(1,633)	(52,363)	(354,349)	(314,206)
IT maintenance	(206,351)			(2,337)			(1,866)	(91,292)	(208,688)
General consumables/maintenance	(158,173)		(58,849)			(919)	(67,517)	(244,347)	(217,941)
Student scholarships	(263,976)		(85,695)				(31,856)	(297,768)	(349,671)
Public relations and advertising	(113,975)				(5,389)		(9,289)	(105,160)	(119,364)
Laboratory analyses	(307,733)						(29,900)	(212,256)	(307,733)
Consultants	(108,075)						0	(90,290)	(108,075)
Visiting academics	(19,311)						(9,002)	(9,900)	(19,311)
New appointment expenses	(9,267)						0	0	(9,267)
Unspent node funds returned to CODES	5,535					(5,535)	0	0	0
Miscellaneous (expend and refunds)	0						7,561	0	0
Total expenditure	(3,199,419)	(121,637)	(360,231)	(135,254)	(17,866)	(12,793)	(545,114)	(2,770,893)	(3,847,200)
Balance remaining at end of year	492,171	(34,211)	(9,003)	32,366	230,656	0	954,886	1,345,188	711,979

* annual ARC income that is transferred to the CoE nodes as per the CoE agreement (see Table 3)

Figure 3 Expenditure of ARC Centre of Excellence Grant 2007

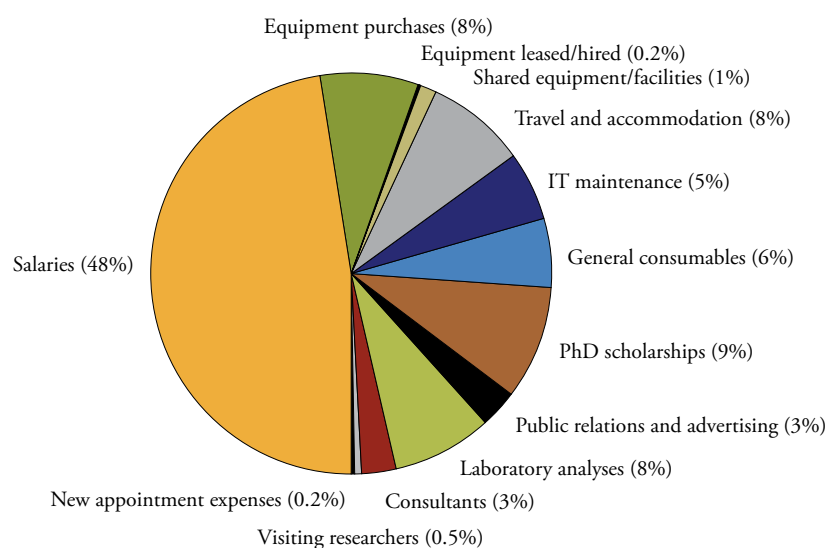


Table 2 Current status of the CoE core income agreement with its collaborators/contributors –

Original agreement						
Name of collaborator/contributor	Agreed annual cash income to the Centre of Excellence					
	half yr 2005	2006	2007	2008	2009	half yr 2010
University of Tasmania	545,500	1,129,000	1,215,000	1,413,000	1,819,500	1,038,000
CSIRO Exploration and Mining (CoE node)	25,000	75,000	100,000	100,000	100,000	50,000
University of Queensland (CoE node)	25,000	50,000	50,000	50,000	50,000	25,000
University of Melbourne (CoE node)	25,000	50,000	50,000	50,000	50,000	25,000
Australian National University (CoE node) *	0	45,000	55,000	50,000	50,000	50,000
AMIRA International	495,440	993,470	888,810	673,280	282,500	0
Minerals Council of Australia (MCA/MTEC)	70,000	140,000	70,000	0	0	0
State Government of Tasmania	100,000	200,000	200,000	100,000	0	0
Industry partner - Anglo American	15,000	35,000	40,000	45,000	50,000	25,000
industry partner - AngloGold Ashanti	10,000	22,500	25,000	27,500	30,000	15,000
Industry partner - Barrick Gold	10,000	22,500	25,000	27,500	30,000	15,000
industry partner - BHP Billiton (incl. WMC contribution from 2005 onward)	25,000	57,500	65,000	72,500	80,000	40,000
Industry partner - Newcrest Mining	0	20,000	20,000	20,000	20,000	20,000
Industry partner - Newmont Mining	15,000	35,000	40,000	45,000	50,000	25,000
Industry partner - Rio Tinto	10,000	22,500	25,000	27,500	30,000	15,000
Industry partner - Teck Cominco	10,000	22,500	25,000	27,500	30,000	15,000
Industry partner - WMC (taken over by BHP in 2005 - BHP now pays this)	0	0	0	0	0	0
Industry partner - Zinifex	15,000	35,000	40,000	45,000	50,000	25,000
Other industry - Anglo American - Contrib. to Cooke student support	20,000	30,000	10,000	0	0	0
Other Industry - Newcrest Mining - Contrib. to Cadia project	192,224	115,082	126,613	118,147	47,935	0
ARC	1,500,000	3,000,000	3,000,000	3,000,000	3,000,000	1,500,000
Total core cash income listed in the CoE agreement	3,108,164	6,100,052	6,070,423	5,891,927	5,769,935	2,883,000
Additional new industry cash commitments received after signing of the above agreement						
Industry partner - St Barbara Mines	0	30,000	40,000	40,000	0	0
Industry partner - Great South Land Minerals/Zeehan Zinc Tasmania	0	0	40,000	45,000	50,000	0
AMIRA International (new Danyushevsky AMIRA P962 project)	0	0	104,940	142,920	122,920	28,933
Other new cash received from industry for core CoE projects	108,049	575,947	960,964	0	0	0
Total new industry funding	108,049	605,947	1,145,904	227,920	172,920	28,933
Grand total						

* ANU's annual matching funds schedule was revised in 2007 due to late start of their project (their 5-year total of \$100,000 remains the same)

Table 3 Current status of the CoE funding agreement with its nodes –

Original agreement													
Nodes	Agreed annual funding to CoE nodes												
	2005 (half yr)		2006		2007		2008		2009		2010 (half yr)		
	ARC income to be trf'd to node	node matching funds	ARC income to be trf'd to node	node matching funds	ARC income to be trf'd to node	node matching funds	ARC income to be trf'd to node	node matching funds	ARC income to be trf'd to node	node matching funds	ARC income to be trf'd to node	node matching funds	
CSIRO Exploration and Mining	25,000	25,000	75,000	75,000	100,000	100,000	100,000	100,000	100,000	100,000	50,000	50,000	
University of Queensland	50,000	25,000	100,000	50,000	100,000	50,000	100,000	50,000	100,000	50,000	50,000	25,000	
University of Melbourne	50,000	25,000	100,000	50,000	100,000	50,000	100,000	50,000	100,000	50,000	50,000	25,000	
Australian National University *	50,000	0	100,000	45,000	100,000	55,000	100,000	50,000	100,000	50,000	50,000	50,000	
University of British Columbia	0	0	0	0	0	0	0	0	0	0	0	0	
Colorado School of Mines (USA)	0	0	0	0	0	0	0	0	0	0	0	0	
Johns Hopkins University (USA)	0	0	0	0	0	0	0	0	0	0	0	0	
University of Qld (AMIRA P843)	125,000	0	250,000	0	250,000	0	250,000	0	125,000	0	0	0	
Total agreed in CoE Agreement	300,000	75,000	625,000	220,000	650,000	255,000	650,000	250,000	525,000	250,000	200,000	150,000	

* ANU's annual matching funds schedule was revised in 2007 due to late start of their project (their 5yr total of \$100,000 remains the same)

cash promised versus cash received

Summary of agreed cash income owed and received to-date (July 05–Dec 07)

Owed to date	Paid to date	over or under
2,889,500	2,825,943	(63,557)
200,000	200,000	0
125,000	125,000	0
125,000	125,000	0
100,000	100,000	0
2,377,720	2,692,188	314,468
280,000	389,672	109,672
500,000	600,000	100,000
90,000	90,000	0
57,500	57,500	0
57,500	57,500	0
147,500	147,500	0
40,000	40,000	0
90,000	90,000	0
57,500	57,500	0
57,500	57,500	0
0	0	0
90,000	90,000	0
60,000	63,247	3,247
433,919	462,556	28,637
7,500,000	7,837,100	337,100
15,278,639	16,108,206	829,567

New Industry funds

0	70,000	70,000
0	40,000	40,000
0	104,940	104,940
0	1,644,960	1,644,960
0	1,859,900	1,859,900
\$15,278,639	\$17,968,106	\$2,689,467

node funding promised versus funding paid

Summary of CODES ARC income owed and paid to date (July 05–Dec 07)

owed	paid	over or under
200,000	200,000	0
250,000	250,000	0
250,000	250,000	0
250,000	250,000	0
0	0	0
0	0	0
0	40,020	40,020
625,000	625,000	0
1,575,000	1,615,020	40,020

Summary of node matching funds owed and paid to date (July 05–Dec 07)

owed	paid	over or under
200,000	200,000	0
125,000	125,000	0
125,000	125,000	0
100,000	100,000	0
0	0	0
0	0	0
0	0	0
0	0	0
550,000	550,000	0

Notes to, and forming part of, the financial statements for 2007

CODES financial pages for 2007 were prepared by Christine Higgins, CODES Finance Manager. Data for the financial statements were extracted from the University of Tasmania's Financial Management Information System and CODES financial databases. All reports shown here have been audited by the University of Tasmania.

Income statement explanations

All income categories are consistent with last year's reports.

In Table 1 financial statement, sub-categories labelled 'CoE core funding' are used to isolate CoE core funding from other general funds, as the ARC requires us to demonstrate these agreed core funds have been received each year.

The income figures in Table 1 represent actual income recorded in the University's finance system or transferred internally from UTAS to CODES during 2007, apart from the following exceptions:

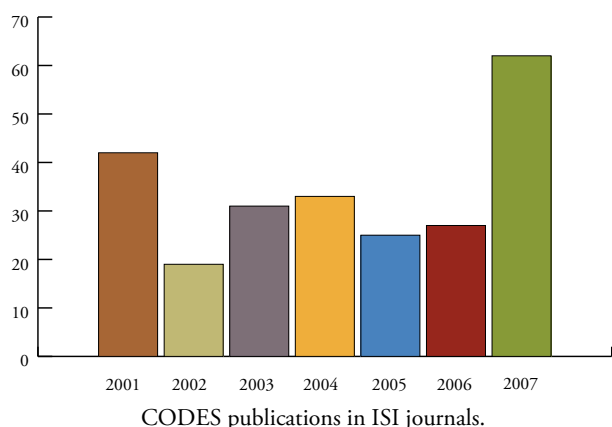
- The CoE node matching funds (approximately \$250,000 per annum) is listed as cash income in the income statement (Table 1) but was not actually received as cash by UTAS. These matching funds are contributed by the nodes but held at their own institutions to be expended there. The CoE agreement (Table 2) requires the nodes make these annual contributions to the CoE in the form of matching funds. The nodes provide relevant income and expenditure statements to the CoE at the end of each year, and their annual contributions are listed as cash income in Table 1 to demonstrate they are meeting their agreed annual contribution to the CoE.
- UTAS total core funding income in Tables 1 and 2 includes \$69,000 of funding that was committed in 2007 but not actually received until March 2008. An adjustment has been made to the 2007 financial statements to count this income in the year that it was due (2007). Similarly it will be deducted from 2008 UTAS income.

Due to the six-month delay to the start of the CoE, very few agreed cash payments between the CoE and its nodes/collaborators were contributed in 2005. Instead there was an 18-month catch-up in 2006. This has artificially inflated 2006 income figures by approx \$400,000 (namely: node income +\$50,000, UTAS +\$200,000, Industry Partners +\$130,000). Any comparison between 2006 and 2007 income figures needs to take this into account.

Expenditure statement explanations

All expenditure categories are consistent with last year's reports.

The expenditure financial statement and pie chart (Table 4 and Figure 3) includes node expenditure to show how the ARC funds transferred to the nodes are being spent.



Chapters in books (2)

- Falloon, T.J.**, Green, D.H. and **Danyushevsky, L.V.** 2007. Crystallization temperatures of tholeiite parental liquids: Implications for the existence of thermally driven mantle plumes. In: G.R. Foulgar and D.M. Jurdy (Eds), *Plates, Plumes and Planetary Processes*. Geological Society of America Special Paper, 430: 235-260. doi: 10.1130/2007.2430(12).
- Lewis, R.S., Vervoort, J.D., Burmester, R.F., McClelland, W.C. and **Chang, Z.** 2007. Age of metasedimentary rocks northwest of the Idaho batholith based on detrital zircons and intrusive sills. In: P.K. Link and R.S. Lewis (Eds), *Proterozoic Geology of Western North America and Siberia*. Society for Sedimentary Geology (SEPM) Special Publication, 86: 37-53.

Refereed journal articles (62)

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- Barron, L.M., **Meffre, S.** and Glen, R.A. 2007. Arc and mantle detritus in the post-collisional, Lower Silurian Kabadah Formation, Lachlan Orogen, New South Wales. *Australian Journal of Earth Sciences*, 54(2-3): 353-362. (Project P1.F1.2)
- Bastrakov, E.N., Skirrow, R.G. and **Davidson, G.J.** 2007. Fluid evolution in Fe-oxide Cu-Au prospects of the Olympic Dam district, Gawler Craton, South Australia. *Economic Geology*, 102(8): 1415-1440. (Project P2.F4)
- Berry, R.F.**, **Chmielowski, R.M.**, Steele, D.A. and **Meffre, S.** 2007. Chemical U-Th-Pb monazite dating of the Cambrian Tyennan Orogeny, Tasmania. *Australian Journal of Earth Sciences*, 54(5): 757-771. (Project P1.F1)
- Bromfield, K., Burrett, C.F., Leslie, R.A. and **Meffre, S.** 2007. Jurassic volcanoclastic-basaltic andesite-dolerite sequence in Tasmania: New age constraints for fossil plants from Lune River. *Australian Journal of Earth Sciences*, 54(7): 965-974.
- Bull, K.F.** and **McPhie, J.** 2007. Fiamme textures in volcanic successions: Flaming issues of definition and interpretation. *Journal of Volcanology and Geothermal Research*, 164: 205-216. (Project P1.F3)
- Cannell, J.B.**, **Cooke, D.R.**, Walshe, J.L. and Stein, H. 2007. Geology, mineralization, alteration, and structural evolution of the El Teniente porphyry Cu-Mo deposit – A reply. *Economic Geology*, 102(6): 1171-1180. (Project P2.F1)
- Chen, Y.J., Chen, H.Y., **Khin Zaw**, Pirajno, F. and Zhang, Z.J. 2007. Geodynamic settings and tectonic model of skarn gold deposits in China: An overview. *Ore Geology Reviews*, 31(1-4): 139-169. (Project P1.L1)
- Cooke, D.R.**, **Wilson, A.J.**, **House, M.J.**, **Wolfe, R.C.**, Walshe, J.L., **Lickfold, V.** and **Crawford, A.J.** 2007. Alkaline porphyry Au-Cu and associated mineral deposits of the Ordovician to Early Silurian Macquarie Arc, New South Wales. *Australian Journal of Earth Sciences*, 54(2-3): 445-464. (Project P1.F1.2)
- Cox, S.F.** 2007. Structural and isotopic constraints on fluid flow regimes and fluid pathways during upper crustal deformation: An example from the Taemas area of the Lachlan Orogen, SE Australia. *Journal of Geophysical Research*, 112, B08208, doi:10.1029/2006JB004734. (Project P2.F1)
- Crawford, A.J.**, **Cooke, D.R.** and Fanning, C.M. 2007. Geochemistry and age of magmatic rocks in the unexposed Narramine, Cowal and Fairholme Igneous Complexes in the Ordovician Macquarie Arc, New South Wales. *Australian Journal of Earth Sciences*, 54(2-3): 243-272. (Project P1.F1.2)
- Crawford, A.J.**, **Meffre, S.**, **Squire, R.J.**, Barron, L.M. and **Falloon, T.J.** 2007. Middle and Late Ordovician magmatic evolution of the Macquarie Arc, New South Wales. *Australian Journal of Earth Sciences*, 54(2-3): 181-214. (Project P1.F1.2)
- Davidson, G.J.**, **Paterson, H.**, **Meffre, S.** and **Berry, R.F.** 2007. Characteristics and origin of the Oak Dam East breccia-hosted, iron oxide-Cu-U-(Au) deposit: Olympic Dam region, Gawler Craton, South Australia. *Economic Geology*, 102(8): 1471-1498. (Project P2.F4)
- Davidson, P.** and **Kamenetsky, V.S.** 2007. Primary aqueous fluids in rhyolitic magmas: Melt inclusion evidence for pre- and post-trapping exsolution. *Chemical Geology*, 237: 116-131. (Project P1.F3)
- Elburg, M.A., **Kamenetsky, V.S.**, Foden, J.D. and Sobolev, A. 2007. The origin of medium-K ankaramitic arc magmas from Lombok (Sunda arc, Indonesia): Mineral and melt inclusion evidence. *Chemical Geology*, 240: 260-279. (Project P1.F6)
- Etschmann, B.E., **Ryan, C.G.**, Vogt, S., Maser, J., Brugger, J., Harland, C.L. and Legnini, D. 2007. Selective x-ray Bragg spectrometry: optimizing fluorescence microprobe sensitivity for precious metals. *X-ray Spectrometry*, 36: 111-121. (Project P5.F4)
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- Falloon, T.J.**, **Danyushevsky, L.V.**, **Crawford, A.J.**, Maas, R., Woodhead, J.D., Eggins, S.M., Bloomer, S.H., Wright, D.J., Zlobin, S.K. and Stacey, A.R. 2007. Multiple mantle plume components involved in the petrogenesis of subduction-related lavas from the northern termination of the Tonga Arc and northern Lau Basin: Evidence from the geochemistry of arc and backarc submarine volcanics. *Geochemistry, Geophysics, Geosystems*, 8: Q09003, doi: 10.1029/2007GC001619. (Project P1.F2)
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- Glen, R.A., **Crawford, A.J.** and **Cooke, D.R.** 2007. Tectonic setting of porphyry copper-gold mineralisation in the Ordovician – Early Silurian Macquarie Arc, Eastern Lachlan Orogen, New South Wales. *Australian Journal of Earth Sciences*, 54(2-3): 465-479. (Project P1.F1.2)
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- Hou, Z., **Khin Zaw**, Pan, G., Xu, Q., Hu, Y. and Li, X. 2007. The Sanjiang Tethyan metallogenesis in S.W. China: Tectonic setting, metallogenic epochs and deposit types. *Ore Geology Reviews*, 31(1-4): 48-87. (Project P1.L1)
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- Large, R.R., Maslennikov, V., Robert, F., Danyushevsky, L. and Chang, Z.** 2007. Multi-stage sedimentary and metamorphic origin of pyrite and gold in the giant Sukhoi Log deposit, Lena Gold Province, Russia. *Economic Geology*, 102(7): 1233-1267. (Project P2.L4)
- Lickfold, V., Cooke, D.R., Crawford, A.J. and Fanning, C.M.** 2007. Shoshonitic magmatism and the formation of the Northparkes porphyry Cu-Au deposits, New South Wales. *Australian Journal of Earth Sciences*, 54(2-3): 417-444. (Project P1.F1.2)
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- Bath, A.B., Logan, J.M. and Kamenetsky, V.S. 2007. Apatite in Cu-sulfide ore from the Mount Polley alkalic porphyry, BC Canada: Mineral Exploration Roundup 2007 conference, Vancouver, British Columbia (poster).
- Begg, G., Loucks, R., Gray, D., Foster, D., Kent, A. and Cooke, D.R. 2007. Gold and tectonics: a dynamic link. Ores and Orogenesis Symposium, Tucson, Arizona, 24 - 30 September 2007. 90-91.
- Belford, S., McPhie, J., Davidson, G. and Large, R.R. 2007. The volcanic sequence hosting the Archaean Jaguar VHMS deposit, Western Australia. IGCP 502 Global comparison of VMS districts: Relationship between VMS (Kuroko) deposits and the evolution of volcanic arcs, Japan, 27 October - 4 November 2007. Poster presentation.
- Berry, A.J., Harris, A.C., Kamenetsky, V.S., Newville, M. and Sutton, S.R. 2007. The speciation of metals in natural fluid inclusions at temperatures up to 700°C. *Geochimica et Cosmochimica Acta*. 71, Supplement 1: A86.
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- White, N.C., Hedenquist, J.W., Chang, Z., Deyell, C.L. and Cooke, D.R. 2007. Lithocap summary. AMIRA P765 Final Report, CODES Centre of Excellence in Ore Deposits, March 2007, Santiago, Section 8.1, pp. 1–20. (Project P3.L2)
- Zukowski, W. 2007. Geology, alteration, mineralisation and geochemistry of the Endeavour 41 Au prospect, Cowal district, NSW. Alkaline project annual report, Year 2 – Epithermal Module – Update to Project Sponsors, September 2007, Vancouver, pp. 2.1–2.10. (Project P2.L3)

Appendices

CODES Postgraduate Students 2007

<i>Student</i>	<i>Supervisors</i>	<i>Project</i>	<i>Support</i>
Bachelor of Science (Honours)			
Alyce Brownlie	Roach, Reading	Reliability study of the Durham soil moisture and density indicator utilizing time domain reflectometry; a Tasmania-specific study	GHD
Michelle Farran	McPhie, Berry	Volcanic, metamorphic and structural architecture of the Prospero-Tapinos nickel sulfide host succession	Sir Samuel Mines NL
Jodi Fox	Duffett, Roach	Potential field modelling of magnetite lenses in the Attuttra Metagabbro, NT	Arafura Resources Ltd
Laura Frankcombe	Selley, Cooke	Geochemical and structural controls of gold mineralisation, Mars Mine, Western Australia	St Ives
Cam Hamilton	Roach, Reading	A potential field investigation of the Wagon Pass Pb/Zn prospect, Lennard Shelf, Western Kimberley, WA	CBH Resources Ltd, CSA Australia Ltd, Southern Geoscience Australia
Meg Humphrys	Crawford, McNeill	The origin of felsic segregations and massive granophyre in Jurassic dolerite intrusions	MRT (TGMS Scholarship)
Tom Lorimer	Roach	An investigation of the upper crustal structure of eastern Tasmania using active source seismic tomography	MRT
Thomas Methorst	Roach	Gravity survey of Flinders Island	MRT
William Reynolds	Harris, Cooke	Distal alteration at Ridgeway deposit, New South Wales	Newcrest Mining
Jeneta Wellard	Bull	Sequence stratigraphy of the Myrtle Formation, Gordon Group Limestone, Zeehan western Tasmania.	Zeehan Zinc Exploration
Ian Woolward	Danyushevsky, McNeill	The geochemistry and mineralogy of the Centralnyi Creek Sill, Dovyren mafic-ultramafic complex	Anglo-American, BHP Billiton, Votorantim (AMIRA P962)
Master of Economic Geology			
Corrie Chamberlain		Geology, geochemistry and genesis of the Kilkenny low-sulfidation epithermal deposit, Cracow, Queensland	Newcrest-Kracow, Qld
Cain Fogarty		Course work	
Cesar Eduardo Aguirre Mascarelli		Course work	Newcrest Resources Inc
Paluku Batsotsi		Course work	Anvil Mining
Colin Carter		to be decided	CMT
Jennifer Catoc		Aisajura porphyry copper gold project - Philippines	Anglo American
Aaron Hantler		Course work	Anglogold Ashanti
Irianti		Course work	Anglogold Ashanti
Yansan Jamyanbaatar		North Parkes porphyry copper deposit	Rio Tinto Gobi Expl. JV
Benjamin Jones		Course work	Anglogold Ashanti
Budi Santoso		Course work	Phelps Dodge
Kalem Wright		Course work	Perilya
Master of Exploration Geoscience			
Terence Hoshcke	Large, Roach	Geophysical signatures of gold-copper porphyry systems	
Master of Science			
Paul Ferguson	Davidson	Origin of large negative anomalies in oceanic crust, Macquarie Island	SEG
Takayuki Manaka	Zaw, Meffre	Geological setting and mineralisation characteristics of the Long Chieng Track and Ban Houayxai deposits, Lao PDR	ARC Linkage, CoE, Pan Australian
Doctor of Philosophy			
Andrea Agangi	Kamenetsky, McPhie, Allen	Magmatic and volcanic evolution of giant intraplate felsic igneous provinces and associated ore deposits: Gawler Range Volcanics and Hiltaba Suite, South Australia	TPRS co-fund Scholarship, CoE
Darren Andrews	Reid, Berry	Geophysical monitoring of acid mine drainage at Savage River Mine, Northwestern Tasmania	Australian Bulk Minerals, APA-I
Michael Baker*	Crawford, Berry	Palaeoproterozoic magmatism in the Georgetown Block, N Queensland, and comparisons with Broken Hill Block	TPRS Scholarship
Adam Bath	Kamenetsky, Crawford, Cooke	The geochemistry of melt inclusions and mineral phases from the Mount Polley and Lorraine alkalic Cu-Au porphyry deposits: implications for the formation of ore deposits	BCGS, SEG, CoE Top-up, APA Scholarship, Alkalic project, UBC, MDRU
Susan Belford	Davidson, McPhie, Large	Genetic and chemical characterisation of the Archaean Jaguar VHMS deposit	APA-I, SEG
Jacqueline Blackwell	Cooke, McPhie	Characteristics and origins of breccias in an alkalic epithermal gold deposit: Ladolam, Lihir Island, Papua New Guinea	CoE, Alkalic project, TPRS co-fund Scholarship
David Boakye (BRC)	Walters, Bye (UQ)	Geostatistical modelling of geomettallurgical attributes	GeM project
Natalee Bonnici	Walters, Berry	Textural and mineralogical characterisation of Cu-Au systems in relation to process mineralogy	GeM project, TGRS Scholarship

<i>Student</i>	<i>Supervisors</i>	<i>Project</i>	<i>Support</i>
Bryan Bowden	Davidson	Geology, geochemistry and genesis of the Prominent Hill IOCG deposit, South Australia	CODES, AGSO, Minotaur Resources, Goldstream Mining NL, PIRSA
David Braxton*	Cooke	Boyongan and Bayugo porphyry Cu-Au deposits, NE Mindanao, Philippines: geology, geochemistry, and tectonic evolution	Anglo American, IPRS
Reia Chmielowski	Berry, Cooke	The metamorphic history of Tasmania	TGMS, TPRS co-fund Scholarship
Mawson Croaker	Selley, McGoldrick, Bull	Geology and genesis of the Nkana copper deposit, Zambia	AMIRA, TPRS Scholarship
Paul Cromie	Zaw, Cooke, White	Geological setting, geochemistry and genesis of the Sepon Mineral District, Laos PDR	Oxiana, SEG, CSIRO, APA Scholarship
Ana-Liza Cuison	Cooke, Harris, Berry	Geology and genesis of the Ridgeway porphyry Au-Cu deposit, NSW	Newcrest
Kim Denwer	Large	Mineralogical, geochemical and isotopic investigation of the Mount Lyell Cu-Au ore body and alteration system	CMT, TGMS
Sang Quang Dinh	Crawford, Berry	Geochronology and geological evolution of the northern margin of the Kontum massif, central Vietnam	Vietnamese Govt., CODES
Cathy Evans (JKMRC)	Walters, Johnson, Manlapig, Kojovic (UQ)	The relationship between mineral characteristics of ores and the variation in their processing attributes	GeM project
Lee Evans	Davidson, Cooke	Ground waters in wet, temperate sulfide mining districts: delineation of modern fluid flow and predictive modelling to improve management after mine closure (Rosebery, Tasmania)	Pasminco, APA-I
Nathan Fox	Cooke, Harris	Controls on alteration and mineralisation in the Cadia East Au-Cu porphyry copper deposit, NSW, Australia	Newcrest
Russell Fulton	Gemmell, Berry	Geology and geochemistry of the hanging wall argillite, Greens Creek VHMS deposit, Alaska: implications for ore genesis and exploration	Kennecott Greens Creek Mining
Victor Galvan Gutierrez	Cooke, Gemmell, McPhie	Palmarero carbonate base-metals silver-gold epithermal deposit, Trogon Project, Chihuahua, Mexico	IPRS, Bolnisi Gold NL
Sarah Gordee	McPhie, Allen	Characteristics of subaqueous pyroclastic facies in arc settings	TPRS co-fund Scholarship, CoE, CODES P1
Timothy Ireland	Cooke, Berry, Gemmell	Geological framework of porphyry and epithermal mineralisation in the Collahuasi District, Region de Tarapaca, Chile	AMIRA (P765), SEG, APA Scholarship, Compania Minera Quebrada Blanca S. A., Compania Minera Dona Ines de Collahuasi, Anglo American plc, Newmont Mining Corporation
Benjamin Jones	Large, Crawford	Tectonic setting and magmatic evolution of the Antapaccay porphyry copper-gold and skarn deposit, Peru	BHP, APA Scholarship
Martin Jutzeler	McPhie, Allen	Behaviour of submerged eruption plumes using data from facies analysis of a variety of submarine pyroclastic successions	CoE
Teera Kamvong	Zaw, Meffre	Geology and genesis of porphyry-skarn Cu-Au deposits at the northern Loei Fold Belt, Northeast Thailand and Laos	IPRS, ARC Linkage, CODES, SEG, Pan Australian
Luke Keeney (JKMRC)	Walters, Morrison (UQ)	Integrated geometallurgical modelling of the Cadia East deposit	GeM project
Lyudmyla Koziy*	Large, Bull, Selley	Numerical simulation of fluid flow and fluid chemistry in sedimentary basins	AMIRA P552
George Leigh (JKMRC)	Gay, Morrison	Multi-resolution image analysis for process mineralogy	GeM project
Steven Lewis *	Davidson, Berry	Sulfidic hydrothermal alteration in late brittle faults, Macquarie Island	Australian Antarctic Division, AusIMM, SEG
Wallace Mackay	Selley, Bull	Sedimentology and structure of the Curdimurka Subgroup, Willouran Range, South Australia	APA-I, AMIRA
Rodney Maier	McGoldrick, Large	Pyrite and base-metal trace-element halos in the northern Australia Zn-Pb-Ag deposits	Anglo American
Claire McMahon	Davidson	Controls on the major- and trace-element content of pyrite in hydrothermal alteration envelopes	ARC
Janina Micko (MDRU)	Tosdal, Dipple (MDRU)	The hydrothermal genesis of the alkalic Cu-Au porphyry deposit Galore Creek, Northwestern British Columbia	Alkalic project
Robert Josephus Moye Jr	Cooke, Scott	Genesis and chemical and kinematic evolution of the late Proterozoic Ridgeway gold deposit in the Carolina Terrane of the central South Carolina piedmont, USA	CoE, Kennecott Minerals, Kennecott Exploration Inc, SEG, TPRS Scholarship

CODES Postgraduate Students 2007 cont.

<i>Student</i>	<i>Supervisors</i>	<i>Project</i>	<i>Support</i>
Anita Parbhakar	Walters, Edraki (UQ)	Predictive environmental mineralogy and geochemical techniques: a new approach to integrated ARD characterisation	GeM project
Heidi Pass	Cooke, Davidson, Chang	Chemical and mineralogical zonation patterns in alkalic mineral systems - Implications for ore genesis and mineral exploration	Imperial Metals, TPRS co-funded Scholarship
Nicole Pollington	McGoldrick, Bull	Sedimentology, mineral paragenesis and geochemistry of the Konkola North copper deposit, Zambia	AMIRA, APA-I
Lee Robson	Roach	Application of remote sensing for geological mapping in western Tasmania	TGMS, TPRS co-funded Scholarship
Carlos Jose Paulino Rosa*	McPhie, Gemmell, Relvas	Submarine volcanic successions in the Iberian Pyrite Belt, Portugal	Portuguese Science and Technology (FCT) fund, Mining and Geological Institute (IGM) of Portugal
Patrick Sack	Gemmell, Berry	Characterisation of the footwall lithologies, Greens Creek VHMS deposit, Admiralty Island, southeast Alaska	Greens Creek Mining, SEG, IPRS
Abhisit Salam	Zaw, Meffre, McPhie	Geology and genesis of the Chatree deposits, Phetchabun Province, central Thailand	Kingsgate Consolidated Ltd, IPRS, ARC Linkage, CoE
Ralf Schaa	Fullagar, Roach	Rapid approximate imaging of electromagnetic data acquired using distributed multichannel data acquisition systems	APA-I, CODES
Blackwell Singoyi	Davidson, Zaw, Large	Controls on the geochemistry of magnetite in hydrothermal fluids	IPRS, CODES, TGMS, SEG
Weerapan Srichan	Crawford, Berry	Petrochemistry, geochronology and tectonic implications of Chiang Khong-Lampang-Tak Volcanic Belt, Northern Thailand	Royal Thai Govt., CODES, IGCP, Oxiana Ltd
Craig Stegman*	Scott, Large	Geochemistry and structure of gold base metal mineralisation in the Cobar Gold Field, NSW	Rio Tinto
Bronto Sutopo	Gemmell, Cooke	The Martabe Au-Ag high-sulfidation epithermal mineralisation in the Tapanuli Selatan District, North Sumatra Province, Indonesia: Implications for ore genesis and exploration	Newmont Mining Corporation
Sofia Tetroeva	Danyushevsky, Crawford	Petrology and geochemistry of adakites and related rocks from the Hunter Ridge, Southwest Pacific	IPRS, CODES
Felipe Urzua	Cooke	Regional geology of the Escondida district, northern Chile	BHP Billiton Chile
Olga Vasyukova	Kamenetsky, Davidson, Danyushevsky	The origin of quartz and fluid inclusions in mineralised porphyries	CoE, IPRS
Adel Vatandoost Kohneshahri	Walters, Roach, Fullagar	Automated petrophysical characterisation of drill core as a link to mineral processing attributes	GeM project
Wojciech Zukowski	Cooke, Crawford	Geology and mineralisation at Lake Cowal district NSW, Australia	Barrick Gold, SEG, CoE, TPRS co-funded scholarship, Alkalic project

Research collaborations with CODES 2007

International collaborations (in addition to Centre partners)

<i>Institution</i>	<i>Researcher</i>	<i>CODES collaborators</i>	<i>Project</i>
Department of Mineral Resources, Thailand	S Khositantont	K Zaw, S Meffre	P1.L1 Geochronology, metallogenesis and deposit styles of Loei Fold Belt in Thailand and Laos PDR
GeoForschungs Zentrum Potsdam, Germany	R Thomas	V Kamenetsky, P Davidson, M Kamenetsky	P1.F3 Felsic magmas: volatile and metal budgets during magma evolution in a combined melt inclusion and volcanological approach
Geological Survey of Canada	J Peter	JB Gemmell	P2.F3 Volcanic-hosted massive sulfide deposits
Geological Survey of Canada	K Simpson	D Cooke, C Deyell	P2.L3 Shallow and deep-level alkalic mineral deposits
Hefei University, China	Taofa Zhou	D Cooke, Z Chang	P2.N3 Polymetallic mineralisation and associated magmatic and volcanic activity in the Luzong basin, middle and lower Yangtze River, eastern China P3.L2 Transitions and zoning in porphyry-epithermal districts
Imperial College (UK)	A Berry	A Harris, D Cooke, V Kamenetsky L Danyushevsky	P5.F3 Developmental research into the use of synchrotron in ore deposit studies P1.F2 Modern magmatism in the southwest Pacific
Indian School of Mines	D Asthana	A Crawford, A McNeill, P Davidson, S Meffre, R Berry	P1.F1 Geodynamic controls on the fertility of fold belts and cratons
Institute of Earth Sciences-Academia Sinica, Taipei, Taiwan	G Zellmer	V Kamenetsky, M Kamenetsky	P1.F3 Felsic magmas: volatile and metal budgets during magma evolution in a combined melt inclusion and volcanological approach
Colorado State University	Holly Stein	Khin Zaw	Project P1.L1. Ore deposits of SE Asia

Research collaborations with CODES 2007 cont.

<i>Institution</i>	<i>Researcher</i>	<i>CODES collaborators</i>	<i>Project</i>
Institute of Experimental Mineralogy, Moscow	E Konnikov	L Danyushevsky, A Crawford, V Kamenetsky, A McNeill	P1.F4 Ni-PGE potential of mafic and ultramafic magmas in a combined melt inclusion and numerical modelling approach
Institute of Geochemistry and State Key Laboratory of Ore Deposit Geochemistry, Chinese Academy of Sciences, Guiyang, China	X Y Song	L Danyushevsky, V Kamenetsky A Crawford	P1.F1 Geodynamic controls on the fertility of fold belts and cratons
Institute of Geological and Nuclear Sciences, NZ	C de Ronde	V Kamenetsky	P1.F3 Felsic magmas: volatile and metal budgets during magma evolution in a combined melt inclusion and volcanological approach
Institute of Geological and Nuclear Sciences, NZ	K Faure	A Harris, D Cooke, R Berry, J McPhie	P2.L1 District- to deposit-scale structural and geochemical study of the Cadia porphyry Au-Cu deposits
Institute of Geology and Mineralogy, Novosibirsk, Russia	S Smirnov	V Kamenetsky, M Kamenetsky V Kamenetsky, R Large	P1.F3 Felsic magmas: volatile and metal budgets during magma evolution in a combined melt inclusion and volcanological approach P2N1 Phase and chemical composition of high-temperature hydrothermal systems undergoing interaction between silicate rocks/magmas and aqueous fluid
National Isotope Centre, GNS Science, NZ	K Faure	A Harris	Stable isotopes
Lakehead University, Canada	Peter Hollings	D Cooke	P3.L2 Transitions and zoning in porphyry-epithermal mineral districts
University of Witwatersrand (South Africa)	Allan Wilson	J Foster	New initiatives
Otago University, NZ	Dave Craw Doug Mackenzie	R Large	P3.F2: Sediment-hosted gold-arsenic deposits: Genesis and exploration models
University of British Columbia, Canada	Jim Mortenson	B Gemmell	P2.F3 Volcanic-hosted massive sulfide deposits
University of Ottawa, Canada	Jeff Hedenquist	D Cooke	P3.L2: Transitions and zoning in porphyry-epithermal mineral districts
University of Malaya	Azman Ghandi	Khin Zaw	IRGS Grant: U-Pb geochronology and tectonic-metallogenic significance of Main Range granitoids, Malaysia
IGM, Lisbon	C M.C.Inverno	M Solomon	P2F3 Nevas Carvo massive sulfide deposits in Portugal
Hefei University, China	Feng Yuan, Yu Fan Luojun Zhang	D Cooke	P2.N3 Polymetallic mineralisation and associated magmatic and volcanic activity in the Luzong basin, middle and lower Yangtze River, E China
Nanjing University, China	Lianxing Gu	Khin Zaw	P2.F3 Volcanic-hosted massive sulfide deposits in China
MDRU	Richard Tosdal	D Cooke	P2.L3 Shallow and deep-level alkalic mineral deposits
University of Alberta	Robert Creaser	A Harris	P2.L1 District- to deposit-scale structural and geochemical study of the Cadia porphyry Au-Cu deposits
Laurentian University	Steve Piercey	B Gemmell	P2.F3 Volcanic-hosted massive sulfide deposits
University of Malaya	Teh Guan Hoe	Khin Zaw	P2.F3 Volcanic-hosted massive sulfide deposits in Malaysia
University of Ottawa	Thomas Monecke	B Gemmell	P2.F3 Volcanic-hosted massive sulfide deposits
Chinese Academy of Geological Science	Zengqian Hou	Khin Zaw	P2.F3 Volcanic-hosted massive sulfide deposits In China
Queens University, Canada	D Layton-Matthews	JB Gemmell, R Large	P2.F3 Volcanic-hosted massive sulfide deposits
Russian Academy of Science	V Maslennikov	R Large, R Scott, S Bull, W Herrmann, L Danyushevsky, S Gilbert, S Meffre, Z Chang R Large, R Scott, S Meffre, Z Chang	P2.L2 Controls on the formation and sulfide trace-element signatures of sediment-hosted gold deposits P2.L4 Genesis of the giant Sukhoi Log gold deposit, Siberia
United States Geological Survey	P Emsbo	S Bull, P McGoldrick, R Large, R Scott, S Bull, L Danyushevsky, S Gilbert, S Meffre, Z Chang, D Selley, S Bull, R Scott, M Duffett, P McGoldrick, M Hitzman*	P1.F5 Global ocean chemistry, marine basins and mineralisation P2.L2 Controls on the formation and sulfide trace-element signatures of sediment-hosted gold deposits P3.L3 Origin and setting of Congolese-type copper deposits
University of California, USA	T Lyons	S Bull, P McGoldrick	P1.F5 Global ocean chemistry, marine basins and mineralisation

Research collaborations with CODES 2007 cont.

<i>Institution</i>	<i>Researcher</i>	<i>CODES collaborators</i>	<i>Project</i>
University of Oregon USA	K Cashman P Wallace	S Allen	P1.F3 Felsic magmas: volatile and metal budgets during magma evolution – a combined melt inclusion and volcanological approach
University of Hong Kong	MF Zhou	A Crawford, A McNeill, J McPhie, P Davidson, S Meffre, R Berry	P1.F1 Geodynamic controls on the fertility of fold belts and cratons
University of Huelva, Spain	R Saez, M Toscano	JB Gemmell, M Solomon, R Large, K Zaw, A Harris	P2.F3 Volcanic-hosted massive sulfide deposits
University of Lisbon, Portugal	J Relvas F Barriga	A Crawford, R Berry, P Davidson, A McNeill, J McPhie, S Meffre	P1F1 Geodynamic controls on the fertility of fold belts and cratons
Institute of Frontier Research on Earth Evolution	Y Tamura	S Allen	P1.F3 Felsic magmas: volatile and metal budgets during magma evolution – a combined melt inclusion and volcanological approach
University of Lubumbashi/ Gécamines, Zambia	S Sebagenzi	D Selley, S Bull, R Scott, M Duffett, P McGoldrick, M Hitzman*	P3.L3 Origin and setting of Congolese-type copper deposits
University of Naples Federico II, Napoli, Italy	B De Vivo	V Kamenetsky, M Kamenetsky	P1.F3 Felsic magmas: volatile and metal budgets during magma evolution ñ a combined melt inclusion and volcanological approach
University of Ottawa, Canada	M Hannington	JB Gemmell	P2.F3 Volcanic-hosted massive sulfide deposits
Smithsonian Institution, USA	R Fiske	S Allen	P1.F3 Felsic magmas: volatile and metal budgets during magma evolution – a combined melt inclusion and volcanological approach
Vernadsky Institute, Moscow	A Ariskin	A Crawford, A McNeill A Crawford, L Danyushevsky, V Kamenetsky, A McNeill	P1.F1 Geodynamic controls on the fertility of fold belts and cratons P1F4 Ni-PGE potential of mafic and ultramafic magmas - a combined melt inclusion and numerical modelling approach
Vernadsky Institute, Moscow	V Naumov	V Kamenetsky, P Davidson	P1.F3 Felsic magmas: volatile and metal budgets during magma evolution - a combined melt inclusion and volcanological approach
Geomarine Research, NZ	B Hayward	S Allen	P1 F2 Modern magmatism in the Southwest pacific

National collaborations (in addition to Centre partners)

Australian National University	M Shelley	L Danyushevsky, V Kamenetsky, P McGoldrick, P Robinson, S Gilbert	P5.F1 Developments in LA-ICPMS of sulfides, fluid inclusions and carbonates
Australian National University	I Campbell, C Allen	A Harris, D Cooke, R Berry, J McPhie, R Tosdal*	P2.L1 District-to-deposit-scale structural and geochemical study of the Cadia porphyry Au-Cu deposits
Monash University	Reid Keays	J Foster	New initiatives
University of Adelaide	David Giles	A Crawford	P1.F1 Geodynamic controls on the fertility of fold belts and cratons
Primary Industry & Resources S.A	M Fairclough S Curtis	J McPhie	P1.F3 Felsic magmas: volatile and metal budgets during magma evolution – a combined melt inclusion and volcanological approach
Geological Survey of NSW	B Stevens, D Glen	A Crawford	P1.F1 Geodynamic controls on the fertility of fold belts and cratons
Geological Survey of Qld	I Withnall	A Crawford, R Berry	P1.F1 Geodynamic controls on the fertility of fold belts and cratons
Geoscience Australia	T Mernagh	V Kamenetsky , P Davidson M Solomon, K Zaw, A Harris	P1.F3 Felsic magmas: volatile and metal budgets during magma evolution ñ a combined melt inclusion and volcanological approach P2.F3 Volcanic-hosted massive sulfide deposits
Monash University	R Keays	A Crawford	P1.F1 Geodynamic controls on the fertility of fold belts and cratons
Primary Industries NSW	Ian Percival	A Harris, D Cooke, R Berry, J McPhie, R Tosdal*	P2.L1 District- to deposit-scale structural and geochemical study of the Cadia porphyry Au-Cu deposits
University of Queensland, Dept of Earth Sciences	S Golding	K Zaw, S Meffre	P1.L1 Geochronology, metallogenesis and deposit styles of Loei Fold Belt in Thailand and Laos PDR
Australian National University	A Harris	J Mavrogenes	P5.F3a Developmental research into the use of synchrotron in ore deposit studies
Australian National University	L Danyushevsky	M Shelley	Developments in LA-ICPMS of sulfides, fluid inclusions and carbonates

* Partner research organisation team member

Visitors to CODES 2007

International academic and government visitors

<i>Visitor</i>	<i>Institution</i>	<i>Purpose of visit</i>	<i>Date</i>
Rodney Allen	Lulea University	Stuart Bull and Ross Large	Feb
Dan Layton-Matthews	Queens University, Canada	P2.F3 collaboration with Bruce Gemmell	Feb
Christian Schardt	Johns Hopkins University, Baltimore, U.S.A	Ross Large and everyone else	Apr
Alexi Ariskin	Vernadsky Institute of Geochemistry, Moscow, Russia	P962 collaborator	Jan-Apr
Edward Konnikov	Institute of Experimental Mineralogy, Chernogolovka, Russia	P962 collaborator	Dec
Jamie Wilkinson	Imperial College, London	CODES Advisory Board Meeting	Jun
Garth Graham	Colorado School of Mines	CODES Planning Meeting	Jun
Greg Dipple	MDRU	CODES Short Course	Jun
Mengist Teklay	University of Asmara, Eritrea	Tony Crawford and Leonid Danyushevsky	Jan-Dec
Jan Peter	Geological Survey of Canada	P2.F3 collaboration with Bruce Gemmell	Feb
Jim Mortensen	University of British Columbia	P2.F3 collaboration with Bruce Gemmell	Jun
Ian R Jonasson	Geological Survey of Canada	Bruce Gemmell	Oct
Somboon Khositonont	Department of Mineral Resources, Bangkok, Thailand	Khin Zaw	Apr-Jun
Benchawan Charukalas	Department of Mineral Resources, Bangkok, Thailand	Khin Zaw	May
Nigel Cook	Geologisk Museum, University of Oslo, Norway	Khin Zaw	Jun
Poul Emsbo	USGS	P923 final meeting	Dec
Kevin Tuckwell	Minerals Council of Australia	MTEC	Feb

National academic and government visitors

David Huston	Geoscience Australia	Ross Large and Bruce Gemmell	May
Huntly Datter	Geoscience Australia	Ross Large and Bruce Gemmell	May
Phil Blevin	Department of Primary Industry, NSW	Ross Large, CODES Short Course	June
Janet Hergt	University of Melbourne	CODES Planning Meeting	Jun
Jon Woodhead	University of Melbourne	CODES Planning Meeting	Jun
Chad Paton	University of Melbourne	CODES Planning Meeting	Jun
Ben Adair	JK Mineral Research Centre	CODES Advisory Board Meeting	Jun
Graham Carr	CSIRO	CODES Advisory Board Meeting	Jun
Stephen Cox	Australian National University	CODES Advisory Board Meeting	Jun
Alan Goode	AMIRA International	CODES Advisory Board Meeting	Jun
Angela Lorrigan	Zinifex	CODES Advisory Board Meeting	Jun
Noel White	Consulting economic geologist	CODES Advisory Board Meeting	Jun
Anthony Brown	Mineral Resources Tasmania	CODES Advisory Board Meeting	Jun
Karol Czarnota	Geoscience Australia	Bruce Gemmell	Jul
Hamish Treeby	Monash University	David Cooke	Sep
Dave Craw	Otago University	SEG Student Chapter, Ross Large	Sep
Ian Plimer	University of Adelaide	Ross Large, Seminar and Debate	Sep
Ian R Jonasson	Ex GSE Ottawa	Bruce Gemmell	Oct
Oliver Gardner	Commonwealth Government	Various	Oct
Dick Stanton	Australian National University	Ross Large	Nov
John Elliston	Elliston Research Association	CODES Symposium	Nov
Tom Healy	University of Melbourne	CODES Symposium	Nov
Lynton Jaques	Geoscience Australia	CODES Symposium	Nov
Chris Ryan	CSIRO	P5.F4 and P5.F3	Nov
Weihua Liu	CSIRO	P5.F4 and P5.F3	Nov
Louise Edwards	University of Melbourne	Leonid Danyushevsky	May
Antti Kallio	Australian National University	Leonid Danyushevsky	Jun
Roland Maas	University of Melbourne	Dima Kamenetsky	Mar
Greg Yaxley	RSES, Australian National University	Dima Kamenetsky	Mar
David Falvey	ARC	Ross Large	Sep
Alan Goode, Belinda Coates	AMIRA International	P843 meeting	Feb
Ben Adair, Cathy Evans, George Leigh, Khoi, Nguyen, Luke Keeney, Nenad Djordjevic, Rob Morrison, Simon Michaux, Stephen Gay, Toni Kojovic	JK Mineral Research Centre	P843 meeting	Feb

<i>Visitor</i>	<i>Institution</i>	<i>Purpose of visit</i>	<i>Date</i>
National academic and government visitors cont.			
Lesley Wyborn	Geoscience Australia	Short course	Jun
Nick Oliver	James Cook University	Short course	Jun
Lin F Sutherland	University of Western Sydney	Khin Zaw	May
Melissa Quigley	CSIRO	David Cooke	Apr
Melissa Quigley	CSIRO	P843 meeting	Feb
Industry visitors			
Terry Lemon	Anvil Mining	Dave Selley and Stuart Bull	Ma
John Dow	DowGold Consultants	CODES Advisory Board Meeting	Jun
Steve Beresford	BHP Billiton	CODES Advisory Board Meeting	Jun
Steve Turner	Newmont	CODES Advisory Board Meeting	Jun
Stuart Smith	Oxiana	Garry Davidson and Jeff Foster	Oct
Greive Brown	Bemax Resources	CODES Symposium	Nov
Peter Buckley	Plat Search NL	CODES Symposium	Nov
Andrew Browne	Geosynthesis P/L	CODES Symposium	Nov
Rob Ryan	Consultant	CODES Symposium	Nov
Bob McNeil	MACMIN Silver	CODES Symposium	Nov
Ian Gould	Toro Energy	CODES Symposium	Nov
Bob Richardson	Plat Search NL	CODES Symposium	Nov
Aert Driessen	Canberra ACT	CODES Symposium	Nov
Colin Brooks	Consultant	CODES Symposium	Nov
Brian Williams	Consultant	CODES Symposium	Nov
Wendy Corbett	Plat Search NL	CODES Symposium	Nov
Peter Kitto	Iron Ore Holdings Ltd.	CODES Symposium	Nov
John Elliston	Elliston Research Pty.Ltd.	CODES Symposium	Nov
Ray Soper	Plat Search NL	CODES Symposium	Nov
Linda Daley	Newmont	AMIRA Meeting	Dec
Wes Sherlock	Newmont	Rob Scott P923	Dec
Paul Wallis	Perseverance	AMIRA Meeting	Dec
Neil Norris	Perseverance	AMIRA Meeting	Dec
Trevor Beardsmore	Barrick Gold	AMIRA Meeting	Dec
David First	Freeport	AMIRA Meeting	Dec
Paul Agnew	Rio Tinto	AMIRA Meeting	Dec
Glen Masterman	Kinross	AMIRA Meeting	Dec
Mike Cawood	Teck Cominco	AMIRA Meeting	Dec
Paul McInnes	Barrick Gold	AMIRA Meeting	Dec
Chris Oates	Anglo-American	Leonid Danyushevsky	May
John Holliday	Newcrest Mining	CODES Advisory Board Meeting	Jun
Ian Willis	Anglo American	CODES Advisory Board Meeting	Jun
Brian Levett	Newmont	Bruce Gemmell and Bronto Sutopo	Jul
Roger Leighton, Robert Schouwstra	Anglo Platinum	P843 meeting	Feb
Gavin Yeates	BHP Billiton	P843 meeting	Feb
Steve Ellis	Barrick Gold	P843 meeting	Feb
Tracey Kerr	CVRD (Rio Doce Australia)	P843 meeting	Feb
Dwayne Povey, Jennifer Woodgate	Ernest Henry Mining (Xstrata Copper)	P843 meeting	Feb
Andrew Richmond	Golder Associates	P843 meeting	Feb
Adrian Dance	Metso	P843 meeting	Feb
Foy Leckie, Dean Collett	Newcrest	P843 meeting	Feb
John Hammond	Newmont	P843 meeting	Feb
Dewetia Latti, Greg Wilkie, Annette Pal	Rio Tinto	P843 meeting	Feb
Nichola McKay	Teck Cominco	P843 meeting	Feb
Trevor Ellice	Zinifex	P843 meeting	Feb

Major externally funded research projects*

AMIRA-ARC Centre of Excellence projects 2007 †

<i>Investigators</i>	<i>Project</i>	<i>Industry Partners</i>	<i>Period</i>	<i>CoE-ARC Funding for 2007</i>	<i>AMIRA Funding for 2007</i>	<i>Misc Funding for 2007</i>
Walters, Berry, Djordjevic, Fullagar, Hunt, Huntington, Kojovic, Bye	AMIRA P843. GeM ^{III} Geometallurgical Mapping and Mine Modelling	Newmont, Rio Tinto, Teck Cominco, Xstrata, Newcrest, Inco, AngloGold Ashanti, Anglo Platinum, Barrick, Vale Inco, WMC, Zinifex, BHP Billiton, Datamine, Geotek, Golder Associates, Codelco, Metso Minerals	2005–2009	\$545,450	\$1,065,773	\$235
Scott, Large, Embso (USGS), Maslennikov (RASCI)	AMIRA P923. Controls on the formation and sulfide trace element signatures of sediment-hosted gold deposits	Barrick, Newcrest, Newmont, Perseverance, St Barbara Mines, Golden Gryphon	2005–2008	\$51,000	\$155,000	
Danyushevsky, Crawford, Kamenetsky, Sobolev (Max Planck Inst)	AMIRA P962. Ni-PGE potential of mafic and ultramafic magmas - a combined melt inclusion and numerical modelling approach	Anglo American, BHP Billiton, Votorantim Metals	2007–2010	\$98,000	\$104,940	

AMIRA-ARC Linkage projects 2007 ^

<i>Investigators</i>	<i>Project</i>	<i>Industry Partners</i>	<i>Period</i>	<i>ARC Funding for 2007</i>	<i>AMIRA Funding for 2007</i>	<i>Misc Funding for 2007</i>
Cooke, Gemmell, White, Hedenquist (Ottawa U)	AMIRA P765. Transitions and zoning in porphyry-epithermal districts: indicators, discriminators and vectors	Anglo American, AngloGold Ashanti, Goldfields, Newcrest, Newmont, Placer Dome (now Barrick), Teck Cominco	2004–2007	–\$59,380	\$33,060	\$1,526
Selley, Bull, McGoldrick, Hitzman (CSM)	AMIRA P872. Sediment-hosted Cu-deposits of Congolese, Zambian & Central Australian basin systems	African Rainbow Minerals, Anglo American, Anvil Mining, BHP Billiton, Vale Inco, Enterprise Generale Malta Forrest, Equinox Minerals, Phelps Dodge, Rio Tinto, Gecamines	2005–2008	\$137,985	\$254,536	\$16,338

Other ARC Linkage projects 2007 ^

<i>Investigators</i>	<i>Project</i>	<i>Funding Body</i>	<i>Period</i>	<i>ARC Funding for 2007</i>	<i>Other Major Funding for 2007</i>	<i>Misc Funding for 2007</i>
Davidson	Genesis of Platinum Group Element-rich, unconformity-style, hydrothermal mineral deposits, as inferred from a Northern Territory example	Department of Primary Industry, Fisheries & Mines	2006–2009	\$25,627	\$8,000	

ARC Discovery Grants 2007 ^

<i>Investigator</i>	<i>Project</i>	<i>Period</i>	<i>ARC Funding for 2007</i>	<i>Misc Funding for 2007</i>
Allen	Discovery Grant: Submarine explosive eruptions of silicic magma: constraints on products and processes from modern sea-floor examples, ancient successions and experiments	2004–2008	\$103,639	
Kamenetsky	APF and Discovery Grant: Unmixing in magmas: melt and fluid inclusion constraints on identity, timing and evolution of immiscible fluids, salt and sulfide melts	2005–2009	\$173,654	

* projects with greater than \$10,000 external (non CoE-ARC) funding per year

† ARC funding for these projects comes from the CoE-ARC Grant

^ ARC funding for these projects comes directly from the ARC Discovery or Linkage programs

Industry and other externally funded research grants 2007

<i>Investigators</i>	<i>Project</i>	<i>Funding Body</i>	<i>Period</i>	<i>Industry Funding for 2007</i>
Chang, Cooke	Caijiayang Zn-Au deposit: Geological characteristics and their implications to exploration	Hebei Hua Ao Mining	2007–2009	\$37,500
Cooke	Palmarejo carbonate base-metals silver-gold epithermal deposit, Chihuahua, México	Bolnisi Gold NL	2006–2008	\$68,163
Cooke, Deyell, Tosdal (UBC)	Shallow and deep-level alkalic mineral deposits	University of British Columbia	2005–2008	\$92,712
Gemmell	Deposit to district-scale study of the Gosowong Goldfield	Newcrest Mining Limited	2007–2010	\$10,000
Gemmell	Geology of Niblack VHMS Deposit, Alaska: Implications for Ore Genesis and Exploration	Niblack Mining Corporation	2007–2010	\$
Gemmell, Berry	Geology and geochemistry of the footwall phyllite, Greens Creek VHMS deposit, Alaska: implications for ore genesis and exploration	Kennecott Greens Creek Mining Company	2004–2008	\$38,400
Harris, Cooke, Berry	District- to deposit-scale structural and geochemical study of the Cadia porphyry Au-Cu deposits	Newcrest Mining Limited	2005–2008	\$117,249
McNeill	Vectors to VHMS, Rosebery district	Zinifex	2006–2007	*
Zaw, Meffre	Geochronology, metallogenesis and deposit styles of the Loei Fold Belt in Thailand and Laos PDR	Pan Australia, Kingsgate, Oxiana	2006–2008	\$63,050

\$ project started 2007, funding to start in 2008

* total project funding of \$40,804 was received in 2006

Activity Plan 2008

Program 1

<i>Project</i>	<i>Team leader(s)</i>	<i>Activity plan</i>
P1.F1	A Crawford	There are three major components of this project in 2008: • Complete and publish the magmatic-hydrothermal model on Broken Hill; all Pb isotope data is completed, and collaborator R Maas will visit CODES in late January 2008 to contribute to the write-up. • Perilya Ltd are keen to build on the 'facing studies' deriving from sill geochemical profiles, and it is anticipated that this will be done with John Miller (CET, UWA) early in 2008, funded by Perilya. • We are keen to follow up the initial work on the Potosi Gneiss that has suggested that diverse lithostratigraphic packages make up this well known unit, and that the geochemical identification of these will greatly assist in near-mine, and perhaps regional, exploration.
P1.F2	T Falloon, S Allen	Preparation for research voyage SS08/2008 will be completed by mid-April, which will enable placement of all equipment on the vessel when it docks in Hobart. A new PhD student, Fiona Best, who will work on the behaviour of chalcophile elements during subduction-related magma evolution, is expected to arrive to Hobart in April 2008, in time to take part in the research voyage. Pavel Plechov is expected to visit CODES for 3 months in June-August 2008 to continue work on developing Petrolog 3.0 and to take part in the research voyage. Samples from the new voyage will be submitted for initial analysis by September 2008. Research on samples from SS10/2004 and SS08/2006 will continue throughout the year.
P1.F3	J McPhie, V Kamenetsky	Fieldwork and sampling at Olympic Dam – May? – Isabelle Chambeftor, JM, VK Analyses of OD samples – June-November - IC, VK Fieldwork in the Ohanapocosh Formation – June-July? – M Jutzeler, JM Fieldwork and sampling in Mexico - Emily Johnson, JM Complete and write up Dogashima volcanology – M Jutzeler, JM, SRA Complete and write up quartz study – A Agangi, VK Complete and write up Glyde Hill Volcanic Complex volcanology – AA, JM, SRA Complete and write up Milos pumice breccia – S M Gordee, SRA, JM Complete and write up Shirahama facies architecture – SMG, SRA, JM Design analogue experiments with Ross Griffiths at ANU – Sept-Oct - SRA Attend and present papers at the IAVCEI conference, Iceland – VK, SRA, JM, AA, MJ, SMG.
P1.F4	L Danyushevsky	Sponsors' meeting to be held in Hobart in April 2008 (date to be decided). Quarterly reports will be submitted to AMIRA at the beginning of February, May, August, November 2008. Collaborator Alexei Ariskin will visit CODES for 3 months in January-April 2008. New PhD student Kirill Bychov, who will work within Module 3 of the project, will arrive in March 2008
P1.F5	P McGoldrick	Appointment of shared Research Fellow with UC-Riverside (6 months at CODES in late-2008) Winter field work with North American collaborators in the southern McArthur Basin to complete the BCDC stratigraphic sampling Begin negotiations with Zinifex to undertake detailed investigations at Century Continue CAS, geochemical and isotopic (Sr and S) work at Riverside, Denver and UTAS on existing sample sets Complete reviews of manuscripts submitted to <i>Mineralium Deposita</i> special issue from CODES 'Ores in Sediments' meeting.
P1.F6	A Crawford	All data collection for this project is complete, and the task at hand is to write the planned paper for 'Geology' with Reid Keays (MonashU).

Program 2

P2.F2.1	S F Cox, D Cooke	Initial training of post-doc Angela Halfpenny in research methodologies endemic to this project. Several periods of fieldwork by Halfpenny at Porgera mine site; total of approximately 8 weeks in 2008, comprising an initial short visit to scope the project, followed by several longer periods of fieldwork. One or two sites visits to Porgera by Cox and Cooke to work with A Halfpenny and site geologists. Analysis of field data, microstructural analysis, and analysis of stress and fluid pressure states during evolution of the hydrothermal system at Porgera. Develop firm plan for commencement of a second field case study site, and commence fieldwork there in the middle part of 2008. Visit by Halfpenny and Cox to CODES for mid-year reporting/planing meetings and collaboration with Cooke – to be followed by a longer research collaboration visit to CODES later in 2008. Explore strategies for developing modelling/analytic studies on the effects of inflation/deflation cycles and fluid pressure evolution on dynamics of stress states around active magma chambers.
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P2.F2.3	B Gemmell, M Solomon	<i>Sub-project 1: The nature and origin of fluids that form high-salinity, volcanic-hosted massive sulfide deposits</i> Extension of PIXE and LRM work on Hellyer and Aznalcollar. Study of Lombador orebody, Neves Corvo – stage 2. <i>Sub-project 2: The nature, diversity and genesis of volcanic-hosted, Cu-Pb-Zn-Ag-Au, massive sulfide deposits</i> Complete zircon U/Pb and hornblende Ar/Ar dating of Mount Read Volcanic Belt lithologies at UBC. Continue investigating the Mount Lyell (Tasmania), Jaguar (Western Australia), Greens Creek (Alaska), Yaman-Kasy (Russia), Hongtoushan and Baiyinchang (China) and Tasik Chini (Malaysia) VHMS deposits. Find student and initiate Niblack PhD study. Write VHMS alteration summary paper with Ross Large and Wally Herrmann for the Mineralium Deposita special issue. <i>Sub-project 3: Hydrothermal event recognition and target vectoring in sedimentary strata for volcanic-hosted and sedex massive sulfide deposits</i> Help write joint AMIRA-CAMIRO proposal, solicit funding from industry and initiate project. Meet project leaders in Canada for planning meeting with industry sponsors Finish writing Que River Shale pyrite chemistry paper with Dan Layton-Matthews and submit to Economic Geology. <i>Sub-project 4: Active base and precious metal-rich massive sulfide-sulfate deposition associated with submarine volcanism</i> Complete LA-ICPMS and LA-sulfur studies on PACMANUS, Palinuro and Panarea samples at UTAS. Attend post-cruise meeting in Germany to present results of research. Help write paper outlining results from cruise for submission to Geology. Organise and chair black smoker and seafloor mineralisation session at the AusIMM PACRIM conference on Gold Coast in November. Write extended abstract outlining cruise results for this meeting.
P2.L1	D Cooke, R Berry, A Harris	The project is sub-divided into two research themes: <i>Deposit-Scale Studies</i> Ridgeway (Anna-Liza Cuisson, PhD) : Field work is completed and research activities will be directed towards a 3D analysis of intrusive geometries and vein orientation. Final thesis chapters will be prepared. Cadia East (Nathan Fox, PhD) : The bulk of the fieldwork of this project will be undertaken this year, focusing on the better documenting the upper lithologically controlled alteration facies. A significant amount of geochemical data (including microprobe, LA-ICPMS and stable isotope geochemistry) will be acquired to trace fluid pathways. Cadia East-Cadia Hill (Malissa Washburn, Masters): Thesis preparation and completion this year. Ridgeway (Anthony Harris) : Infill geochemical data will be acquired building on research outcomes of William Reynolds. New project definition (Colin Carter) : A new Masters project will be established in consultation with Newcrest. <i>District-Scale Studies</i> Geology (Anthony Harris) : New geologic sections will be constructed systematically across the Cadia Valley. A 3D digital model of the district geology (including volcanic and intrusive architecture, alteration and sulfide mineral distribution, together with grade) will be established. Geochemistry (Anthony Harris) : Building on the newly defined volcanic architecture, we will reinterpret the existing whole-rock geochemistry data (~300 samples). Significant effort will be put into a comprehensive set of microanalyses to aid in litho-geochemical subdivision of stratigraphic units (building on successful pyroxene chemistry). Chronology (Anthony Harris, Ian Percival, Charlotte Allen, Richard Tosdal) : Sampling of microfossils will be undertaken across the Weemalla Formation. Additional Re-Os, Ar/Ar and U-Th-He will be undertaken to comprehensively define timing of hydrothermal alteration, mineralisation and subsequent dismemberment of the Cadia Valley.
P2.L3	R Tosdal, D Cooke, T Bissig, K Simpson	Janina Micko to continue petrographic, geochemical and geological studies of Galore Creek, compiling geological and alteration/sulfide distributions on three cross-sections across the Central Zone. Comprehensive exams scheduled for February 2008. Possible visit to CODES in mid-2008. Depending on access, Kevin Byrne to complete his second field season at Galore Creek, and to undertake detailed analysis of samples collected during the July-September 2007 field season. Paul Jago to defend MSc thesis on Mt Milligan in February 2008. Meghan Jackson to defend MSc thesis on Mt Polley in February 2008. Heidi Pass to finalise the compilation of the geology, alteration and mineralisation on the Mt Polley long section, complete all geochemical studies and write the first draft of her PhD thesis. Adam Bath to undertake detailed geochemical investigations of the Lorraine system. Jacqueline Blackwell to conduct final field season at Lihir, mapping in the Lienetz pit, and to commence writing of thesis chapters. Wojciech Zukowski to complete geochemical studies of the E41 gold deposit (Cowl), and to write the first draft of his PhD thesis. Amber Henry to submit MSc thesis of the structural controls on the E42 gold deposit (Cowl, NSW) in mid-2008. Thomas Bissig to determine the geochronology of the Cowl volcanic and igneous complexes. Kirstie Simpson to complete a synthesis of breccia facies that occur in alkalic systems. Dick Tosdal and David Cooke to complete the 3D synthesis of alkalic systems. Final sponsors meetings to be held in British Columbia and NSW in late 2008.

P2.N2	Z Chang	XRD check of the spectral results. Geochronology – date zircons from pre-mineralisation and syn-mineralisation dykes, illite in retrograde alteration, and if possible, sericite associated with mineralisation. More fluid inclusion work, especially on fluid inclusions in sphalerite. O, C, and S isotope study. Trace elements in sulfides, especially the content of Au and associated elements, using the LA-ICPMS methods.
P2.N3	T Zhou, D Cooke	Visit to CODES by Taofa or his co-workers. Visit to China by Dave Cooke, Ross Large or Zhaoshan Chang or other CODES people. Dates will be set after further discussions. 4-12, further field work to Luzong and Ningwu basins in order to investigate aspects of the magmatic rocks and mineralisation. Attend international conference to present results. Data processing and paper writing. Papers will be published both in international journals and top Chinese journals.
P2.N4	K Simpson	<i>Breccia Textures: a guide to the description and interpretation of breccias in mineralized environments</i> The following individuals are responsible for writing these book chapters: Chapter 1: Introduction (Kirstie to lead) • Define 'breccia' • Introduce the varied, overlapping and complex environments in which breccias occur • Introduce the importance of breccias in mineralised successions and the challenges they pose Chapter 2: Breccia Description (Kirstie to lead) • Descriptive nomenclature for all elastic rocks regardless of fragmentation, transport and depositional processes (integrate schemes for sedimentary, volcanic and subsurface breccias) • Recognition and description of important features/textures that will be used for interpretation Chapter 3: Fragmentation, Transport and Depositional Processes (suggested division between Jocelyn, Dave and Andrew) • Fragmentation - explosions, quenching, dynamic stressing, physical and chemical weathering, mass wasting, dissolution, hydraulic, decompression, shear. • Transport and deposition • Pseudo-breccia textures due to alteration Chapter 4: Genetic nomenclature (suggested division between Jocelyn, Dave and Andrew) • Surface: volcanic (pyroclastic, autoclastic), epiclastic • Subsurface: volcanic-hydrothermal, magmatic-hydrothermal, magmatic, tectonic, etc. Chapter 5: Interpretation of breccias (all of us) • key textures, geometry, facies associations, etc. Chapter 6: Case studies: • Epithermal - Kelian (Andrew to lead) • Porphyry (Dave and Kirstie) • Non-magmatic system? (MVT/Irish/CRD) (Jamie Wilkinson?) • Structural Breccias? (Steve Cox?) • VHMS? (Bruce) Chapter 7: Digital data integration and applications to exploration (Kirstie and Andrew to lead) • Logging codes • Database structures
Program 3		
P3.F1	M Roach	Publish potential field classification technique in appropriate A1 journal Complete development of gravity survey optimisation software for general use Establish PhD project on application of geophysical and geological modelling techniques for interpretation of Mount Read Volcanics distribution under magnetic cover in northwestern Tasmania Commence pilot sub-project using underground gravity measurements to assess accuracy of bulk rock volume densities determined by core sampling

P3.F2	R Large	Discuss project aims and plan with Bendigo Mining, Glass Earth and SkyGold Ventures Select several drill holes for detailed logging and sampling in each district Select sediment packages at different stratigraphic levels Develop sedimentological models Multi-element whole-rock geochemistry of samples Petrography and paragenesis of pyrite LA-ICPMS low level gold on sediment matrix LA-ICPMS geochemistry of pyrite S-isotopes of pyrite types Compare sediment geochemistry in each district: Victoria, Carlin, Otago, Spanish Mountain, Sukhoi Log Report results to company sponsors
P3.L1	P Fullagar	Complete the implementation of approximate 3D transient electromagnetic (TEM) inversion in the VPmg framework. Investigate the circumstances under which the superposition of moments of individual spheres is a valid approximation to the bulk TEM response of the sub-surface. This will entail comparison with synthetic TEM data computed using independent fully 3D algorithms. Test approximate conductivity inversion over 3D models for which synthetic TEM data are available. Demonstrate constrained approximate 3D TEM inversion on field data.
P3.L2	D Cooke, B Gemmell	Appoint two postdoctoral Research Fellows, 1 PhD and 1 MSc student, and 1 Research Assistant at CODES, and 1 Masters student (Gabe Sweet) at Lakehead University. Analyse samples stored at CODES from the main P765 study sites (Baguio, Mankayan, Batu Hijau, Collahuasi) that could not be analysed due to financial constraints. Undertake field investigation in the Baguio district in early 2008. For finalising the new sites, a questionnaire has been distributed to sponsors regarding the various new study sites offered to the research team; responses expected in late January. Assign coordinators (Research Fellows) for each new site. Data compilation and literature reviews of new study sites. Initial field investigation at new study sites. PhD field investigation at Ixhuatan work already started, with supervisory visits scheduled for January and February 2008. Evaluation of magnetite and carbonate chemistry. Set up blind test schedules at the first sponsor meeting (around May), then start the blind tests.
P3.L3	D Selley, S Bull, M Hitzman	Complete isopach mapping of Nguba and lower Kundelungu levels from southern and western portions of the Congolese Copperbelt, with an aim to elucidate extensional basin architecture and its control on ore distribution. (Selley) Produce three balanced cross-sections of the outer Lufilian Fold Belt, constrained with recently acquired gravity and aeromagnetic data. (Selley and Duffett) Develop and apply a numerical code for coupled buoyancy-compaction fluid flow to a restored profile of the outer Lufilian Fold Belt. (Koziy) Complete sequence stratigraphic model for the Roan Group, integrating Dipeta Subgroup data collected from the data from Tenke-Fungurume district. (Bull) Determining the extent of REE anomalism and its relationship to Cu mineralisation in the Kolwezi Klippe. Through chemical characterisation of REE-bearing resistate mineral phases, the study aims to develop an indicator mineral suite that can be used as a vector to ore in both transported, and highly leached residual soils. (Selley) Characterisation of the ore fluid(s) in a classical Congolese deposit via Cl-Br solute analysis of fluid inclusions from sulfide and gangue phases at Kolwezi. Complete two deposit case studies at Lupoto and Kambove-Kamoya. (Hitzman and Selley) Undertake Pb-isotope study of sulfide phases from a variety of Congolese and Zambian ores, with an aim to constraining metal source(s). (McGoldrick)
P3.L4	M Roach	Completion of starting models in other inversion software (VPmg, UBC-GIF). Run required series of constrained inversions within range of starting parameters governed by determined petrophysical constraints. Production of final 3D geological models. Algorithm evaluation and reporting.
P3.L7	A McNeill, B Gemmell	Commence fieldwork for carbonate component of project (second half). Complete sampling and analysis for pyrite compositions (first half). Complete interpretation of regional shale geochemistry database (first half). Final report to sponsors November 2008.

P3.L8	B Gemmell	Completion of Bronto Sutopo's thesis on Martabe by mid-year. Find appropriate personnel and initiate Gosowong and Kencana projects. Interview applicants, hire and start research. Submit hydrothermal alteration associated with epithermal Au-Ag deposits and Kencana discovery papers for publication to <i>Economic Geology</i> and <i>Mineralium Deposita</i>, respectively. Completion of Corrie Chamberlain's Master of Economic Geology thesis on the Killkeny deposit, Cracow, Queensland by end of year.
P3 New initiatives	J Foster	Appoint Research Fellow to investigate the geology and geochemistry of the Platreef, Bushveld Igneous Complex. Appoint PhD student to investigate the geology, geochemistry and genesis of the Avebury Ni deposit. Fully develop and seek industry funding for the Global Discovery Initiative. Key aspects of this program will include: •Geophysical and petrophysical characterization of four major deposit types •Petrophysical and geologically constrained 3D inversion models •Ambient noise seismic tomography •Geochemical templates for ore deposits •Geochemical Terrane fingerprinting •High temperature to low temperature 'fluid' models •Inverse theory applied to multivariate geochemical datasets •Target generation through scale-independent data coring Research and knowledge transfer will occur through reporting and publication in conjunction with the development of industry friendly software through alliances with key technology partners.

Program 4

P4.L1.1	S Walters	Complete logging of Boddington, Cadia East Phase 2, Ernest Henry Phase 2, and Aqaluk Phase 2 core samples. Investigate new GEOTEK MSCL sensor types and configurations. Deploy new GEOTEK XYZ imaging logger. Liaise with CSIRO on greater integration of SWIR and TIR-based HyLogging. Investigate quantification procedures for SWIR HyLogging. Release protocols for operation of logging suite. Develop new software for core image handling. Complete initial site visits and planning for Bingham and Sudbury.
P4.L1.2	R Berry	Provide protocols for integration of Leica optical systems and Definiens software. Commission the new Horiba micro-XRF system. Continue to provide support for GeM microscopy suite applications. Develop new Definiens protocols for other sponsor sites and ores.
P4.L1.3	S Walters	Provide more user friendly software for application of wavelet based image analysis. Develop Texture Viewer version 2. Deliver a more effective methodology for meso- and micro-scale texture analysis relevant to processing attributes. Deliver beta version of ioGeM software.
P4.L1.4	T Kojovic	Complete development of new Compressed Bed Breakage test and relate this to comparative HPGR performance. Support application of GeM integrated comminution suite. Apply Floatability Index testing to sponsor sample sets. Support technology transfer of GeM JK Comminution Index.
P4.L1.5	A Bye	Evaluate application of advanced geostatistical techniques to non-grade processing attributes. Demonstrate new approach to class-based modelling for geometallurgical domaining.
P4.L1.6	S Walters, R Large, B Adair	Develop concept of a Masters level course for geometallurgy.
F4.1	T Napier-Munn	Prepare industry proposal for P1000 enviroGeM project and secure funding.

Program 5

P5. F1	L Danyushevsky	Testing a new ablation cell built in the CSL workshop will be completed in April. Sulfide standard will be developed by June and should be fully tested by the end of the year. Thermometric experiments with fluid inclusions from selected quartz porphyries and Sn-granite (1st half 2008) LA-ICPMS analysis of coeval fluid inclusions and calculation of element ratios (2nd half 2008) Both powdered (homogenised) and natural carbonates will be analysed by LA-ICP and solution ICP to assess their suitability as a standard for LA-ICPMS. Previous whole-rock analyses of one of the siderite samples (from Lady Loretta) indicate high levels for a range of trace elements.
P5.F5.2	J Hergt, J Woodhead, C Paton, S Meffre	Continued application of laser ablation in situ analytical technologies (Pb isotopes) on the multi-collector ICPMS to research projects of interest to CODES members. Further development of Cu isotope analytical protocols for wholerock analysis.
P5.F5.3a	A Harris	In situ high temperature spectroscopy experiments of natural and synthetic fluid inclusions to collect a more representative suite of metal species from fluid inclusion (including salt-rich and vapour-rich) plus a complete temperature cycle. Microanalysis (via PIXE, LA-ICPMS and Raman) of the inclusions prior to detailed high-temperature spectroscopy to confirm their compositions.

P5.F5.3b	C Ryan	Coordinate the development, construction and testing of an advanced massively parallel X-ray fluorescence detector system aimed at high-throughput, high-definition synchrotron fluorescence and XANES imaging for the AS. Develop the embedded spectral deconvolution approaches for real-time performance. Develop spectroscopy techniques for imaging chemical state using X-ray absorption near-edge structure (XANES) and the new CSIRO-BNL detector systems. Continue experiments on the properties of P species as Cu complexes in ore fluids.
P5.F4b	Z Chang	PIXE analysis of alunite and pyrite. CL/SEM characterisation of the paragenesis of fluid inclusions. Laser Raman identification of daughter minerals in fluid inclusions. PIXE analysis of individual fluid inclusions. LA-ICPMS analysis of individual fluid inclusions.
P5.F5	R Large, S Meffre, L Danyushevsky	Hire postdoc to be involved (50% of time) in the project. Purchase gold rock standards. Collect a range of fine to coarse grained igneous, sedimentary, metamorphic rocks and gold ores for analysis. Investigate various sample preparation and analytical procedures for whole rock, crushed rock and powders. Test a range of ore types for free gold and refractory gold proportions. Test ore types for gold grainsize and distribution.
P5.F6	S Meffre	Pb isotopes in galena. Analyses of five galena standards of different Pb isotopic compositions which have recently been analysed using the solution ICPMS method. Sulfur isotope analysis on the ICPMS. Reworking through some of the data collected in 2007 to characterise the nature of outstanding problems. Ablation cell developments. The new cell developments will initially involve making a prototype in collaboration with Peter Dove (CSL) and Peter Cornish followed by an extensive testing phase.
P5.F8	G J Davidon, H Pass, K Harris, K McGoldrick	February-April: Testing of a modified CAS extraction system. Submission of an application to the Yellowstone park authority to undertake sampling at Mammoth hot springs in June 08. This was planned for 2007 but did not occur due to reprioritisation of the Mt Polley program. Completion of Mt Polley microprobe analysis and imaging, and statistical analysis of microprobe data. April-July: Write-up of techniques paper, and the Mt Polley sulfate distribution paper, with assistance of K Orth. Submission before the start of Semester 2. June: Mammoth hot springs sampling program (1 week). April-October: Running of hydrothermal carbonate samples using new modified CAS technique: Kelian, Mt Polley, Sunrise Dam (samples obtained in 2007). July-December: Processing of Yellowstone carbonate samples, and Sunrise Dam lode gold carbonate samples for CAS extraction, as well as microprobe imaging of samples.